

CHAPTER VIII.

BEACHES FORMED WHEN LAKE AGASSIZ OUTFLOWED NORTHEASTWARD.

Fourteen shore-lines of Lake Agassiz have been traced, with determination of their heights, through portions of their extent, which lie below the McCauleyville beaches and were formed after the lake ceased to outflow southward. The River Warren, no longer receiving the drainage from the melting ice-sheet and from the rainfall of the vast basin of Lake Agassiz, was suddenly reduced, when the lake obtained a lower northeastern outlet, to the much smaller Minnesota River; and the alluvium of this stream formed a watershed between Lakes Traverse and Big Stone, partially filling the former channel of outflow from the glacial lake. Chapter V has already considered the courses of the successive new avenues of outflow to the northeast, probably at first flowing back southward along the border of the retreating ice-sheet, and thus passing through the great Laurentian lakes to the Mississippi, and later to the Hudson. Though the courses of the northeastward outlets remain unexplored, the beaches marking the stages of Lake Agassiz while tributary to them are found to be separated only by vertical intervals varying from 10 or 15 to 45 feet through all the time of its reduction from the level of Lake Traverse and the McCauleyville beaches to Lake Winnipeg. On the latitude of the south end of Lake Winnipeg the fall of the surface of the glacial lake during this time was about 280 feet, Lake Winnipeg having stood at first above its present height and having been since lowered 20 feet by the erosion of the Nelson River.

The three highest shore-lines on the area from which the lake receded during its northeastward drainage are named the Blanchard beaches, and the next five in descending order the Hillsboro, the two Emerado, and the two Ojata beaches, from towns on or near their course in North Dakota.

The remaining six, enumerated in the same order, are designated, from places of their typical development in Manitoba, as the Gladstone, Burnside, Ossowa, Stonewall, and two Niverville beaches. Like the shores marking the higher stages of the lake while flowing southward, these beaches are found to have a northward ascent, due to the differential uplifting of the earth's crust. The gradual decrease of their ascent from a considerable amount along the earlier and higher shore-lines to very little along the latest and lowest shows that the northward uplifting was in progress while the ice barrier was receding. It had been nearly completed before the glacial recession uncovered the area traversed by the Nelson, changing Lake Agassiz to Lake Winnipeg.

Beyond the limit of my survey, which was extended into Manitoba to Gladstone and Orange Ridge and to the south ends of Lakes Manitoba and Winnipeg, very interesting observations of the beaches east and northeast of Riding and Duck mountains are supplied by Mr. J. B. Tyrrell in his exploration of that district for the Canadian Geological Survey.¹ It is there found that the earlier shore-lines of the series formed during the northeastern outflow were uplifted about a foot per mile from south to north for 150 miles northward from the latitude of Gladstone, and that this rate diminishes in the successively lower beaches. According to my correlation of Mr. Tyrrell's observations with my own in southern Manitoba and southward, the last shore-line known to have been formed by Lake Agassiz is about 60 feet above the south end of Lake Winnipeg and 80 feet above its north end, having thus a northward ascent of only 20 feet in a distance of about 275 miles from south-southeast to north-northwest. Here, too, as in the earlier uplifting of the large region on the south, the upward movement of the earth's crust was interrupted by stages of repose or of only very slow progress, affording time for the accumulation of beach gravel and sand; and these recognized shore marks are most numerous northward, where the extent of the uplift was greatest. The Emerado beach thus seems to be represented in Mr. Tyrrell's observations by two beaches on

¹Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, Vol. III, for 1887-88, Part E, 16 pages, with map. Bulletin, G. S. A., Vol. I, 1890, pp. 395-410. Am. Geologist, Vol. VIII, pp. 19-28, July, 1891.

Kettle Hill, near the south side of Swan Lake, separated by a vertical interval of 20 feet; and the Niverville beach is subdivided into three at the Grand Rapids of the Saskatchewan. Instead of the eleven or twelve shore-lines observed by me in the United States and in southern Manitoba, belonging to the time of northeastward outflow, Mr. Tyrrell therefore has at least fourteen upon the country 150 to 200 miles farther north.

From the following detailed descriptions of the beach deposits of these lower shores it will be seen that their magnitude and the distinctness of their development are very similar to those of the earlier and higher shores formed during the stages of southern outflow. It should be noted, however, that on account of the favorable surface of the lake bed in North Dakota, consisting in large part of gently sloping till, they are more generally traceable there than on the Minnesota side of the Red River Valley, where some extensive tracts, having mostly a surface of silt with smaller areas of till, were traversed and cursorily examined without detecting distinct shore-lines. If they should be more thoroughly searched for on these tracts, with leveling along their known height, as shown by their nearest beaches observed elsewhere, doubtless some evidences of shore erosion or deposition would be found almost continuous, though their character and significance might not be otherwise recognizable with certainty; but it has been impracticable to give the time for field work that would be required to survey and map in this manner the exact course of these shores through their whole extent. It is believed that the portions which have been mapped with leveling, shown mostly on Pls. XXIII to XXXIII, inserted in Chapter VI, are sufficient to show reliably the successive stages in the concurrent uplifting of the land and subsidence of the lake.

BEACHES OF THE BLANCHARD STAGES.

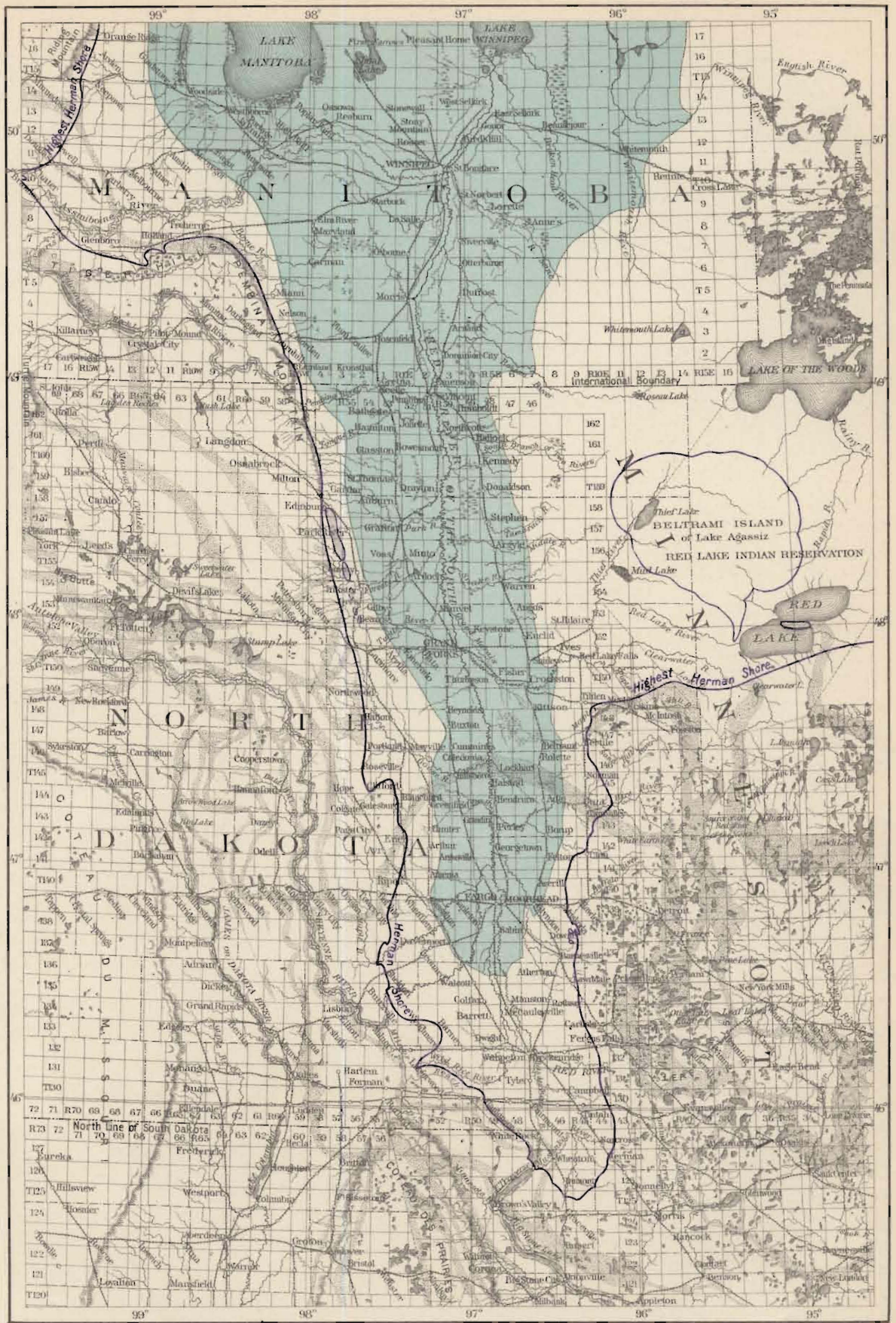
Three successive levels of Lake Agassiz, or pauses in the crustal uplift while the lake shore passed near Blanchard, N. Dak., seem to be indicated by sand and gravel deposits which are crossed by the Duluth and Manitoba Railroad 5 to 7 miles southeast of Euclid, Minn., and by the Manitoba and Northwestern Railway near Midway station, Manitoba. The lowest of these, however, has most definitely the form of a beach ridge, and the

stage of the lake to which it belongs, mapped on Pl. XXXV, is the only one of the three which is generally marked plainly by a shore-line in Minnesota and North Dakota.

