

CHAPTER VII.

LOWER BEACHES WITH SOUTHWARD OUTFLOW.

Extensive portions of the lower beaches that were formed while Lake Agassiz outflowed to the south have been exactly mapped, with determination of their heights by leveling. These are described in the following pages, the successive beaches being treated in their order from higher to lower. Four well-defined levels of the glacial lake are exhibited by the shore-lines of its southern part, which have been named, from localities of their typical development in Minnesota, the Norcross, Tintah, Campbell, and McCauleyville beaches. In advancing northward each of these beaches, similarly with the uppermost or Herman series of beaches described in the last chapter, is found to become subdivided into two or more separate and distinct beaches or shore-lines.

The attempts here made to correlate these multiple northern shores of Lake Agassiz with the fewer southern shore-lines rest on the determination of many altitudes along the course of these former planes of the ancient lake levels. The several shores, both at the south and north, were separated from each other partly by the progressing erosion of the outlet, and partly by the gradual decrease of the attraction of the lake by gravitation toward the waning ice-sheet, but more by the intermittent uplifting of this part of the earth's crust, due evidently to its relief from the pressure of the departing ice. Considerable irregularities in this uplifting would be expected, by which the gradients of northward ascent of the beaches would be made variable, being comparatively steep or changing abruptly in elevation in some places, and elsewhere being of small amount or even showing a reversal, that is, a descent toward the north. In this survey, however, I have not discovered any remarkable divergences or exceptions from an approximate parallelism of the beaches. The northward ascent of the highest beach in the Herman series, ranging from 6 to 18 inches per mile,

is gradually diminished in the successive lower shore-lines, each having slightly less ascent than the preceding, to the McCauleyville beaches, which rise 1 to 3 or 4 inches per mile. In all of these shore-lines the rate of ascent is found to increase as one advances from south to north.

BEACHES OF THE NORCROSS STAGES.

FROM LAKE TRAVERSE TO NORCROSS AND MAPLE LAKE, MINNESOTA.

(PLATES XXIII TO XXVI.)

The Norcross shore-line of Lake Agassiz lies near the Herman shore on the slope of eroded till which reaches about 4 miles east from the northeast end of Lake Traverse. Thence eastward, from near the south line of section 35, township 127, range 47, Lake Agassiz was very shallow during the Herman stage, and its fall of 20 feet, or, to speak with more correctness, the rise of the land to this amount, between the times of formation of the Herman and Norcross shore-lines, caused the lake margin to fall back about 6 miles from its most southern portion. The Norcross beach, having a height of 1,043 feet above the sea, is crossed by the Fargo and Southern branch of the Chicago, Milwaukee and St. Paul Railway at a distance of nearly 1 mile north of Dumont. It is here a very slight ridge of gravel and sand, rising only 2 or 3 feet above the uniform slope of the very flat expanse of till.

Within the next 3 miles to the east this beach becomes more conspicuous and has been excavated in several places to obtain sand for masons' use. In section 12, Croke, it is a typical beach ridge about 25 rods wide, with a descent of 5 or 6 feet from its broadly rounded crest toward the north and 2 or 3 feet toward the south. At an excavation near the line between sections 11 and 12 its crest has a height of 1,045 feet. The depth of the beach sand and fine gravel, containing pebbles up to an inch in diameter, is 5 feet, with till beneath.

Thence the Norcross beach ridge, mostly 2 to 4 feet high, runs east to Twelve Mile Creek, and beyond turns to the north and northeast. In sections 32 and 33, Clifton, its height is 1,038 to 1,041 feet above the sea;

and in the northwest quarter of section 26, this township, 1,042 feet, with descent of about 5 feet on each side. Crossing next the northwest part of Logan, its crest is at 1,043 to 1,048 feet.

Between a half mile and 1 mile south of Norcross this beach is admirably developed, the elevation of its higher portions being 1,045 to 1,048 feet, from which there is a descent of 3 to 5 feet eastward and of 10 feet westward. It is a massive gravel and sand ridge, about 25 rods wide, including its slopes, lying on till.

Nearly the same features characterize it also at Norcross station, where its height is 1,041 feet. There is a depression 3 feet lower on the southeast, and the surface 10 to 15 rods northwest from the top of the beach, on the side where the lake was, has a height of 1,034 to 1,036 feet. Thence a very smooth plain of till descends to Tintah, Campbell, and the Red River at Breckenridge. About 50 rods northeast from Norcross station the beach attains its greatest height in this village, 1,045 feet. It is a rounded low ridge of sand and gravel, lying on an area of till, and closely resembles the Herman beach, which lies nearly parallel with it at a distance of 3 miles to the east.

Thence northward the course of the Norcross beach has been mapped, mostly without leveling, to the Red River, which it crosses near the northeast corner of section 31, township 132, range 44, in the west edge of Ottertail County. Through this extent of about 25 miles the Norcross shore-line is marked almost continuously by a distinct beach ridge, 3 to 5 feet above the land on the east, and twice as high above the adjoining surface at the west which was covered by the lake while this beach was being formed. Its distance from the Herman beach on the east varies mainly from 3 to 2 miles, but between 1 and 5 miles south of the Red River the two beaches are only 1 mile apart.

Where the Norcross beach is crossed by the road from Fergus Falls to Campbell, near the west line of section 29, Western, it has an elevation very nearly 1,045 feet above the sea. It is a wave-like ridge of sand and gravel, about 15 rods wide, with nearly flat surfaces of till or boulder-clay on each side. In crossing it the ascent from the east is about 5 feet and the descent toward the west about 10 feet. In sections 19, 18, and 7,

Western, where this beach ridge runs nearly due north, the height of its crest, according to my leveling, is 1,043 to 1,045 feet.

Continuing northward beyond the Red River, the Norcross shore-line traverses the northeast corner of township 132, range 45, passing west of a small lake which lies a mile south of the Northern Pacific, Fergus Falls and Black Hills Railroad. Thence its course is nearly north-northwest across the next two townships in this range; but in Tanberg and through the next 10 miles to Humboldt (the next township east of Barnesville) it runs in a nearly direct course only a few degrees west of north. On the west side of the very remarkable marshy and springy belt which lies just within the Herman shore-line in Akron and Tanberg, the Norcross beach rises as a ridge of gravel and sand a few feet high, forming in considerable part the boundary between the bogs, springs, and numerous watercourses on the east and the firm land, capable of cultivation, on the west. In Tanberg it passes along the east border of sections 32, 29, 20, and 17, having at its crest a height of 1,050 to 1,060 feet above the sea.

Close east of the Norcross beach ridge a large spring in the northwest corner of the southwest quarter of section 28, Tanberg, having a diameter of about 15 feet and depth of 10 feet, issues with so strong a current as to throw up the sand at its bottom to a height of 2 or 3 feet into the water. A creek 5 to 15 feet wide and 1 to 3 feet deep, in which many pickerel live, flows from this spring southward along the east side of the beach about a mile, then turning west into the southeast quarter of section 32, where it sinks into the gravelly and sandy ground and is lost.

About $1\frac{1}{2}$ miles east from Barnesville the Norcross beach is well exhibited at D. D. Daniels's house, in the southeast quarter of section 20, Humboldt, being a low, smoothly rounded ridge of gravel and sand, with the elevation of 1,061 feet above the sea.

Through Riverton and in sections 35 and 26, township 140, range 46, the eroded western border of the delta of the Buffalo River marks the shore of Lake Agassiz at the time of the Norcross beach.

In the west part of section 24, township 140, range 46, and for 4 miles northward, the Norcross beach lies only 1 mile to a half mile west of the Herman beach, and is about 50 feet lower. The terrace-like area between

these beaches is strewn with occasional boulders up to 6, 8, or 10 feet in diameter and rarely of larger size, much more abundant than upon the average surface of the till in this region, indicating that the surface there has been considerably eroded by the waves of the lake.

The elevation of the foot of the western slope of the upper or Herman beach along the north part of the east line of township 140, range 46, is 1,095 to 1,100 feet. Crest of the Norcross beach in section 12 of this township, 6 miles north of Muskoda, 1,080 feet, and along the distance of 3 miles through sections 13, 12, and 1 it varies from 1,075 to 1,085 feet. In section 31, Keene, its height is 1,085 feet. Like the Herman beach, it is a low, smoothly rounded ridge of gravel and sand, usually having a depression of 3 to 5 feet or more at its east side.

Through the west part of Keene the Norcross beach is 1 to $1\frac{1}{2}$ miles west of the upper beach. Thence it crosses Hagen in a north-northeast course, lying 2 to 3 miles northwest and west of the upper beach. Its height in these townships is approximately 1,080 feet.

Both the Herman and Norcross beaches in this northern part of Clay County, between the Buffalo River and the South Branch of the Wild Rice, have an altitude notably higher than would coincide with a uniform ascent of these shores from Lake Traverse to Maple Lake. The normal height of the Herman beach on this tract would be 15 to 20 feet below where that beach is found; and the Norcross beach lies fully 10 feet above where it would be expected. The uplift of the earth's crust here was disproportionate by these amounts with its upward movement along the other explored portions of the eastern shore of this glacial lake.

Proceeding onward through Norman County, the position of the Norcross beach is shown approximately on Pl. XXV, but its course has not been exactly mapped. Two small beach ridges, having nearly the same height, probably belonging to the Norcross stages of this lake, were noted, running nearly from south to north, in the east half of section 8, Wild Rice Township. Again, on the north line of Norman County, in leveling from Rolette eastward, a well-marked beach ridge, 10 to 15 rods wide, with a depression of 4 to 5 feet on its east side, was crossed on the western edge of the delta of the Sand Hill River, near the northeast corner of

Spring Creek Township. This beach, which appears to be one of the upper Tintah shore-lines, has a height of 1,060 feet above the sea. About a quarter of a mile farther east beach gravel and sand are spread in a somewhat flattened, broad ridge, at a height of 1,070 to 1,073 feet, bounded by a hollow 2 or 3 feet lower on the east. This probably belonged to a slightly higher Tintah beach of Lake Agassiz. The Norcross shore-lines are not distinctly exhibited here on the very gradual ascent of the delta sand deposit, which extends eastward across the next mile or more to tracts of dunes.

On the Fosston branch of the Great Northern Railway, about 14 miles north of the last described locality and on the same latitude with the eastwardly curving Herman beaches north of Maple Lake, three small beach ridges are crossed about $2\frac{1}{2}$ miles east of Benoit, the elevation of their crests being successively 1,062, 1,069, and 1,069 feet in their order from west to east. These probably represent the upper Tintah beach. One and a quarter miles farther east a more massive beach is crossed, with its crest at 1,092 feet, which is probably the lowest Norcross shore-line. Other beach ridges crossed $1\frac{1}{3}$ miles and $1\frac{3}{4}$ miles east of the last, with crests respectively at 1,114 and 1,120 feet, are apparently referable to upper Norcross stages of the lake. The next beach noted on this railroad, three-quarters of a mile farther east, at the height of 1,142 feet, belongs to the lower portion of the Herman series.

In the southeast part of Lake Pleasant Township the lower Norcross shore is marked by a belt of gravel and sand about half a mile wide, extending from the southwest to the northeast and east, having an elevation in section 27 of 1,083 to 1,095 feet.

My only further observation of shore-lines referable to the Norcross stages of the eastern border of Lake Agassiz is within 1 to 2 miles west of St. Hilaire, where indistinct lower Norcross beaches, at a height of about 1,090 feet, are crossed by the St. Hilaire branch of the Great Northern Railway.

Thence northward the Norcross shores lie in a wooded country where they can not practicably be traced. From the altitudes of the region it is known that, after passing northward and then eastward around the higher

district of the Beltrami Island, they curve east-southeasterly to the valley of the Rainy River and the vicinity of Rainy Lake, and thence sweep back to the northwest and north across the hilly Archean region east of the Lake of the Woods.

THROUGH NORTH DAKOTA, FROM LAKE TRAVERSE TO THE INTERNATIONAL
BOUNDARY.

(PLATES XXIII AND XXVII-XXX.)

On and near the line between South and North Dakota, at a distance of 3 to 7 miles west of White Rock and the Bois des Sioux, the Norcross stages of Lake Agassiz formed no less than four separate and parallel beach ridges of gravel and sand, 3 to 8 feet high, lying on a surface of till. In section 1, township 128, range 48, South Dakota, where these small ridges run to the northwest and north-northwest, the elevations of their crests in order from west to east are, first, 1,045 to 1,048 feet above the sea; second, 1,043 to 1,045 feet; third, 1,033 feet; and, fourth, 1,030 feet. The highest beach of this series passes about a half mile west of Mr. L. H. Foote's house, which is in the southeast corner of this section; the second runs about 40 rods west of this house; and the third and fourth lie about a third of a mile and a half mile east of it, passing thence northward through the northeast corner of this section 1. Following these beach ridges in their curving course to the northwest and west-northwest into section 28, township 129, range 48, the higher two are found to rise to 1,050 feet, and the height of each of the lower two is increased by 10 feet. The continuations of these shore-lines northwestward to the east side of the Lightnings Nest and to the delta of the Sheyenne River have not been exactly traced. No other tract of the Norcross shore of this southern part of Lake Agassiz, so far as observed by this survey, is thus marked by several beach ridges. The multiplication of their number here, which elsewhere is commonly single along all the southern part of the lake, probably was due to a slight intermittent elevation of this tract while the adjacent country was at rest, until an uplift of the whole area about Lake Traverse led to the formation of the Tintah beaches, the next lower in the descending series.

The next definite observations of the Norcross shore were on the northern part of the Sheyenne delta. In the southwest corner of section 20, Helendale (the most northwestern township of Richland County), this shore is marked by a low beach ridge, which runs to the north-northwest, passing about 20 rods west of Mr. R. L. Porter's house. The crest of the ridge rises 5 to 8 feet above the general surface of this sand delta, from which it is distinguished by being somewhat more channeled and heaped up by the winds into low dunes, 5 to 10 feet in height. Scattered cottonwoods, growing either alone or in clumps of a few trees, are more frequent along the course of the beach than on the adjoining tracts. About 5 miles farther north, where this shore is crossed by the Fargo and Southwestern Railroad, 3 to 4 miles west of Leonard, it bears three small beach ridges, with crests at 1,062 to 1,065 feet. The most westerly and highest is about 18 rods wide, with a depression of 6 feet on the east and 5 feet on the west.

Thence northward across Cass County the contour of the western border of Lake Agassiz shows that the Norcross shore-line runs nearly parallel with the Herman beach, from which it is distant 1 to 3 miles eastward; but only small fragments of its course have been mapped.

Beginning in southwestern Traill County, near Clifford, the Norcross shore has been traced nearly continuously more than 100 miles north to the international boundary. About a mile northwest from Clifford it is marked by a broad swell or ridge of sand and gravel, 1 to 2 feet above the surface of till on the west. Its elevation is 1,072 feet above the sea. One to 1½ miles farther north, in the south half of section 9, Norman, the shore deposit becomes a typical beach ridge, with crest at 1,075 to 1,077 feet, having a hollow of 2 to 4 feet on the west and a descending slope on the east which falls 30 feet in a third of a mile. Thence northward in section 4 of this township the shore forms an eroded cliff of till, 10 to 15 feet high, with its base at 1,075 feet. In the next mile to the north, through section 33, township 146, range 53, the line of erosion is continued, crossing an area of gravel and sand. The escarpment rises about 10 feet in 4 to 6 rods from east to west, its base being at 1,073 to 1,075 feet, from which a smooth slope of sand and fine gravel falls about 25 feet in two-thirds of a mile eastward. In the north part of section 20 two wells on this tract of modified

drift are respectively 22 feet and 31 feet deep, wholly in loose and caving sand and gravel. Here and through the west half of section 17 the Norcross beach is a very finely developed ridge, rising 15 feet above its east base and descending 4 or 5 feet on the west. The elevation of its crest is 1,087 to 1,091 feet. In the southeast part of section 7 an aboriginal mound, 5 feet high and 60 feet in diameter, is situated on the top of the beach ridge; and two others of similar size were seen within a half mile to the southwest.

Thence the lake shore turns to a northwestward course for the next 5 miles, passing through the northeast corner of Primrose to the Middle Branch of Goose River, which it crosses in the southwest part of section 27, Enger. In the south half of section 2, Primrose, the crest of the beach, there unusually massive, is 1,094 feet above the sea, with a descent of 10 feet in 20 to 30 rods eastward and of 5 feet in a shorter distance to the west. Passing northward through Enger Township, this shore bears a typical beach ridge in sections 22, 15, 9, and 3, with crest at 1,080 to 1,085 feet.

