

CHAPTER VI.

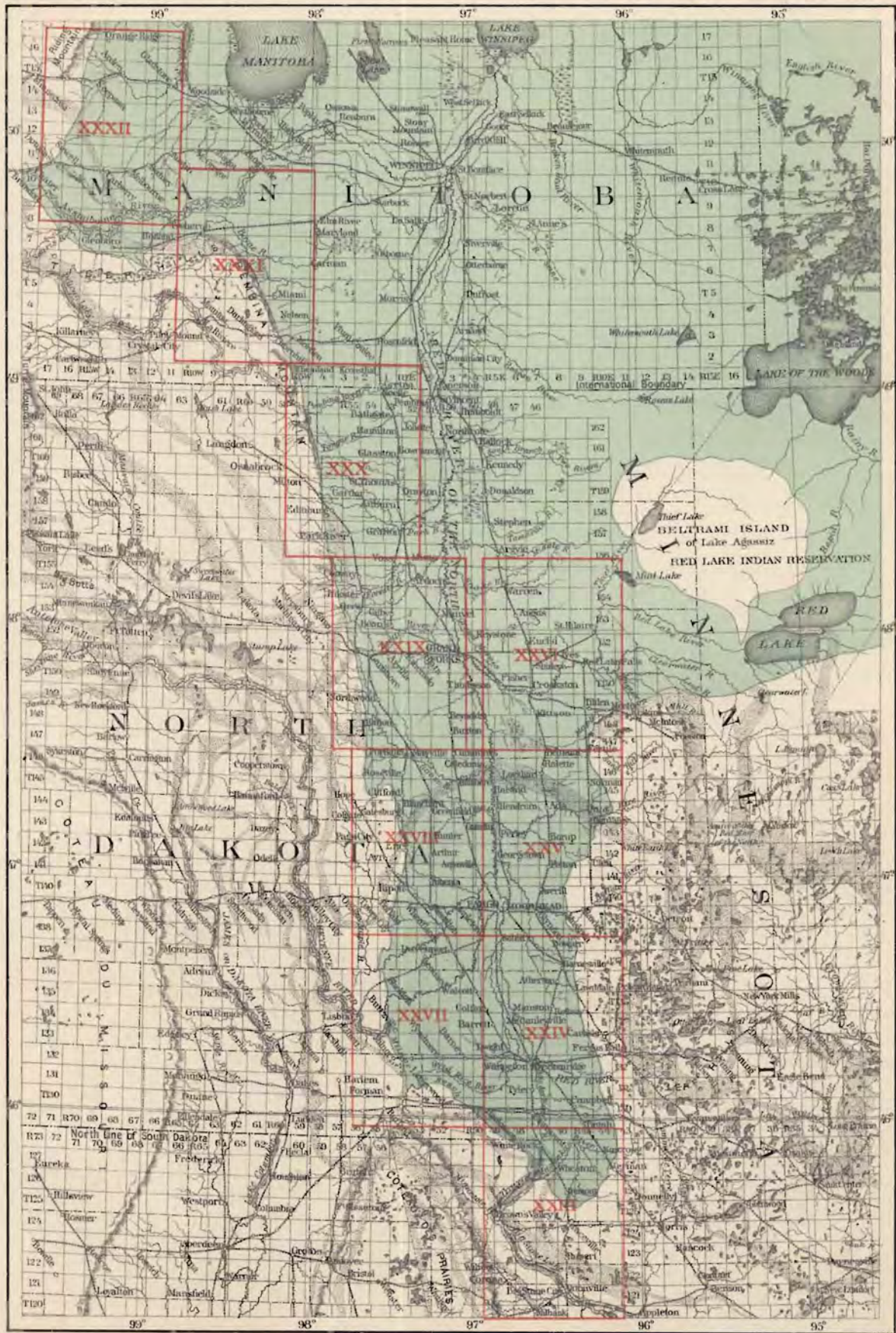
BEACHES AND DELTAS OF THE HERMAN STAGES.

In this and the two following chapters the shore-lines of Lake Agassiz are described in considerable detail, with notes of their altitude and of the topographic features of their tracts marked by erosion, and of the more extensive tracts where beach ridges were accumulated. The fullness and convincing character of the evidence that these are the shore-lines of an ancient lake of vast size, occupying the Red River Valley and the present lake region of Manitoba, are thus impressively exhibited; and the diverse phases of the results produced by waves and shore currents are brought into comparison.

Ten plates (XXIII to XXXII), on the scale of 6 miles to an inch, covering consecutive areas as indicated on Pl. XXII, display the definite geographic location of the shores; and all their more remarkable portions are described, with statement of the sections or often the quarter-sections under consideration, in the text. The arrangement of the sections in each township is shown in fig. 1, on page 11.

Many of the farmers whose houses are built on or near to the old beaches have decided to their own satisfaction, as I learned by conversation with them during the progress of these surveys and levelings, that these beach ridges of gravel and sand are the same as those of now existing lakes of large size, and that consequently the flat Red River Valley so bounded was once the bed of a great lake. These residents will be enabled by the following descriptions and maps to trace the continuity of the shores seen near their own homes to distances of many miles away and, indeed, around all the prairie portion of the ancient lake.

With the progress of agriculture, which is rapidly bringing all this lake bed into cultivation, certain features of the deserted shores that were very distinct at the time of my examination will doubtless be obscured or obliterated. Many of the groves here noticed as occurring along stream courses



or elsewhere in the neighborhood of the old shore-lines will probably cease to exist within a century, or in some cases within a score of years. On the other hand, many artificial groves surrounding farmhouses, and lines of trees cultivated on the divisions of property or of adjacent fields, will probably more than replace such loss, making the country more beautiful and less liable to be swept heavily by winds. But the extensive views enjoyed by the writer and his assistant rodman as they advanced along the course of the beaches, mapping them and determining their elevation, will be then hindered by the cultivated groves, tree rows, and hedges. Only upon a prairie country, such as this was when its shore-lines were first traced, can the grandeur of the proofs of existence of glacial lakes, held by the obstruction of the departing ice, be taken in by an unimpeded vision of the smooth lake bottom on one side stretching out to a distance of 10 or 20 miles within sight, of the bordering beach, running as one unbroken ridge of gravel and sand in a nearly direct course discernible for several miles, and of the broad, slightly higher expanse of more undulating and knolly glacial drift outside the lake area.

From these descriptions of the beach ridges and eroded shores of the old lake, its levels at the time of formation of these shore-lines are deducible approximately. The elevations of the crests of the beach ridges, as recorded in these notes, are commonly 5 to 10 feet, or rarely 15 feet or more, above the level held by the lake when the beaches were heaped up by the waves, chiefly during storms. Where the descents of the slopes of these gravel and sand ridges are noted, the lake level was nearly always below the depression which borders the landward side of the beach and was near the foot of the lakeward slope. Cliffs eroded by the lake waves give more definitely the plane of the water surface which cut into the base of the eroded escarpment, usually consisting of till, undermining it and carrying away its material to form a very gently descending slope, which was covered by the margin of the lake.

Fluctuations of the lake level, which doubtless rose in summer a few feet higher than in winter, because of the variations in the volume of water supplied from the melting ice-sheet, have given a variability within limits generally 5 feet and perhaps sometimes 8 or 10 feet apart to the heights of

the lake and of its shore deposits and planes of erosion in each of the more than thirty stages which these shore-lines exhibit. The high-water surface of the summers, however, had probably a nearly uniform elevation during many years in each stage, producing therefore a beach or eroded line of nearly constant height. On the other hand, the reduced lake level of the winters, when the superficial melting of the ice-sheet ceased and the lake doubtless became mostly frozen over, was likewise at nearly the same elevation from year to year; but the beach ridges formed by the strong wave action of the autumn, winter, and spring storms, with the effects of the drifting lake ice during the breaking up in spring, would be mostly washed away by the ensuing high water of the summer, when the glacial melting attained its maximum. As the result of these annual oscillations of the lake surface, gravel and sand from the material eroded during the storms of winter, both from bordering cliffs and from the shallow lake bed close along the shore, have been chiefly preserved in beach deposits at the higher plane of the fluctuation reached in summer.

Periodic oscillations occupying several years between successive maxima of the lake level were also probably caused by cycles of increase and diminution in temperature and rainfall, with consequent irregularity in the yearly amount of the glacial melting. The cycles of rise and fall of the great Laurentian lakes have a somewhat uniform average length of ten to twelve years, as stated in Chapter XI, the maximum heights of these lakes being 5 to 6 feet above their lowest recorded stages. But, on account of the great variation of the tribute received by Lake Agassiz from the departing ice-sheet in the alternating warm and cold portions of each year, probably its annual fluctuations of level equaled or exceeded the changes of longer periods in the Laurentian lakes, which receive a somewhat steady supply through all the seasons, but are raised by excess of rainfall during a few years together and then lowered by a series of drier years.

THE UPPER OR HERMAN BEACHES AND DELTAS IN MINNESOTA.

Our description of the highest shore-lines of Lake Agassiz may well begin at the mouth of this lake, the present site of the northern end of Lake Traverse. Thence the uppermost or Herman beach was traced

eastward and northeastward through Traverse County and the most northwestern township of Stevens County, Minn., to Herman, in Grant County, nearly 20 miles east of Lake Traverse. From this place the Herman beach runs nearly due north 132 miles to the north side of Maple Lake, in Polk County, about 20 miles east-southeast of Crookston. Beyond Maple Lake the course of this shore-line is known to be nearly east to the south side of Red and Rainy lakes; but it passes through a wooded and uninhabited country where it is impracticable to trace its course exactly and determine its height by leveling.

Along the distance of about 160 miles, as measured by long, straight lines, or about 175 miles, following the larger bends of the shore-line, from Lake Traverse to Herman and Maple Lake, the boundary of Lake Agassiz lies in a prairie region, mostly having a very smooth and regular surface, which could not be surpassed in its adaptability for receiving and preserving a record of the old lake level. The Herman beach lines, single on the southern part of the lake border, but double and even quadruple in Clay County and northward, have been carefully mapped across this expanse of prairie, and their heights have been determined by leveling. The principal features of this series of beaches are described in the following pages.

Especial description is also given of the two chief delta deposits of this part of the old lake border. These were brought into the lake, contemporaneously with the formation of the Herman beach, by the glacial representatives of the Buffalo and Sand Hill rivers. They cover small areas, in comparison with the Sheyenne, Elk Valley, Pembina, and Assiniboine deltas on the west margin of this glacial lake.

FROM LAKE TRAVERSE EAST TO HERMAN.

(PLATE XXIII.)

Within the first 4 miles eastward from the northeast end of Lake Traverse the Herman shore of Lake Agassiz is an eroded bluff of till, rising from the south side of the Mustinka River to a height of 75 to 100 feet above the river and lake. The altitude of Lake Traverse at its lowest and highest stages is 970 and 976 feet above mean tide sea-level. When the lake falls below 973 or 972 feet, which occurs during the dry

season nearly every summer, it ceases to outflow by the Bois des Sioux, and that stream becomes reduced to a series of stagnant pools. The eroded bluff noted, and others of the same character lying on each side of the Bois des Sioux at a distance of 3 to 4 miles apart between Lake Traverse and White Rock, were finished by the outflow of the glacial River Warren, but probably their erosion was begun by a stream outflowing here from the Red River Valley during the Aftonian interglacial stage between the Kansan and Iowan stages of ice accumulation and extension.¹

After following the old lake shore eastward to a distance of about 4 miles from Lake Traverse, the steep bluff gives place, in sections 2 and 11, Walls, to a gentle slope of the surface, which allowed the accumulation of a distinct beach ridge of gravel. This is smoothly rounded, 15 to 20 rods in width, bounded eastward on the side toward the ancient lake by a moderately steep slope which descends 10 or 12 feet, the land 1 to 4 miles distant northeastward within the area that was covered by the lake being 20 to 40 feet below this beach. On the other side this ridge is succeeded by a slight depression 2 to 5 feet deep, beyond which the land soon rises 10 to 15 feet above the beach. The material of the beach is gravel, containing pebbles up to 2 or 3 inches in diameter, but all the surface elsewhere on each side is till. The crest of the beach here is 1,060 to 1,062 feet above the sea.