With the description of the Blanchard beaches in Minnesota, closely associated portions of the next lower or Hillsboro beach are also described near Glyndon and from 5 to 15 miles north of Crookston.

The principal and lowest Blanchard shore, having a height of about 925 feet, crosses the Red River close to Wolverton station, on the Great Northern Railway, almost exactly halfway between Wahpeton and Moorhead. Passing northward into Clay County, this shore is marked by a belt of gravel and sand thinly spread upon a broad, gently rising swell of till which is known as Pleasant Ridge, traceable in a nearly due-north course about 15 miles through the west parts of Alliance, Elmwood, and Glyndon townships. The South Branch of the Buffalo River flows nearly parallel with it, at a distance of a half mile to 1 mile farther east. Shore currents, carrying southward much of the gravel and sand derived from the shallow wave erosion of the till along the northern part of the ridge, deposited it in a rounded and partly almost flat tract a half mile to three-fourths of a mile wide in the northwest part of Alliance, having a height of 925 to 935 feet above the sea. Through Elmwood and Glyndon the beach deposits are narrow and scanty, lying on the western slope of Pleasant Ridge and along its crest. At Sabin they are bounded on the west by a typical beach slope, with its top at 930 feet, from which there is a descent of about 10 feet westward within 40 or 50 rods. In Glyndon the crest of the ridge is in part a sand and gravel beach, extending north through the centers of sections 32, 29, 20, and 17, declining slowly in height from 927 feet at the south to 922 feet at the north. Where the continuation of this line crosses the Northern Pacific Railroad the surface was a few feet below the Blanchard level of Lake Agassiz, and no beach was accumulated.

A few miles south of this railroad a scanty lower beach deposit was noted in sections 30 and 19, Glyndon, three-fourths of a mile west of the preceding, with its crest at 919 to 921 feet. This represents the Hillsboro stage of the lake, and, indeed, the formation of the main beach in this township, as just described, seems referable to the time of recession of the lake between the lower Blanchard and Hillsboro stages.



MAP OF THE SOUTHERN PORTION OF LAKE AGASSIZ, SHOWING ITS EXTENT IN THE LOWER BLANCHARD STAGE.

Scale, about 42 miles to an inch.

From Glyndon to the vicinity of Crookston the Blanchard shore is mapped approximately in accordance with the known elevations and slope of the land, but its beaches have not been examined.

About 5 miles northeast of Crookston, in the southern edge of section 3 and of the southwest quarter of section 2 in this township, a portion of the Hillsboro shore-line extending a mile from east to west bears a well-defined, rather wide beach ridge, which rises 5 to 15 feet above the adjoining surface of till, with crest mostly 936 to 940 feet above the sea. S. M. McKee's house is built on an exceptionally high part of this beach, at the elevation of 944 feet, the thickness of its sand and gravel there being 20 feet.

One and a half miles northeast from this beach deposit the lowest Blanchard shore in Parnell, the next township northward, bears a scarcely higher beach ridge of gravel and sand, which rises 5 to 10 feet above the adjacent till and extends northwestward across section 35, having an elevation at its crest of 935 to 940 feet. Thence the Blanchard shore runs due north or a few degrees west of north through Parnell and the next two townships. It is marked along the greater part of this distance of 18 miles by a definite beach ridge which varies in height from 938 to 946 feet. A half mile to a quarter of a mile west from this beach a lower and smaller gravel and sand ridge on the northward continuation of the Hillsboro shore, with crest at 930 to 932 feet, was observed along a distance of about 4 miles, passing nearly through the center of section 4, Parnell, and sections 33, 28, and 21, Belgium.

The profile of the Duluth and Manitoba Railroad on the south line of sections 35 and 34, Belgium, shows beach ridges of three Blanchard stages, with their crests at 962 feet, 954 feet, and 946 feet, in their order from east to west. Again, about 8 miles farther north two or three small beach ridges of gravel and sand, lying on the surface of till and separated by successive intervals of about a mile, were noted between the lower Blanchard and McCauleyville beaches. The Blanchard shore-lines on the east side of Lake Agassiz have not been traced farther northward, but they are known to lie close west of the McCauleyville shore in its north-northwestward course across Marshall and Kittson counties, Minn., to the international boundary.

In North Dakota the lowest Blanchard shore runs northwestward from the Red River for its first 35 miles, passing close west of Davenport and close east of Everest and Casselton, but it is not easily traceable across this area of lacustrine silt associated with the Sheyenne delta. Next it extends north about 40 miles, running a few miles east of Amenia, Arthur, and Hunter, and about $1\frac{1}{2}$ miles east of Greenfield and Blanchard. The height of this shore in the distance of 75 miles from the Red River to Blanchard, ascends from 925 to 935 feet, approximately, above the sea-level. It crosses the Goose River about 8 miles north of Blanchard, and thence runs several miles northeastward, beyond which it curves to the north, passing about 3 miles west of Cummings and 1 mile west of Buxton, where it is marked by a prominent beach ridge, with crest at 945 feet, very nearly. This gravel and sand ridge runs thence at least 15 miles northwestward. Near the southwest corner of section 7, Michigan, about 11 miles northwest from Buxton, its crest has an elevation of 942 to 945 feet. It there lies nearly 4 miles east of the principal McCauleyville beach, but within a few miles farther northwest the distance between them is diminished to less than 2 miles. Thence they continue close together and nearly parallel through their whole extent of about 80 miles northward in North Dakota; but this part of the Blanchard shore has not been followed with leveling.

The shores formed during the middle and upper Blanchard stages of Lake Agassiz have not been traced in North Dakota. Their elevations determined in Minnesota and Manitoba, however, indicate that Greenfield and Blanchard are situated on the middle shore or very near it. A single observation of the upper shore, which passes about 2 miles west of Blanchard, was obtained 7 miles farther north. It there is marked by a low escarpment of till, which descends 3 or 4 feet from west to east, between 965 and 960 feet, along a south-to-north line that is crossed by the railway about a mile north of Murray station.

On the international boundary the Blanchard shore-lines enter Manitoba in the west part of township 1, range 4, passing near Kronsfield, in section 7 of this township, and extending north-northwest within about a mile east of Morden; but they are not marked along this distance by distinct beach deposits or lines of erosion. The lowest of these shore-lines crosses

the Canadian Pacific Railway a mile west of McGregor, where it forms a slight swell on the gentle eastward slope of the Assiniboine delta. On the Manitoba and Northwestern Railway three Blanchard beaches appear to be identifiable, being crossed successively 2 miles and three-fourths of a mile west and 1 mile east of Midway. The upper two are nearly flat tracts of fine gravel and sand, an eighth to a quarter of a mile wide, at 994 and 979 feet above the sea, each being bordered on the west by a depression of about 2 feet and on the east by a gentle slope descending 4 or 5 feet. The third and lowest is a beach ridge of the usual form, about 30 rods wide, with a descent of 5 feet both to the east and west from its crest, which is at 969 feet. After crossing the McCauleyville beaches on the way from Arden to Gladstone the surface is wholly silt and sand, with fine gravel, very flat, excepting these slight ridges and others at lower levels. In their continuation northward, portions of the Blanchard beaches are noted on the plats of the Dominion Land Surveys through townships 15 to 20, range 13.

The highest of the Blanchard shores is probably represented on Mr. Tyrrell's map of the Riding and Duck mountains by two observations of beach ridges, namely, on the Ochre River, about 8 miles south of Lake Dauphin, at 1,025 feet above the sea; and on latitude 52° , close south of the Duck River, at 1,151 feet. A few miles north of the Duck River the second Blanchard beach, according to my correlation, is shown at the height of 1,135 feet; and the third and lowest beach formed during these stages appears to be represented on the north side of Swan River, nearly 25 miles farther west, by a beach approximately at 1,070 feet, being 100 feet higher than near Midway, on the latitude of Gladstone, about 160 miles distant to the south-southeast.

THE HILLSBORO BEACH.