Across the large delta of sand and silt which extends from McCanna and Larimore southward beyond Hatton, the Norcross shore is indistinct in portions of its course, but elsewhere has a well-defined beach ridge. Through sections 8 and 5, Garfield, close northeast of Hatton, the crest of the beach is 1,078 feet above the sea, with descent of 6 or 7 feet in 15 rods east and 2 to 3 feet in 10 rods west. In the west part of section 15, Washington, the beach has an elevation 1,083 feet, from which its eastern slope falls 5 feet in 20 rods, and its western slope 3 feet to a slough 10 to 30 rods wide, which is mown for hay. The material of the beach ridge is fine sand. Three to 4 miles farther north, in sections 33 and 29, Pleasant View, the irregular deposits of the Norcross beach are about 1,085 feet above the sea. In the northwest corner of this township, passing through sections 7 and 6, this shore has a finely developed beach ridge of sand and gravel, with crest at 1,090 to 1,095 feet above the sea.

On the Devils Lake and Great Falls line of the Great Northern Railway two Norcross beaches are crossed, about 3 and 3½ miles east of Larimore, with their crests respectively at 1,092 and 1,080 feet. Through the next 4 miles northward these beach ridges appear to have lain on opposite sides of the Turtle River and of its North Branch, causing these

streams to take their southerly course instead of passing eastward in the direction of the slope of the surface. Originally confined between the low beach ridges, they have since eroded channels 50 to 75 feet deep in the general sheet of till. In section 29, Hegton, the elevation of the upper Norcross beach, lying west of the North Branch, is 1,106 feet. Along the next 2 miles northward in sections 20 and 17 the crest of this beach varies from 1,100 to 1,105 feet. It is intersected by the North Branch in the southwest quarter of section 20. Remnants of the lower Norcross beach on the east side of this stream in section 29 have an average height of 1,090 feet, above which they are partly heaped 10 to 15 feet in dunes.

The Norcross shore-line runs northward through the east part of Agnes and Inkster townships. In sections 11 and 2, Agnes, the upper beach, a fine ridge of gravel and sand, passes about 25 rods west of Orr's station, on the Park River and Langdon branch of the Great Northern Railway. Its crest here has a height of 1,102 to 1,105 feet. In sections 23 and 14, Inkster, about a mile west of Inkster village, two Norcross beaches are distinctly developed, crossing a tract of gravel and sand. The crest of the western ridge is at 1,092 to 1,097 feet and that of the eastern at 1,090 to 1,092 feet. Depressions 4 or 5 feet deep lie on the west side of each of these ridges, which are about 50 rods apart. A half mile and $1\frac{1}{4}$ miles farther west, two other well-marked beach ridges, running northward parallel with the foregoing, belong to the lowest part of the Herman series. The crest of the eastern one is at 1,113 to 1,122 feet, and of the western at 1,127 to 1,130 feet. It is to be remarked, however, that the Herman and Norcross series of beaches here lie very near together, being less distinctly separated than farther south and in general on most other parts of the borders of the lake area.

In the east edge of section 10, Inkster, on the north side of the Forest River, the upper Norcross beach is well-developed, attaining a height of 1,100 to 1,102 feet. About 3 miles farther northwest it crosses the south line of section 28, Eden, with an elevation of 1,107 feet. In sections 5 and 6 of this township it is marked only by a slightly more rapid descent of the eroded surface of till, which is strewn with frequent boulders. Through Eden and the next 15 miles northward to the vicinity of Edinburg,

the Norcross shores on the eastern side of "the mountains" lie mostly within a half mile to 1 mile distant from the highest Herman shore. Upon this somewhat steep slope, intersected by numerous ravines, neither the Herman shores nor the Norcross shores are so distinctly traceable as usual, either by beach deposits or by lines of erosion.

From the northern end of "the mountains," near Edinburg, the Norcross shore-lines run north-northwestward, passing about 2 miles east of Gardar, less than a mile west of the little village of Mountain, and about $1\frac{1}{2}$ miles east of Young post-office. At the locality last named the upper Norcross shore lies about a third of a mile east of the lowest Herman beach, and is marked by a ridge of gravel and sand 10 to 20 rods wide, with a depression of 1 to 4 feet on its west side and a descent of about 6 feet in a few rods to the east. Its crest has an elevation of 1,143 to 1,145 feet, being 30 feet lower than the adjacent Herman ridge.

The outer border of the plateau of the Pembina delta, forming the "first Pembina Mountain," was the Norcross shore of Lake Agassiz. After the Herman stages of this lake all its lower levels with southward outflow washed the front of the Pembina delta, carrying away much of this deposit southward and eastward, and producing the steep escarpment, mostly 100 to 175 feet high, by which it is bounded on the east.

On the more gradually sloping northern edge of this delta, 2 to 4 miles west of Walhalla, a beach formed during the lower Norcross stage passes from east-southeast to west-northwest. In the north half of section 23, township 163, range 57, where its crest has an elevation of 1,135 to 1,140 feet, it is a broad, low ridge, chiefly of sand, with fine gravel, containing pebbles up to 1 or 2 inches in diameter. Most of the gravel is derived from the Cretaceous shale of the Pembina Mountain, but a part is of limestone and crystalline Archean rocks. A depression of 5 or 6 feet, 15 to 20 rods wide, lies on the southern side of the beach, away from the lake; and its northern side falls off into the lacustrine area with a gentle slope.

Two miles farther northwest the Norcross shore-lines, with the entire Herman series, leaving the Pembina delta, sweep into the great Cretaceous escarpment of the second Pembina Mountain, with which they coincide through several miles northward, crossing the international boundary.

WESTERN NORCROSS SHORES IN MANITOBA.

(PLATES XXX-XXXIII.)

Through township 1, range 5, the Norcross shores of Lake Agassiz lie on the escarpment of the Pembina Mountain, and the first observations of their beaches were in sections 7, 18, and 19, township 2, range 5, where the mountain wall is reduced to a gradual ascent in the vicinity of Mountain City and Thornhill. About a half mile southeast of Mountain City the upper Norcross beach is well displayed at John Borthwick's house, which is built on its crest, 1,167 feet above the sea, in the southwest corner of section 19. Digging for wells here shows that the gravel and sand of the beach extend only to a depth of 6 or 8 feet, there resting on the Fort Pierre shale. From the crest of this beach ridge its slopes fall 8 or 10 feet within a few rods on the east and about 4 feet on the west. It is bordered on the west at this locality by a surface strewn with very abundant boulders up to 5 feet or rarely more in diameter, nearly all being Archean granites, with perhaps a third of 1 per cent of magnesian limestone. Generally, however, the surface in this vicinity has few or no boulders; and a shallow depth of ordinary till or of lacustrine deposits overlies the Cretaceous shale. The second Norcross beach, also forming a distinct ridge, lies a third of a mile farther east, with its crest about 1,150 feet above the sea. A large excavation for sand to be used in plastering has been made in this ridge in the south edge of this section 19. A mile farther south John W. Stodders's house is built on it at an elevation of 1,148 feet. His well, 12 feet deep, passes through gravel and sand, 11 feet, and then enters the shale, the top of which, to a depth of 6 to 12 inches, is a hard, calcareous layer, including nodules and veins of calc spar. Pieces of the hard surface of this layer thrown out of the well were plainly marked with glacial striæ. The continuation of these beaches is traceable through the next 7 miles northward across the Southwestern Branch of the Canadian Pacific Railway, passing about 3 miles east of Thornhill to Bradshaw's Creek, beyond which to near Treherne they again coincide with the Pembina Mountain escarpment.

About $1\frac{1}{2}$ miles east of the Little Boyne River, near Treherne, the Manitoba and Southwestern Railway cuts the upper Norcross beach ridge,

the crest of which is 1,195 feet above the sea, with a descent of about 5 feet on the west and 10 feet on the east. A half mile farther east it cuts the lower Norcross beach, with its crest at 1,167 feet, from which there is a descent of 10 feet to the west and 15 feet to the east. This beach has been extensively excavated for ballast, a spur track being run along its course a quarter of a mile northwestward from the railway. The excavation, varying along this distance from 6 to 8 rods in width and from 5 to 15 feet in depth, shows that the ridge is composed of interbedded sand and gravel, the layers of sand constituting about half of the entire deposit. The gravel layers differ in coarseness from those that contain no pebbles more than 1 or 2 inches in diameter to others containing waterworn masses of shale a foot across and Archean cobbles 6 inches in diameter. By estimate, nearly nine-tenths of the gravel is the hard Fort Pierre shale which makes up the principal mass of the Pembina Mountain, the Tiger Hills, and Riding Mountain, this shale gravel being often almost unmixed with other material; about a twentieth part consists of two classes of limestones, derived in nearly equal proportions from the yellowish-gray arenaceous limestone of Niobrara age, plentifully fossiliferous, which outcrops beneath this shale on the Boyne and Assiniboine rivers, and from the Paleozoic limestones of the flat country about Lakes Manitoba and Winnipeg; and the remaining twentieth is from the Archean rocks that lie east and north of Lake Winnipeg. Continuing northwesterly and northerly, this massive beach ridge crosses sections 8 and 17 and the eastern edge of section 19, township 8, range 9, beyond which it is lost sight of on the undulating and partly wind-blown surface of the Assiniboine delta.

The next definite observations of the Norcross shores of this lake are near Neepawa, where the Manitoba and Northwestern Railway, a half mile west of this station, crosses small beach ridges referable to the upper Norcross stage, with their crests 1,223 to 1,225 feet above the sea. Close to the west is an eroded escarpment of till 15 feet high, rising from 1,225 to 1,240 feet. On the other side of the station, between a half mile and 1 mile east from it, the railway crosses a surface of wind-blown sand with hollows 2 to 4 feet deep, the crests of its low dunes being at 1,193 to 1,192 feet. These occupy the level belonging to the lower Norcross beach. The

bed of the railway here, formed of the sand of the Assiniboine delta, further worn and redeposited by the lake waves, proves somewhat insecure because of its liability to be channeled by the wind. The road leading northward from Neepawa to Eden and Riding Mountain runs on the crest of the upper Norcross beach ridge through the east part of sections 21 and 28, township 15, range 15, 3 to 5 miles north of the railway, its crest there having a nearly constant height of 1,223 feet, with a descent of 5 or 6 feet from it to the east and half as much to the west. Thence this beach ridge continues north-northeasterly to the east part of section 23, township 16, range 15, where it has an elevation of 1,225 to 1,230 feet, with width of about 30 rods and descent of 10 to 15 feet on its east side. It next runs north or slightly west of north to Thunder Creek, in the south part of township 17, beyond which its course, with that of the lower Norcross shore, is along the steep ascent of Riding Mountain. In the journey from Eden post-office (southwest quarter of section 22, township 16, range 15) to Orange Ridge post-office (northwest quarter of section 32, township 16, range 14) a nearly flat surface of till with frequent bowlders is crossed upon the width of 3 miles between this beach and the upper Campbell beach, descending in that distance from 1,200 to 1,100 feet, approximately. Bowlders are especially abundant within the first mile from the upper Norcross beach, whence the erosion of the lake bed supplied its gravel and sand. This even tract of till would seem most favorable for the accumulation of the beaches belonging to stages of Lake Agassiz between its upper Norcross and upper Campbell levels; but no beach ridge nor other deposit of gravel and sand, nor line of erosion which sometimes takes the place of these to mark a shore-line, was seen in the intervening distance. It seems probable that not far south and north from this route of observation the lower Norcross and the two Tintah beaches will be found.

My study of the beaches of Lake Agassiz mapped by Mr. J. B. Tyrrell¹ on the eastern flanks of Riding and Duck mountains leads me to correlate the two highest gravel ridges near the Valley River, having elevations of 1,280 and 1,260 feet above the sea, with the upper and lower Norcross beaches traced by me in North Dakota and southwestern Manitoba. The

¹Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, Vol. III, for 1887-88, Part E.

ascent of these beaches in the 70 miles northward from the latitude of Gladstone and Neepawa to the Valley River is about 75 feet, or very closely 1 foot per mile, being slightly more than from the international boundary to Neepawa.

On Shanty Creek, 20 miles farther north, these beaches, according to Mr. Tyrrell, are 1,365 and 1,319 feet above the sea, showing the very remarkable northward ascents, respectively, of 85 and 59 feet, or about 4 and 3 feet per mile.

Along the next 25 miles north to the Pine River, where, according to my correlation, the upper Norcross beach has a height of 1,440 feet,¹ its ascent continues at the rate of 3 feet per mile. This is the highest altitude at which any beach of Lake Agassiz has been recorded. Its latitude is $51^{\circ} 52''$ north, being 200 miles north of the international boundary. It is 422 miles north of Lake Traverse and the mouth of Lake Agassiz, in which distance this shore has a total ascent of about 400 feet.

The significance of the more rapid northward rise of these shore-lines and others below them in the district of Riding and Duck mountains than along all the portion of the lake border explored by me farther south has been partly discussed in Chapter V, on the history of this lake, and will be again considered in Chapter IX, on the changes in the levels of its beaches.

BEACHES OF THE TINTAH STAGES.

EASTERN TINTAH SHORES FROM LAKE TRAVERSE TO TINTAH AND NORTHWARD
IN MINNESOTA.

(PLATES XXIII-XXVI.)

The plateau, 3 to 4 miles across, which formed an island in Lake Agassiz, situated between Wheaton and the Mustinka River, on the southeast, and the Bois des Sioux River and White Rock station, on the northwest, rising to an altitude of 1,040 to 1,055 feet, is encircled by the Herman, Norcross, and Tintah shore-lines. This high tract has a base of till, but the plain forming its top consists, to a depth of 10 to 20 feet or more, of

¹ Stated to be 1,460 feet by Mr. Tyrrell, in the Bulletin of the Geological Society of America, Vol. I, 1890, p. 406; but later published by him as 1,440 feet in the Am. Geologist, Vol. VIII, p. 23, July, 1891.

delta sand and gravel, brought by the glacial representative of the Sheyenne River, apparently at the time of formation of the Dovre moraine, when the retiring ice-sheet began to uncover the edge of the area of Lake Agassiz (p. 150). Previous to the lower Tintah stage of the lake, the River Warren, outflowing by two broad channels, one south and the other west of this plateau, had eroded the upper portion of the valleys, respectively 2 and 4 miles wide, which are occupied by the Mustinka and the Bois des Sioux. At the time of the lower Tintah beach and during the later Campbell and McCauleyville stages the River Warren outflowed wholly west of this tract, completing the erosion of the valley of the Bois des Sioux from White Rock south to Lake Traverse, where it now contains a great marsh with numerous permanent areas of water 1 to 3 miles in length.

In the south half of section 2, township 128, range 47, at a distance of about $1\frac{1}{2}$ miles east of White Rock, the upper Tintah shore bears a well-defined beach ridge of sand and gravel, lying on a surface of till. This ridge is 15 to 20 rods wide, rising 3 feet above the surface on each side, with its crest about 1,015 feet above the sea. Thence it was traced nearly 4 miles in a curving course to the northeast and east, passing through sections 31 and 32, Taylor. At the center of section 31, Mr. David Wariner's farm buildings are situated on its top, which has a height of 5 to 8 feet above the surface of till at the south and north. His well shows that the beach gravel and sand reach to a depth of 10 feet. In this vicinity the beach is somewhat irregular in its development and varies from 10 to 30 rods in width. Other irregular sand and gravel deposits belonging to this shore-line were found extending from south to north in sections 21 and 16, Taylor, lying on a tract of till slightly elevated above long sloughs on the south and east.

Two very small beach ridges, from 1 to 3 feet high, consisting of sand and gravel on a nearly flat surface of till, are crossed by the Evansville and Tintah line of the Great Northern Railway, about $1\frac{1}{4}$ miles and 1 mile east of Tintah.¹ The heights of their crests are respectively 1,010 and 1,007 feet above the sea. On the Minneapolis and Pacific Railway, 2 miles

¹A Dakota name meaning *prairie* (A. W. Williamson in Thirteenth Annual Report, Geol. and Nat. Hist. Survey of Minnesota, for 1884, p. 110).

farther north, these inconspicuous beach ridges pass about 1 mile and a half mile east of Nash, their elevations being 1,012 and 1,010 feet. One to 2 miles onward, in sections 25 and 26, Champion, both ridges are somewhat more distinctly developed at 1,012 and 1,008 feet, each being 3 to 4 feet high above the till on each side.