The beach next passes southeastward through sections 30 and 32, Croke, having in places a maximum altitude of 1,067 feet, being piled several feet above its average height.

Between 2 and 3 miles farther southeast, near the middle of section 9, Tara, the beach ridge sinks to the height of 1,057 feet. Its contour and material, and those of the adjoining areas, are nearly the same as at the locality first described. The width of the gravel beach here is 25 or 30 rods; the smoothed surface of till which descends thence northward is 10 to 20 feet lower in its first mile; on the south the sheet of till is at first for 40 or 50 rods about 5 feet lower than the top of the beach, but beyond this

¹Am. Geologist, Vol. XV, p. 281, May, 1895. The nomenclature of these subdivisions of the Glacial period was proposed by Prof. T. C. Chamberlin in Chapter XLII of James Geikie's "The Great Ice Age," third edition, 1894, and more fully, first naming the Aftonian stage, in the Journal of Geology, Vol. III, pp. 270-277, April-May, 1895.

it gradually rises to a height 10 to 25 and 50 feet above the beach. The average height of its moderately undulating surface 6 miles to the south, at Graceville, is nearly represented by the railroad at the depot there, 1,109 feet. Farther to the east, through this township, the crest of the beach ranges from 1,057 to 1,062 feet.

For the next 3 miles eastward, lying in the northwest part of Leonardsville, the beach is less conspicuous than usual, but in sections 8, 5, and 4 of this township the shore-line is again distinctly marked by a slight terrace in the till, descending northward in a moderately steep slope 5 to 10 feet, rather than by the usual accumulation of gravel. The top of this terrace is at 1,056 to 1,057 feet.

A few miles farther north, in the southeast part of section 24, Doleysmount, the beach is a low gravel ridge, 20 rods wide and 5 feet high above the adjoining surface, its crest being 1,060 to 1,061 feet above the sea.

These determinations indicate that in Traverse County the surface of Lake Agassiz during its maximum stage was very nearly 1,055 feet above our present sea-level.

In the northwest corner of Stevens County this upper or Herman beach is well displayed in the northwest quarter of section 19, Eldorado, having an elevation of about 1,063 feet. Through section 18 it is 20 to 25 rods wide, with its crest at 1,063 to 1,066 feet, being a gently rounded ridge of sand and gravel, containing pebbles up to 2 or 3 inches in diameter. Its height is 7 to 10 feet above the land next west and 5 feet above the depression next east. The surface on each side is till, slowly falling westward and rising eastward.

In the southeast part of section 7 in the same township the crest of the beach is at 1,067 to 1,070 feet. Here and onward the next 2 miles, through the northwest quarter of section 8, the southeast part of section 5, and the western and northern part of section 4, this formation is finely exhibited in a ridge of gravel and sand 20 to 30 rods wide, 15 feet or more above its base westward, where lay the glacial Lake Agassiz, and 8 to 10 feet above the depression eastward, which divides it from the higher, moderately undulating expanse of till beyond. In the east part of section 5 its elevation is 1,065 feet, and through section 4, 1,065 to 1,072 feet.

This beach near the middle of section 15, Logan, Grant County, is about 30 rods wide, with a broad, nearly flat top, at 1,070 feet, having a descent of about 15 feet on its northwest side to the area of Lake Agassiz and half as much on the southeast, the surface thence rising very gradually in the $1\frac{1}{2}$ miles eastward to Herman. The beach ridge is gravel, the land at each side till.

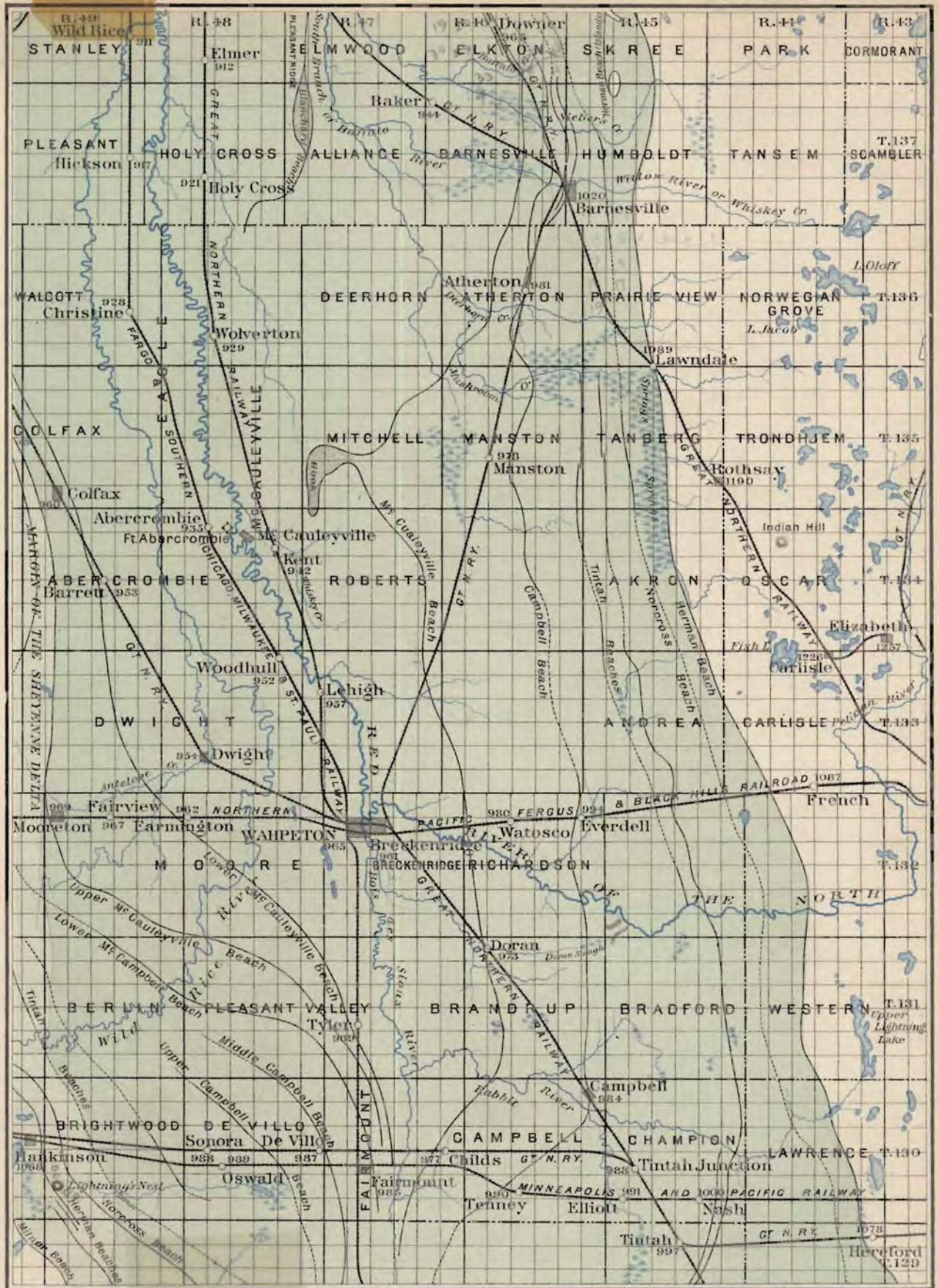
Elevations determined in this vicinity by the railway surveys are as follows: Track at Herman, 1,072 feet above the sea; crest of the beach about $1\frac{1}{2}$ miles northwest of Herman, where it is cut by the railway, and for 50 rods southwestward, 1,064 to 1,066 feet; depression, 40 rods wide, next southeast at the railroad (lowest 20 rods from the top of the beach), 1,060 to 1,063 feet; surface of till at the southeastern snow fences of the railroad, about a third of a mile southeast from the beach, 1,073 feet; at the northwest end of the northwestern snow fences, about 25 rods northwest from the highest part of the beach, 1,054 feet; and at the original one hundred and eightieth mile post, about a quarter of a mile northwest from the last, 1,049 feet.

FROM HERMAN NORTH TO THE RED RIVER.

(PLATES XXIII AND XXIV.)

Several farmhouses are built on the top of the Herman beach between 6 and 10 miles north of Herman. At Joseph Moses's house, in the northwest quarter of section 18, Delaware, the crest of the beach ridge has a height of 1,066 to 1,067 feet, and the piazza of the house is at 1,067 feet. H. D. Kendall's house, at the east side of the southeast quarter of section 12, Gorton, on the western slope of this beach, is at 1,062 feet; while the top of the beach ridge, about 25 rods east of Mr. Kendall's house, is at 1,067 feet.

Crest of the beach through the next $1\frac{1}{2}$ miles north from Mr. Moses's house, along the west side of sections 18 and 7, Delaware, 1,066 to 1,068 feet. The beach for this distance is finely exhibited, having a width of about 25 rods, rising 5 to 8 feet above the depression at its east side and 10 to 15 feet above the land west. L. I. Baker's house sill, in the southwest quarter of section 6, same township, of same height with the top of the beach ridge, on which it is built, 1,068 feet.



JULIUS WIEN & CO. NY.

MAP OF THE EASTERN SHORES OF LAKE AGASSIZ FROM CAMPBELL NORTH TO BARNESVILLE, COMPRISING WILKIN COUNTY, MINNESOTA, AND PARTS OF ADJOINING COUNTIES.

Scale, 6 miles to an inch.

Beach in section 31, Elbow Lake, not so conspicuous as usual, 1,066 feet; in the southwest quarter of section 18, same township, at the house of Henry Olson, a gracefully rounded low ridge, as elsewhere, composed of gravel and sand, including pebbles up to 3 inches in diameter, 1,065 to 1,066 feet; at Mrs. John S. Ireland's, in the northwest quarter of the same section 18, 1,070 feet; at Dr. J. M. Tucker's, in the northeast quarter of section 2, North Ottawa, 1,071 feet; about a mile north of the last, near the north side of section 35, Lawrence, 1,075 feet; and about a mile farther north, also 1,075 feet. Through nearly the whole of this distance it is a typical beach ridge of sand and gravel.

Crest of beach about 30 rods west of M. L. Adams's house, in the northeast quarter of section 26, Lawrence, 1,075 feet, being 4 feet above the land adjoining this ridge on the east and about 10 feet above the flat land near on the west; in section 23, same township, 1,076 feet; and near the south side of section 10, same township, 1,069 to 1,074 feet.

Extensive sloughs or marshes occur in section 36 and in sections 25 and 24, Lawrence, each being about a mile long, lying on the east side of the beach ridge at Dr. Tucker's and reaching $2\frac{1}{2}$ miles northward; the elevation of these above sea-level is about 1,060 feet.

In the north part of section 10 and the south part of section 3, Lawrence, this shore-line of Lake Agassiz is not marked as usual by a gravel ridge, but by a somewhat abrupt ascent or terrace in the drift sheet of till, the elevation of the top of which, composed partly of gravel, is 1,085 to 1,079 feet; base of this terrace and land westward, consisting of till, slightly modified on the area of Lake Agassiz, 1,060 to 1,050 feet. This escarpment, the eroded shore-line of the lake, passes about 40 rods west of N. S. Denton's house, at the north side of section 10.