My only observations of the shore-line in Minnesota which seems referable to the Hillsboro stage of Lake Agassiz, excepting as already noted with the descriptions of the Blanchard beaches, were in Alma and Wanger townships, Marshall County.

A somewhat broad beach ridge, 915 to 923 feet above the sea, consisting of gravel and sand on an area of till, extends from a cemetery in the

northeast corner of section 26, Alma, northward through the east edge of sections 23 and 14 to the Middle River. This deposit, however, is about 15 feet lower than would seem accordant with the Hillsboro beach 5 to 15 miles north of Crookston and on the opposite side of the lake in North Dakota, while yet it is distinct from the next lower Emerado beach, which was observed at its normal elevation a mile distant to the west. The low position of the Hillsboro beach here may be due to its subdivision in advancing from south to north, this beach being referable to a secondary Hillsboro stage; otherwise it would imply a noteworthy and very exceptional irregularity in the crustal uplift.

Probably the same Hillsboro shore continues north through the distance of 6 miles to another beach ridge noted on the Tamarack River, in or near the west edge of sections 13 and 12, Wanger. A search with leveling to the south and north from these localities would quite surely prove this shore to be traceable through long distances on the east side of the lake.

The elevation of the Hillsboro shore where it crosses the Red River, near Holy Cross and Hickson stations, about 15 miles south of Moorhead and Fargo, is approximately 915 feet. Thence its course in North Dakota is first northwestward about 20 miles, passing by Horace, to Durbin, on the Maple River. It here lies on an area of fine silt, and is not distinctly marked either by a beach ridge or by erosion.

Along the northwest and north side of the Maple River, at an average distance from it decreasing from 2 miles to 1 mile, a prolonged beach of sand and fine silt (mapped on Pl. XXVIII) was formed by erosion from the margin of the Sheyenne delta and from the adjoining lake bed, and by transportation toward the northeast and east, being thus built out into the lake as a spit, during the Blanchard and Hillsboro stages. This spit, which is sometimes called the Maple Ridge from its parallelism with the Maple River, is crossed by the Great Northern Railway 2 miles northwest of Durbin. It is there a wave-like, massive swell about 50 rods wide, rising 10 feet above the flat expanse on each side, with its top 930 feet above the sea, showing that this portion was formed during the time of the Blanchard beach. Six miles to the northeast, where it is crossed by the Northern Pacific Railroad at Greene, it has a width of 60 rods, with its crest at 919

feet, from which its eastern slope descends 10 feet and its western slope about 5 feet. This part of the Maple Ridge was accumulated by Lake Agassiz at the stage of the Hillsboro beach, rising then only 2 or 3 feet above the level of the lake. Following the ridge onward 9 miles farther to the northeast and east, it is found to become broader and less definite, and its height sinks slowly about 20 feet to 900 or 895 feet in the south edge of section 13, Raymond, about a quarter of a mile north of the Maple River, where it ceases to be traceable even as a slight swell above the general level of the surrounding expanse of lacustrine and alluvial silt. Shore currents appear to have come together from both the north and south along this curved spit while the Blanchard and Hillsboro beaches were being accumulated and during the fall of the lake surface below each of these stages.

From the vicinity of Greene the Hillsboro shore-line runs northward 50 miles, passing about 3 miles west of Grandin and Kelso, $1\frac{1}{2}$ miles west of Hillsboro, about three-fourths of a mile east of Cummings, and 1 mile west of Buxton. Opposite to Grandin and Kelso it is marked by a typical gravel and sand ridge, with slopes descending 10 feet on the east and 5 or 6 feet on the west to the adjoining surface of till. Mr. R. T. Kingman's house, west of Hillsboro and close south of the Goose River, is built on the crest of the Hillsboro beach ridge of gravel and sand, at an elevation of about 920 feet above the sea. The slopes of this beach fall about 15 feet toward the east and 5 feet westward. Within a quarter of a mile farther west, an escarpment of till rises 10 feet, from 915 to 925 feet, approximately, having been cut by the waves of the lake when it stood a few feet above its later level by which the beach ridge was deposited. One and a half miles south of Mr. Kingman's the Hillsboro shore has no beach deposit, being indicated only by an escarpment of till which rises 6 to 10 feet within a distance of 15 to 20 rods from east to west.

A slightly higher shore-line, marked by an escarpment 6 to 8 feet high, eroded in fine silt, was observed a mile west of each of these localities, being thus traced about 2 miles southward from the Goose River.

Three pauses in the crustal uplift are thus shown near Hillsboro by the former levels of Lake Agassiz, approximately at 925 or 928 feet, 920

feet, and 915 feet, represented successively by the western escarpment of silt, the eastern escarpment of till, and the shore deposit of sand and gravel at Mr. Kingman's house. Elsewhere these stages seem to be united, unless the lower one was also observed, as before noted, in Marshall County, Minn.

Where it is crossed by the Great Northern Railway, 2 miles south of Cummings, the Hillsboro shore is an eroded escarpment of till, ascending somewhat steeply 8 or 10 feet, with no considerable beach deposits. Continuing thence on the east side of the railway for 12 miles northward by Cummings and Buxton, it is marked through nearly the entire distance by a conspicuous beach ridge of gravel and sand, bordered on each side by till. The crest of this beach is 925 to 930 feet above the sea, with an average descent of 10 feet to the east and 5 feet to the west. At its next intersection by the railway, $1\frac{1}{2}$ miles south of Reynolds, the gravel and sand of the beach have been extensively excavated for railway ballast. The ridge there is about 30 rods wide; the elevation of its crest is 928 feet, and its slopes to the northeast and northwest fall respectively about 8 and 6 feet.

Through its further course of about 100 miles in North Dakota this shore-line runs to the northwest and north-northwest, excepting that it deviates to a north-northeastward course for 15 miles, between the North Branch of Park River and Tongue River, turning thus aside to pass by the Pembina delta. In section 27, Michigan, about 3 miles northwest of Reynolds, the crest of its beach ridge is 926 feet above the sea, having a descent of 6 feet eastward and 3 feet westward. In section 16 of this township the beach is a broad, flattened ridge of sand and fine gravel, about 40 rods wide, with top at 923 to 926 feet. It slowly rises 10 feet above the flat surface of till on the east, and descends 3 to 5 feet westward to a depression which is partly a grassy slough mown for hay. Through its next mile northwestward the shore is an escarpment of till, rising a few feet, with its crest at 923 feet.

No exact determination of the height of the Hillsboro shore was obtained along its next 25 miles to the southeast part of section 25, township 153, range 54, about 2 miles west of Beans station, on the Duluth and Manitoba Railroad, where the crest of its gravel and sand ridge is very nearly 930 feet above the sea. Again, about 20 miles farther north the beach ridge

of this shore has the same height, or 930 to 935 feet, in sections 25, 24, and 13, Rushford. Thence through an extent of about 50 miles to the international boundary, although the course of the Hillsboro shore is mapped approximately on Pl. XXX, its height is known by leveling in only one place, near the center of section 15, Walhalla, about $2\frac{1}{2}$ miles northeast of Walhalla village, where the top of the beach is 940 feet above the sea, rising 15 feet above its base 20 rods distant to the east and bordered by a depression of 2 to 5 feet on the west.

The Hillsboro beach enters Manitoba near the middle of the south side of range 4 and passes north-northwestward. It is not conspicuous on the international boundary, but near the west line of section 21, township 1, range 4, about a mile east of Blumenfeld, it is a noticeable ridge, with a descent of 3 to 5 feet on the east, its crest being about 940 feet above the sea. Its sand has there been excavated for use in plastering. Northward it passes about a half mile east of Oesterwick, $1\frac{1}{2}$ miles east of Morden, and nearly 4 miles east of Miami, where Henry York's house is built on its crest, at an elevation of about 950 feet. Thence its slopes descend 15 feet in a short distance to the east and 5 feet or more to the west, the beach being much larger than along most of its course. Mr. York's cellar and well are in sand and fine gravel, but the lower land adjoining on each side is till. Twelve miles farther north this beach passes near Mr. Field's house, in the southeast quarter of section 4, township 7, range 6, about three-fourths of a mile west of Almasippi post-office. The road from Carman to Treherne there ascends a few feet, and in its next third of a mile northwestward crosses a tract of sand with hollows 3 to 5 feet below its highest portions, showing that it was formerly wind-blown. This beach deposit is derived from the erosion of the eastern margin of the Assiniboine delta, within a few miles to the north. On the road from Arden to Gladstone this beach was not noticed, but it seems to be traceable on the township plats northward nearly through the middle of townships 15, 16, and 17, and through the west part of townships 18, 19, and 20, in range 12.