Thence northward between the Rabbit and Red Rivers the level of these beaches was carefully followed with leveling across a very smooth and flat expanse of till; but no distinct shore marks, either of ridged beach deposits or of any noticeable erosion, were found. The shore passes almost due north, lying from a half mile to 1 mile west of the east side of Bradford, and crosses the Red River in the southeast part of township 132, range 45, between 2 and 3 miles above its most southern bend.

Within a half mile to $1\frac{1}{2}$ miles north of the Red River two Tintah beach ridges are well developed, consisting of gravel and sand which lie on till. The eastern and higher ridge in the northwest quarter of section 26 and southwest quarter of section 23, township 132, range 45, varies in width from 10 to 25 rods; its crest is 1,019 to 1,023 feet above the sea, and both its eastern and western slopes fall 3 to 7 feet. Three-quarters of a mile to the west the crest of the lower ridge, which is of similar size, has a height of 1,012 to 1,015 feet. Through the next 2 miles these beaches are not distinctly traceable, and the surface consists of slightly undulating till. In the east edge of section 4, this township, the upper shore-line again bears a conspicuous gravel ridge, with crest at 1,020 to 1,022 feet, from which within 10 rods there is a descent of 5 feet eastward and 6 to 8 feet westward.

In the northeast corner of section 28, Andrea, the upper Tintah beach, a typical gravel and sand ridge, has an elevation of 1,017 to 1,018 feet above the sea. Along the next 2 miles northward, in sections 21 and 16, its crest holds a nearly uniform height of 1,017 to 1,019 feet, being 3 to 4 feet above the hollow east of the beach, and 6 to 7 feet above the adjoining surface on the west. Through the west half of section 9 and the southwest quarter of section 4 this beach is not distinctly a ridge, but is represented by a somewhat broad tract of gravel and sand. In the east edge of section 6, Andrea, about a mile west of the foregoing, the lower Tintah beach

forms a massive gravel and sand ridge, with crest at 1,015 to 1,017 feet, rising 10 feet above the adjoining area of till on each side; and it continues north with the same conspicuous development through the east edge of section 31 and the southeast quarter of section 30, Akron.

Across the next 3 miles both these beaches fail, and the surface in their course is nearly flat till, with a thin covering of lacustrine silt, which is apparently due to the action of the lake during the deposition of the glacial till from the melting and receding ice-sheet.

Again, the upper Tintah beach has a very massive and higher development in the southwest corner of section 8, Akron, and extends with a width of 30 to 40 rods and an elevation of 1,024 to 1,029 feet above the sea along the east side of sections 7 and 6, the top of its ridge coinciding nearly with the south-to-north section line. Its maximum width and height are attained at the quarter-section stake between sections 7 and 8. On the east the descent from its crest is 3 to 6 feet, and on the west 10 to 15 feet within 20 rods. This gravel and sand beach passes onward, less massive, but having a distinctly ridged form, through the western tier of sections in Tanberg. In the east edge of sections 31 and 30 its elevation is approximately 1,028 feet. In section 19 it is offset a quarter of a mile to the west, and thence runs nearly due north 3 miles, being lost near the center of section 6 in a marshy tract.

The lower Tintah beach also forms a conspicuous gravel ridge, nearly parallel with the foregoing, at a distance of 1 mile to a half mile west, beginning in the northeast quarter of section 12, township 134, range 46, and running slightly west of north, with an elevation of 1,015 to 1,017 feet, about 3 miles to the east part of section 25, Manston. There it is offset a quarter of a mile to the east, and thence runs due north along the west line of Tanberg, having a height of 1,016 to 1,018 feet, to the marshes in which, like the upper Tintah beach, it is lost near the northwest corner of this township.

Both the Tintah beaches were next identified in the vicinity of Barnesville. On the northern border of a boulder-strewn higher tract of till the upper Tintah shore-line is marked in the south part of section 36, Barnesville, at a distance of about a quarter of a mile east of the railway line to

Breckenridge, by a sand and gravel deposit several feet deep, which runs from west to east. Thence this beach, having a height of 1,030 to 1,035 feet above the sea, curves to the northeast and north, passing through the city of Barnesville not far east of the railway station, and onward a little east of north to section 7, Humboldt, where it bends northwestward. The lower Tintah beach in Barnesville is a shallow, slightly ridged tract of gravel and sand, resting on the general slope of till, above which it rises 1 to 2 feet on the east, while its western side falls 10 or 15 feet within 20 or 25 rods. It lies close west of the street which runs north from the railway station for a third of a mile to the bridge crossing the Willow River (also called Whiskey Creek), beyond which the street itself occupies the beach. Its height in the city is 1,015 to 1,018 feet. This shore, mostly marked by a well-defined gravel ridge, runs north the next 2 miles, lying in the west edge of sections 19 and 18, Humboldt, and then turns to the north-northwest, passing through sections 12 and 1, Barnesville.

Thence northward the Tintah shore-lines in Minnesota have been traced in only a few localities. Through Clay and Norman counties, however, to the Sand Hill River, their position is shown approximately on Pl. XXV, in accordance with the general westward slope of the east border of this lacustrine area.

As already noted in the description of the Norcross shore-lines (p. 387), two beaches observed on the western margin of the Sand Hill delta deposit, at the heights of 1,060 and 1,070 to 1,073 feet, seem referable to the upper Tintah stages of the glacial lake; and the continuations of these beaches are crossed by the Fosston Railway line at the elevations of 1,062 and 1,069 feet above the sea. Three-fourths of a mile to 1 mile west of these, and at a distance of nearly 2 miles east of Benoit, this railway intersects two less conspicuous beach ridges, with crests at 1,047 and 1,044 feet, which are believed to mark the lower Tintah stage.

These shore-lines are inconspicuous on the St. Hilaire railway branch, but 3 to 5 miles northward several beach ridges were noted by Mr. E. C. Davis in leveling for a proposed canal from the Red Lake River at Crookston to its southward bend at the mouth of the Thief River. A gravel ridge probably belonging to the lower Tintah level of Lake Agassiz lies about 3 miles east of the Black River and has an elevation of 1,050 feet. The

upper Tintah shore was not recognized, but three gravel ridges, successively crossed at 2 miles, $2\frac{1}{2}$ miles, and $4\frac{1}{2}$ miles northeast from the 1,050-foot beach, with their crests respectively at 1,086, 1,088, and 1,092 feet, appear to be lower Norcross beaches.

Farther to the north the Campbell shore-lines are the highest that have been observed by me on the east side of Lake Agassiz; but information from others gives approximately the course of the Tintah shores to the international boundary and the south and west sides of the Lake of the Woods.

According to Mr. Charles Hallock, the road from Stephen to Roseau Lake runs on a gravel ridge, apparently one of the Tintah beaches, in townships 159 and 160, range 45, passing close along the northwest side of two lakes. Crossing the South Fork of Two Rivers about 2 miles northeast of these lakes, the road is described as continuing for the next 15 miles upon this beach ridge or another closely associated with it, lying 5 to 8 miles southeast of the Great Roseau Swamp. The beach forms a massive, smoothly rounded ridge of sand and gravel, with pebbles and cobbles up to 4 inches or more in diameter. Its width is 20 to 40 rods, with crest 5 to 10 feet above the adjoining surface of till, and it is in many places bordered on the side that was away from the lake by narrow swampy tracts. A trail which leaves this road before reaching Roseau Lake and passes east to the Lake of the Woods at the mouth of War Road River is said to lie for considerable portions of its extent on a beach ridge. This also doubtless belongs to one of the Tintah stages, and is, indeed, quite likely the direct continuation of the beach occupied by the Roseau road.

Dr. George M. Dawson has kindly supplied a manuscript profile of the international boundary from the Lake of the Woods to the Red River, as surveyed by the British Boundary Commission, which shows four low ridges, probably Tintah beaches. They are crossed successively at 12 miles, 22 miles, 24 miles, and 32 miles west of the Lake of the Woods, their crests being, in the same order, 1,088 feet, 1,081 feet, again 1,081 feet, and 1,070 feet above the sea. The first and second of these ridges are respectively about 5 miles east and 5 miles west of the crossing of the North Branch of the Roseau River; and the fourth is 3 miles west of Pine River. The elevation of the Lake of the Woods, varying at its stages of low and high

water from 1,057 to 1,063 feet above the sea, shows that this large lake was first separated from the diminishing expanse of the glacial Lake Agassiz between the times of formation of the Tintah and Campbell beaches.

WESTERN TINTAH SHORES IN NORTH DAKOTA.

(PLATES XXVII-XXX.)

In the northeast corner of South Dakota, two beach ridges, belonging to the upper Tintah shore of this glacial lake, run north-northwestward across the northeast part of section 6, township 128, range 47. The eastern ridge is 20 to 30 rods wide, consisting of gravel and sand on the westwardly ascending surface of till. It has a height of 1,014 to 1,018 feet above the sea, with a descent of about 15 feet on the east and of 3 to 6 feet on the west. A smaller parallel gravel ridge, rising 5 feet from its eastern base and falling 1 to 3 feet toward the west, with crest at 1,015 to 1,021 feet, lies a quarter of a mile farther west. The eastern beach, curving northwestward, was traced several miles into North Dakota, to the northeast quarter of section 22, township 129, range 48, where its elevation is 1,015 to 1,018 feet. Thence it is probably continuous to two small beach ridges that were observed, without determination of their height (known, however, to be approximately 1,015 feet), in or near the north edge of section 34, township 130, range 49, on the south side of a little creek which there emerges from the sand area of the Sheyenne delta.

The Tintah shore-lines cross the eastern portion of this delta, but are seldom traceable, even on its smooth areas, and still less among its frequent tracts of dunes. The altitudes of the Northern Pacific, Fergus Falls and Black Hills Railroad show that they cross this line 1 to 2 miles east of Barney. Along the northern border of the delta they coincide with the escarpment and slope descending from its plateau, which pass close north of Leonard and thence extend 8 miles westward to the Maple River. On the Fargo and Southwestern Railroad the upper Tintah level of Lake Agassiz eroded an escarpment in the delta sand and gravel whose top has an altitude of 1,034 feet above the sea; and the lower Tintah shore bears three beach ridges, 5 to 7 feet above the intervening hollows, with their crests at 1,017, 1,016, and 1,014 feet.

Across an extent of nearly 60 miles next northward we have only scanty observations of the Tintah shores, the most important being $1\frac{1}{4}$ miles east of Clifford, where a well-defined gravel ridge upon an area of till was seen along a distance of 2 miles from south to north. Its crest has an elevation of 1,040 to 1,045 feet above the sea, with descent of a few feet on its west side and of 15 to 25 feet within 30 or 40 rods eastward.

From the South Branch of the Goose River, 10 miles north of Clifford, a Tintah shore-line, marked in portions of its course by an eroded slope and in other portions by a ridged beach deposit, passes to the north and northeast through township 147, range 53, crossing the railway line from Portland and Mayville to Larimore near the southwest corner of section 2 and the North Branch of Goose River near the center of this section. Here and onward to the north through the eastern tier of sections in township 148, range 53, and to the north-northwest through the next two townships of the same range, and onward to the Devils Lake line of the Great Northern Railway and to the Turtle River, this shore lies mostly on the eastern slope and near the border of the extensive delta of sand and fine clayey silt brought into Lake Agassiz by the glacial river of the Elk Valley. In section 14, Washington, and through several miles northward, the shore bears a well-defined beach ridge, which in the southeast quarter of section 34, Pleasant View, has been excavated to obtain sand for plastering. In portions of sections 8 and 5, Pleasant View, and in section 31, Chester, the beach deposit, with crest at 1,050 to 1,055 feet above the sea, changes to a low, eroded escarpment of till 10 to 20 feet high, with its top 5 to 15 feet above the beach. The delta here extends nearly or quite to the Tintah shore, which divides it from an eroded tract of till on the east.

North of the Turtle River, which is crossed by this shore-line 2 miles west of Arvilla, it continues in the same north-northwestward course, crossing an area of till. One mile east of Orr's station it is a distinct gravel and sand ridge, and about three-quarters of a mile west of Inkster it has two beach ridges, the crest of the western one being 1,070 to 1,072 feet above the sea, and that of the lower and less massive eastern ridge 1,060 feet. In the east edge of section 28, Eden, the Tintah levels of Lake Agassiz are shown by erosion upon the eastwardly sinking till slope. The

upper limit of the steeper eroded belt is at 1,062 to 1,070 feet, being about 20 feet above its base. Beyond this township, northward to the Pembina delta, the courses of the Tintah shores, though not exactly traced, are known very nearly from the rate of eastward descent of the land and from the mapped course of the next succeeding Campbell beach. At one locality a Tintah beach ridge was noted, near the middle of the line between sections 19 and 18, Kensington, about 2 miles northwest from the town of Park River; but the next two miles or more northward have a rather irregularly rolling surface, with no definite beach observable.

The Tintah shores are only a short distance below those of the Norcross stages on the flanks of the Pembina delta and on the lower part of the Pembina Mountain escarpment for several miles thence northward.

WESTERN TINTAH SHORES IN MANITOBA.

(PLATES XXX-XXXIII.)

In proceeding northward from the international boundary, the Tintah beaches were first observed near the line between townships 1 and 2, range 5, lying on a terrace which forms the lower part of the Pembina Mountain. On the boundary this terrace is about three-fourths of a mile wide, its eastern margin being an escarpment that rises from 1,040 to 1,090 or 1,095 feet; and from its verge it gradually rises 25 to 35 feet in its width, so that its western limit at the base of the main escarpment has a height of 1,120 to 1,125 feet. Its surface is till with plentiful boulders, nearly all Archean, up to 5 feet in diameter, mostly embedded or only projecting a foot or less; but the slope on its east side consists of weathering and pulverized Cretaceous shale, which is thus shown to form the principal mass of the terrace, beneath a thin mantle of till. In the distance of 6 miles northward across township 1 this terrace widens to 2 miles, and its eastern verge sinks to 1,055 feet; but it is bordered by only a slight escarpment, about 15 feet high, the base of which is thus at the same level as on the international boundary. In its width of 2 miles it there rises about 90 feet to the base of the mountain escarpment, at 1,140 to 1,150 feet. A quarter to a third of a mile east of this escarpment a line of erosion rises from 1,110 to 1,125 feet, approximately, marking the upper Tintah shore. In the southeast

quarter of section 5, township 2, this shore bears scanty deposits of beach gravel and sand, with their crest at 1,110 to 1,115 feet. The lower Tintah beach lies a third of a mile farther east, and is a distinct ridge of gravel and sand with its crest at 1,083 to 1,085 feet, bordered on each side by till, the surface of which is 5 feet lower on the east and 3 feet lower on the west. Thomas Kennedy's well, 14 feet deep, in the northeast quarter of section 5, township 2, range 5, found the till only 4 feet deep, underlain by the Fort Pierre shale. This terrace doubtless owes its form, like the far more prominent Pembina Mountain, to preglacial erosion of these Cretaceous beds. It continues along the foot of the mountain, with a width of $1\frac{1}{2}$ to 2 miles, at least to the South Branch of Tobacco Creek, which crosses it near Miami post-office, 25 miles north of the international boundary. Throughout its whole extent it has a considerable ascent upon its width from east to west, as in the localities noted. Much of its surface is till with many boulders, but some portions have no boulders, such tracts being overspread with lacustrine gravel and sand, or perhaps occasionally consisting of Cretaceous shale next below the soil, with no drift or lacustrine deposit.

A mile west of Morden the escarpment bordering this terrace has an ascent of about 40 feet, with its top approximately 1,070 feet above the sea. Within an eighth of a mile to the west is the lower Tintah beach, a small ridge of gravel and sand which has been excavated for use in plastering, its crest being at 1,085 feet, nearly, with a descent of 5 or 6 feet from it to the east and 2 or 3 feet to the west. It extends a considerable distance nearly parallel with the verge of the terrace. The road thence to Thornhill ascends slowly in the next 2 miles across a somewhat uneven surface on which eight or ten beach ridges are discernible, belonging to the upper Tintah, Norcross, and Herman stages.