Beach in section 34, Western, the most southwest township of Otter-tail County, near John F. Wentworth's, 1,070 to 1,075 feet; surface at Mr. Wentworth's barn, 1,072 feet. Beach 25 rods east of Albert Copeland's house, in the southwest quarter of section 28, Western, 1,070 to 1,066 feet; where it is crossed by the old road from Fergus Falls to Campbell, near the northwest corner of this section 28, 1,072 feet; through the next 2 miles north, finely developed, with nearly constant height, 1,072

feet, being 7 to 10 feet above the depression at its east side and 20 feet above the area westward, which was covered by Lake Agassiz; at Michael J. Shortell's, section 9, same township, 1,073 feet; 1 mile farther north, 1,078 feet; and at A. J. Swift's, in the northwest quarter of section 4, 1,076 feet. The beach at Mr. Swift's and for half a mile farther north is well exhibited, and, as in many other places, is bordered on its east side by a narrow strip of marsh.

Beach in the northeast quarter of section 33, township 132, range 44, 1,076 feet; top of large aboriginal mound, situated on the beach here, 1,082 feet; land 30 rods west, 1,060 feet; lakelet 250 feet in diameter, about an eighth of a mile northeast from the large mound, 1,051 feet.

Red River of the North, near the northeast corner of section 33, township 132, range 44, 1,014 feet; on the line between this township and Buse, 1,041 feet; and at Dayton bridge, in the southwest quarter of section 20, Buse, 1,064 feet, being 8 feet below the bridge. S. A. Austin's house foundation in the southwest quarter of section 29, Buse, 1,147 feet. Old grade for railroad at Dayton bridge, about 1,102 feet.

No noticeable delta was brought into Lake Agassiz by the Red River.

FROM THE RED RIVER NORTH TO MUSKODA.

(PLATES XXIV AND XXV.)

Crest of beach near the south side of section 21, township 132, range 44, 1,077 feet; in this section 21, an eighth of a mile north of the road from Fergus Falls to Breckenridge, 1,079 feet; and for the next mile north, 1,077 to 1,080 feet. This is a typical beach ridge, gently rounded, composed of sand and gravel, containing pebbles up to 3 inches in diameter; its width is 30 to 40 rods, and its height above the very flat area on its west side, which was covered by Lake Agassiz (usually somewhat marshy next to the beach), is about 15 feet. On the east there is first a depression of 4 to 6 feet, succeeded within a fourth of a mile eastward by a gentle ascent, which rises 5 to 10 or 15 feet above the beach. The material on each side of the beach is till, slightly modified by the lake on the west. It is all fertile prairie, beautifully green, or in many places yellow or purple with flowers during July and August, the months in which this survey was

made. In August, 1881, no houses had been built on this beach, nor within 1 mile from it, along its first 11 miles north from the Red River, the first house found near the beach being in section 26, Akron, in Wilkin County.

Beach at a low portion, probably in the southeast quarter of section 5, township 132, range 44, 1,075 feet. A lake nearly a mile long lies on the flat lowland about $1\frac{1}{2}$ miles west from this low part of the beach. The elevation of this lake was estimated at 1,055 or 1,050 feet; it is only a few feet lower than the general surface around it. Beach, probably near the north side of this section 5, 1,078 feet. On its east side here and for a half mile both to the south and north is a slough, partly filled with good grass and partly with rushes; its width is about a quarter of a mile, and its elevation about 1,070 feet. The land west of the beach descends, within 1 or 2 miles, from 1,060 to 1,050 feet.

Beach at its lowest portion for this vicinity, about a half mile north of the preceding and near the center of section 32, Carlisle, 1,070 to 1,068 feet, being only 2 feet above the marsh or slough on its east side. A railroad grade, abandoned, lies a third of a mile east of this. Beach a fourth of a mile farther north, 1,077 feet, and, about 1 mile north from its lowest portion, 1,075 feet, cut by a ravine, the bottom of which is nearly at 1,063 feet. This ravine is some 30 rods west of the abandoned railroad embankment.

Railroad grade where it crosses the beach, about a mile northwesterly from the ravine mentioned, 1,077 feet. Beach here, 1,076 feet, being 8 to 10 feet above the slough on its east side, and having about the same height above the marsh next to it westward. The material of the beach, shown by the railroad embankment, which is made of it along a distance of a third of a mile, is coarse gravel, with abundant pebbles of all sizes up to 6 inches in diameter, fully half of them being limestone.

Crest of beach in the south half of section 23, Akron, 1,079 to 1,080 feet; in the northwest quarter of this section 23, 1,075 to 1,080 feet. Through sections 14, 10, and 3, Akron, the beach does not have its ordinary ridged form, but is mostly marked by a deposit of gravel and sand lying upon a slope that rises gradually eastward. Its elevation here is

1,075 to 1,085 feet. In the southern part of this distance, probably in the southwest quarter of section 14, the margin of the flat, somewhat marshy area that appears to have been covered by Lake Agassiz is very definite at 1,075 feet, which thus was probably the height of the lake here.

Beach in the southwest quarter of section 34, Tanberg, composed of gravel, nearly flat, 25 to 30 rods wide, 1,084 to 1,087 feet, bordered by a depression of 2 to 5 feet on the east and by an expanse 10 to 15 feet lower on the west. Beach in the northwest quarter of this section 34, also 1,084 to 1,087 feet. Here the land next east does not present the usual slight hollow dividing the beach ridge from the higher land eastward; instead is a springy belt, mostly 1,089 feet, quite marshy, yet slowly rising 2 to 4 feet above the belt of beach gravel. Occasional hummocks, about 2 feet above the general surface and covered with rank grass about 6 feet high, form part of this belt of marsh and shaking bog. Next to the east is a slough about 1,086 feet, or 3 feet below the springy tract, and this is succeeded by a surface of moderately undulating till, which rises gradually eastward.

Sloughs, mostly filled with rushes and having areas of water all the year, occupy a width of 1 to 2 miles next west of the shore-line and beach of Lake Agassiz and extend nearly continuously 10 miles from south to north, from the middle of Akron to the south edge of Prairie View Township. The elevation of this belt of sloughs is 1,080 to 1,050 feet, being considerably lower on its west than on its east border. The highest land westward in the west part of Tanberg, between these marshes and Manston, is about 1,060 feet. Along most of this distance the ordinary beach ridge is wanting.

Great Northern Railway track at Lawndale water tank, 1,089 feet. Here a side-track has been laid, extending about a third of a mile northward, with its northern end some 50 rods east of the main line, to take ballast from the beach, which is well exhibited here and onward, having its typical ridged form. The elevation of its crest is 1,091 to 1,094 feet. It is composed of gravel and sand in about equal amounts, interstratified mainly in level layers, but with these often obliquely laminated. Most of the gravel is quite fine, and the coarsest gravel found here has pebbles only 2 to 3 inches in diameter. About half of it is limestone.

Beach ridge 1 mile farther north, 1,094 feet; three-fourths of a mile north of the last and close south of a ravine, 1,099 feet. Beach about 3 miles north from Lawndale water tank, probably in the south part of section 16, Prairie View, not ridged, but a belt 25 rods wide, of gravel and sand, on a slope of till that rises eastward, 1,080 to 1,102 feet. Beach, a ridge of gravel and sand, a third of a mile north from the last, 1,105 feet. The beach in section 9 of this township is spread more broadly than usual, its higher parts being 1,095 to 1,107 feet. Here the beach deposits are crossed obliquely by several broad depressions 10 to 15 feet deep, running south-southwest. The depression east of all these banks of gravel and sand is about 1,090 feet above the sea.

Entering Clay County, the elevation of this upper or Herman beach at the east side of section 33, Humboldt, is 1,100 feet above the sea. The land thence for two-thirds of a mile east is low and smooth, not higher than the beach. Beyond this the next third of a mile northeastward, in the north part of section 34, is very rocky, with many bowlders up to 6 and rarely 10 feet in diameter, the contour being moderately rolling 10 to 30 or 40 feet above the beach. Farther eastward here and through the next 15 miles north to the Northern Pacific Railroad, the moderately rolling or smoothly hilly till rises 100 to 250 feet above this beach within the distance of about 10 miles between it and the east line of the county.

Elevation of the crest of the beach ridge in the east half of section 28, Humboldt, one-fourth to three-fourths of a mile south of Willow River, 1,098 to 1,100 feet. In the 3 miles westward to Barnesville the area that was covered by Lake Agassiz shows here and there bowlders projecting 1 to 2 feet above the surface, which is till, slightly smoothed by the lake.

Great Northern Railway track at Barnesville, 1,020 feet.

The beach for three-fourths of a mile north from Willow River consists of a belt of gravel and sand, lying on an eastwardly ascending slope of till. Through the next $1\frac{1}{2}$ miles northward, in the northwest quarter of section 22 and in section 15, Humboldt, the shore of Lake Agassiz is not marked by the usual beach of gravel and sand, but instead becomes a belt of marshy and springy land 20 to 50 rods wide, rising by a gentle slope eastward, rough with many hummocks and hollows, in some portions forming a quaking bog, in which horses and oxen attempting to cross are mired.

In the next 2 miles northward, through sections 10 and 3, Humboldt, the beach is nowhere well marked as a ridge, but is mainly a belt of gravel and sand, lying on a slope of till, which gradually rises 30 or 40 feet higher at the east. The lack of typical beach deposits on this shore through the north half of this township is probably due to its sheltered situation in the lee of islands on the northwest. The course of the shore currents, determined by the prevailing winds, seems to have been southward, as on the shores of Lake Michigan.

Highest part of southern island in the east edge of Lake Agassiz, in the northeast quarter of section 5, Humboldt, extending northward into Skree, 1,117 to 1,122 feet. This island was about 1 mile long from south to north. Crest of beach on its west side, a well-developed ridge of gravel near the middle of the north line of section 5, 1,095 feet; and for a third of a mile north-northwest from this, 1,094 to 1,096 feet. On the east side of the beach, as it continues northward, is a slough two-thirds of a mile long from south to north and about 30 rods wide, 1,085 feet. This was evidently filled by a lagoon, sheltered on the southeast by the island and separated from the main lake by the beach. Toward the northeast it widened into a shallow expanse of water 8 to 15 feet deep, about $1\frac{1}{2}$ miles wide, divided from the broad lake on the west by two islands and this beach or bar which connected them. Lake Agassiz here appears to have stood at the height of 1,090 to 1,095 feet.

Top of the beach or bar in the north part of section 32, Skree, a broad rounded ridge of gravel, with pebbles up to 3 or 4 inches in diameter, 1,103 feet, and through the next half mile, in the south half of section 29, 1,102 to 1,104 feet. Along part of this distance the beach ridge is bounded eastward by a steeper descent than usual, the land next east being 1,085 to 1,090 feet above the sea. This beach or bar continues northward in a typical ridge through sections 29 and 20, same township.

Beach or bar at L. Williams's house, in the southeast quarter of section 20, Skree, 1,101 feet; a quarter of a mile farther north, 1,106 feet; three-quarters of a mile north of Mr. Williams's, near the middle of the north line of section 20, 1,110 feet, continuing a very definite ridge through the south half of section 17, 1,109 to 1,110 feet.

Near the middle of this section 17 the beach deposit of gravel and sand ceases at the west side of the northern island, which was situated in the east half of this section and extended also eastward in a long, low projection nearly across the south side of section 16, and northward half way across section 8. Highest part of this island, in or near the northeast quarter of the northwest quarter of section 17, about 1,125 feet. The old shore of the north half of this island has no beach ridge nor other deposits of gravel and sand, but is plentifully strewn with large boulders up to 5 and 10 feet in diameter, and many of these project 2 to 5 feet above the general surface. The lake waves eroded here, and deposited the sand and gravel gathered from this till as a beach a little farther south.