On the Swan River and its tributaries, north of Duck Mountain, the Hillsboro beach, according to my correlation of Mr. Tyrrell's observations, has been traced fragmentarily along a distance of 20 miles from east to

west, having an elevation of about 1,030 feet above the sea; and it was again noted at the height of 1,070 feet some 30 miles farther northeast, on Kettle Hill, close south of Swan Lake.

BEACHES OF THE EMERADO STAGES.

The Emerado shore-line, approximately 885 feet above the sea, crosses the Red River between Kragnes, Minn., and Harwood, N. Dak., a few miles north of Moorhead and Fargo; but its course has not been traced for the first 50 miles thence northward to the vicinity of Crookston, Minn., and Reynolds, N. Dak. Through both of these States it appears as a single shore-line, and is perhaps the one most clearly traceable of all that belong to the time of northeastward outflow. The crustal uplifting of this part of the lake basin had become very slow at the time of formation of the Emerado beach, but in Manitoba a somewhat rapid uplift was in progress, increasing in amount from south to north, and two beaches there, separated by a vertical interval of 10 to 20 feet, seem to represent the single beach farther south.

In the west part of sections 17, 8, and 5, Crookston, a beach ridge of the Emerado stage was traced 2 miles in a nearly due-north course. Harvey Cook's house, in the south edge of section 8, is built on its top, which ranges in height from 898 to 902 feet above the sea, having a descent of 10 or 12 feet on the west and half as much on the east. About a mile northwest from the north end of this beach irregular and short gravel and sand ridges, accumulated on an area of till, mark this shore on the Great Northern Railway, and extend thence close along its east side 2 miles northward to Shirley, the elevations of their crests being 905 to 910 feet. Portions of these deposits have been excavated for railway ballast.

From 1 to 2 miles north of Shirley the Emerado beach is a typical and continuous gravel ridge, with crest at 910 feet, approximately, rising about 5 feet above the adjoining surface of till. Here and through the next 3 miles northward the shore lies an eighth to a half of a mile east of the railway. It continues in a nearly due-north course through the west edge of Belgium and of township 153, range 46, passing $1\frac{1}{2}$ miles east of

Euclid and 4 miles east of Angus. In the southeast part of Angus Township and the southwest part of township 153, range 46, its beach deposits of gravel are somewhat irregularly accumulated in three belts lying on an area of till and separated by intervals of about 1 mile and a half mile in order from east to west. The crests of these short gravel ridges vary in elevation from 900 to 905 feet, their higher portions being usually 3 to 5 feet above the surface on their east side and 6 to 8 feet above the land next west.

Twelve miles north of Angus a short beach ridge of gravel and sand, having nearly the same height with the foregoing, was noted on the east edge of section 15, McCrea, close south of a creek tributary to the Snake River. Again, 4 to 5 miles farther north, a broad, irregular sand beach, with crest at 905 feet, being 3 to 5 feet above the general level, runs along the east line of section 22, Alma. It reaches a mile or more south from the Middle River, and is a mile west of the Hillsboro beach. Its surface has been somewhat changed into small ridges and hollows by wind action at some former time, but it is now wholly covered by grass. Thence the Emerado shore runs nearly due north through Wanger and Augsburg, townships 157 and 158, range 47, as shown by their contour; but it has not been traced there nor in its farther course, which is slightly west of north through Kittson County to the international boundary.

In North Dakota the Emerado shore-line runs nearly along the Great Northern Railway by Harwood, Argusville, Gardner, and Grandin, and within 1 to $1\frac{1}{2}$ miles east of Kelso, Alton, and Hillsboro; but most of its course is not distinctly traceable on the flat surface of fine silt which is crossed in this distance of 30 miles. Through the next three townships north of Hillsboro, passing Cummings and Buxton, it lies $1\frac{1}{2}$ to 2 miles east of the railway, but approaches within about 1 mile at Reynolds. The Emerado shore here traverses a large area of till, which reaches eastward across the Red River Valley. On this more favorable surface it is doubtless clearly marked, like the next higher Hillsboro shore, by a well-defined beach ridge, or in part by a low, eroded escarpment.

The railway intersects this beach ridge $1\frac{1}{2}$ miles north of Reynolds, its crest being about 900 feet above the sea, with descent of 3 or 4 feet

to the southwest and 8 or 10 feet to the northeast. Thence the Emerado shore runs north-northwesterly 70 miles through Grand Forks and Walsh counties. In sections 20 and 17, Allendale, 9 to 10 miles northwest of Reynolds, it bears an excellent gravel ridge, which rises 10 feet from its northeast base and 3 to 5 feet above the surface on the southwest, the land on both sides being till. The elevation of its crest is 898 to 902 feet.

At Emerado, on the Devils Lake line of the Great Northern Railway, this beach is crossed less than a quarter of a mile east of the station. Its crest is 894 feet above the sea, being 10 feet above the adjacent surface of till on the east; but within the next mile, both to the southeast and northwest, its height is mostly 895 to 900 feet. Two to 3 miles northwest, in section 26, Mekinock, the crest of the beach lies at 897 to 900 feet, with a descent of 5 to 8 feet eastward and half as much toward the west.

In sections 33, 32, and 29, Gilby, the Emerado beach ridge is magnificently developed, passing close west of Beans station, on the Duluth and Manitoba Railroad. The top of the beach has an elevation of 898 to 902 feet, with descents of about 10 feet in 15 or 20 rods east and 3 to 5 feet within 10 rods west to very flat expanses of till on each side. Again, in sections 19 and 18, Gilby, it has the same character and elevation; but in the northwest part of section 7 and on the west line of this township, also thence northward 3 miles into section 25, Strabane, there is no beach deposit, its place being taken by an escarpment of till, 6 to 8 feet high, with its top at 900 to 902 feet. Northward from the northwest part of this section 25, Strabane, the Emerado shore is again marked by the usual ridged deposit of gravel and sand, with its crest very level, varying not more than a foot above or below 901 feet in its extent of about 3 miles to the Forest River.

Entering Walsh County, the crest of this beach ridge in sections 35 and 34, Ops, is still 901 feet above the sea, with descent thence of 6 or 7 feet in 6 rods northeastward and 4 feet in the same distance to the southwest. Through sections 27, 22, 16, 9, and 4, Ops, it also holds very constantly the same character and height, 900 to 902 feet, being a typical ridge of sand and gravel, lying on till. In the east half of section 29,

Prairie Center, its elevation is 903 feet, and it continues as a well-defined gravel ridge, with crest at 901 to 903 feet, through this township, and at a slightly greater height, 902 to 906 feet, through the west part of Fertile and the east part of Dundee, crossing the South and Middle branches of Park River.

In the southern part of Pembina County the Emerado shore curves to a north-northeast course, passing by Crystal to Willow Creek, and thence runs nearly north, crossing the Tongue River about a mile west of Cavalier. Along a distance of 6 miles north from Willow Creek a low and broad secondary beach ridge, or more likely in part an offshore sand deposit that was formed a few feet beneath the lake surface, has an elevation of 890 to 895 feet, with slopes sinking a few feet below this on each side. The adjoining surface is lacustrine silt, deposited in front of the Pembina delta, and the ridge is fine sand which has been somewhat gullied and hummocked by the wind, but is now all grassed.

Between the Tongue and Pembina rivers and onward to the international boundary this beach takes a northwestward course. Turning to that direction about 2 miles northwest of Cavalier, it thence runs nearly straight 10 miles to St. Joseph, being through the greater part of the distance a typical beach ridge of sand, with scanty layers of very fine gravel. Its crest is mainly 892 to 898 feet above the sea, having a gradual ascent from south to north; but as it approaches St. Joseph and the Pembina River its last 2 miles rise to 900 and even 905 feet. The slopes fall commonly 5 to 10 feet northeastward and 2 to 4 feet southwestward. The depth of the beach deposit is the same as the fall of its eastern slope, with hard and dark stratified clay beneath. In section 2, and again in section 13, township 162, range 55, lying 2 to 5 miles southeast of St. Joseph, this beach widens into sandy tracts, each of which has a width of a quarter of a mile or more and is slightly raised, like the typical narrower ridge, above the adjacent surface of clayey lacustrine and alluvial silt.

About a mile north of the Pembina River the Emerado level of Lake Agassiz formed a low escarpment of erosion, which passes north-northwest-erly by the northeast corner of section 17, township 163, range 55. Within

40 rods or less from west to east it descends about 10 feet, from 905 to 895 feet above the sea, approximately.