The most remarkable feature of this tract is its extraordinary abundance of boulders, nearly all Archean, usually less than 5 feet in diameter, but in many places ranging in size to 10 feet or more. Upon an area that extends at least 1 to 2 miles both south and north of the road and railway the surface is as thickly strewn with boulders as are the most typical terminal moraines seen by me in Minnesota and South and North Dakota. Many of these rock masses, instead of being embedded in the drift, as is

generally the case in this region, project 2 to 3 or 4 feet above the surface, or lie wholly on it with no portion concealed. Here the ice-sheet probably terminated, depositing these boulders in the west margin of Lake Agassiz, during the time of its accumulation of the terminal moraine that forms the west part of the Tiger Hills and the Brandon and Arrow hills.

About a mile south and west of Nelson, the lower Tintah beach ridge, having an elevation of 1,085 feet, approximately, lies an eighth of a mile west from the margin of the terrace; and the upper Tintah beach probably extends along its west side, close to the base of the Pembina Mountain, where the elevation is about 1,100 to 1,120 feet. The width of the terrace here is about $1\frac{1}{4}$ miles.

A half mile east of the lower Norcross beach, near Treherne, the upper Tintah shore seems to be indicated where it crosses the railway by a line of erosion in the Assiniboine delta, with descent approximately from 1,140 to 1,120 feet.

On the profile of the Manitoba and Northwestern Railway the upper and lower Tintah beaches are apparently shown about 3 miles and $5\frac{1}{2}$ miles east-northeast of Neepawa, with their crests respectively at 1,158 feet and in two ridges at 1,116 and 1,111 feet above the sea. Within its next 3 miles northward the upper beach is represented by a tract of low dunes extending through the east edge of township 15, range 15, to Snake Creek. Thence the course of these shore-lines, as shown by the contour, is nearly due north to the foot of the escarpment of Riding Mountain, in township 17.

Along the eastern base of Duck Mountain the Tintah shores of Lake Agassiz have been observed by Mr. Tyrrell, according to my correlation of the beaches shown on his map (see p. 395), as follows: The upper Tintah beach, close north of the Valley River, at an elevation of 1,220 feet above the sea; both the upper and lower Tintah beaches on Shanty Creek, respectively, at 1,287 feet and 1,235 feet; and the upper of these beaches, extending several miles between the Pine and Duck rivers, at 1,365 feet. In proportion with the northward ascent of the upper Tintah beach thus indicated, its height on the Pine River would be about 1,335 feet, and on the Duck River, a dozen miles farther north, at latitude 52° , about 1,375 feet.

BEACHES OF THE CAMPBELL STAGES.

The Campbell shore-lines have in general somewhat the most conspicuous development of all below the Herman series. They belong to stages of Lake Agassiz much below its highest level, and furnish a very useful record of the boundary and depth of this body of water, as shown on Pl. XXXIV, near the time when it ceased to outflow to the south at Lake Traverse. Considerable portions of the lower and principal Campbell shore are marked by a low, eroded escarpment in the general sheet of till; and the aggregate length of such terracing by this one level of the lake is probably equal to that of the numerous shorter lines of escarpment formed during all its other levels, both above and below. Probably the land reposed without upward movement longer at this stage than at any other in the history of the lake, unless the earliest and highest stage of the Herman series must be excepted. It is also to be remarked that no other shore of Lake Agassiz bears at any place so extensive an embankment of beach gravel and sand, transported a long distance by the action of waves and coastal currents, as that swept southward from the Pembina delta during the Campbell stages.

Between the rate of northward ascent of the uppermost Herman beach and that of the Campbell beach there is a remarkable contrast. Along the 300 miles from the mouth of Lake Agassiz to Gladstone explored by me the land had been considerably uplifted after the formation of the Herman beach; but its level in all this extent has been only slightly changed since the old lake shore was at the present site of the town of Campbell, in Minnesota. Farther to the north, however, on the east side of Duck Mountain, a large amount of differential northward uplifting took place after the Campbell stages of the lake. The rate per mile of northward ascent of the Campbell beaches there exceeds that of the first and highest Herman beach upon all the country south of Gladstone.

Unusual interest, therefore, appertains to the Campbell shores, and they have been more fully mapped, especially in North Dakota, with leveling to ascertain their height continuously, than any other of the successive boundaries of this glacial lake, whether belonging to its stages of southward or of northeastward outflow, excepting only the Herman beaches.

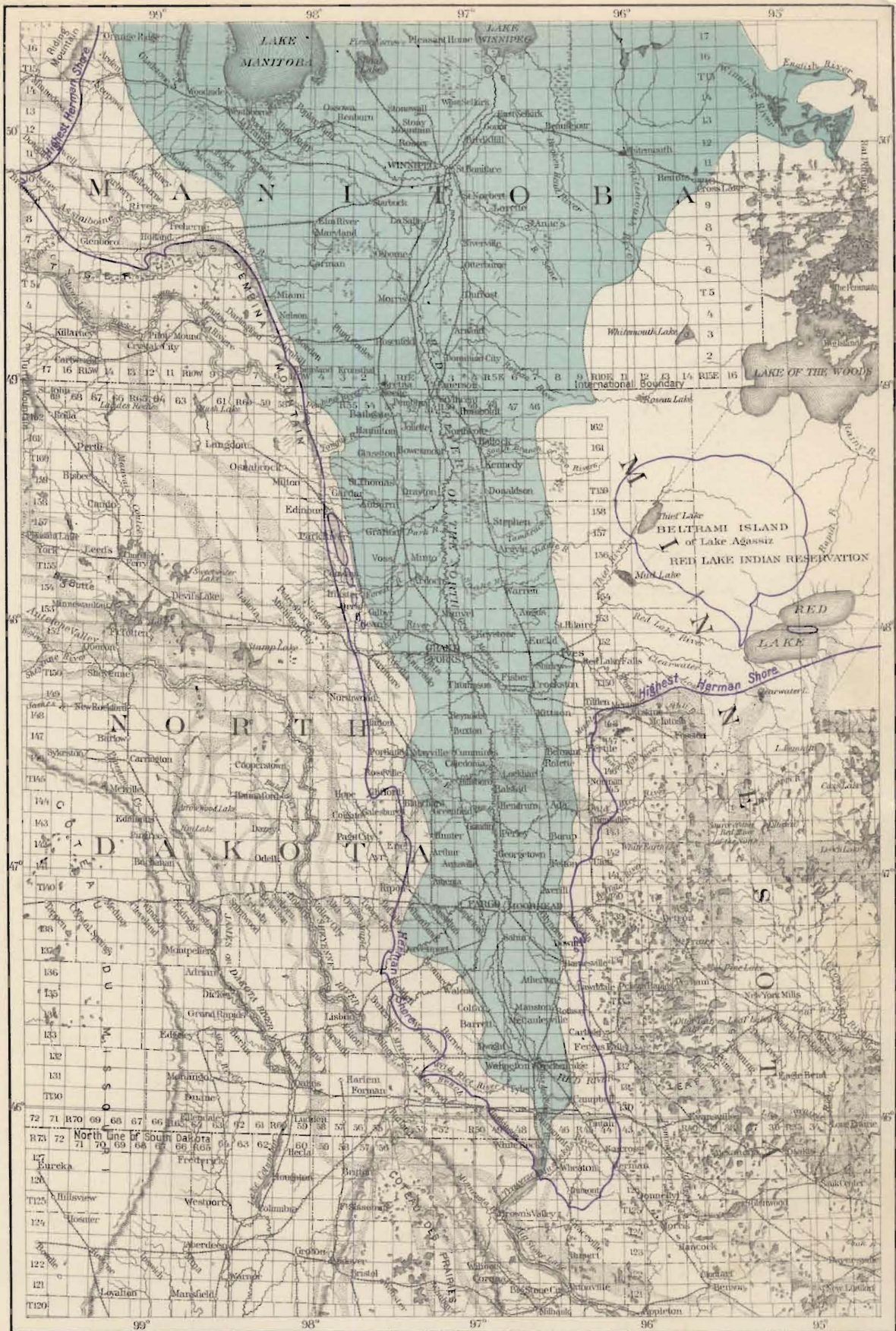
FROM LAKE TRAVERSE AND CAMPBELL NORTH TO THE TAMARACK RIVER, IN
MINNESOTA.

(PLATES XXIII-XXVI.)

For a distance of about 18 miles north from the mouth of Lake Agassiz the Campbell shore-line is within a half mile to 1 mile east of the marsh with lakelets and of the Bois des Sioux River, through which Lake Traverse outflows. Perhaps, however, it would be better, at this stage of the decrease of Lake Agassiz in area and depth, to regard its mouth and the beginning of the River Warren as transferred from Lake Traverse 12 miles north to the vicinity of White Rock.

Parting company with the Bois des Sioux 5 or 6 miles north of White Rock, the Campbell shore runs northeastward across Campbell Township, passing less than a mile north of Tenney station, on the Minneapolis and Pacific Railway, and crossing the Breckenridge line of the Great Northern Railway at Campbell. Near the center of section 31, Campbell, it is recognized by a beach ridge which has been excavated for masons' sand. On the Minneapolis and Pacific Railway the crests of its scanty gravel and sand deposits are 980 to 983 feet above the sea; and on the Aberdeen Branch of the Great Northern Railway the top of the beach is at 989 feet, with adjoining land on the northwest 5 feet lower. The vicinity of the town of Campbell, however, has no definite ridge. A half mile to 1 mile north of Campbell the beach is dimly traceable, with crest at 984 to 986 feet, rising only 2 to 3 feet above the general surface; and it has the same inconspicuous development in its course thence nearly due north to the Red River.

In the northeast part of Richardson this shore bears a well-defined ridge of gravel and sand, which runs through the center of section 14 and the east part of sections 11 and 2. It has been excavated in the southeast quarter of section 11, showing pebbles up to $1\frac{1}{2}$ inches in diameter. The crest of the beach ranges in height from 987 to 995 feet, from which there is commonly a descent of 2 to 5 feet on the east and twice as much on the west to the general surface of till. This beach, about 30 rods wide and 5 feet high, with its top at 992 to 995 feet, is crossed by the Northern Pacific,



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

Scale, about 1/2 miles to an inch.

Fergus Falls and Black Hills Railroad a quarter of a mile west of Everdell station. Thence for the next 15 miles its course is a few degrees west of north to the vicinity of Manston.

Through sections 15, 10, and 3, township 134, range 46, and northward in Manston, the Campbell shore-line is mostly marked by a definite gravel ridge, the land on each side being till. The ridge varies in elevation from 987 to 992 feet, attaining the latter height $1\frac{1}{2}$ miles southeast of the village of Manston, where it rises 6 or 7 feet from its east base and has a descent of about 10 feet toward the west.

In Atherton this shore is intersected three times by the railway from Breckenridge to Barnesville. A beach ridge, for the greater part scantily and irregularly developed, passes northwestward across section 34 and the railway. Thence curving to the north and northeast, it lies close west of the railway for 2 miles, nearly to the Deerhorn Creek. About a quarter of a mile south of this creek it again crosses the railway, from which a spur track turns off to take gravel ballast from the ridge, its excavation being 6 to 10 feet deep. For the next 2 miles this upper Campbell beach runs nearly parallel with the railway and close on its east side to the south part of section 10; and thence, after its third crossing of the railway, it extends 3 miles nearly due north to a cemetery about $1\frac{1}{2}$ miles west of Barnesville. The elevation of the beach crest in sections 15, 10, and 3, Atherton, and also in the cemetery, is 990 to 992 feet above the sea, with a descent of 3 or 4 feet on the east and of 6 to 10 feet on the west.

A second beach ridge, of smaller size, a tenth to a quarter of a mile west of this, with its crest 5 to 7 feet lower, about 985 feet, begins near Atherton Station and is continuous, or nearly so, through section 15 and the south part of section 10. The foot of the western slope of the lower ridge, at 980 feet, indicates approximately the level of Lake Agassiz when it was formed. A slight elevation of the land, probably amounting to 5 feet, had apparently taken place between the times of formation of these two beaches.

Both the upper and the lower Campbell beaches are also well exhibited 2 to 3 miles north of Barnesville, near the railway bridge over Siebers Creek. In the northwest corner of section 13, Barnesville, less than a quarter of a mile south of this creek, the upper beach, forming an irregular belt of

gravel and sand from 992 to 980 feet on the descending slope of till, is crossed by the railway, and thence runs northward as a more definite ridge, with crest at 992 to 995 feet, through the west half of section 12. The top of the lower beach ridge, which lies an eighth of a mile to the west, running nearly along the west line of this section, is at 985 feet, with descent of 2 or 3 feet eastward and about 10 feet westward.

Through the next four townships to the north, extending 24 miles, the Campbell shore-lines have not been exactly mapped, but their position is known very nearly by the general westward descent of the border of the lacustrine area toward the flat Red River Valley plain which forms its central part. Near the middle of this distance, however, on the Northern Pacific Railroad, two beach ridges, belonging to the Campbell stages, lie between 3 and $3\frac{1}{2}$ miles west of Muskoda. The railroad profile shows that the elevation of the eastern one of these ridges is 1,004 feet above the sea, with descent of 4 feet east and 11 feet west in its width of 30 rods, and that the crest of the second ridge is at 1,000 feet, 7 feet above its east base, while its west slope falls almost 20 feet, the whole width of this beach being about 50 rods. The unusually massive development of the Campbell beaches here, and of the closely associated McCauleyville beach, is due to their derivation partly from the delta of the Buffalo River, and in larger part from exceptional erosion in the slope of till that formed the lake shore northward. This slope is strewn with many boulders, the remnants from a considerable depth of till worn away by the lake waves.

In Hagen the Campbell shore is mainly traced by a line of erosion forming a somewhat steep escarpment, from 5 or 10 to 25 feet in height, near the foot of the slope of till which thence rises gradually toward the east; but beach gravel and sand deposits mark its course where it crosses the depression occupied by the South Branch of the Wild Rice River. Likewise through Rockwell this lake margin is an eroded till escarpment.

The shore again bears a well-defined gravel ridge in Lake Ida Township, passing from the southeast quarter of section 34 north-northeastward across section 26 to the Wild Rice River, and thence nearly due north through the west edge of sections 13, 12, and 1, there rising 6 to 8 feet from its eastern base and descending 20 feet toward the west. The height

above the sea was not exactly determined here, nor along the next 12 miles of this shore northward, mostly marked by a low escarpment of till, in Green Meadow and Spring Creek townships.

Close south of the Sand Hill River, in section 34, Liberty, the top of this Campbell escarpment is 1,010 feet above the sea, being probably 10 feet higher than the lake level when it was made. It runs in a nearly due-north course, parallel with the well-developed McCauleyville beaches which lie a half to two-thirds of a mile farther west. Continuing northward through Liberty and Onstead townships and the southern two-thirds of Kretchmarville, this shore-line is almost continuously a terrace cut in the till, having a descent of 10 to 30 feet within as many rods. Numerous residual boulders are strewn upon a narrow belt below the terrace. Erosion was in progress along the greater part of this terrace during both the upper and lower Campbell stages of the lake; but a beach ridge of gravel and sand, which was accumulated along its base during the lower stage, extends through section 5, Onstead, and into the adjoining sections.

From the southeast part of section 9, Kretchmarville, the Campbell shore takes a north-northeastward course for the next 10 miles to the southwest corner of the township of Red Lake Falls and to the Red Lake River. Along this extent it bears a conspicuous beach deposit, on which several farmhouses are built, their cellars being dug to the depth of 6 or 8 feet in gravel and sand, while the surface on each side of the shore-line is till. For the greater part of this distance there are two parallel beach ridges, usually occupying together a width of about 50 rods. The crest of the eastern and higher beach is 1,012 to 1,015 feet above the sea, and that of the lower beach about 1,000 feet, varying from this only 1 or 2 feet. Each ridge has a descent of 4 to 6 feet toward the east, and their western bases are respectively at 995 and 985 feet, approximately. The upper and lower Campbell levels of Lake Agassiz, which heaped up these beaches by their waves, were very nearly at 1,000 and 990 feet.

In the west edge of section 30, Red Lake Falls, only the upper beach ridge is present. Its width is about 30 rods, and its elevation varies from 1,013 to 1,020 feet, with descent of several feet eastward and 15 to 20 feet to its western base. On the top of this prominent sand and gravel ridge,

about a quarter of a mile south from the Red Lake River and the north-west corner of this section, lie five dome-shaped artificial mounds, of gradually increasing size in their order from south to north. The southernmost is about 30 feet in diameter and 2 feet high; the second measures 50 feet across and is 3 feet high; the third is slightly larger, with a height of 4 feet; the fourth is 70 feet in diameter and rises 6 feet above the beach; and the most northern has a diameter of 80 feet and a height of about 8 feet. These mounds, which were undoubtedly used for burial, overlook a broad prospect, especially toward the west, including many miles of the well-wooded river valley.