North and northeast from this northern island a lower expanse, nearly level and in some portions marshy, resembling the broad, flat valley of the Red River, extends $1\frac{1}{2}$ miles to the east shore of Lake Agassiz, its height being 1,075 to 1,090 feet, or 10 to 25 feet below the surface of the ancient lake. The distance between these islands was 2 miles, and the distance from the summit of the first to that of the second, nearly due north, 4 miles. Each of them rose about 25 feet above Lake Agassiz. The strait between them and the mainland eastward was 10 to 20 feet deep and from 1 to $1\frac{1}{2}$ miles wide, excepting a narrow place near the southeast corner of section 16. East of the northern island the main shore of the lake was indented by a bay a third to a half of a mile wide and about 10 feet deep, stretching $2\frac{1}{2}$ miles southeastward from the lakelet at the northwest corner of section 10 to the west part of section 23, Skree. The shore of the lake east of its islands along this bay and northwesterly to the north line of this township lacks the beach deposits which elsewhere distinguish it.

In its continuation northwestward the shore-line of the old lake runs diagonally across section 32, Hawley, where it again presents the anomalous character of a very springy and marshy belt, 20 to 40 rods wide, rough with hummocks and in many places so deeply miry that it is dangerous for teams. This boggy tract has a gentle descent westward, its lower portion being about 1,085 feet, and its upper border, very nearly level across this entire section, being 1,098 to 1,100 feet, which was almost exactly the height of Lake Agassiz, as shown by its distinct beach of gravel and sand at the

south and north. Next eastward rises a moderately undulating slope of till, strewn with abundant bowlders; and rarely a bowlder 2 to 5 feet in diameter is seen on the springy land that marks the border of the ancient lake.

DELTA OF THE BUFFALO RIVER.

(PLATE XXV.)

The delta brought into the east side of Lake Agassiz by the Buffalo River extends about 5 miles southwestward from Muskoda, forming a continuously descending plain of stratified sand and fine gravel, declining from 1,100 feet near Muskoda to 1,073 feet at its southwestern limit in the north part of section 34, Riverton. Here and northward along a distance of 3 miles to the Buffalo River this delta plain is terminated by a steep slope, 25 to 40 feet high, like the face of a terrace. The outer portion of the original delta, beyond this line, has been carried away by the waves and shore currents of the lake when it stood at the lower levels marked by the Norcross and Tintah beaches, as shown in fig. 11.

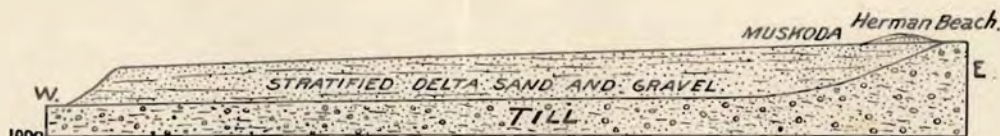
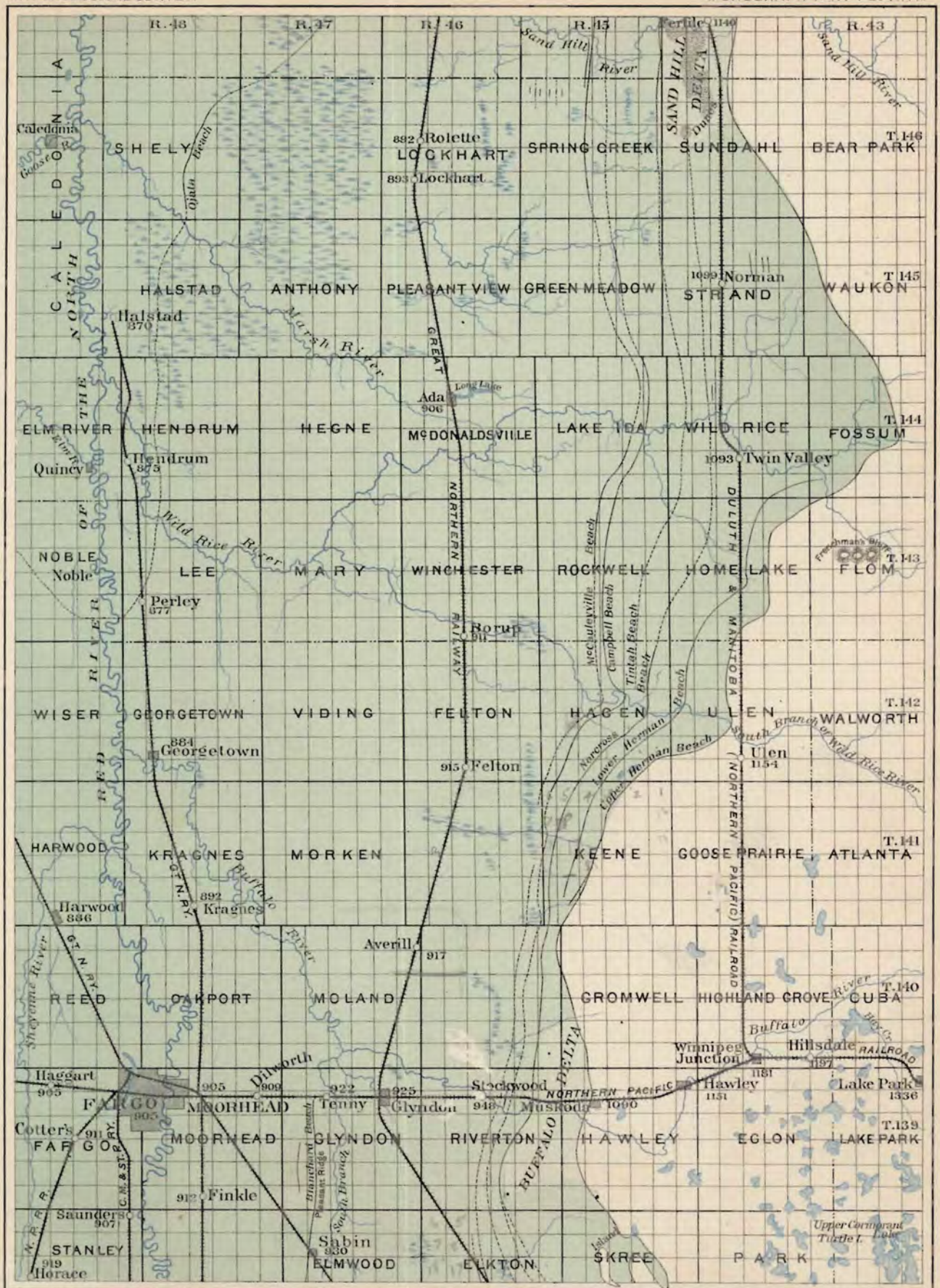


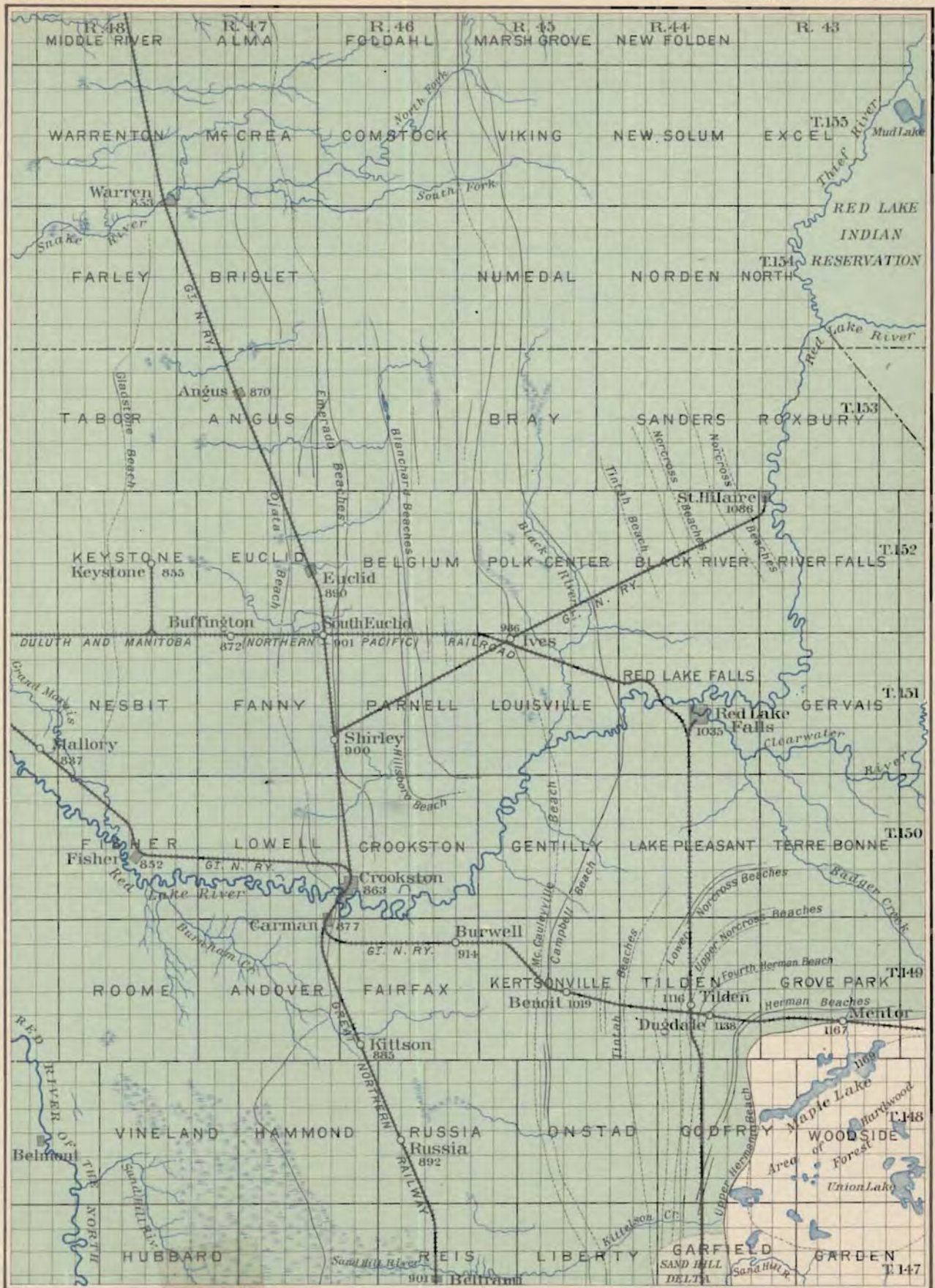
FIG. 11.—Section across the delta of the Buffalo River. Horizontal scale, one-half mile to an inch.

North Pacific Railroad track at Muskoda, 1,090 feet. Threshold of church a quarter of a mile southeast from Muskoda depot, 1,113 feet. Beach here and for a third of a mile south to the Buffalo River, as also at the excavation for the railroad, 25 rods north of the church, nearly uniform elevation of its crest, 1,113 to 1,114 feet. The beach is 35 rods wide, rising 14 or 15 feet in a gentle swell above the edge of the delta of modified drift on the west and descending the same amount to the depression at its east side. It is made up of interstratified gravel and sand, the former prevailing, including pebbles up to 3 or 4 inches and rarely 6 or even 9 inches in diameter, all waterworn. Half or two-thirds of these pebbles and cobbles are limestone. No bowlders occur here, nor are they found in any of the beach deposits of Lake Agassiz.



MAP OF THE EASTERN BEACHES AND DELTAS OF LAKE AGASSIZ FROM MUSKODA NORTH THROUGH CLAY AND NORMAN COUNTIES, MINNESOTA TO THE SAND HILL RIVER.

JULIUS BUCHER & CO. N.Y.



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MAP OF THE EASTERN SHORES OF LAKE AGASSIZ IN THE VICINITY OF MAPLE LAKE AND NORTHWARD, IN POLK AND MARSHALL COUNTIES, MINNESOTA.