The Emerado beach crosses the international boundary about $1\frac{1}{2}$ miles east of the west line of range 3, Manitoba, passing thence northwestward. In townships 1 and 2, range 4, the Memmonite villages of Rheinland, Neuenburg, and Rosenthal are partly built on it. At the windmill in Rheinland, and thence along its course as seen for a half mile or more to the south-southeast and north-northwest, this shore is marked by an ascent of 3 to 6 feet in as many rods from east to west; and from its crest, about 905 feet above the sea, the surface extends nearly level westward. The beach consists of loamy sand, while the adjoining land is fine lacustrine silt or clay. On the Canadian Pacific Railway this beach is raised a few feet above the general slope of the Assiniboine delta, passing in a west-northwest course 2 miles east and 1 mile north of Bagot. The Manitoba and Northwestern Railway crosses it 5 miles west of Gladstone, where it is a ridge about 30 rods wide, wind-blown in hollows 1 to 2 feet below the crest, which is 927 to 929 feet above the sea, with descent of 5 feet from it to the west and 12 to 15 feet to the east. A lower and less conspicuous beach ridge, also belonging to this stage, lies three-fourths of a mile farther east, with its crest at 916 feet. The Emerado beach continues north through the east part of townships 15 to 19, range 12, and through the center of township 20, to the east side of Lake Mary.

Two Emerado stages are again noted by Mr. Tyrrell, according to my correlation, at the heights of 1,015 and 995 feet above the sea, as shown by beaches on Kettle Hill, about 150 miles north of Gladstone. The upper beach has an ascent of 95 feet in this distance, and the lower, 85 feet, approximately.

The lower of these shores, which is the more strongly marked on Kettle Hill, is probably also shown by a beach ridge mentioned by Tyrrell near the Pine River, some 40 miles farther south, at a height of 960 feet above the sea, as determined by the original location of the Canadian Pacific Railway.

BEACHES OF THE OJATA STAGES.

The upper Ojata shore-line has an elevation between 870 and 875 feet above the sea where it crosses the Red River near Perley, Minn., and Noble, N. Dak., about 20 miles north of Moorhead and Fargo. Its course in Minnesota has been mapped approximately for 25 miles through Norman County, lying from 2 to 6 miles east of the river, according to the contour shown by the Drainage Survey; but it is not known how much of the shore is there marked by any beach ridge or line of erosion. Probably a considerable part is thus definitely traceable, especially northward, where the surface is till.

After curving eastward, near the boundary between Norman and Polk counties, to a distance of 10 miles from the Red River, this shore turns to the north and north-northwest, crossing the east part of the great marsh which is formed by the waters of the Sand Hill River and of many springs. In the northeastern edge of this marsh it bears a conspicuous beach ridge, which runs from near the center of section 10, township 147, range 47, 6 miles to the north side of section 18, Hammond. The crest of the dry ridge of sand and gravel is 873 to 878 feet above the sea, and the surface of the marsh adjoining it is about 3 feet lower on the east and 5 feet lower on the west.

About 2 miles northwest from Crookston a large beach deposit of gravel and sand on this shore-line is crossed by the Great Northern Railway in sections 24 and 23, Lowell, and has been much excavated for railway ballast. The elevation of its crest is 880 to 882 feet, and its thickness is 3 to 5 feet, lying on till. The pebbles of the gravel seldom exceed 3 inches in diameter, and are mostly magnesian limestone, similar to the strata which outcrop near Winnipeg.

The Drainage Survey shows that the farther course of this shore is nearly due north for the next 40 miles, passing about 2 miles west of Shirley, a mile west of Euclid, $1\frac{1}{2}$ miles east of Angus, about 3 miles east of Warren, and 5 miles east of Argyle. Through the greater part of this extent it lies on or near the western edge of the till, which is succeeded toward the Red River by lacustrine and alluvial silt. In a few places the

shore is known to be indicated by erosion or by gravel and sand deposits, but more commonly it is not clearly traceable. It thence runs slightly west of north to the international boundary, but has not been examined along that distance of nearly 50 miles.

Lying about 10 feet below the preceding, the lower Ojata shore crosses the Red River near Caledonia and the mouths of the Goose and Marsh rivers, being there about 865 feet above the sea. From 5 to 12 miles northward in Minnesota it runs along the west margin of the great marsh of the Sand Hill River. Onward through this State it must lie mostly 1 to 2 miles west of the upper Ojata beach, though generally it is indistinct and its course has been nowhere exactly noted.

Portions of the Ojata beaches in North Dakota have come under my observation from the vicinity of Reynolds and Thompson north-northwestward across Grand Forks and Walsh counties. The upper shore is not clearly exhibited where it is crossed by the Great Northern Railway, about 2 miles south of Thompson, but the lower shore is marked by a beach ridge of gravel and sand, which is crossed 1 mile north of this station. The crest is about 868 feet above the sea, with descent of 6 to 8 feet from it toward the northeast and 2 or 3 feet southwestward.

On the south line of section 36, Oakville, and of section 31, Brenna, 7 to 8 miles northwest from Thompson and 5 miles south of Ojata,¹ the heights of the crests of the well-developed upper and lower Ojata beaches are respectively about 880 feet and 872 to 875 feet. One to 2 miles southeastward, however, these shore-lines have neither beach deposits nor any notable erosion on the smooth, gently sloping surface of till.

The Great Northern Railway between Emerado and Ojata intersects the crest of the upper Ojata shore-line a quarter of a mile west of the northeast corner of section 8, Oakville, about 3 miles west of Ojata. It consists of a somewhat prominent escarpment of till, which falls from west to east at first 7 or 8 feet within 15 or 20 rods, and as much more within the next third of a mile, its base being 862 to 865 feet above the sea, whence

¹ Meaning *forks* in the Dakota or Sioux language, and referring, like Grand Forks, to the junction of the Red and Red Lake rivers (A. W. Williamson, in Thirteenth Annual Report, Geol. and Nat. Hist. Survey of Minnesota, for 1884, p. 110).

a very flat and almost level surface of till, with alkaline soil, extends eastward. The top of the escarpment is capped to the depth of a few feet with beach gravel and sand, at 877 and 880 feet, deposited during the upper Ojata stage of the lake, and the erosion of the steep slope below may have been accomplished mostly during a lower and later portion of this stage. A better interpretation, however, seems to be found in attributing the upper gravel to the highest fluctuation of the lake when raised several feet by the rapid glacial melting in the summer, the till below having been cut away by the reduced water level in the winters, when it was lashed into powerful waves by storms.

But a large share of the erosion of the less steep lower slope was done by the lake during the lower Ojata stage. In the latest and lowest portion of that stage there was also formed a discontinuous beach ridge of gravel and sand, which lies in isolated, irregular accumulations a half mile east of the escarpment, and rises 6 to 8 feet above the flat expanse on each side, with crests at 870 feet, approximately. This fragmentary beach divides a tract of till on the west which has suffered much erosion of its surface, being therefore strewn with frequent or abundant boulders, from another tract on the east, where the upper part of the till to the depth of 5 to 10 feet or more, still lying as it was deposited in Lake Agassiz, bears marks of imperfect stratification, and has fewer boulders and less gravel on the surface than at a slight depth. Within 10 to 15 feet beneath the surface, as shown by wells and the ravines of streams in the neighborhood of Ojata, the lacustrinely modified till, which was englacial, is succeeded below by the wholly unstratified ground moraine. It is also to be noted that a thin layer of lacustrine clayey sand and fine silt, doubtless derived chiefly from the erosion of the escarpment on the west, is spread with a thickness varying from a few inches to a few feet on much of the surface eastward from the lower Ojata beach.

Ten to 15 miles northwest of Ojata the upper one of these two shorelines is well-marked in Gilby by a typical beach ridge of gravel and sand, lying on or near the eastern limit of the till, beyond which lacustrine and alluvial silt stretch east to the Red River. Mr. John Gilby's house, in the southwest quarter of section 22, is built on the gravel beach, which thence

runs north-northwestward through the middle of section 9, a half mile east of Gilby station, on the Duluth and Manitoba Railroad. The lower Ojata shore lies about a mile farther east, but was not examined. The upper shore extends from section 4, Gilby, into the southwest quarter of section 33, Milan, being there an escarpment 5 feet high, eroded on an area of fine silt. Its base and crest are approximately 870 and 875 feet above the sea. This shore passes about a mile west of Johnstown, and the lower shore lies close east of that railroad station.

A conspicuous beach ridge of gravel and sand, running nearly along the boundary between till on the west and silt on all the country eastward, extends from the west half of section 36, in an almost straight course, a few degrees west of north, 5 miles to the northwest corner of section 2, Ops, having an elevation at its crest of 875 to 880 feet, with descent of 5 to 10 feet east and 2 to 5 feet west. A mile farther east a smaller ridge, about 10 feet lower, marks the second Ojata shore. Through the remaining 50 miles of its course northward to the international boundary the upper shore-line is mapped approximately on Pl. XXX, conforming with the eastward descent of the land surface. It will probably be found easily traceable if followed by leveling.