The St. Hilaire Branch of the Great Northern Railway crosses the Campbell beach a half mile east of Black River, the crest of its gravel ridge being 1,019 feet above the sea, with a descent of 6 feet toward the east and about 10 feet westward. Within a few miles farther north the line of the survey by Mr. Davis, mentioned on page 400, found the elevation of this beach 1,022 feet, from which its slopes fall 6 or 7 feet on each side. Farther northward its elevation has not been determined, but its position has been accurately mapped. In townships 153, Bray, and 154, range 45, it runs nearly due north as a prominent gravel ridge, passing close west of the centers of these townships, and lying from 2 miles to 1 mile east of the old Pembina trail, which follows the McCauleyville beach. But near the south line of Viking the Campbell beach turns slightly, thence bearing north-northwestward, and for a few miles in the central and northwest portions of Viking the trail runs on its top.

Along the greater part of its explored extent north of the Red Lake River this shore is marked by a single large gravel ridge, 20 to 30 rods wide, 5 feet or more above the adjoining surface of till on the east and 10 to 20 feet above its western edge; but in the northwest part of Viking two Campbell beaches, a quarter to a half mile apart, run from section 17 to section 6, the western being less typically ridged and mostly 10 to 15 feet lower than the eastern. On the top of the western beach, near the middle of the west half of section 6 and a quarter of a mile south of the Snake River, a conspicuous aboriginal mound was noted, having a diameter of 50 feet and a height of 6 feet. Only a few feet south from its edge a smaller

mound, about 15 feet in diameter, rises $1\frac{1}{2}$ feet above the beach. No other earthworks were seen in this vicinity.

Snake River, where it intersects the Campbell and McCauleyville beaches, has only stagnant pools in hollows of its bed during dry summers, while the Middle and Tamarack rivers, next to the north, seldom or never fail to carry running water, although reduced nearly to the size of brooks. Just after crossing the Snake River the Pembina trail turns westward three-fourths of a mile to the McCauleyville beach, on which it runs nearly all the way for 15 miles northward. The Campbell shore, continuing in the line of its western beach before described, passes almost due north along the west side of Marsh Grove Township, and thence runs a little to the west of north, bearing a fine ridge of gravel and sand, underlain and bordered on each side by till. Its distance east from the Pembina trail is between 1 and 2 miles, to the Tamarack River. Beyond this stream the trail turns to the northwest, diverging from these beaches, which continue to the north and north-northwest.

Through Marshall County the Campbell shore lies nearly on the limits of the chiefly prairie country on the west and of the wooded region on the east. The beaches are mostly grassed, with no bushes or trees, but brush and small poplars occupy much of the adjoining land on the west and between these gravel ridges, and almost the entire area on the east bears a small growth of poplars, where they have not been lately burned. At a distance of 10 to 20 miles eastward a forest of many species begins, comprising the common poplar or aspen, the large-toothed poplar, the balsam poplar, cottonwood, canoe birch, black and bur oaks, white elm, white and black ash, red and sugar maple, basswood, and the white, red, and jack pines. In the swamps, and frequently on higher land, tamarack, black spruce, and balsam fir grow in abundance, often festooned with moss. Crossing Kittson County, the most northwestern in Minnesota, the Tintah shore-lines extend here and there into heavily timbered tracts, while the Campbell and McCauleyville beaches continue approximately along the somewhat definite boundary dividing the woods and the prairie.

CAMPBELL SHORES IN NORTH DAKOTA

(PLATES XXVII-XXX.)

On the west side of Lake Agassiz one of the Campbell shore-lines begins to be marked by a beach ridge in the northwest corner of section 5, township 128, range 47, South Dakota, where it lies about 15 rods east of L. H. Eldred's house, running in a north-northwesterly course and immediately passing into North Dakota. The crest of this gravel ridge is 988 to 990 feet above the sea, with slopes that fall 12 feet to the east and 3 to 6 feet to the west, the surface on each side being till.

The Minneapolis and Pacific Railway and the Aberdeen Branch of the Great Northern Railway cross three Campbell beaches west of the Bois des Sioux. Wider spaces separate the shore-lines here than elsewhere, because the land is very nearly level and the lake had only a slight depth to a distance of several miles offshore. When the district was uplifted or the level of the water fell away even 4 or 5 feet, the emerging belt varied from 1 to 3 miles in breadth. The most eastern of these beaches, lying within a half mile east of Fairmount, forms small, irregular ridges, with crests at 979 to 984 feet. The next, passing by De Villo station, has an elevation of 987 feet; and the third, which is the continuation of the ridge at Mr. Eldred's, runs northwestward nearly through the center of De Villo Township, rising 5 feet above the general level, with its crest at 993 feet. But probably the earliest Campbell stage of Lake Agassiz here is represented by a line of dunes only 3 to 5 feet in height, with crests at 995 to 997 feet, crossed by these railways about 2 miles west of Oswald and Sonora. The lake levels thus indicated range from 992 feet, very nearly, downward to 980 feet, or perhaps 2 or 3 feet lower.

Continuing northwestward, these shores converge, on account of the increasing rate of westward ascent of the surface, as they approach the Sheyenne delta. They cross the Northern Pacific, Fergus Falls and Black Hills Railroad on the very gentle southeastward slope of the delta about 2 miles west of Mooreton, but are not definitely traceable there. Eight miles farther north the Campbell and upper McCauleyville shores begin to be marked by the escarpment or steep slope, descending eastward 20 to 50 feet within about a mile, which forms the eastern border of the principal

plateau-like mass of the Sheyenne delta, having been sculptured by wave erosion during these stages of the glacial lake. The same shore-lines continue near together along this frontal slope through a distance of 30 miles to the north and northwest, passing about 3 miles west of Barrett, 1 to 2 miles west of Colfax, a similar distance southwest of Walcott, about 3 miles southwest of Kindred, and 1 to 1½ miles north of Leonard. In many places, however, the eroded surface as it was shaped by the lake waves has been much changed since by the winds, which have heaped up its sand in dunes 10 to 30 feet high.

Beyond the northern limit of the Sheyenne delta, near Leonard, the border of the lacustrine area rises somewhat steeply from the Red River Valley plain, and the lower and best-defined Campbell shore-lines are mostly united or lie close together, whether marked by beaches or by an eroded escarpment. This very finely developed margin of the old glacial lake has been mapped, with determination of its height by leveling, through all the distance from Leonard to the international boundary, about 175 miles.

The Fargo and Southwestern Railroad crosses the Campbell shore close below the Tintah beaches and slightly more than a mile northeast of Leonard, but it is not distinctly marked there, lying near the foot of the northeastwardly declining slope of the Sheyenne delta. Its course is thence west-northwest about 8 miles, crossing the Maple River, to the southeast part of section 29, Walburg, where it turns to the north and holds mainly a north-northeast course through the next 25 miles to Wheatland and Arthur. About a quarter of a mile south of the Maple River the Campbell shore is marked by an exceptionally massive beach ridge which passes through a cemetery in the north part of section 3, Watson, its crest in the cemetery and close westward being 1,008 to 1,013 feet above the sea and some 75 feet above the river. This ridge consists of sand and fine gravel, largely derived from Cretaceous shales, with no pebbles exceeding 2 inches in diameter. North of the narrow valley cut by this river the beach ridge continues with an elevation of 1,006 to 1,009 feet for nearly 2 miles to its northward bend, beyond which the shore along its next 2 or 3 miles, having left the thinned margin of the delta sand brought into Lake Agassiz by the

Sheyenne, is traced as a low, eroded escarpment of till, 10 to 15 feet in height, with base at 995 feet.

Four to 6 miles north of its bend the Campbell shore is compound and irregularly developed, bearing three beach ridges of gravel and sand, which rise 5 to 10 feet above the adjoining surface of till and range from 986 to 1,000 feet above the sea. The uppermost forms a northwardly projecting spit in the southwest quarter of section 4, Walburg, on which Mr. Luther Wyckoff's well found sand and gravel to the depth of 10 feet and till beneath. Along its course of 6 miles onward to Wheatland some portions of this shore are marked by beach gravel, with crest at 992 to 995 feet; but commonly there is no beach deposit, its place being occupied by a somewhat steep descent toward the east, falling from 990 or 995 feet to about 975 feet, eroded in the general sheet of till. Below this a tract a half mile or more in width is fine lacustrine silt, descending eastward with less slope.

In the east part of Wheatland village the Northern Pacific Railroad intersects the Campbell beach a quarter of a mile from the station. A massive gravel and sand ridge here occupies a width of about 60 rods, including its slopes, and rises 15 feet above the nearly level expanse thence eastward. Its crest, at 994 feet, is 10 feet above the hollow, 40 rods wide, on its west side. This ridge appears to have been formed during the lower and more important of the Campbell stages of the glacial lake, when its level was about 990 to 985 feet. The accompanying upper shore-line, which should be looked for 10 to 15 feet higher, crosses section 15 between 2 and 3 miles north of Wheatland, where Mr. Joseph Fuller's house is built on the top of its beach ridge, about 1,012 feet above the sea. His well was dug 15 feet in sand and gravel, then passing into till.

North-northeastward from Wheatland the crest of the lower and principal beach holds a nearly constant elevation, varying in the first 3 miles, to Swan Creek, from 993 to 996 feet, with descent of 12 to 15 feet in 20 rods east, and usually 3 to 5 feet in 10 rods west. About two-thirds of its gravel, which has pebbles and cobbles up to 4 inches in diameter, are limestone; three-tenths, by estimate, are granite and other crystalline rocks; while about a thirtieth part is Cretaceous shale. Looking east from this

beach, one sees a very flat country, originally a monotonous prairie, which is in view to a distance of about 10 miles, and is hidden beyond only by the curvature of the earth's surface. In the summer nearly all this expanse is occupied by vast fields of wheat and oats, with frequent groups of substantial farm buildings, some of them surrounded by trees. The thriving towns of Everest, Casselton, and Amenia are seen in their order from south to north; and at these and many smaller stations of both the Northern Pacific and Great Northern Railways, also on some of the large farms, elevators tower above the flat lands, waiting to be filled with their grain. It is a most beautiful prospect, completely characteristic of the Red River Valley.

Through the next 5 miles to the Rush River the same features of the beach ridge continue, with elevation varying from 990 to 996 feet, except that occasionally the gravel and sand deposit is replaced by an escarpment of till, with crest at the same height as that of the beach, and having a steep descent of 10 to 15 feet from west to east. For nearly 4 miles onward after crossing this river (a puny stream, which is reduced to a series of stagnant pools during summer droughts) the Campbell shore is a till escarpment, as just described. Thence through the next 3 miles, to the town of Arthur, it is again a massive gravel and sand ridge, with elevation of 994 to 998 feet. Along the middle part of this distance, in section 32, Arthur, the descent from its crest westward, away from the lake area, is 3 to 5 feet, and its eastern slope falls 10 to 15 feet to a slough or moist tract, wholly mowing land, beyond which, at a distance of an eighth to a quarter of a mile from this beach, there is a lower beach ridge, probably representing the highest of the McCauleyville stages, with crest at about 985 feet.

At Arthur the Campbell beach curves to a north and almost north-northwestward course. It passes about an eighth of a mile east of the railway station, where its elevation is 994 to 997 feet above the sea, with slopes descending 3 or 4 feet to the west and about 10 feet eastward. Thence through 3 miles north the top of this gravel ridge varies from 996 to 1,002 feet. For the next 20 miles north-northwest, crossing the South and North branches of the Elm River (very small streams, wholly dry or

chains of pools in summer), the Campbell shore is almost continuously an escarpment of till, as shown by fig. 7 on page 26, with its crest and the level of the surface westward at 995 to 1,005 feet, from which a somewhat steep slope falls 10 to 20 feet eastward. It passes about three-fourths of a mile west of Hunter and 2 miles west of Greenfield. Along all this distance the nearly parallel McCauleyville shore, 20 to 30 feet below the top of the Campbell escarpment, lies about a mile, or in part only a half mile, farther east.

From a mile east of Roseville the Campbell shore runs nearly due north 4 miles to the west edge of the town of Portland, where it is an escarpment 12 to 15 feet high, with its crest and base respectively about 1,000 feet and 985 feet above the sea. The escarpment is eroded in the southern extremity of the sand and silt delta which reaches from McCanna to Portland, deposited by a river flowing into Lake Agassiz from the Elk Valley while lobes of the melting and retreating ice-sheet lay on each side. For its next 8 miles this shore-line passes northeastward to Morgan Township, in which it curves to the north and north-northwest; and thence it holds the latter course, with only deviations of a few degrees, through a distance of 75 miles north to the Pembina delta. Between Portland and Arvilla it is mostly marked by a well-defined beach ridge of gravel and sand, lying on till, at a distance of 2 to 3 miles east from the margin of the delta, which coincides nearly with the Tintah shore-lines.

The Great Northern Railway crosses this ridge three-fourths of a mile east of Arvilla, where it occupies a width of about 60 rods. Its crest has an elevation of 1,014 feet, from which there is a descent of 23 feet to the east and 9 feet to the west. Close south of the Turtle River, nearly 2 miles farther north, its top is at 1,011 to 1,013 feet; and within the next mile north of this stream its elevation is 1,007 to 1,010 feet. In the vicinity of Arvilla and through nearly 15 miles onward, passing through townships 152, Hegton, and 153, range 54, both the Campbell and McCauleyville shores bear conspicuous beach ridges, which are nearly parallel at a distance of about a half mile apart.

In section 5, township 153, range 54, and for 6 miles thence northward in Strabane and Inkster, passing a third of a mile east of Inkster station,

the Campbell shore is a low escarpment in the general surface of till, with crest at 1,018 to 1,026 feet, from which there is a somewhat steep descent of 15 to 25 feet. A few miles farther north, however, this is changed to a massive beach ridge of gravel and sand, which lies about a half mile west of Conway station.

Beyond Conway, along a distance of about 35 miles of very direct north-northwest course, this shore-line, passing through the west edge of the town of Park River and close by the east side of the village of Mountain, is almost uninterruptedly an eroded escarpment of till, with eastward descent of 20 to 30 feet, or rarely 40 feet, within an eighth of a mile, or often a less distance. At Park River the Campbell escarpment falls rather abruptly from 1,035 feet to 1,015 feet above the sea; and thence a gentle slope of till sinks about 15 feet lower in a half mile east to the McCauleyville beach and railway line. In the northwest corner of Dundee, 10 miles



FIG. 17.—Profile of the Campbell escarpment in section 6, Dundee. Scale, 100 feet to an inch.

north of Park River, the escarpment falls from 1,045 to 1,015 feet, being steep for the upper half, which consists of till; then it descends more slowly a few feet, also in till, with frequent boulders; and its lower third is a somewhat steep slope of beach sand and coarse gravel (fig. 17).

From its foot a smoothed surface of till sinks gradually eastward, having an estimated descent of 100 feet within 3 miles. In section 2, Gardar, the crest of the escarpment, at 1,045 feet, bears a slight ridge of beach gravel and sand, 2 to 3 feet high above the surface of till on the west; but the face of the escarpment, here falling 25 feet within 30 rods to the east, is till inclosing plentiful boulders of granite and gneiss. A few miles farther north, at a distance of about 1 mile south of Mountain village, the steep slope falls from 1,040 to 1,000 feet, and is covered with a beach deposit of gravel and sand from 1,030 to 1,020 feet, while its higher portion and a broader belt forming its foot, like the lower land extending eastward,

are till (fig. 18). At Mountain this shore descends 30 feet, from 1,045 to 1,015 feet, within a distance of about 25 rods. It is wholly till, with no associated beach formation, as also are the more gentle slopes on both sides, sinking toward the east and rising westward. During all the Campbell stages of Lake Agassiz erosion was in progress upon this long escarpment; but in some localities the action of the waves in cutting away and removing the till was temporarily changed, alternating with accumulation of shore deposits of wave-brought gravel and sand.