The area of the Buffalo delta extends 7 miles from north to south, with a width of 2 to $3\frac{1}{2}$ miles. Its average thickness is probably about 50 feet, and its volume is therefore approximately one-sixth of a cubic mile. It would make a very slightly hill if its material were piled on the flat plain of the Red River Valley, for it would cover a circle 2 miles in diameter and rise to a peak about 900 feet high. Lying on the slope which rises east from this valley, however, and being spread over a considerable area with comparatively little thickness, its mass does not especially command attention until investigation reveals that it came almost wholly from drift that was contained within the ice-sheet, being deposited here by the streams from its melting.

The existence of well-defined and conspicuous delta deposits having the altitude of the Herman beach, where the Buffalo and Sand Hill rivers enter the east side of the area of Lake Agassiz, while no such deposits are found where other streams of equal or larger size enter this area, as the Red River, the Wild Rice, and the Red Lake River, seems explicable only by the derivation of the gravel and sand forming these deltas mostly from the englacial drift of the melting ice-sheet upon the adjacent area at the east. Comparatively small tribute was brought into this glacial lake from the erosion of the stream valleys after their areas became uncovered from the ice, excepting where it received the very large rivers flowing from other glacial lakes at the west. Here and there, because of irregularities in the outline of the ice-sheet, by which the drainage of its surface was poured down upon certain limited tracts and was discharged thence along the courses of now existing streams, as the Buffalo and Sand Hill rivers, and because the retreat of the ice was now rapid and anon was interrupted by halt or readvance, with the accumulation of moraines, much of the material which had been inclosed within the basal part of the ice-mass seems to have been washed away by its streams and carried into Lake Agassiz to form deltas.

When such glacial streams encountered no lake to receive their tribute, and flowed far before reaching the sea, the gravel, sand, and fine silt or clay which they brought were spread by the rivers along their courses as plains of modified drift. In some instances, since the ice-sheet disappeared and

the drainage from it ceased, these plains are left far from any important stream. Similarly, on the west side of Lake Agassiz, a large delta extending southward from the Elk Valley was deposited by a proportionally large river flowing from the ice-sheet, but no considerable river now enters the lake area there.

Opposite to the Buffalo delta, within a distance of about 30 miles to the east, the ice front was indented by a great embayment or reentrant angle at the time of formation of the eighth or Fergus Falls moraine. While the ice border was receding from the seventh or Dovre to the Fergus Falls moraine, the conditions of its melting were probably unfavorable for the formation of deltas in this glacial lake; but during the accumulation of the Fergus Falls moraine the drainage from the ice border converged toward the Buffalo River and caused its delta to be formed. Again, when the ice-sheet had retreated another stage and was forming its ninth or Leaf Hills moraine, this indentation of the ice front, having fallen back about 40 miles northward from its former position, sent its glacial streams to the Sand Hill River, and a second delta was brought into the lake.

In the same manner, the much larger Sheyenne, Elk Valley, Pembina, and Assiniboine deltas, brought into Lake Agassiz from the west and having likewise the height of the early Herman beaches, are referable chiefly to the drainage from the melting ice-sheet, and in less measure to erosion of the river valleys. The material of all the deltas of this lake is principally modified drift, rather than alluvium like that which the streams now transport and spread over their bottom-lands at every stage of flood.

FROM MUSKODA NORTH TO THE SAND HILL RIVER.

(PLATE XXV.)

In the next 2 miles north of Muskoda the crest of the Herman beach ridge ranges mainly from 1,113 to 1,125 feet above the sea; at its lowest depression, about 1 mile north of Muskoda, its height is 1,105 feet; at William Perkins's house, in the southeast quarter of section 30, Cromwell, 1,122 feet; an eighth to a third of a mile south-southeast from Mr. Perkins's, 1,130 feet. A nearly or quite continuous depression, from a fifth to

a third of a mile wide, lies at the east side of this beach, declining in elevation from 1,118 feet near Mr. Perkins's house to 1,100 feet at Muskoda. This distance is about 3 miles.

The surface of Lake Agassiz in its maximum stage was, at Muskoda, 1,105 feet, very approximately, above our present sea-level. Within 5 to 10 miles northward its height seems to have been 1,110 to 1,115 feet.

Beach through the north half of section 30, Cromwell, 1,128 to 1,131 feet, and through the west part of sections 19 and 18, same township, 1,125 to 1,130 feet, composed of sand and fine gravel, not generally in a typical ridge, but often with a depression 2 to 5 feet lower eastward and bounded on the west by a descent of about 30 feet within an eighth of a mile. A surface of slightly undulating till rises very gradually from this beach eastward.

Herman beach at a high portion in or near the southeast quarter of section 1, township 140, range 46, 1,136 feet. For a mile next south from this point it is a finely rounded ridge of gravel, rising northward from 1,130 to 1,136 feet. The depression at its east side is 4 to 6 feet lower; then the surface gently rises at a quarter to a third of a mile from the beach to 1,135 or 1,140 feet, beyond which eastward this nearly level but slightly undulating expanse of till rises only 5 or 10 feet per mile. Beach a fourth of a mile north-northeast from the high point mentioned, probably in the northwest quarter of section 6, Cromwell, 1,128 to 1,127 feet. This is an ordinary beach ridge of gravel and sand, with a depression of 2 or 3 feet next east.

Near the south line of section 29, Keene, both the Herman and Norcross beaches, here about two-thirds of a mile apart, are intersected by a watercourse. At its north side the upper or Herman beach, near the east line of section 29 and in the northwest quarter of section 28, consists of two well-marked ridges of gravel and sand, some 30 rods apart and about 10 feet above the land eastward and between them. These ridges unite in or near the southwest quarter of the southwest quarter of section 21, at the height of 1,130 to 1,132 feet. Beach three-fourths of a mile farther north, probably near the north line of section 21, a typical gravel ridge, 1,134 feet, 10 feet above the land next east; but a sixth of a mile farther northeast this beach ridge is depressed to 1,123 feet.

A lower beach, contemporaneous with the Herman beach farther south, but formed when the surface of the lake in this latitude had fallen slightly from its highest level, is finely exhibited at a distance of one-third to two-thirds of a mile west from the upper beach, through the 4 miles from the south side of section 20 to the northeast corner of section 4, Keene. The elevation of this secondary beach in the south part of section 20 is 1,115 feet; thence to a stream near the east line of the southeast quarter of section 17, 1,118 to 1,123 feet; at each side of this stream, 1,118 feet; northward, in the northwest part of section 16 and in the southwest quarter of section 9, 1,118 to 1,121 feet; and in the north part of section 9, 1,121 to 1,127 feet.

Upper beach through the west part of section 10, Keene, 1,130 to 1,137 feet, increasing in height from south to north. This is a typical beach ridge of gravel, with a rather abrupt descent on its east side to land 6 or 8 feet lower, which thence ascends with a slightly undulating surface eastward. The elevation of the upper beach in this township, 1,123 to 1,137 feet, shows that the height of Lake Agassiz here, during its maximum stage, was about 1,120 feet. The secondary beach was made by the lake after it had fallen 6 to 10 feet.

In section 3, Keene, the crest of the upper beach is at 1,134 to 1,137 feet, 10 feet above the land next east; and the top of the secondary Herman beach, parallel with this and about three-fourths of a mile distant to the northwest, in sections 4 and 34, is at 1,123 to 1,127 feet, being thus 10 feet lower than the highest parts of the eastern beach. Extensive sloughs, inclosing lakelets, lie between these beaches in sections 34 and 35, Hagen, at an elevation of 1,115 to 1,120 feet, but sinking northward to 1,105 feet. The secondary beach continues to the northeast corner of section 26, declining in height northeastward as it approaches the South Branch of the Wild Rice River, being at 1,125 to 1,115 feet.

Upper beach in section 35 and in the south part of section 25, Hagen, 1,140 to 1,142 feet. This is a typical beach ridge of sand and gravel, about 30 rods wide, with the land next southeast 5 to 8 feet lower, and divided from the secondary beach northwesterly by a slough about 1 mile wide, this slough being at 1,115 to 1,105 feet.

Crest of beach at B. O. Helde's house, in the south half of the southwest quarter of section 30, Ulen, 1,138 feet. The flat expanse of the Red River Valley reaches east on the South Branch of the Wild Rice River to section 16, Hagen, probably being there about 975 feet above the sea, or 160 feet below this upper beach of Lake Agassiz, 4 or 5 miles southeast.

Beach through sections 30 and 29, Ulen, extending $1\frac{1}{2}$ miles east-northeast from Mr. Helde's to the South Branch of the Wild Rice River, in a low, gently rounded ridge of gravel, 30 rods wide, 5 to 8 feet above the area of till next southeast and about 15 feet above the surface close at its northwest side, 1,138 to 1,142, mostly 1,140 feet.

South Branch of Wild Rice River, in the southwest quarter of section 21, Ulen, 1,095 feet. The beach is developed as a typical gravel ridge, in or near the west half of section 16, Ulen, a half mile to $1\frac{1}{2}$ miles north of the South Branch, with its crest at 1,140 to 1,143 feet; surface of till an eighth to a quarter of a mile next east, 1,135 feet. Farther east the slightly or moderately undulating expanse of till has an average ascent of about 10 feet a mile for 15 miles to the base of the high land at the White Earth Agency, which is dimly visible, blue, close to the horizon. Westward the surface gradually descends to the Norcross beach, nearly 60 feet lower, which is the farthest land in sight in that direction, about 3 miles distant, beyond which lies the flat Red River Valley.

Entering Norman County, an unusually high portion of the Herman beach is found in or near the southeast quarter of the southeast quarter of section 33, Home Lake, having its crest at 1,149 feet. It holds this elevation for an extent of some 20 rods, on each side of which its height is mostly from 1,139 to 1,145 feet. Its material is coarse gravel, principally limestone, with pebbles and cobbles up to 4 and 6 inches in diameter. Surface close east of this beach, 1,137 feet. A slight swell above the general descending slope westward, about 2 miles distant, has a height very nearly 1,125 feet. This may be the continuation of the secondary beach that was seen in Keene Township. It hides the view farther west, except from the highest point of the beach (1,149 feet), where the distant belts of timber along the Red and Wild Rice rivers are visible.

Beach at J. T. Huseby's house, in the northwest quarter of section 26, Home Lake, 1,147 feet; through $1\frac{1}{4}$ miles next north, in the northwest

quarter of section 26 and the west part of section 23, forming a broad, low ridge of gravel and sand, 1,145 to 1,149 feet. In or near sections 17 and 16, Flom, a prominent, massive hill, called "Frenchman's Bluff," of somewhat irregular form, composed of morainic till, rises 150 feet or more above this beach.

Through the west part of the northwest quarter of section 14, Home Lake, the beach is mostly a typical gravel ridge, with its crest at 1,147 to 1,152 feet. In the northwest quarter of section 11, same township, it curves northeastward and attains an unusually massive development, its crest being at 1,150 to 1,158 feet, rising 15 feet above the land next southeast and 25 or 30 feet above the border of the area of Lake Agassiz at its northwest side.

Crest of beach, a well-marked gravel ridge, near the southwest corner of section 1, Home Lake, 1,156 feet, and an eighth of a mile east-northeast from this, 1,150 feet. J. G. Aurdal's house, foundation, in the northeast quarter of section 6, Flom, 1,148 feet. This is situated on the beach, which here is a deposit of gravel and sand 8 feet or more in depth, lying upon a slope of till that ascends southeastward. Anton Johnson's store, foundation, on this beach, in the southeast quarter of section 31, Fosum, 1,142 feet. Creek flowing northwesterly between the last two, about 1,105 feet. Wild Rice River, 2 miles north of Johnson's store, approximately 1,050 feet.