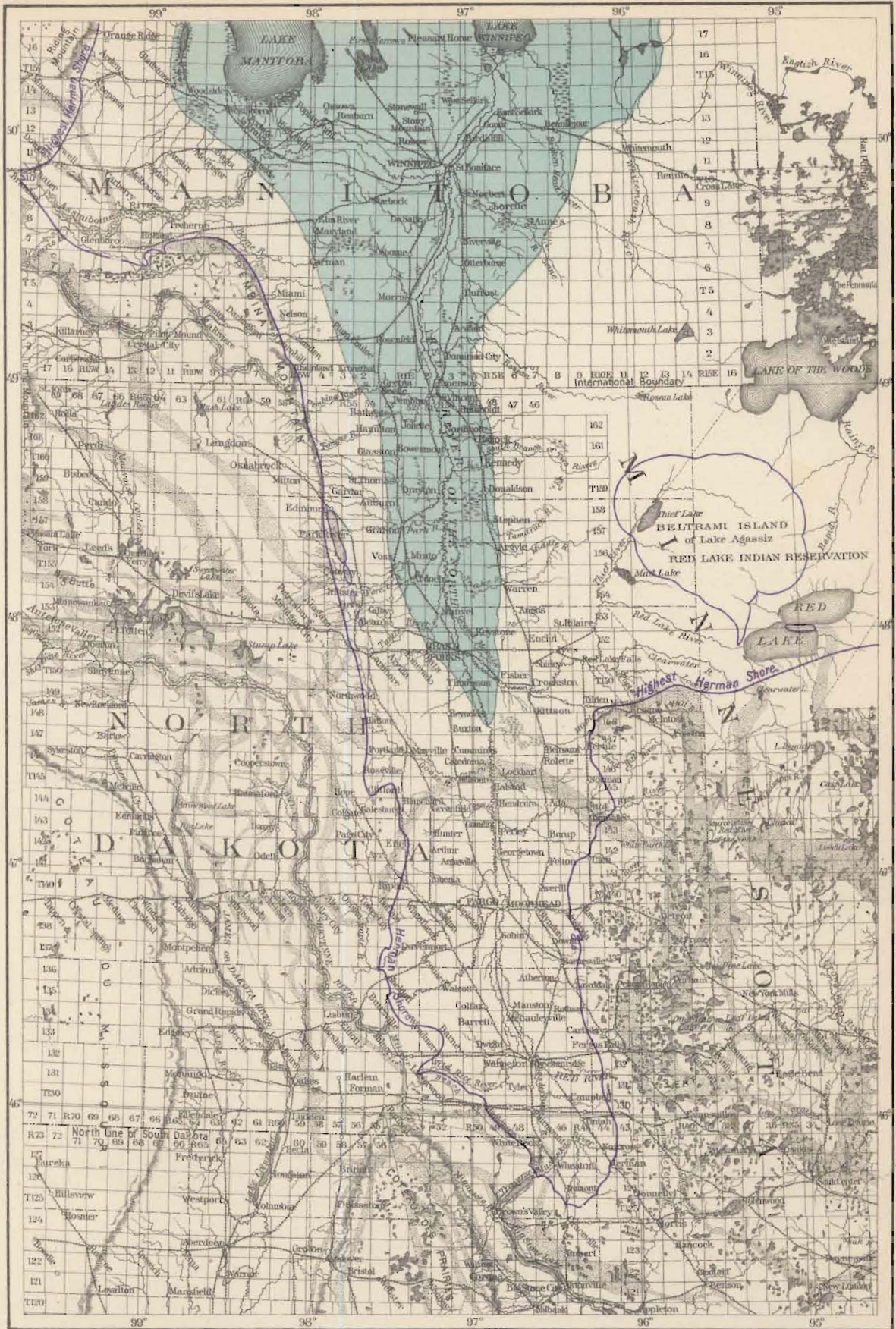
Along the course of the Ojata shores, lying between the Emerado and Gladstone beaches, no ridge of gravel and sand nor line of erosion was observed where they were crossed on the international boundary and elsewhere during my exploration in Manitoba, excepting a slight beach ridge, 3 to 5 feet high, which runs from Pomeroy, in section 19, township 5, range 4, north-northwest through the east part of township 6, range 5, passing about 2 miles west of Carman.

Mr. Tyrrell notes the lower Ojata beach on Kettle Hill, if my correlation is true, at the elevation of 955 feet above the sea.

THE GLADSTONE BEACH.

The extent of the southern part of Lake Agassiz at the time of formation of the Gladstone beach is shown approximately on Pl. XXXVI.

Crossing the Red River near Belmont, N. Dak., about 20 miles south of Grand Forks, at a height approximately 845 feet above the sea, the



JULIUS RIEN & CO. N.Y.

MAP OF THE SOUTHERN PORTION OF LAKE AGASSIZ, SHOWING ITS EXTENT IN THE
 GLADSTONE STAGE.
 Scale, about 42 miles to an inch.

Gladstone shore-line runs northward through Minnesota, mostly at a distance of about 15 miles east of the Red River. It crosses the Red Lake River near the head of the Grand Marais, about a mile northwest of Fisher.

Thence northward for a distance of more than 25 miles to Warren there is frequently found along the contour line of 840 feet a somewhat more rapid descent from east to west than on the adjoining surface of fine clayey silt at each side. This may be due mainly to erosion by the waves of great storms, especially when the lake surface was lowered a few feet on account of the diminished rate of melting of the ice-sheet during winters. In part, however, there appears to have been formed along this course an offshore deposit several feet thick, rising nearly to the lake level. Such a broad ridge, with crest at 838 to 841 feet, runs northward through the center of section 15 and the west half of section 10, Tabor, having a descent of 1 to 3 feet eastward and of 3 to 5 feet westward within a third of a mile from its top. Wells on this swell obtain good water at the depth of 10 to 12 feet, in layers of sand from a quarter of an inch to 1 foot thick, inclosed in the fine stratified silt which, excepting these sandy beds, is almost impervious to water.

In the northern part of Kittson County the old St. Paul trail, lying 12 to 14 miles east of the Red River, ran for 6 miles south-southeastward from the international boundary on and near to the Gladstone beach, whose crest there has a height of 858 to 863 feet above the sea. It is a ridge of gravel and sand 10 to 30 rods wide, resting on till, to which its eastern slope falls 2 to 3 feet and its western slope 5 to 8 feet.

Through North Dakota the Gladstone shore has been mapped approximately, passing from Belmont north-northwesterly by Merrifield, Kelleys, and Voss, lying about 4 miles west of Grafton, 2 to 3 miles west of Auburn, St. Thomas, and Glasston, about 4 miles west of Hamilton and Bathgate, and 5 miles west of Neche. In this distance of 100 miles the shore rises from 845 to 857 feet, approximately, above the sea. Only small portions of its course have been examined, these near Merrifield and 2 miles east of Ojata being marked by slight erosion in the lacustrine and alluvial silt over which it asses.

On the international boundary and for several miles thence to the north-northwest the Gladstone beach is a prominent ridge, having an ascent of 10 to 15 feet in a distance of 30 to 50 rods west from its base to its crest, which is approximately 860 feet above the sea. The slightly undulating surface of this shore deposit occupies a width of a quarter of a mile or more, and thence westward there is no noteworthy descent, but a nearly level expanse. In many shallow pits dug to obtain sand for masons' use the material of the beach is shown to be fine sand, unmixed with gravel, excepting that very rarely a pebble is found inclosed in it, the largest being a half to two-thirds of an inch in diameter. This ridge enters Manitoba about $1\frac{1}{2}$ miles west of Blumenort, and crosses sections 5, 7, and 18, township 1, range 2, to Kronsthal, which is situated upon it. Northward it passes about a mile west of Lowestoft post-office and a mile east of Carman. George Anderson's house is built on its crest in the northeast quarter of section 31, township 6, range 4, 2 miles north-northeast of Carman, at an elevation of 865 feet. It crosses the Canadian Pacific Railway near the Rat Creek bridge, and is well developed along a distance of several miles thence to the northwest, passing through the southeast corner of section 12, township 12, range 9, where the elevation of its crest is about 875 feet, with a descent of 4 to 6 feet to the northeast and 1 to 3 feet to the southwest. Thence its course is along the southwest side of the Squirrel Creek marsh and east of the chain of Dead Lakes (a former channel of the White Mud River), which lie in sections 17, 18, and 19, township 14, range 11. A half mile east of Gladstone this shore is marked by a line of erosion in the expanse of lacustrine silt, with slope from 882 to 875 feet in a short distance, and by a small beach ridge of sand with its crest at 878 feet. Continuing almost due north, this Gladstone shore-line, occasionally marked by beach gravel and sand, lies a half mile to 1 mile west of the Big Grass Marsh, through townships 15, 16, and 17, range 11, the elevation of the marsh being, approximately, 865 feet, and of Lake Agassiz here during this stage about 875 feet above the present sea-level.