Erosion of the base of the "first Pembina Mountain"—that is, the front of the Pembina delta, along a distance of 6 miles to the southeast from Walhalla—supplied an extraordinarily massive Campbell beach or embankment, varying from a quarter of a mile to nearly 1 mile in width, which extends 8 or 9 miles in a curving course, convex to the southeast, through sections 5, 8, 17, 20, 29, and 30, township 161, range 55, and the south half



FIG. 18.—Profile of the Campbell escarpment 1 mile south of Mountain. Scale, 100 feet to an inch.

of section 25, the southeast quarter of section 26, and the west half of section 35, township 161, range 56. This broad belt consists of gravel and sand, 15 to 40 feet or more in depth, which were carried southward by the shore currents of Lake Agassiz in its Campbell stages, the greater portion being transported 6 to 12 or 15 miles. A section crossing this deposit is shown in fig. 19. The crest or somewhat plateau-like top of the embankment in its course of 6 miles south of the Tongue River has an elevation of 1,020 to 1,030 feet above the sea. In its narrower part, north of this river, its crest ranges from 1,028 to 1,033 feet along the first mile from the river; 1,030 to 1,035 feet along the next mile; and 1,035 to 1,045 feet, averaging 1,040 feet, in its third and most northern mile, passing through the southwest edge of section 29, township 162, range 55, where it becomes an ordinary beach ridge only 20 to 30 rods wide, with descent of 15 feet to the east and 5 feet to the west. The process of accumulation of the

extensive embankment was by transportation of its material along the shore that is marked by this beach ridge, and by building it thence out into the lake in this long hook bent to the west, which grew gradually in length and in height until it rose to the lake level, its growth afterward being by additions to its width. From its eastern verge a slope of the same gravel and sand falls 30 to 40 feet in a third or half of a mile, to a south-to-north belt of dunes and sand ridges, 10 to 15 feet high, which appears to represent the McCauleyville beaches. West of this embankment a basin 15 to 40 feet below it, mostly consisting of fertile wheat land, well drained by the Tongue River, extends 6 miles from south to north, with a maximum width of about 3 miles, lying between the embankment and the southeastern border of the Pembina delta, which was the lake shore during the Norcross and Tintah stages. The prevailing course of the coastal currents of Lake



FIG. 19.—Section across the Campbell embankment in sections 20 and 21, township 161, range 55. Horizontal scale, one-third of a mile to an inch; vertical scale, 100 feet to an inch.

Agassiz, and of the transportation of its beach material here and elsewhere, on both its western and eastern sides, was from north to south, as now on Lake Michigan, due then and now to the prevailing directions of the winds, and especially of gales in severe storms, when the broader and higher portions of the beaches were chiefly amassed.

At Walhalla and northwestward the Campbell shore-lines run along the base of the escarpment of the Pembina delta, where its steep descent is succeeded by a more gentle slope. Rev. John Scott's house, a half mile west of Walhalla, and the houses of H. A. Mayo and John Harvey, respectively about a half mile and 2 miles farther northwest, are on the principal lower Campbell shore, which in part is a well-developed beach ridge, with crest 1,030 to 1,035 feet above the sea, but mostly is a terrace eroded in the delta deposit, falling from 1,040 to 1,020 feet, approximately. In the

northeast part of section 14, township 163, range 57, about 3 miles northwest of Walhalla, the upper Campbell shores form such a terrace, which falls from 1,075 to 1,035 feet; while a more moderate slope of sand and fine gravel below, to 1,025 feet at the road running northwest from Walhalla, probably represents the lower Campbell stage.

Three miles farther northwest and about 1 mile south of the international boundary a terrace of gravel and sand in the west part of section 34, township 164, range 57, marks the Campbell levels of the lake. The front of the terrace rises steeply from 1,015 to 1,035 feet above the sea, and its top has a further gentle ascent of 10 or 15 feet in its width of about 50 rods to where it abuts on the base of the lowest escarpment of the Pembina Mountain, which rises from 1,050 to 1,100 feet. From the top of this escarpment a terrace or plateau of till and underlying Cretaceous shale extends across a width of three-fourths of a mile west to the principal Pembina escarpment. The upper Campbell level probably passed along the top of the sand and gravel terrace, near the elevation of 1,045 feet; the second level of the series was near the verge of this terrace, approximately 1,035 feet; and the third and lowest stage coincided with the lowest third of its steep front.

CAMPBELL SHORES IN WESTERN MANITOBA.

(PLATES XXX-XXXIII.)

Along the course of the Cretaceous terrace, thinly covered with till, which borders the base of the Pembina Mountain for at least 25 miles northward from the international boundary, as described in connection with the Tintah beaches, the upper Campbell shore-line, there having an elevation of 1,045 to 1,050 feet, coincides generally with the low escarpment which forms the east margin of this terrace. A portion of the sculpturing of this escarpment was doubtless done by the waves of the lake; but the main outlines of the terrace as a bench intermediate between the expanse of the Red River Valley and the high Pembina escarpment seem clearly attributable to subaerial erosion before the Ice age. The first locality where I observed a distinct beach ridge of gravel and sand referable to this stage is in section 3, township 4, range 6, a half mile west of Nelson, and thence

through a distance of a mile or more north-northwestward. It lies close east of the terrace escarpment, and has an estimated elevation at its crest of 1,055 feet. In township 7, range 8, this shore is marked by a conspicuous beach ridge, passing through sections 22, 27, and the east edge of 33, lying an eighth to a half of a mile west of the Boyne River, with its crest about 1,055 to 1,060 feet above the sea. The descent from the crest is 10 to 15 feet on the east and 5 to 8 feet on the west. The lake at this stage, or at a slightly higher level, also cut an escarpment 15 to 20 feet high, with its top at 1,075 feet, approximately, which passes northwestward across sections 28 and 29 of this township and northward through the east part of sections 6 and 7, township 8, crossing the railway about 7 miles east of Treherne.

The lower Campbell beach, in its course northward from the international boundary, lies close east of the terrace face which was the upper Campbell shore. In sections 2 and 11, township 1, range 5, the elevation of its crest is 1,036 to 1,040 feet. On the west a nearly level surface extends an eighth of a mile to the terrace. On the east a slope of beach gravel and sand sinks to 1,028 feet in about 25 rods; and a similarly descending surface of till continues to 1,015 feet in the next 25 rods, beyond which there is a much slower descent eastward. The road on the line between townships 1 and 2, range 5, crosses this shore about three-eighths of a mile west of the northeast corner of section 34, township 1, where it is marked by a typical beach ridge, with its crest at 1,034 feet, from which there is a descent of 10 feet in 10 rods to the east and 3 or 4 feet in 10 rods to the west. This ridge was seen to hold nearly the same outline and height through a distance of 1 mile or more to the south and a half mile north to a small creek. About a half mile west of Morden, where it has been considerably excavated for plastering sand, it has a nearly flat top 10 to 20 rods wide, with ascent on this width from 1,030 to 1,040 feet, approximately, resting on the base of the terrace escarpment. Five to 6 miles farther north the road from Nelson to Miami runs along the top of this beach through the north half of section 3 and the southwest quarter of section 10, township 4, range 6. It is there a broad, low ridge of sand and gravel, 20 to 30 rods wide, the elevation of its crest being about 1,035

feet, or 10 feet above Nelson. Continuing northward, it crosses the northeast quarter of section 6, township 5, range 6, a mile west of Miami.

The course of these shore-lines was not traced across the Assiniboine delta, but their elevation shows that they lie on its eastward slope, where they are intersected by numerous ravines, and are doubtless obscured in many places among its dunes. On the Canadian Pacific Railway profile three massive beach ridges, the two higher referable to the upper Campbell stage and the third to the lower Campbell stage of the lake, are shown 3 miles to $2\frac{1}{2}$ miles west of Austin, their crests being, respectively, 1,087, 1,081, and 1,066 feet above the sea. These beaches are each about 30 rods wide, with descents of 10 to 20 feet from their crests to their east bases and half as much to the west.

On the Manitoba and Northwestern Railway the upper Campbell beach is a very massive rounded ridge, 30 to 50 rods wide, along whose eastern slope the railway runs about 3 miles, from the south side of section 6, township 15, range 13, north-northwest to Arden. Before the railway was built, the old trail from Winnipeg to the Saskatchewan River passed along the top of this ridge the same distance and to a point about a mile north of Arden, there leaving it and turning to the west. This portion of the trail was a good dry road throughout the year, being thus remarkably contrasted with the deep mud along most of its extent during rainy seasons. Because of this character of the road and the beauty of the smooth beach, which is prairie, without tree or bush, but is bordered on each side by groves, this avenue-like tract received its widely known name, the Beautiful Plain. It is not flat, however, as the name seems to imply, for the crest of the beach ridge, at Arden, 1,090 feet above the sea, and not varying more than a few feet above or below this elevation in its course through several miles south and north, is 15 to 25 feet above the nearly straight margin of the woods an eighth to a quarter of a mile east, and 7 to 10 feet above the more irregular margin of bushes and woods on the west, commonly 10 to 30 rods distant. The barrier of this beach ridge was sufficient to turn the White Mud River southward 3 miles along its west side. In a section cut 6 feet deep close north of Arden, for the passage of the railway and in excavation of ballast, the material of this beach is mainly fine gravel, with pebbles

only a quarter to a third of an inch in diameter, but also includes layers of sand and coarser gravel, with pebbles up to 2 inches in diameter, of which about three-fourths are from the Paleozoic formations of magnesian limestone that occupy the country eastward to Lake Winnipeg and northward to the Saskatchewan.

From Arden this beach extends north-northwest through the northeast part of township 15 and nearly through the center of township 16, range 14. In the north half of township 16 it has in several places a narrow, terrace-like secondary beach on its eastern slope 5 to 10 feet below the crest of the main beach; and it is closely bordered on the west by a low escarpment of till which rises 5 to 10 feet above the beach ridge and forms the margin of a flat or slightly uneven expanse of till that ascends slowly westward. A post-office situated close west of this beach and escarpment, in section 32, township 16, is named Orange Ridge, in allusion to the orange-red lilies (*Lilium philadelphicum* L.) which grow in abundance on the sandy and gravelly soil of the beach. The elevation of the Orange Ridge or Beautiful Plain beach on the north line of the northeast quarter of section 32, township 16, is approximately 1,080 feet above the sea; and of the escarpment on the west, which was eroded during the early part of this upper Campbell stage, 1,090 feet.

The lower Campbell beach is crossed by the railway near the southeast corner of section 6, township 15, range 13, where the elevation of its crest is 1,061 feet, with a descent of 8 feet in about 15 rods to the east and 5 feet in a few rods to the west. Through the next 15 miles northward it lies a half to two-thirds of a mile east of the Beautiful Plain and Orange Ridge. East of the latter, on the line between townships 16 and 17, range 14, the elevation of its crest is about 1,070 feet, with descent of 15 feet to the east and 10 feet to the west.

The northward continuations of the Campbell beaches pass through sections 5 and 8, township 17, range 14, to Thunder Creek, and thence a few degrees west of north to the Big Grass River, in section 31 of this township. Thence they traverse sections 6, 7, and 18, in township 18, range 14, and the northeast part of township 18, range 15, where a swamp

on the west about 2 miles wide separates them from the base of Riding Mountain.

Mr. Tyrrell's observations and map of the beaches of Lake Agassiz adjacent to the northern part of Riding Mountain and on the eastern and northern sides of Duck Mountain, as correlated with my mapping from Lake Traverse to the southern end of Riding Mountain, show the principal Campbell shore, there probably the upper one, to be marked by a prominent gravel ridge, which Mr. Tyrrell has traced through distances of many miles.¹ The elevation of this beach ridge where it crosses the Ochre River, on latitude $50^{\circ} 56'$, is 1,115 feet above the sea. On the Valley River, about 30 miles farther northwest, its height is 1,135 feet. Twenty miles thence northward, on Shanty Creek, this shore has two beach ridges, respectively 1,180 and 1,190 feet above the sea. The lower one of these beaches has been followed continuously 15 miles to the north, attaining there an elevation of 1,225 feet. Nearly 20 miles farther north, the elevation of the Campbell beach at its most northern observed locality, on latitude 52° , is 1,290 feet, perhaps corresponding to its upper ridge on Shanty Creek.

This well-defined, massive gravel ridge, double in portions of its course, is doubtless the continuation of the similar beach which is called the Beautiful Plain and Orange Ridge, having at Arden an elevation of 1,090 feet above the sea. For the distance of about 70 miles north from Arden to the Ochre and Valley rivers its ascent continues somewhat as from the international boundary to Arden, averaging two-thirds of a foot per mile. But northward from Valley River to Duck River, in a distance of about 55 miles, between latitudes $51^{\circ} 13'$ and 52° , this beach rises 145 feet, or more than $2\frac{1}{2}$ feet per mile. After the Campbell stages of Lake Agassiz, the southern part of the lacustrine area was only slightly uplifted; but the region of Duck Mountain subsequently experienced a greater differential uplift, increasing in amount from south to north, than that of the earliest Herman beach farther south, where nearly all of its inclination had taken place before the Campbell beaches were formed.

¹Pages 395 and 406, this chapter. Geol. 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.

BEACHES OF THE M'CAULEYVILLE STAGES.

The channel of the River Warren, outflowing from Lake Agassiz, had been eroded below the level of Lakes Traverse and Big Stone when the McCauleyville beaches began to be accumulated. Portions of the bottom of the river-course are now the beds of these lakes, whose maximum depths are reported to be respectively about 15 and 30 feet. In the vicinity of White Rock the bottom of the River Warren, eroded in till, is 965 to 970 feet above the sea. Along the broad tract of marsh, with lakelets, between White Rock and Lake Traverse, the depth of the alluvial swampy deposit probably ranges from 10 to 15 feet, reaching down to the level of the deepest part of the bed of Lake Traverse, approximately 955 feet above the sea. This or a slightly greater depth of the channel continued between Lakes Traverse and Big Stone, where alluvium has since been brought in by the head stream of the Minnesota River to the depth of 25 feet or more. The bed of Big Stone Lake sinks to about 935 feet in its deepest part, and the alluvium of the Whetstone River, which is spread along the Minnesota Valley below this lake, has probably a corresponding thickness of at least 30 feet.

The southern portions of the McCauleyville shore-lines of Lake Agassiz coincide nearly with the levels of high and low water in Lake Traverse, which are approximately 976 and 970 feet above the sea. The highest yearly stage of the glacial lake attended the more rapid melting of the ice-sheet in summer, while its winter stages doubtless fluctuated so low at times as to reduce the depth of the River Warren to only a few feet. No appreciable epeirogenic movement of the south part of the lacustrine area appears to have taken place during the time of formation of the McCauleyville beaches; but northward, in Manitoba, the earth's crust was uplifted 15 to 50 feet within this time, as shown by its upper and lower shore-lines.

Along nearly all of their course the Campbell and McCauleyville shores lie nearly parallel, and are only a few miles or mainly less than 1 mile apart, permitting both to be mapped, with determination of their heights, from a single line of survey. The latter are 10 to 20 or 30 feet below the former in their southern portion, but the vertical range of the two series increases to 70 feet in southwestern Manitoba, while the highest

McCauleyville beach appears to be 90 feet below the highest Campbell beach at the northern end of Duck Mountain.

The McCauleyville shores are seldom marked by an eroded escarpment, like that which characterizes the principal Campbell shore through considerable distances. Instead, they are traced by beach deposits, which are generally well defined and often form a conspicuous ridge, vying in size with any other beach of this lake.

EASTERN M'CAULEYVILLE SHORES IN MINNESOTA.

(PLATES XXIII-XXVI.)

Through a distance of 47 miles, from Lake Traverse north to the southern edge of Mitchell, a few miles east of McCauleyville, the border of Lake Agassiz at its lowest level of southward outflow is mapped on Pls. XXIII and XXIV, the line being drawn on the second of these plates in accordance with the elevations determined at each quarter-section corner on east-to-west section lines by the Red River Valley Drainage Commission of Minnesota in 1886. It is not exactly horizontal, however, but has a descent from the known level of the lake at White Rock, about 970 feet above the sea, to the level indicated by the beaches between McCauleyville and Barnesville, which is approximately 960 feet. Thus there appears to have been a slight differential northward depression of this area, or else an increase of the height of the land at Lake Traverse as compared with the country northward, since Lake Agassiz ceased to outflow to the south. These changes in relative elevations were opposite to those which were intermittently in progress throughout all the explored portion of this glacial lake during its whole history, giving to the shores their present northward ascent. But the discordant movement reached no farther north, for beyond Barnesville these shores on both sides of the lake rise continuously, though very slowly, from 1 inch to 3 or 4 inches per mile, to the international boundary.