Secondary Herman beach, a well-marked, broad, smoothly rounded gravel ridge, extending from southwest to northeast, crossed by the township line road at the north side of the northeast quarter of the northwest quarter of section 2, Home Lake, 1,137 feet. It is about 30 rods wide, and rises 5 to 10 feet above the depression at its southeast side.

A broad belt of timber borders the Wild Rice River, lying mostly on its north side, in Fosum and Wild Rice townships, and at the time of this survey, in 1881, no road or bridge afforded a crossing here. Therefore this series of levels was resumed north of the Wild Rice River by starting from Rolette station of the St. Paul, Minneapolis and Manitoba (now the Great Northern) Railway, 892 feet above the sea, near the middle of section 17, Lockhart, about $1\frac{1}{2}$ miles north of the Lockhart farm. Proceeding

eastward from this point, the first observations of the upper beach were in Waukon, Sundal, and Garfield townships.

This beach is intersected by the Wild Rice River near the middle of Fosum, and thence it passes north-northwesterly through the west part of Waukon. In sections 7 and 6, Waukon, it is a low, smooth ridge of gravel and sand about 25 rods wide, rising 5 to 10 feet. In the west half of this section 6 and in section 36, Sundal, the old Pembina trail lies on it.

About 2 miles west of the upper beach, a secondary Herman beach, of similar material and contour, probably 20 feet lower, was observed a few rods east of the stake at the middle of the north side of section 14, Strand, having a height of 6 to 8 feet above its base, with a smaller ridge of sand and gravel, 3 feet high above its base, close west of this stake. Again, a half mile farther west, in the northeast corner of section 15, Strand, another Herman beach, probably 10 feet below the last, was noted, having a height of 4 or 5 feet above its base.

Traveling northwestward along the Pembina trail, the upper beach ridge was not distinctly observed after leaving section 36, Sundal, until it is again occupied by the trail in section 9 of this township. The intervening 3 miles are flat and nearly level. Probably the beach, less noticeable than usual, lies within a half mile or 1 mile east of the trail here. In the eastern part of section 9 this beach is about 25 rods wide, rising 5 feet from its east side, and descending 10 feet to its western base, which was the margin of Lake Agassiz.

Thence the upper beach extends nearly due north through the east edge of section 4, Sundal, and section 33, Garfield. In the east edge of the southeast quarter of section 28 and the west edge of the northwest quarter of section 27, Garfield, it is a typical ridge of gravel and sand, with its crest 1,166 to 1,173 feet above the sea. There is a gradual descent toward the west. The depression on the east is a sixth to a fourth of a mile wide, sinking 6 to 10 feet below the beach. Farther eastward the land is moderately undulating till, rising 20 to 30 feet above the beach and bearing frequent groves of small poplars, bur oak, and canoe birch.

Water in the Sand Hill River at the ford of the old Pembina trail, in the west part of section 28, Garfield, ordinary low stage, July 26, 1881, 1,071 feet.

DELTA OF THE SAND HILL RIVER.

(PLATES XXV AND XXVI.)

When Lake Agassiz stood at its greatest height, the Sand Hill River brought into its margin a delta 6 miles long from south to north and 3 miles wide, reaching from the upper beach to the west side of Garfield and Sundal townships (fig. 12). This deposit of stratified gravel and sand has about an equal area and thickness with the delta of the Buffalo River at Muskoda. Its surface descends slowly westward and is crossed by the lower Herman and the Norcross shores, though these lake levels are not generally traceable. The Tintah shores pass along its western margin, which in some portions was worn away to a low escarpment, steeper than its original frontal slope, while the eroded sand and gravel, after being carried some distance southward, but not wholly beyond the delta, were deposited in beach ridges. Upon the delta plain many dunes of small and



FIG. 12.—Section across the delta of the Sand Hill River. Horizontal scale, one-half mile to an inch.

large size, seen from a distance of 10 or 12 miles across the lower expanse at the west, have been heaped up by the winds, probably mostly before vegetation had spread over this area after the withdrawal of the glacial lake.

As was stated on page 291, in the description of the Buffalo delta, both these river deposits in the edge of Lake Agassiz seem attributable to conditions of the recession of the ice-sheet. Their gravel and sand were doubtless mainly englacial drift and were brought into this lake by streams which had gathered their freight upon the ice surface during the time of formation of terminal moraines. One of these glacial rivers, supplying a part or perhaps nearly all of the Sand Hill delta, flowed from an angle of the ninth or Leaf Hills moraine in a channel which has been traced 16 miles to its junction with the Sand Hill River, as described on page 164. Its sand and fine silt were carried more than 30 miles by the strong current

of the river in its irregular course before they were deposited in Lake Agassiz, where they at once settled to the bottom of the still water.

In the south half of section 32, Garfield, and in a belt which thence extends approximately north and south, the surface of this delta, as it was originally deposited, falls toward the west with a slope of 25 or 30 feet in 1 mile, from 1,125 or 1,130 feet to about 1,100 feet above the sea. Beneath this plane, however, channels have been eroded by the winds, and sand hills 25 to 75 feet above it have been blown up in irregular groups and series, scattered over a tract about a mile wide and extending 3 or 4 miles southward from the Sand Hill River, in section 29, the northeast part of section 30, and in sections 31 and 32, Garfield, and reaching southward in sections 5 and 8, Sundal. The most southern of these hills is an isolated group in the east part of the northeast quarter of section 18, Sundal. Another isolated group lies north of the Sand Hill River, in the northwest quarter of section 16, Garfield. These sand dunes are in part bare, being so frequently drifted by the winds as to allow no foothold for vegetation; other portions are clothed with grass or with bushes and scanty dwarfed trees, including bur oak, the common aspen or poplar, cottonwood, green ash, black cherry, and the frost grape.

Elevations of the highest points of these dunes, in order from south to north, are approximately 1,190, 1,180, and 1,200 feet. The highest dune appears to be in or near the east half of the northeast quarter of section 30, Garfield.

Secondary Herman beach, a smoothly rounded ridge of gravel and sand 10 to 15 feet high above the adjacent level, 1,148 to 1,153 feet above the sea, about three-fourths of a mile east of the old Pembina trail, in the west half of sections 21 and 16, Garfield, extending $1\frac{1}{2}$ miles north from the Sand Hill River to the cluster of dunes in the northwest quarter of section 16.

VICINITY OF MAPLE LAKE.

(PLATE XXVI.)

The upper Herman beach, the first of the series which was formed in the vicinity of Maple Lake contemporaneously with the single Herman beach farther south, runs approximately from south to north, through or

near the northeast corner of section 4, Garfield. It is a smooth gravel ridge, in some parts hidden by scattered groves, with its crest 1,165 to 1,175 feet above the sea. Farther east is a large area of woodland. The second Herman beach, in the east part of section 5, this township, and section 32, Godfrey, about a mile west from the upper beach, has a height of 1,149 to 1,153 feet, being a ridge of gravel and sand about 40 rods wide, with very gentle, prolonged slopes toward both the east and west. Natural surface at the northeast corner of section 32, Godfrey, 1,146 feet. Third Herman beach, running north, in the northwest quarter of section 5, Garfield, and the west part of section 32, Godfrey, a half or two-thirds of a mile west from the last, 1,130 to 1,135 feet, consisting of a distinct ridge in its southern part, but farther north being a flat area of gravel and sand, slightly elevated above the land next east.

Second Herman beach, a broad, low ridge of gravel and sand, extending north-northeast through section 28, Godfrey, from its southwest corner to its north line, 1,148 to 1,150 feet. The northward continuation of this beach is a low, flattened ridge, the western one of two parallel ridges of gravel below that of the upper beach, extending northeasterly and northerly through or near the west edge of section 10, Godfrey, 1,150 to 1,154 feet. Through the next 3 miles in section 3, Godfrey, and in the east part of sections 35 and 26 and the northwest quarter of section 25, Tilden, it is a prominent beach ridge, with its crest at 1,153 to 1,161 feet, somewhat steep on its east side, which descends about 10 feet to a belt of lowland and marsh that divides it from the parallel beach a quarter to a third of a mile east.

The eastern one of these parallel beach ridges is only 8 or 10 feet below the average elevation of the upper beach. It probably marks a slight rise of the land here; but no corresponding beach formation has been observed on this latitude in North Dakota. It is clearly continuous 8 miles, the first 4 miles extending northerly and the next 4 miles easterly. These parts are connected in section 25, Tilden, by a graceful curve, that portion of this beach and its extent thence eastward being known as the "Attix ridge," from Henry and William Attix, brothers, who have built their houses upon it. In its northward course, nearly through the middle of sections 10 and

4, Godfrey, its crest is at 1,158 to 1,163 feet; in the west edge of section 36, Tilden, and along its curved course to the northeast and east at the west and north sides of section 25 and in the southeast part of section 24, Tilden, 1,163 to 1,168 feet, and in sections 21 and 22, Grove Park, 1,171 to 1,173 feet. A slough, a third to a half of a mile wide, extends along the east side of this beach in section 3, Godfrey, and in the southeast part of Tilden, having a height of 1,155 to 1,160 feet.

Upper beach in the southwest quarter of section 11, Godfrey, forming a plain of stratified gravel and sand a quarter or a third of a mile wide from east to west, 1,168 to 1,173 feet. This beach near the south side of section 11 becomes a distinct gravel ridge of the usual character, about 25 rods wide, with its crest at 1,173 feet, bordered by a slough 20 to 40 rods wide at its east side. About a third of a mile farther southeast and some 50 rods west of the southwest extremity of Maple Lake, in section 14, Godfrey, the elevation of this beach ridge is 1,175 to 1,178 feet.

Maple Lake, water surface July 28, 1881, 1,169 feet. This lake, 6 miles long and averaging about a half mile wide, has a maximum depth of 20 feet near its southwestern end, and is mainly 10 to 15 feet deep along its central portion.

Upper beach, top of its well-marked gravel ridge in the east edge of the northeast quarter of section 3, Godfrey, about 20 rods north of Mr. Horton's, 1,180 feet. Beyond this point, through its next $2\frac{1}{2}$ miles, curving from a northward to a northeastward and eastward course, this upper beach of Lake Agassiz is magnificently exhibited, forming a massive, gently rounded ridge of gravel and sand about 30 rods across, with its crest 1,178 to 1,186 feet above the sea. A view of this beach ridge is given in Pl. VI (page 26), taken on its top, near the south line of the southeast quarter of section 35, Tilden, and looking northeastward along its course. It is bordered on the southeast side by a tract of slightly undulating till 10 to 15 feet lower, mostly covered with small timber and brush and holding frequent sloughs and lakelets in its depressions. The top of the beach is not wooded, but small trees and bushes originally encroached upon its slopes. A road extends along the crest of its curving portion for a distance of about a mile through section 36, Tilden.

The marsh which borders the northwest side of the northeast part of Maple Lake shows a descent of 5 to 7 feet northwestward, or away from the lake, in its width of 1 to 1½ miles. Maple Lake is prevented from flowing in this direction by a beaver dam near the lake. The creek draining this marsh where it intersects the upper beach near the east line of the northeast quarter of section 27, Grove Park, has a height of 1,163 feet. Here the beach skirting the north side of the marsh is a flat deposit of gravel and sand, a fourth to a half of a mile or more in width, highest next to the marsh, above which it rises 5 to 8 feet in a moderate slope. Its elevation in the north half of sections 26 and 27 is 1,169 to 1,172 feet, being even 1 or 2 feet lower than the Attix ridge, which lies some two-thirds of a mile farther north, in the south half of sections 21 and 22. This belt of beach gravel and sand continues 6 miles in a nearly due-east course, and beyond that it extends still eastward along the north side of a great tamarack swamp, which begins in section 34, Badger, and is said to be 8 miles long. Maple Lake and this tamarack swamp hold the same relation to the upper beach ridge, which was a barrier between them and Lake Agassiz and which now wholly or partially obstructs the drainage of these areas.