The Gladstone beach is noted by Mr. Tyrrell on Kettle Hill at 920 feet. Combined differential uplifting of the land and depression of the

geoid surface of level, both due to removal of the ice-sheet, have amounted to about 45 feet in the distance of 150 miles northward from Gladstone to this locality.

THE BURNSIDE BEACH.

From its crossing of the Red River at Grand Forks the Burnside shore in Minnesota runs northeastward to the southwest corner of Tabor Township, and thence northward at a distance of 10 to 13 miles from the river for about 70 miles to the south line of Manitoba. Although its course is known approximately by the Drainage Survey and by railway leveling, no portions of it distinctly showing marks of erosion or beach accumulation have been observed in this State excepting close upon the international boundary. There it is found at "the Ridge," about 11 miles east of the Red River and Emerson, which is a low, eroded escarpment extending from south to north across the boundary. It consists of till with frequent boulders, nearly all Archean granites, gneiss, and schists. A deposit of beach gravel and sand a few feet deep rests on the base of this slope, 835 to 840 feet above the sea.

Two miles northward, in the southwest quarter of section 15, township 1, range 4 east, Manitoba, the Burnside beach is a typical gravel and sand ridge 20 to 25 rods wide; its crest is 845 feet above the sea, and the descent from it to the east is about 3 feet and to the west 6 or 7 feet. About a mile farther north, near the southeast corner of section 21, the elevation of this beach ridge is 844 feet, with a descent of 1 or 2 feet on the east and 10 feet within 20 rods on the west. Another mile to the north its elevation is 846 feet, with 2 feet descent east and 6 feet west in 6 rods; next a surface of till, with many boulders, falls about 5 feet in 40 rods to the west; beyond this a tract of gravel and sand continues with the same slope, falling from 835 to 830 feet, and is succeeded farther west by a slowly descending surface of till. The beach ridge continues with similar features through the east half of section 28, excepting a short distance in the southeast quarter of this section, where it is replaced by a line of erosion in the very rocky till. Through the next 3 miles the uneven contour causes the beach ridge to be somewhat irregular in its course and size; but it again attains its typical development in section 9, township 2, range

4 east, where it was excavated several years ago along a distance of a third of a mile for railway ballast, a branch track nearly 8 miles long being laid for its transportation to Dominion City. The crest of the beach at Charles Aime's house, near the north end of this excavation, is 846 to 847 feet above the sea, with a descent of 2 to 5 feet on the east and 6 to 8 feet in 8 to 12 rods west. Its width, including both slopes, is 15 to 30 rods, and the maximum depth of the gravel and sand deposit is about 8 feet, lying on till. The coarser portions of the gravel contain pebbles up to 3 inches or rarely 6 inches or more in diameter. Nine-tenths or a larger proportion of them are magnesian limestone, the remainder being almost wholly Archean granite and gneiss. This shore-line continues north and north-northeast by Green Ridge post-office and through the east part of townships 3 and 4, range 4 east, beyond which it has not been traced.

In North Dakota the course of the Burnside shore is known somewhat nearly and has been drawn provisionally on Pls. XXIX and XXX, in accordance with the elevations ascertained by railway surveys; but, as in Minnesota, no part of it has been observed to be clearly traceable by either a continuous beach ridge or an eroded escarpment. It lies on the wide, flat tract of silt which adjoins the Red River, a surface most unfavorable for the preservation of definite shore-lines; yet undoubtedly it can be found and followed by careful search with leveling.

A few feet below the average Burnside level of Lake Agassiz marks of wave action, perhaps belonging to the lowest fluctuations of the lake in this stage, are somewhat indistinctly exhibited by an irregularly ridged contour which was seen near Schurmeier and along the east side of the railway thence northwestward to Manvel, also in the west edge of Manvel village. These swells, extending parallel with the railway, rise 2 to 3 feet above the depressions on either side, their crests being 820 to 825 feet above the sea. Proceeding northwest along the railway, which holds a nearly level grade, no further noteworthy observations of this kind were obtained for the next 12 miles to Ardoch, where again a beach-like swell or very low ridge, 2 to 3 feet high and having a width of 30 rods or more, with crest at 826 to 827 feet, runs from south to north across the railway about an eighth of a mile north of the station.

This western Burnside shore enters Manitoba near Blumenort, 19 miles west of the Red River, but it is not distinctly marked on the international boundary. Passing northward about a mile east of Lowestoft and 3 miles east of Carman, it crosses the Carman Branch of the Manitoba and Southwestern Railway at Maryland, where the elevation of the crest of its beach ridge is 844 feet. About a mile north-northwest of Maryland this ridge has been extensively excavated, its gravel and sand being used for railway ballast. One and a half miles farther north it crosses the main line of this railway about a mile west of Elm Creek station (the junction of the branch), its crest there being at 845 feet, from which its slopes fall 10 feet in 25 rods east and 7 feet in an equal distance west.

The Canadian Pacific Railway crosses this shore about halfway between Portage la Prairie and Burnside, and in the next 10 miles of its course, passing northwest nearly through the center of township 12, range 8, it is marked by a large gravel ridge, the crest of which, in the south part of section 11, $1\frac{1}{2}$ to 2 miles north of Burnside, has an elevation of 858 to 860 feet, with descent from it of 6 to 10 feet northeastward and half as much to the southwest. This beach is similarly prominent on the Manitoba and Northwestern Railway, by which it is crossed and excavated for ballast halfway between Westbourne and Woodside, its crest there being 860 to 862 feet above the sea. Along the next 40 miles the Burnside shore-line is generally marked by a well-developed beach ridge which is traceable on the plats of the Dominion Land Surveys parallel with the west shore of Lake Manitoba and 4 to 5 miles distant from it, passing about halfway between the lake and the Big Grass Marsh. It thus lies near the line between ranges 9 and 10 as far north as to the east side of the lake in sections 13 and 24, township 18, range 10, beyond which it runs north-northwest.

Between the south ends of Lakes Manitoba and Winnipeg the country about Shoal Lake was uncovered by the fall of Lake Agassiz from the Gladstone to the Burnside beach, which latter is crossed by the Winnipeg and Hudson Bay Railway near the southwest corner of section 36, township 14, range 2, about 3 miles south of Shoal Lake. The crest of the beach is 860 feet above the sea, being 10 feet above Shoal Lake. Here its

course is from west to east along the verge of a nearly level expanse of till reaching to the lake, to which its drainage is tributary. Two or 3 miles farther east, where the road to Stonewall and Winnipeg crosses this beach, it has a descent of 20 feet in 30 or 40 rods south from its crest, the whole slope being gravel and sand, the combined shore deposits of the Burnside and Ossowa stages of Lake Agassiz. Westward the beaches of these stages are separated by a width of 1 to 2 miles, the Burnside beach running southwest and west through the south half of township 14, range 3. Near the west side of this township it curves northward, and thence passes north and north-northwest between Shoal and Manitoba lakes. East of the road before mentioned the course of this beach is northeastward across township 15, range 1 east, and township 16, range 2 east, to Pleasant Home post-office. Numerous short beach ridges noted on the township plats northwest of this beach, between it and Shoal Lake, were probably formed during the Gladstone stage of Lake Agassiz where the highest parts of that area rose above its level.

Passing over the eastern Mossy portage from Lake Winnipegosis to Cedar Lake, on the Saskatchewan, Mr. Tyrrell found that the highest land crossed is a gravel ridge with crest 921 feet above the sea, being 93 feet above the first of these lakes. It probably is a beach belonging to a level of Lake Agassiz near 910 feet, the same stage that formed the Burnside shore-line farther south. This locality is about 70 miles northeast of Kettle Hill, and the continuation of the Gladstone beach with the gradient which it has from Gladstone to Kettle Hill would carry it at Mossy portage 35 or 40 feet above the Burnside level there.

THE OSSOWA BEACH.

Lake Agassiz at the time of the Ossowa beach extended into the United States nearly 60 miles, but the only part of this shore which has been recognized and examined south of the international boundary is an extent of a few miles in Pembina County, N. Dak. In sections 21, 16, and 17, township 162, range 52, close south of the Tongue River, at a distance of 4 miles northeast from Hamilton, two or three parallel low,

beach-like ridges were observed, elevated 2 to 4 feet above the intervening hollows and general surface, their height being between 815 and 820 feet above the sea. They run from southeast to northwest, and their continuation north of this river was noted at the same height 4 to 6 miles northwestward in sections 36 and 25, Neche, about $2\frac{1}{2}$ miles east-northeast from Bathgate. Both the ridges and the adjoining surface are fine silt.