In the southwest part of Mitchell a broad, curved embankment, which may be called a hook, extends from the south part of section 21, 2 miles westward, and then about an equal distance southward, forming a plateau-like tract a quarter of a mile to nearly 1 mile wide. The narrowed southern

end of the hook lies about 3 miles east-northeast of McCauleyville. It consists of gravel and sand that were borne from northeast to southwest by the currents and waves of Lake Agassiz and were accumulated in this broad deposit as a curved cape of its shore, which, on account of the prominence of this earliest portion observed by me, has been named for the neighboring pretty village of McCauleyville, on the Red River, opposite to Fort Abercrombie. The elevation of its top is 960 to 970 feet above the sea, being 5 to 10 feet or more above the general surface of till on the east, while westward a flat plain of stratified clay and fine silt, 25 to 35 feet below this beach, extends 3 miles to the Red River.

Following the McCauleyville shore northeastward 8 miles from the base of this hook to the Deerhorn Creek, which it crosses about $1\frac{1}{2}$ miles southwest of Atherton station, it is found to be marked chiefly by considerable

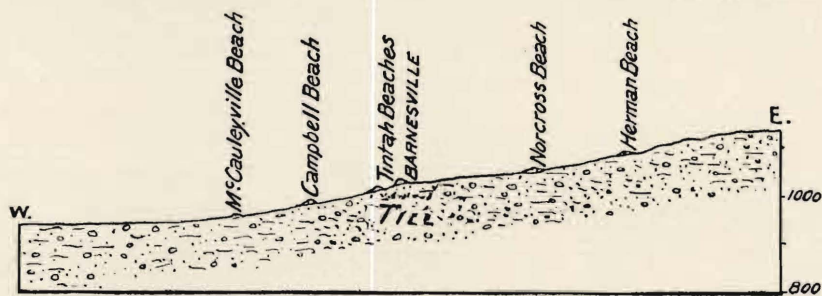


FIG. 20.—Profile across beaches at and near Barnesville, Minn. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

erosion of the till, but not by a well-defined escarpment. At only two localities, in the southwest corner of section 11, Mitchell, and again in the southwest part of section 29, Atherton, short and inconspicuous beach ridges occur, their crests being in each place 965 feet above the sea.

Beyond the Deerhorn Creek the course of this shore is nearly due north for the next 10 miles, lying mostly about 1 mile west of the Campbell beach. It runs nearly through the middle of section 4, Atherton, where a small beach deposit has been dug for masons' sand; and in Barnesville it passes 2 miles west of the town. Fig. 20 shows a profile crossing the eastern border of Lake Agassiz from west to east through Barnesville. In the southwest part of section 2, Barnesville, it forms a rather broad gravel and sand ridge, rising to 966 feet above the sea, with springy and boggy ground about 10 feet lower on each side.

One to 4 miles farther north, in sections 34, 27, 22, 21, and 16, Elkton, two McCauleyville beach ridges are distinctly developed, extending north-northwesterly close alongside of the railway that runs from Barnesville to Glyndon. The upper beach has an elevation at its crest of 970 to 976 feet above the sea. It lies about an eighth of a mile east of the railway and was seen to be continuous at least 3 miles, attaining its most massive development and maximum height near Downer station, where its gravel, 8 to 10 feet in depth, has been largely excavated for railway ballast. The lower beach is smaller, and in part consists of a belt of sand and gravel, lying on the westwardly descending slope of till, without forming a definite ridge, while other parts are ridged up 1 to 2 feet above the east margin of the belt. Its gravel contains pebbles and cobbles up to 3 inches in diameter, and the depth of this deposit ranges from 3 to 5 feet. The elevation of its top is 964 to 966 feet, and its western base at 960 feet marks approximately the lake level when this second beach was formed, probably 8 or 10 feet lower than at the time of the higher beach.

About a mile north of Downer these shore-lines turn to a nearly due-north course, leaving this line of the Great Northern Railway. On the Northern Pacific Railroad they are united in a beach ridge that is crossed 5 miles east of Glyndon, having a width of about 20 rods, with descent of 3 feet to the east and 10 feet to the west from its crest, which is 983 feet above the sea. Thence through a distance of about 20 miles to the north the McCauleyville shore is not exactly traced, but is known to lie close west of the higher shore-lines, because the border of the lacustrine area rises steeply eastward.

In Rockwell and Lake Ida townships a well-marked McCauleyville beach ridge of gravel and sand, with till on each side, was traced several miles, lying about a half mile west of the Campbell escarpment and beach. Where it is crossed by the road on the north line of the northwest quarter of section 26, Lake Ida, its width is about 30 rods, and its east and west slopes fall respectively about 5 and 15 feet, its crest being 10 to 15 feet lower than that of the similarly massive Campbell ridge, which is a half mile distant to the east. The elevations of these ridges were not ascertained by leveling, but are probably about 985 and 1,000 feet above the sea.

My next observations of the McCauleyville beach are 10 to 15 miles farther north, in the townships of Spring Creek and Liberty. A large gravel and sand ridge, situated about two-thirds of a mile west of the Campbell escarpment, runs from south to north along the east edges of sections 9 and 4, Spring Creek, and sections 33 and 28, Liberty, to the Sand Hill River. Mr. Jacob Stambaugh's house is built on the top of this beach, in the northeast corner of section 33; and two aboriginal mounds, each about 3 feet high, were noted on the same ridge, one close north and the other a third of a mile south of this house, but no other Indian mounds are known in the vicinity.

The following notes of elevations describe a section (fig. 21) drawn from east to west, at Mr. Stambaugh's, across the Campbell and McCauleyville shore-lines. From the crest of the Campbell escarpment of till, 1,010 feet above the sea, there is a descent westward to a hollow of till a third



FIG. 21.—Section of the Campbell and McCauleyville beaches in sections 33 and 34, Liberty, Minn. Horizontal scale one-fourth mile to an inch.

of a mile wide, extending from south to north, at 980 to 975 feet; and west of this the McCauleyville beach ridge rises to 990 feet, holding this elevation, within 1 or 2 feet of variation above or below it, for a distance of at least 2 miles. Next westward the beach falls about 15 feet within 20 rods, and bears on its western border a secondary beach ridge, which in its most definite portions rises 4 or 5 feet from the east and falls about 10 feet on the west. The western base of this lower beach ridge is 970 feet above the sea, which represents very nearly the latest McCauleyville stage of Lake Agassiz, probably 10 to 12 feet below its earlier stage, when the higher principal beach was accumulated.

For nearly 25 miles between the Sand Hill and Red Lake rivers the McCauleyville shore has not been traced on the ground, but it is mapped approximately on Pl. XXVI, and is so shown by fig. 22, in accordance with the known westward descent of the surface. It lies mostly about a

half mile west of the Campbell shore, but in the vicinity of the Red Lake River and for 10 miles northward their distance apart is 2 to 3 miles.

The Duluth and Manitoba Railroad crosses two McCauleyville beach ridges, and runs a considerable distance on the eastern one, between three-fourths of a mile and 2 miles west of the Black River. Their crests are about 995 feet and 990 feet above the sea. A quarter to a half of a mile farther north the St. Hilaire Branch of the Great Northern Railway crosses these gravel ridges, Ives station being on the course of the western ridge, into which the railway cuts to the depth of a few feet. The crest of this beach, which was followed by the old Pembina trail, is at 990 feet; and that of the eastern beach, a third of a mile distant, is at 997 feet. Within a mile or two farther north the profile of leveling by Mr. E. C. Davis

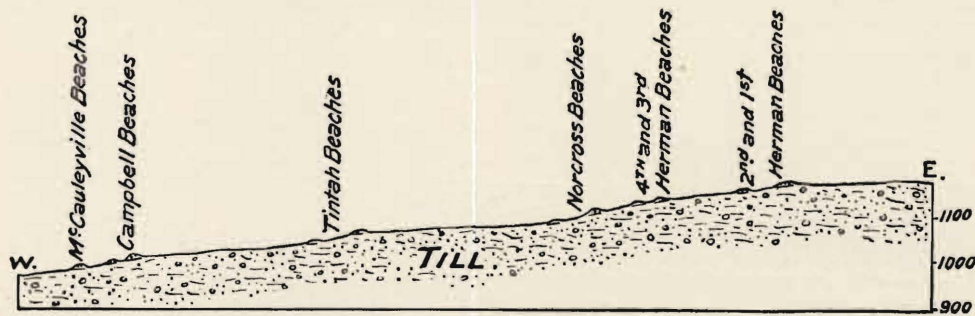


FIG. 22.—Profile across beaches on the north line of Onstead and Godfrey, Minn., west of Maple Lake. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

(p. 400) shows the McCauleyville beach at 996 feet. In this vicinity and along the next 15 miles northward this beach is a conspicuous gravel and sand ridge, mostly 20 to 30 rods wide, with slopes descending 5 feet or more to the east and 10 or 15 feet to the west. Throughout this distance it afforded an excellent roadway for the Pembina trail, on which during many years, until about 1870, long processions of Red River carts, drawn by oxen, traveled from St. Paul and St. Cloud to Fort Garry (now Winnipeg), carrying provisions and supplies for the Hudsons Bay Company, and returned laden with buffalo skins and furs.

Near the north line of section 20, Numedal, the McCauleyville beach ceases for the next few miles as a distinct ridge, and the Pembina trail thence passes to the Campbell beaches, on which it runs through Viking,

the next township on the north. From the ford of the Snake River in the northwest corner of Viking the trail deviates three-fourths of a mile to the west, again taking its way along the crest of the McCauleyville ridge, which is finely developed through the next 18 miles, to the north part of Nelson Park Township. The farther course of this beach, however, was not followed, as it extends into the borders of a more wooded or bushy and swampy country.

The beach is intersected by the Middle and Tamarack rivers, respectively, in the southern and northern edges of township 157, range 46, Wright. Through the south half of Nelson Park, lying next north, the conspicuous beach ridge, rising 5 to 10 or 15 feet above the originally unchanneled surface on the east, was a sufficient barrier to turn the Tamarack River from its normal westward course to one a little east of south for 3 miles before it cut through the ridge. At the center of the township of Nelson Park, where this river first comes to the beach from the east, the Pembina trail departs from it to the northwest. In its extent of 25 miles thence to Hallock, descending about 200 feet, this trail crosses several shore-lines of Lake Agassiz which elsewhere in certain portions of their course are very clearly defined; but no distinct beach ridge or eroded escarpment was seen on the trail or on either side, although the surface is mostly a gentle and regular slope of till, affording apparently very favorable conditions for the formation of shore marks.

Beyond Nelson Park the general course of the McCauleyville shore across Kittson County is to the north and north-northwest. It appears to be represented on the north line of Minnesota, according to the profile of the British Boundary Commission (p. 401), by a massive beach ridge with crest 1,016 feet above the sea and 20 feet above the land on each side, lying 20 miles east of the Red River. Within a short distance farther north, in Manitoba, this shore probably turns east-southeastward for a dozen miles or more, to cross the Roseau River near Pointe d'Orme (Elm Point), on the international boundary. Thence it passes northward and northeastward through the wooded region of southeastern Manitoba to the vicinity of Rennie station, on the Canadian Pacific Railway, and to the Winnipeg River, which it crosses not far above the mouth of the English River.

WESTERN M'CAULEYVILLE SHORES IN NORTH DAKOTA.

(PLATES XXVII-XXX.)

My most southern observations of the McCauleyville shore-lines in North Dakota are on the latitude of Wahpeton and northward, along the eastern border of the Sheyenne delta. Two levels of Lake Agassiz are indicated by the beaches and escarpments of these shores, the upper being now about 970 feet and the lower about 960 feet above the sea. A beach ridge formed by the lake at the upper level is crossed by the Northern Pacific, Fergus Falls and Black Hills Railroad, about a third of a mile west of Mooreton. Its width is about 30 rods, and the elevation of its crest is 974 feet, with descents of 8 feet to the east and 3 feet to the west. This shore continues north and northwest more than 30 miles along the base of the frontal steep slope of the Sheyenne delta, the erosion of which was completed by the lake waves during this stage. With the Campbell shores, which also run along this border of the delta plateau, it passes 1 to 2 miles west and southwest of Barrett, Colfax, Walcott, and Kindred, and about $1\frac{1}{2}$ miles north of Leonard.

Sand and fine silt of the Sheyenne delta, however, extend to a distance of several miles east of this plateau, partly as spread originally in the deep central portion of the lake during the Herman stages, when the delta was formed, and partly as redeposited from the erosion of the delta front during the later and lower stages. On this nearly flat tract of silt, at a distance of $1\frac{1}{2}$ to 2 miles from the plateau front, the lower McCauleyville shore is marked by a beach ridge, which through most of its observed extent of about 15 miles has become a narrow belt of dunes, occupying a width of 20 to 50 rods and rising 5 to 15 feet above the general level. This belt, running from south to north, is crossed by the railway $2\frac{1}{2}$ miles south of Colfax. Thence it gradually curves northwestward, passing about a half mile east of Colfax and Walcott, and is again crossed by the railway 3 miles northwest of Walcott. The land on each side of the beach and its dunes has an elevation of 955 to 960 feet, which represents approximately the former water surface.

As on the opposite portion of the east side of the lake, this latest shoreline, formed during the time of southward outflow, now lies about 10 feet

lower here than the present height of the Bois des Sioux Valley at White Rock, which then was the mouth of Lake Agassiz. The northward depression of the intervening area or its southward uplift, inharmonious with the epirogenic movements of all other explored parts of the lake basin, was

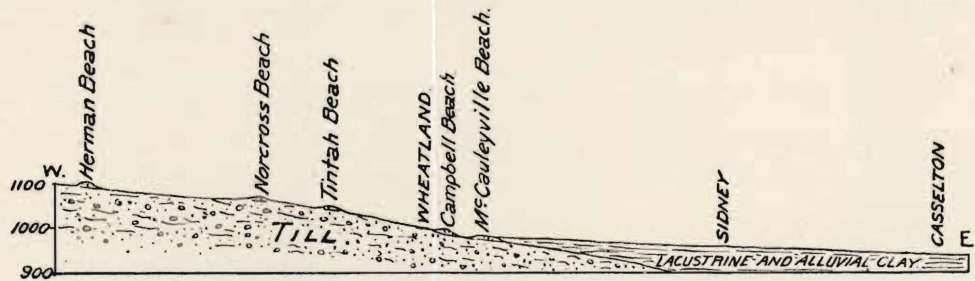


FIG. 23.—Profile across beaches at and near Wheatland, N. Dak. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

about 3 inches per mile along its extent of 40 miles, taking place after the flow of the River Warren ceased.

Northward from the Sheyenne delta, the McCauleyville shore through the next 30 miles lies within a mile, or mostly a half mile or less, to the east of the Campbell shore, both passing close east of Wheatland and Arthur. Fig. 23 presents a profile crossing the western beaches of Lake Agassiz on the Northern Pacific Railroad in the vicinity of Wheatland and westward. About 2 miles south of Arthur these two shore-lines, each there marked by a beach ridge, are only an eighth to a quarter of a mile apart.

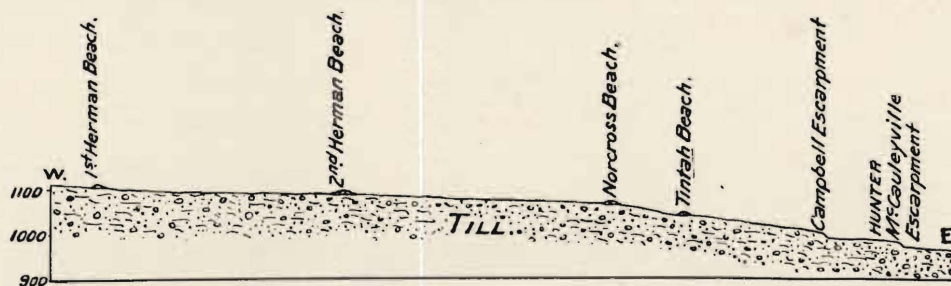


FIG. 24.—Profile across beaches at Hunter, N. Dak., and westward. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

The crest of the lower ridge, which probably belongs to the upper McCauleyville stage, is 983 to 987 feet above the sea. Eight miles north of this locality, the McCauleyville shore at Hunter is a low, eroded escarpment of till, which falls from 980 to 965 feet, passing in a north-northwesterly

course a quarter of a mile east of the railway station and about 1 mile east of the similarly eroded Campbell shore. Fig. 24 shows the westward ascent of the border of the lacustrine area in the vicinity of Hunter. Thence these shore-lines extend 15 miles north-northwest and 6 miles north to Mayville and Portland, holding a distance of about 1 mile to $1\frac{1}{2}$ miles apart.