Third Herman beach, a small ridge of gravel and sand, extending from southwest to northeast, 8 to 10 rods wide, and rising 4 or 5 feet, crossed by the Crookston road in the southwest quarter of section 23, Tilden, and seen to reach at least a mile each way from this road, 1,146 to 1,149 feet.

Natural surface at the southeast corner of section 15, Tilden, 1,134 feet.

Fourth Herman beach, crossed by the road to Crookston and Red Lake Falls near the center of the southeast quarter of this section 15, 1,132 to 1,134 feet. This is a well-marked gravel ridge, mainly single, but twofold where it is crossed by this road. The distance of 1 mile here between these third and fourth Herman beaches consists of till, with a nearly smooth surface, which has boulders up to 3 and rarely 5 feet in diameter quite numerous scattered over it. Southeastward from the third to the first or upper beach the surface mostly is sand and gravel, with no boulders.

EASTWARD TO RED LAKE AND THE BIG FORK OF RAINY RIVER.

(PLATES III AND XII.)

A portion of a shore-line of Lake Agassiz, probably the highest in the Herman series of beaches, has been observed on and near the southwest line of the Red Lake Indian Reservation, between Hill and Lost rivers. It was seen near the north side of sections 31 and 32, and in the central part of sections 27 and 26, township 150, range 40, also for a mile or more thence eastward in the reservation, being 15 to 20 miles east-northeast of Maple Lake. The area is mostly prairie, and the beach is well exhibited. In the southwest part of township 150, range 40, the beach ridge of coarse gravel runs along the northern border of a roughly morainic belt, which is a half to two-thirds of a mile wide. In sections 27 and 26, and onward in the Red Lake Reservation, the beach is a typical gravel and sand ridge, containing pebbles and cobbles, nearly all of Archean gneiss and crystalline schists, up to 6 and 8 inches in diameter. Its trend here for about 3 miles is nearly from west to east. On the south, within about 1 mile, is a typical morainic belt of many hillocks, knolls, and ridges, which cover a width of several miles and rise 100 to 150 feet above the beach and the low, nearly flat tract that was covered by Lake Agassiz on the north, consisting in large part of marshes, through which the Lost and Clearwater rivers flow westward in meandering courses.

About 25 miles farther east in the Red Lake Reservation the road from Red Lake to White Earth crosses a beach of Lake Agassiz, which is probably the highest, being a continuation of the foregoing. This beach runs nearly from west to east, and is approximately 40 feet above Red Lake, or 1,210 feet above the sea. It is a ridge of sand and fine gravel, crossed by the road about 2 miles southwest from Big Rock Creek and Shell Lake. A grove of red pines grows on the beach, but the till on each side bears white pines. Following the road to the southwest, a belt of kames is entered about three-fourths of a mile from the beach, which continues to Sandy River, having a surface of many knolls and short ridges, with no observable parallelism in their trends, the crests being 10 to 20 feet above the inclosed hollows.

The most eastern observation of the upper shore-line of Lake Agassiz in northern Minnesota is by Mr. Horace V. Winchell, on the Bowstring River, more commonly known as the Big Fork of Rainy River, some 60 miles east of Red Lake. In his description of the ascent of this stream Mr. Winchell writes as follows of the locality, probably about 1,250 feet above the sea, where the surface changes from a smooth contour on the north, indicating lacustrine action, to a more undulating and rolling contour on the south, above the level of Lake Agassiz:

At the end of $7\frac{1}{2}$ miles the foot of a rapid nearly one-half a mile long is reached. At the foot of it is a bank of gravel and sand [probably the beach of Lake Agassiz]. It is a very different sort of bank from those seen below here. It is stratified, or partially so, but not horizontally nor all in the same direction. It looks like a stratified river deposit. Under it crops out a little fine bluish-gray clay, of which only a foot or two can be seen. This is supposed to be Cretaceous. * * * There are many limestone pebbles in the bank above the clay, but no shale is seen in it.

This rapid is over an immense number of bowlders. Most of them are hornblende gneiss, but other rocks are frequent. Many of the bowlders are large and stick up several feet above the water. A short distance up the rapid is a small island which seems to be made of bowlders and is covered with trees and bushes. * * *

Above the rapids quantities of bowlders are seen, while below only a few were encountered. The country does not seem to be of one general level, as before, but is knolly. The banks are of sand and gravel and contain much more gravel than those below the rapids. This is about 95 miles up the river, probably in township 62, range 25. It seems probable that the rapid mentioned above is on the boundary or shore of the glacial Lake Agassiz, and that all of the river below this rapid is included in the ancient basin.¹

BELTRAMI ISLAND.

The recent survey for the Duluth and Winnipeg Railroad, passing northwest by the east end of Red Lake and the southwest side of the Lake of the Woods, shows that the former of these lakes lies about 40 feet and the latter somewhat more than 150 feet below the highest level of Lake Agassiz. The height of Red Lake above the sea is ascertained to be 1,172 feet, and of the Lake of the Woods, in its stages of low and high water, 1,057 to 1,063 feet. Northeast of Red Lake the Tamarack River drains a large tract of tamarack, spruce, and arbor-vitæ swamp, which reaches to

¹ Geol. and Nat. Hist. Survey of Minnesota, Sixteenth Annual Report, for 1887, p. 434.

the divide between the Tamarack River and the West Branch of the Bowstring River (more commonly called the Big Fork), tributary to Rainy River, the height of the divide being only 15 to 20 feet above Red Lake. Similar low swamp land forms nearly the whole northern and northwestern shore of Red Lake and is crossed by this railroad survey continuously along its first 18 miles beyond Red Lake; but at a distance of 29 miles from the lake the profile shows an ascent crossing the highest beach of Lake Agassiz, which there is 1,215 feet above the sea. The next 17 miles of the profile extend across the northeastern edge of a large island of Lake Agassiz, rising on that line to a maximum height of 1,283 feet, with a moderately undulating drift-covered surface. In the next 15 miles, which comprise the descent on a similar but smoother drift surface from the highest shore of Lake Agassiz to the War Road River, an affluent of the Lake of the Woods, the profile crosses a succession of ten lower beaches of Lake Agassiz, marking stages in the gradual uplifting of the land and subsidence of the lake, their altitudes above the sea being 1,196, 1,172, 1,156, 1,143, 1,127, 1,116, 1,106, 1,099, 1,093, and 1,087 feet.

These data show that Lake Agassiz in its highest stage had a large island northwest of Red Lake, comprising the headwaters of numerous streams flowing outward from it to the Lake of the Woods, Rainy River, Red Lake, the Red Lake River, and the Red River of the North. This island had probably a diameter of 40 miles or more, with an area exceeding 1,000 square miles, of which apparently more than half is in Beltrami County, the portion farther west being chiefly in Marshall County, Minn. For this tract, which had before been supposed to be comparatively low and perhaps wholly beneath the highest level of Lake Agassiz, the name Beltrami Island is proposed, in recognition of the exploration of the region of Red Lake and the Julian or most northern sources of the Mississippi by Beltrami in 1823.¹ As Prof. N. H. Winchell wrote in the historical sketch here cited, this district "is still nearly as wild and uninhabited as when Mr. Beltrami passed through it." The limits of Beltrami Island are shown approximately on Pls. X, XXII, and other maps in this volume.²

¹ Geology of Minnesota, Vol. I, 1884, pp. 44-50, with map.

² Beltrami Island was first described in the American Geologist, Vol. XI, pp. 423-425, June, 1893; and its earliest mapping was in the Twenty-second Annual Report of the Geol. and Nat. Hist. Survey of Minnesota, for 1893 (pub. 1894), Plate I.

This island lies in the course of northwestward and northward continuation of the Mesabi or eleventh moraine of the series mapped in Minnesota, which next east from the narrows of Red Lake, rises very prominently to a height of 150 to 200 feet for a distance of about 10 miles upon the peninsula dividing the northern and southern parts of the lake. Like nearly the entire western half or two-thirds of Minnesota, this whole region is deeply drift-covered. No outcrops of the bed-rocks have yet been found on the large portion of the Red River basin lying in Minnesota; but the conspicuous escarpment of Cretaceous shales, overspread by drift, along the west border of the Red River Valley, wells penetrating to Cretaceous beds along this great valley plain, and the topographic features of the land rising eastward from it with nearly the same rate of ascent as on the west, lead to the belief that the eastern, like the western, border of this wide valley is formed by an escarpment of Cretaceous shales beneath the drift, and that the moderately elevated area of Beltrami Island consists of these shales enveloped by the glacial and modified drift.

THE UPPER OR HERMAN BEACHES AND DELTAS IN NORTH
DAKOTA.

FROM LAKE TRAVERSE NORTHWEST TO MILNOR.

(PLATES XXIII AND XXVII.)

From the southern extremity of Lake Agassiz, in section 18, Leonardsville, Traverse County, Minn., the upper or Herman beach extends northwestward 75 miles to the most southern bend of the Sheyenne River, in Ransom County, N. Dak., and thence its course is nearly due north, but with slight deflection westward, to the international boundary. The mouth of Lake Agassiz was where now a slough 2 to 3 miles wide, with frequent areas of open water, tributary to the Bois des Sioux River, stretches northward from the northeast end of Lake Traverse. On the west side of this slough and of Lake Traverse bluffs of till rise 100 to 125 feet; their tops and the rolling surface of till which extends thence westward are 1,070 to 1,100 feet above the sea.

The beginning of the upper or Herman shore-line west of the Bois des Sioux is in the northeast corner of South Dakota, in sections 10, 3, and

4, township 128, range 48, nearly 2 miles south from the north line of the Sisseton and Wahpeton Reservation. The ancient shore rises with terrace-like steepness 20 or 30 feet above the surface of undulating till which borders it on the northeast. Its material is sand and gravel, with pebbles up to $1\frac{1}{2}$ or 2 inches in diameter, about half of which are limestone. Beyond its steep margin this deposit of gravel forms a belt about a mile wide, approximately level, but with frequent short swells and low, flattened ridges, 5 to 10 or 15 feet above the intervening depressions. Its elevation is 1,060 to 1,070 feet above the sea, or from 90 to 100 feet above Lake Traverse.

For its first 3 or 4 miles the terrace-like lakeward margin of this belt of sand and gravel sweeps with a gentle curve westerly and northerly to a point in the southwest quarter of section 34, township 129, range 48, where it turns quite abruptly, taking a nearly due-west course for the next 3 miles to the west side of section 31 of this township.

In the northwest quarter of section 3, township 128, range 48, a third of a mile east of W. J. Allen's house, the ascent at the margin of this deposit is about 10 feet, to an elevation of 1,060 feet, approximately. The belt of sand and fine gravel is here about a half mile wide. Occasional hummocks, rising 5 to 10 feet and 50 to 100 feet long, which were observed on this part of the belt, appear to have been heaped up by the wind before the protecting mantle of grass and other herbaceous vegetation was spread over it.

Where this formation enters North Dakota, in the southeast quarter of section 32, township 129, range 48, similar dunes, 1,075 to 1,080 feet above the sea, have been excavated for use as plastering sand. Nearly all portions of this tract, and even its dunes, are now covered with a black soil and plentiful vegetation; but certain species preferring dry, sandy soil, as the dwarf rose (*Rosa arkansana* Porter), grow in greater abundance on the sand and gravel belt, and especially among its hummocks and hollows, than on the flat or slightly undulating surface of till at each side.