Ossowa post-office, from which the shore-line takes its name, is situated near the middle of the north half of section 27, township 13, range 4, Manitoba, on a well-defined beach ridge which runs from west-southwest to east-northeast through this township. Its crest varies in elevation from 843 to 848 feet, with descent of 3 to 8 feet on its north side and 12 to 15 feet on the south. The Canadian Pacific Railway was originally constructed from Stonewall due west to this beach, which it cut through in the east edge of section 28. In the railway cut its material is wholly gravel, in part very coarse, containing pebbles and subangular rock fragments up to 4 inches and rarely 6 or 8 inches in diameter, of which fully nineteen-twentieths are magnesian limestone. On each side the surface is till, with plentiful boulders, mostly Archean granite and gneiss, but including many of this limestone, which is the underlying rock of the region. In the north part of township 13, range 3, this beach curves to the south, east, and northeast, and thence passes through the southeast part of township 14, range 3, and the north half of township 14, range 2, gradually approaching and in some places joining the Burnside beach, with which the Ossowa beach is approximately parallel, lying a half mile to 1 or 2 miles southeast of it onward to Pleasant Home.

The only other locality where a beach referable to this stage was observed is on the top of Stony Mountain, on which a broad, smoothly rounded ridge of gravel and sand extends nearly a quarter of a mile, and is the site of some of the penitentiary buildings. Its crest is about 835 feet above the sea, and the top of the underlying limestone about 825 feet.

The western Ossowa shore-line crosses the international boundary 3 or 4 miles east of Gretna, and the eastern enters Minnesota about three-quarters of a mile west of "the Ridge," but they are not there marked by noteworthy beach deposits nor erosion.

North of Lake Winnipegosis, the Ossowa shore on the ascent of the eastern Mossy portage, as described by Mr. Tyrrell, takes the form of an escarpment, with its crest 63 feet above this lake, or 891 feet above the sea. It was probably eroded by the waves of Lake Agassiz when its surface there was approximately at 875 feet, midway between its Burnside and Stonewall levels at this locality.

THE STONEWALL BEACH.

In the town of Stonewall, Manitoba, the main street crosses a conspicuous beach ridge which runs from south-southwest to north-northeast a third of a mile or more. Its crest is 820 to 825 feet above the sea, and its depth is about 10 feet. Only 2 or 3 feet of till intervene between this gravel and sand and the underlying limestone, which, thinly covered by drift, rises in a swell here about 25 feet above the adjoining country a half mile distant to the east and west. Beach deposits belonging to this stage were not elsewhere observed in southern Manitoba, but they are doubtless traceable from Stonewall northward through the west half of townships 14 and 15, range 2 east. Lake Agassiz, at the time of the Stonewall beach, probably extended on the flat Red River Valley to a distance of about 25 miles south of the international boundary, being some 15 feet deep at Emerson, St. Vincent, and Pembina, while over the site of Winnipeg its depth was about 60 feet.

A somewhat ridged contour upon the otherwise very flat surface of fine alluvial silt was noted 6 to 7 miles east of Hamilton and Bathgate, N. Dak. The wave-like and almost beach-like undulations, rising 2 to 4 feet above the depressions which separate them and above the general level, run north-northwesterly through the east part of section 11 and the central part of section 2, township 162, range 52, close southeast of the Tongue River. Similar contour was also noticed in the continuation of this course within a few miles northward between the Tongue and Pembina rivers. The height of this belt is about 805 feet above the sea.

On the eastern Mossy portage the crest of the Stonewall beach, as observed by Mr. Tyrrell, is 27 feet above Lake Winnipegosis, or 855 feet

above the sea, being probably 10 feet higher than the level of Lake Agassiz there when the beach was accumulated. Again, on the line of the tramway at the Grand Rapids of the Saskatchewan, the same beach is found by Mr. Tyrrell at the elevation of 850 feet; and he states that it is also well seen at Point Brabant and other places along the east side of Lake Winnipegosis, and that it probably is represented by the ridge in the grove behind Manitoba House, which is situated on the west shore of Lake Manitoba, close south of the Narrows.

BEACHES OF THE NIVERVILLE STAGES.

The road on the east side of the Red River between Winnipeg and Emerson crosses a beach ridge about a half mile southeast of Niverville. It has a width of 15 rods, and its crest, 777 to 778 feet above the sea, is raised about 4 feet above the adjoining surface of lacustrine silt on each side. Beginning near Niverville station, it extends southeasterly at least a mile. Another beach ridge of similar size, with its crest at 780 feet, is crossed by this road a third of a mile farther south. This also runs southeast, holding its ridged form a mile or more, beyond which it is less distinct. Again, a few miles to the south from these, a beach ridge extends along this road in a nearly due-south course across the southeast quarter of section 17 and the east half of sections 8 and 5, township 7, range 4 east. It rises 2 to 4 feet above the land adjoining on each side, which is partly sloughs, with water throughout the year, the elevation of the beach crest being 782 to 784 feet. Other beach deposits at nearly the same elevation occur a mile southwest of Otterburne; a few miles farther to the south in the northeast part of township 5, range 3 east; and about a mile east of the Red River, opposite to Morris. At the last-named locality they are excavated for masons' sand. From the southern end of Lake Agassiz in this stage, near Morris, Manitoba, its western shore extended north and northwest to the vicinity of Starbuck, thence north and northeast to Little Stony Mountain, 5 miles northwest of Winnipeg, and thence nearly due north, passing between Stonewall and Stony Mountain and onward along the west side of Lake Winnipeg, at a distance of a few miles from it. Gravelly and

sandy deposits at the base of Stony Mountain on its north and south sides are attributable to erosion by the lake, there only a few feet deep, at the time of formation of the Niverville beach. Its level was 15 to 20 feet above the surface where the city of Winnipeg is built.

Numerous observations of the Niverville beach have been made by Mr. Tyrrell on the shores and islands of Lake Winnipeg. Its occurrence on Black Island, about 150 miles north of the international boundary, is described by him as follows, excepting that his later determination of the height of the beach as 60 feet above Lake Winnipeg is substituted instead of his previous estimate, which was 20 feet lower:

At Ox Head, near the northeastern extremity of Black Island, an ancient beach is very conspicuous at about 60 feet above the water. On the south side of the island the beach is marked by a line of sand dunes, and on the north side a sandy terrace rises gently to a height of 60 feet and ends abruptly at the foot of a steep slope thickly strewn with bowlders. On ascending this slope the land is found to rise to a height of 100 feet above the lake and its summit to consist of an irregular aggregation of knolls, thickly strewn with large bowlders of gneiss, very few or none being derived from the immediately adjoining or underlying Keewatin schists. This ridge is the summit of the Black Island moraine, which would seem to have been dropped here when the higher parts of the island were above the surface of Lake Agassiz, as there is no sign of water action on the moraine above the line of the 60-foot beach. It is possible that the moraine may have been deposited about the water level, and that the water afterwards rapidly receded to a height 60 feet above the present lake.¹

Instead of the view taken by Mr. Tyrrell, however, concerning the depth of Lake Agassiz here when the Black Island moraine was formed, I believe that it was deposited in water 600 to 700 feet deep, bordering the ice front, contemporaneously with the formation of the Herman or Norcross shore-lines. The morainic accumulations, lying thenceforward at the bottom of Lake Agassiz, could not have been exposed to erosion by its waves until the very late change of its northward outlets, by which the lake fell about 50 feet between the Stonewall and Niverville beaches; and this reduction appears to have taken place so quickly that no beach ridge nor eroded escarpment was made on the upper part of Black Island.

At the Grand Rapids of the Saskatchewan, according to Mr. Tyrrell, the tramway of the portage, which is some 4 miles from the mouth of the

¹ *Am. Geologist*, Vol. VIII, p. 25, July, 1891.

river and extends about 1 mile, crosses three beach ridges of gravel and sand that together represent the single Niverville beach farther south. Their heights, in order from west to east, are 95, 90, and 80 feet above Lake Winnipeg, or 805, 800, and 790 feet above the sea. Two Niverville stages of Lake Agassiz, or we may say three, are thus shown to have been caused here by the northward uplifting of the land, with intervals of 5 and 10 feet between its stages of temporary repose.

All the shore-lines described in this chapter and in the two preceding chapters must be referred to the glacial Lake Agassiz, held on its northern side by the barrier of the waning ice-sheet; for the country north of Lake Winnipeg presents no barrier of land through which the Nelson River has cut its passage so high as the Niverville beach. Lake Winnipeg and its outflowing stream have been lowered by erosion only about 20 feet from the level of the beach noted by Hind thirty-five years ago.¹

See Chapter V, p. 221.