The upper McCauleyville shore, approximately 980 feet above the sea, passes about a mile west and northwest of Mayville, but is not definitely marked on the almost level surface of lacustrine silt. For 12 or 15 miles in this part of its course, from 6 miles south to an equal distance northeast of Mayville, the lower McCauleyville shore, on account of the very slow descent of the land, lies probably 2 or 3 miles farther east, but it too is only dimly traceable.

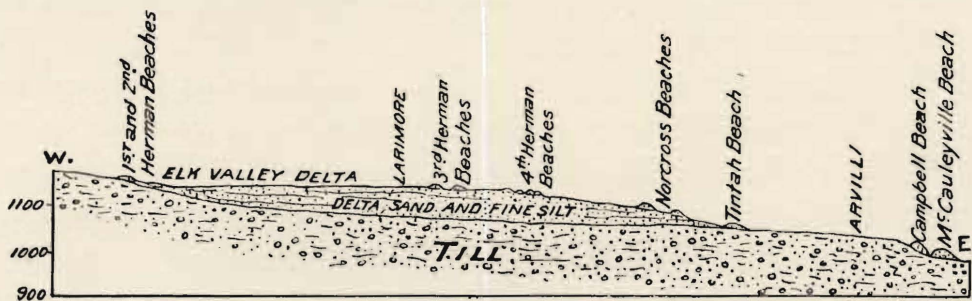


FIG. 25.—Profile across beaches in the vicinity of Arvilla and Larimore, N. Dak. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

Continuing northward to the vicinity of Arvilla, the upper and lower shore-lines converge, and on the Great Northern Railway, as shown on fig. 25, they together form a massive beach ridge, about 50 rods wide, with its crest 991 feet above the sea, from which its slopes descend 18 feet to the east and 8 feet to the west. This ridge lies a mile east of Arvilla, being about a third of a mile east of the still more conspicuous Campbell beach.

Beyond Arvilla the upper and principal McCauleyville shore is almost continuously marked by a fine beach ridge of gravel and sand, 5 to 10 feet above the adjoining surface of till on the west and east, through an extent of more than 30 miles to Park River. In section 14, Hegton, 4 to 5 miles north of Arvilla, the crest of this ridge is 995 feet above the sea, and other determinations of its height in sections 27 and 16 of the next township on

the north were 990 to 995 feet. In the southwest part of Strabane, passing about a mile east of Inkster (fig. 26), its elevation is mostly 995 to 998 feet, rising 5 to 8 feet above the depression, a sixth of a mile wide, in the surface of till on its west or landward side, while its lakeward slope falls 10 to 15 feet.

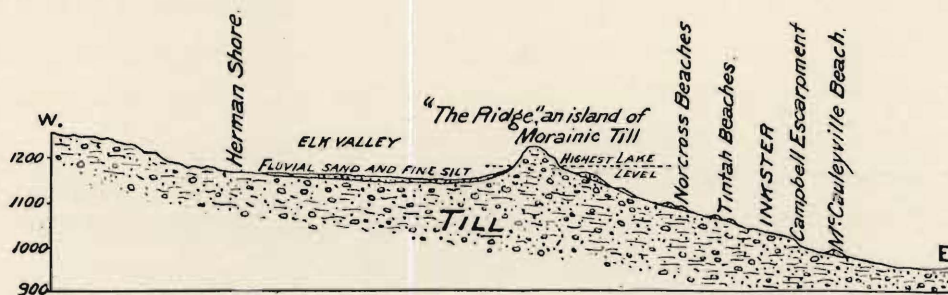


FIG. 26.—Profile across beaches at Inkster, N. Dak., and westward. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

One and a half miles north of Inkster the upper McCauleyville beach is crossed by the Langdon Branch of the Great Northern Railway close south of its bridge over the Forest River. Its crest here is 996 feet above the sea, with descents of 8 feet eastward and 5 feet westward. Thence it runs close along the west side of the railway for a distance of about 8 miles, passing an eighth of a mile west of Conway station. Onward for



FIG. 27.—Profile across beaches at Park River, N. Dak., and westward. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

the next 8 miles to Park River (fig. 27), the railway is built on the top of the beach ridge, which has an elevation of 996 to 998 feet. Thence along the distance of about 25 miles to the Pembina delta, this shore, probably marked throughout by a deposit of gravel and sand, lies about a half mile east of the Campbell escarpment.

A belt of low dunes in sections 28, 21, and 16, township 161, range 55, running along the eastern base of the great Campbell embankment that was built out to the south from the front of the Pembina delta, probably records the McCauleyville stages, approximately at 1,000 to 980 feet. North of the Tongue River the McCauleyville shores lie a third to a half of a mile east of the Campbell embankment and beach ridge along a distance of 5 miles. Thence through the next 6 miles, extending northwest to the Pembina River and Walhalla, they run along the base of the "first Pembina Mountain," which is the very steep ascent, 100 to 175 feet high, of the eroded east border of the Pembina delta plateau.

The road from Olga to Walhalla, coming down from this plateau about a mile southeast of the Pembina River, crosses at its foot a terrace of sand and gravel, 30 to 50 rods wide, having an elevation of 1,000 to 1,004 feet above the sea, which was formed during the upper McCauleyville stage. The highest part of the terrace is where it rests against the "mountain," and its surface descends a few feet to its northeastern verge. There is next a somewhat rapid slope to 985 feet at the bottom of a depression about 15 rods wide, beyond which the road passes over the beautifully developed lower McCauleyville beach. This ridge is 20 to 30 rods wide, with smoothly rounded top at 990 to 993 feet, very level along a visible distance of a third of a mile or more of its course from southeast to northwest, but hidden farther away by trees and bushes scattered here and there on its otherwise prairie surface. Its lakeward northeastern slope falls about 20 feet within 25 rods, and from its base a slower descent continues eastward.

All the land of this vicinity, including the plateau and front of the delta, the terrace and beach ridge, the intervening hollow, and the flat country on the east, consists of gravel, sand, and fine silt, belonging to the delta as it was originally deposited, or as it has been worked over by the lake waves during later stages. Indeed, proceeding eastward 30 miles to the Red River at Pembina, St. Vincent, and Emerson, one crosses only the fine silt which was of like origin with the delta, but was carried farther into the lake, or the similar alluvial beds that have been laid down from floods of the Pembina, Tongue, and Red rivers since Lake Agassiz was drained away.

Between Walhalla and the international boundary the McCauleyville shore-lines lie on the western margin of the flat expanse that stretches from the Red River to the Pembina Mountain, being a quarter of a mile to 1 mile east of the first conspicuous westward ascent, as shown in fig. 28. In section 2, township 163, range 57, about 2 miles south of the boundary, they form a tract of sand and fine gravel, 40 to 50 rods wide, drier than the adjoining surface on the west and east, passing by Elm Point, the eastern limit of the groves, at that place consisting mostly of large white elms, which extend outward from the wooded Pembina escarpment along springy water courses scarcely depressed below the general surface. The elevation of this gravelly tract is 997 to 1,002 feet. It is not a distinct ridge or even swell, and is recognizable chiefly by the contrast of its comparative dryness,

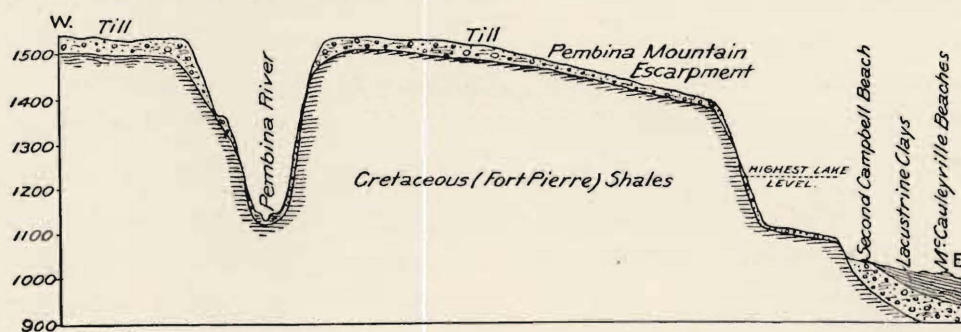


FIG. 28.—Section on the international boundary, south of ranges 6 and 5, Manitoba. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

which has caused it to be selected as the site of farmhouses. The adjoining moist and springy land on the east descends 15 or 20 feet in the first third of a mile; but thence the surface sinks very slowly to the axial lowest part of the lake basin on this latitude, at the Red River, its gradients in this distance being gradually diminished from 15 feet to only 2 or 3 feet per mile.

WESTERN M'CAULEYVILLE SHORES IN MANITOBA.

(PLATES XXX-XXXIII.)

In the southwest quarter of section 12, township 1, range 5, the upper McCauleyville shore is indicated by very scanty deposits of fine gravel, 1,006 to 1,007 feet above the sea, from which there is a descent of 3 or 4 feet in 20 rods east. Through the east half of section 23, the middle of

section 26, and the west half of section 35 of this township, two McCauleyville beaches are developed as small parallel ridges of gravel and sand. The upper one has an elevation of 1,000 to 1,002 feet at its crest, from which there is a descent of 1 to 2 feet within 2 or 3 rods to the west and 5 to 8 feet in 10 or 12 rods to the east. Thence a nearly level surface of till with frequent boulders occupies a width of 10 or 12 rods, and is succeeded on the east by the second ridge, the western slope of which rises 2 or 3 feet to its crest. This is about 5 feet lower than the upper beach, and has a similar descent of 5 feet or more on its east side.

Fig. 29 presents a section crossing the McCauleyville and higher beaches on the latitude of Mountain City, where the Pembina Mountain ascends less steeply than throughout the greater part of its extent.

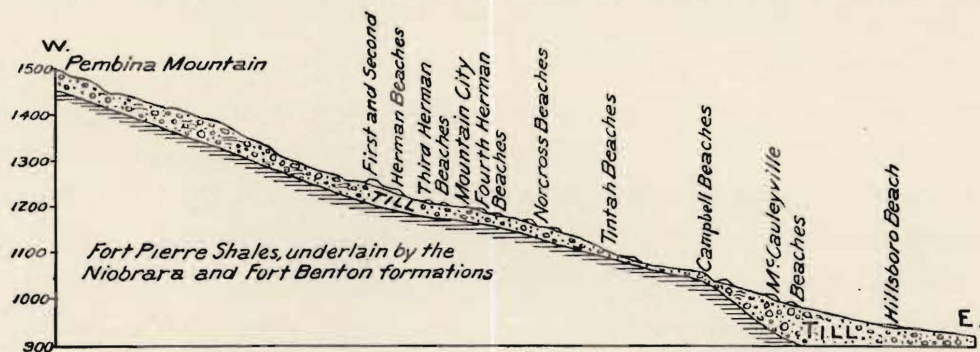


FIG. 29.—Section across ranges 6 and 5, Manitoba, 9 to 10 miles north of the international boundary. Horizontal scale, $2\frac{1}{2}$ miles to an inch.

About a quarter of a mile east of Nelson the upper McCauleyville shore is a line of erosion with a descent of 5 to 10 feet within a short distance from west to east. Four miles thence to the north-northwest it is a well-defined beach ridge running close to the bridge over Boyds Creek, near the northeast corner of section 21, township 4, range 6; and it continues, but is less conspicuous, through the next 3 miles northward to the church in the northeast corner of section 5, township 5, range 6, a quarter of a mile east of Miami post-office. Its crest at Boyds Creek is 8 to 10 feet, and at Miami 5 feet, above the more massive second or middle McCauleyville beach, which lies a quarter to a half of a mile farther east, passing north-northwesterly through the west edge of section 27, and the east half of section 33, township 4, in which latter it is offset nearly a

quarter of a mile to the east, and through the middle of section 4 and the west half of section 9, township 5.

Three McCauleyville beach ridges are crossed by the Manitoba and Northwestern Railway on the north side of sections 32 and 33, township 14, range 13, about 4, 4½, and 5 miles southeast of Arden, the elevations of their crests being respectively 1,039, 1,029, and 1,016 feet above the sea. Each of these rises about 5 feet above the surface on the east. They continue as prominent gravel ridges north-northwestward through the west half of township 15 and the southwest part of township 16, range 13, and through the northeast part of township 16, the east half of township 17, and the west half of township 18, range 14, to the vicinity of Phillips's ranch. The relationship of the Campbell, McCauleyville, and lower beaches near Arden and eastward is shown in fig. 30.

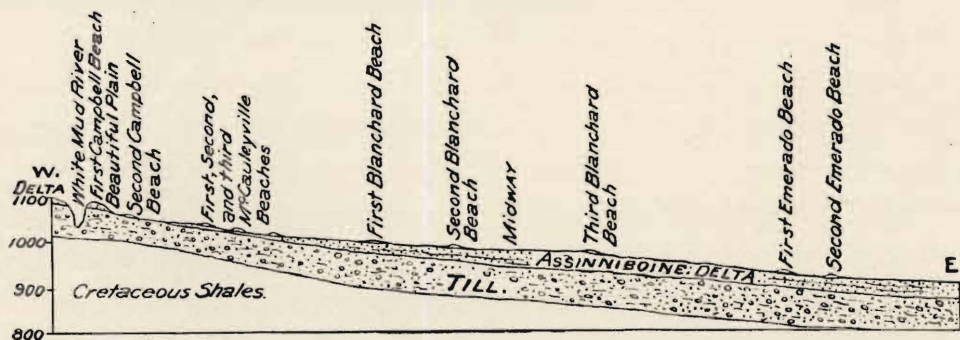


FIG. 30.—Section on the south side of townships 15, ranges 13 and 12, Manitoba, between Arden and Gladstone. Horizontal scale, 2½ miles to an inch.

In township 15, range 13, next east of Arden, the most western and upper one of the McCauleyville beaches is called Lowdons Ridge, from Thomas Lowdon, whose house, the first built on it, is in the middle of the east edge of section 30. The middle beach appears to be twofold in sections 20 and 29, Joshua Ritchie's house being built on one of its ridges and the Rose schoolhouse, a quarter of a mile farther east, on the other. About three-quarters of a mile east of the Rose Ridge is the lower McCauleyville beach, on which the trail to Lake Dauphin runs northward through townships 15 and 16. Lewis McGhie's house is built on the eastern slope of this beach, in the northeast quarter of section 28, township 15. Lowdon's, Ritchie's, and McGhie's wells, and others in this township on these beach ridges, pass through gravel and sand 5 to 15 feet and through till below to

total depths of 30 to 40 feet, obtaining water in gravelly seams, from which it usually rises 10 to 20 feet within a few hours, to its permanent level.

East and north of Duck Mountain beaches of the McCauleyville stages are shown as follows by Mr. Tyrrell's map, according to my correlation with these shores southward in Manitoba and North Dakota:

On the Vermilion River, which flows from the northeastern flank of Riding Mountain to Lake Dauphin, the beach ridges of two of these stages are mapped, the elevation of the lower one being noted as 1,068 feet above the sea. Twelve miles to the northwest their elevations are 1,084 and 1,075 feet, at the north side of the Valley River, which flows from the gap between the Riding and Duck mountains. Both these beaches are probably represented by the upper shore-line farther south.

The higher beach was followed by Mr. Tyrrell 20 miles thence north to the Shanty Creek, but without further notation of its height. About 20 miles farther north, near the south side of Pine River, it is found at 1,175 feet. Fifteen miles onward, at latitude 52° , close south of Duck River, the upper McCauleyville beach is 1,201 feet above the sea, having thus an ascent of 117 feet in its course of 55 miles from the Valley River. Three miles beyond the Duck River where it turns sharply westward, adjacent to the base of the northeastern angle of Duck Mountain, its height is 1,198 feet. After a course of a few miles to the west the beach ridge of this shore, or the foot of its eroded escarpment, was followed along the next 15 miles west-southwesterly, at the base of the steep mountain slope, by the original location survey for the Canadian Pacific Railway.

Curving thence again to the north, this upper McCauleyville shore-line, where it crosses the Swan River, about 30 miles west of its crossing of the Duck River, is marked by a prominent gravel ridge or embankment known as the "Square Plain," 1,160 feet above the sea. It is thus shown that the former lake level has now an ascent here of a little more than a foot per mile from west to east, or about half of its rate of ascent from south to north in this district. The direction of the differential uplift, as in the southern part of the lake area, was from south-southwest to north-northeast, toward the region on which the ice-sheet had been thickest and where it lingered latest as the barrier of Lake Agassiz.