The inner margin of this belt, marking the shore of Lake Agassiz at its maximum stage, passes in its western course about 60 rods north of the southeast corner of section 32 and turns again to the northwest near

the middle of the west side of section 31, township 129, range 48. At the latter locality it is a low, wave-like ridge of sand and fine gravel, about 1,060 feet above the sea. On the south it is bordered by land 3 to 5 feet lower for a width of $1\frac{1}{2}$ miles. J. R. Grimesey's well, 13 feet deep, at the southwest corner of section 31, on this low tract outside the beach ridge, encountered only very fine stratified sand, irregularly laminated and containing numerous tubular limonitic concretions. Farther to the southwest and west, a gently undulating surface of till, scarcely higher than the beach of Lake Agassiz, stretches away several miles, beyond which the highland of the Coteau des Prairies is seen in the far distance.

The Herman beach crosses township 129, range 49, in a diagonal course, entering it a half mile north of its southeast corner and running northwest to the north side of sections 5 and 6. In section 23 and the northeast part of section 22, its elevation is about 1,055 feet, but its dunes rise 3 or 4 feet higher. At the middle of the north side of section 16 it is a ridge of sand and fine gravel about 8 rods wide, rising 4 to 6 feet above the land on each side. Its crest here and for a mile to the southeast and northwest is 1,060 to 1,065 feet above the sea. Northeastward the surface falls about 20 feet in the first mile. On the southwest side of this distinct beach ridge, a smooth, slightly undulating tract $1\frac{1}{2}$ to 2 miles wide, extending through this township, consists of sand and fine clayey silt. Its elevation varies from 1,055 to 1,080 feet, attaining the latter height in the northwest part of the township. This belt, with its continuation southeastward, previously described, was doubtless covered by Lake Agassiz before the erosion of its outlet to the level of the Herman beach; but its stratified sand and silt appear to be modified drift deposited by streams from the melting ice-sheet. The glacial recession here was from southwest to northeast, and this was probably an avenue of drainage during a short time, as was shown on page 150, till the continued retreat of the ice left a considerable expanse of water, the beginning of Lake Agassiz, between itself and the shore.

In the north part of sections 5 and 6, township 129, range 49, and in sections 31 and 32, township 130, range 49, this beach consists of two or

three parallel wave-like ridges of gravel and sand, divided by depressions an eighth to a quarter of a mile wide and 5 to 10 feet lower.

This belt reaches north to the Lightnings (or Thunders) Nest,¹ a massive dune of fine sand (Pl. VII, p. 28), partly bare and now wind-blown, but mostly covered with bushes and herbage, situated near the center of section 30, township 130, range 49. Its base on the south is 1,060 feet and its top 1,120 feet, approximately, above the sea. It covers a space about a quarter of a mile in extent from southeast to northwest, with nearly as great width, and rises in two summits of nearly equal height. The Lightnings Nest is the most prominent in a series of dunes, elsewhere rising only 10 to 30 feet, mostly grassed, which extends a mile or more to the southeast and is traceable several miles northwest to the east end of a very conspicuous tract of dunes 50 to 100 feet above the adjacent level, with summits at 1,100 to 1,150 feet above the sea, which stretches about 4 miles in a west-northwest course in the south part of township 131, range 50, 1 to 2 miles south of the Wild Rice River. By winds, eroding and drifting, these sand hills were heaped up from the Herman beach and its associated belt of modified drift, probably soon after the retreat of the ice, though their forms have been constantly changing since that time.

Outside the area of Lake Agassiz, the southwest part of Richland County is till, mostly undulating or moderately rolling, but in part prominently hilly, with rough morainic contour and abundant bowlders. Taylor Lake, approximately 1,050 feet above the sea, 2½ miles west of the Lightnings Nest, is a very beautiful sheet of water, bordered by a sandy shore and a large grove on the north, and by a shore of bowlders and morainic hills 50 to 150 feet above the lake on the west. These hills and most of the lakes farther west in this county have no timber. Northeastward the area that was covered by Lake Agassiz is mostly smooth and nearly flat till, with frequent marshy tracts called sloughs, but with only very rare and small lakelets.

Swan Lake, 3 miles long, reaches from section 3 to section 7, township 130, range 51, having an estimated height of 1,070 feet above the sea, with

¹A translation of the aboriginal Dakota name.

undulating till 5 to 10 feet higher on the northeast and 10 to 20 feet higher on the south and west.

The Herman beach, a ridge of fine sand, 20 to 25 rods wide and about 3 feet high, near the south line of section 36, township 132, range 52, trends to the west-northwest, and has a height of 1,065 feet, approximately. On the north, the exceedingly flat plain of Lake Agassiz, sinking very slowly northeastward, reaches as far as the eye can see. On the south, flat land, covered by Lake Agassiz before the time of this beach, continues $1\frac{1}{2}$ miles, ascending in that distance from 1,060 feet to about 1,080 feet, and moderately undulating till rises beyond to 1,100 and 1,125 feet.

One and a half miles north of this beach the Wild Rice River is crossed by a bridge near the center of section 25, township 132, range 52. The stream in its ordinary stage is 1 to 2 rods wide, with a depth of about 3 feet, and is filled with grass and rushes. Its bottom land, a sixth to a third of a mile wide, is about 10 feet higher and is annually overflowed by the high water in spring. Its bluffs rise about 40 feet above the river at low water, the elevation of their top and of the adjoining plain being, approximately, 1,050 feet. These bluffs and the surface from the Herman beach north to Elk Creek are till, but the country about Wyndmere and south to Elk Creek is stratified, fine clayey sand. Both formations have a very fertile soil, unsurpassed for wheat and all crops proper to this latitude. Elk Creek is a stream similar to the Wild Rice River, but smaller, and the width and depth of its valley are about two-thirds as great.

Northern Pacific, Fergus Falls and Black Hills Railroad, track at Wyndmere, 1,062 feet above the sea; at the Herman beach, $1\frac{1}{2}$ miles west of Wyndmere, track 1,066 feet, and crest of the beach 1,068 feet, rising 8 feet above the adjacent land 20 rods away both east and west; surface along the railroad thence westward 8 miles, 1,062 to 1,066 feet, with Star Lake, a third of a mile in diameter on this level area, only 2 or 3 feet below the surrounding land close north of the railroad in section 5, township 132, range 52; a higher beach of Lake Agassiz, crossed 3 miles east of Milnor, and therefore called the Milnor beach, crest and track, 1,085 feet, 4 or 5 feet above the adjoining land 10 rods away both east and west;

another beach ridge formed during the same stage of Lake Agassiz, a third of a mile farther west, crest and grade, 1,086 feet; land close east, 1,081, and west 1,087 feet; track at Milnor, 1,097 feet.

The Herman beach west and north of Wyndmere has an irregular surface, with frequent hummocks of sand heaped 5 to 10 feet above adjacent hollows. Most of these dunes are now grassed. From near Wyndmere this beach, with frequent small dunes, extends north through the west edge of township 133, range 51, and thence westerly to another tract of prominent dunes 50 to 100 feet above the adjacent surface, with their top at 1,100 to 1,150 feet, which extends about 10 miles in a west-northwest course from the southwest part of township 134, range 52, to the east part of township 134, range 54, terminating about 2 miles east of the Sheyenne River. Like the similar high dunes south of the Wild Rice River, these are mainly covered by herbage, bushes, and small trees; but many portions are now being drifted by the winds, so that they are wholly destitute of vegetation. These dunes mark the course of the Herman beach, here greatly increased in volume by delta deposits from the Sheyenne River.

Morainic knolls and hills, rising 20 to 50 feet, with plentiful bowlders, lie close west of Milnor, extending in a belt from southeast to northwest. They are referred to the seventh or Dovre moraine, as described in Chapter IV. Near Lisbon, about 15 miles northwest from Milnor, some of these morainic hills are quite conspicuous, rising 100 feet or more above the surrounding country.

Evidence of a stage of Lake Agassiz 20 or 30 feet higher than that of the Herman beach is found, as before noticed, in many places along the southern part of its boundary in North Dakota. The portion of this glacial lake formed earliest by the recession of the ice seems to have reached from Lake Traverse to the Sheyenne River, and its level appears to have been then nearly that of the general surface and the top of the bluffs bordering Lake Traverse. An explanation of the conditions probably producing this Milnor stage of the incipient glacial lake, with the reasons why it was limited to a comparatively short extent on the southwestern border of the lake area, has been presented on pages 150 and 211.

The highest level of Lake Agassiz near Milnor is marked by the Milnor beach, already mentioned, where it is crossed by the railroad. This beach is fine clayey sand, in somewhat irregular and interrupted low ridges and terraces, abutting at the west on undulating till, which gradually rises 10 or 20 feet higher, while on the east a descent of 10 or 15 feet within about 20 rods is succeeded by a flat area, which thence sinks very slowly north-eastward. The elevation of the Milnor beach at the railroad is 1,086 feet, and at Mr. G. V. Dawson's house, at the middle of the east side of section 22, township 133, range 54, 1,092 feet. Its course between these points is north-northwest, and this is continued to the mouth of a former channel of the Sheyenne River, near the center of section 4 in this township, 3 miles east from the most southern bend of the river.

During all the stages of Lake Agassiz the Sheyenne River brought into it much sediment, carrying the clay farther than the sand and gravel, which were laid down near the river's mouth. Extensive areas of these originally flat beds have been changed by wind action to irregular groups and belts of sand hills or dunes, which vary from a few feet to more than 100 feet in height above the surrounding level. Besides the large tract of these dunes before described east of the Sheyenne River, others of even greater extent and equally conspicuous border the river and reach 2 or 3 miles from it in the northeast part of township 135, range 54, and along its next 15 miles.

Watercourses formerly occupied by this stream are found west of the Milnor beach. One of them is marked by a sandy flat, which reaches from the present course of the Sheyenne River, in section 1, township 133, range 55, southeastward through township 133, range 54, to the vicinity of Milnor. Another runs from near the middle of the southwest quarter of section 32, township 134, range 54, about $1\frac{1}{4}$ miles east-southeast to the middle of section 4, township 133, range 54. This is a channel 30 to 50 rods wide, about 40 feet below a ridge of coarse gravel, which extends along its northeast side, dividing it from the lower area that was covered by Lake Agassiz and from the present valley of the river. The crest of the

ridge is nearly flat upon a width of 10 to 30 rods, and is 75 to 100 feet above the river, being highest westward. It contains pebbles and cobbles of all sizes up to 6 inches in diameter, about half being limestone and nearly all the others granitic. This ridge or plateau of gravel is a remnant of an old delta plain of the Sheyenne River, apparently deposited before the formation of the Milnor beach, above which it rises some 40 or 50 feet, which suggests that the deserted channel of that depth on its south side was probably eroded during the Milnor stage of Lake Agassiz. Similar gravel occurs on the side and verge of the bluff, 100 feet high, northwest of the Sheyenne River, in the southwest quarter of section 29, township 134, range 54, but a rolling surface of till extends thence northwest.

The height of the Sheyenne River in section 32, township 134, range 54, is 1,039 feet above the sea; and on the west line of the northwest quarter of section 29, township 135, range 54, 1,021 feet. Its bed through these townships is mostly 4 to 6 rods wide, with water 1 to 2 or 3 feet deep, and is strewn in many places with cobbles and boulders up to 2 or 3 feet and rarely 6 or 8 feet in diameter. Its bottom land near the south bend, about a third of a mile wide, is 15 or 20 feet above the ordinary low stage of water, and during a term of fourteen years preceding this survey in 1885 it had not been overflowed; but driftwood, found by the first immigrants, proves that the river sometimes reaches this height. Bluffs of till here, in the southwest corner of township 134, range 54, rise 100 to 125 feet above the stream.

Bluffs of till close west of the Sheyenne River, in section 20, township 134, range 54, 1,100 to 1,110 feet; moderately rolling till a quarter of a mile farther west, 1,115 to 1,125 feet; same in sections 17 and 18, 1,090 to 1,130 feet; and on the east side of the river, in sections 21, 16, and 17, 1,085 to 1,075 feet, descending northeastward. Prominent swell of till west of the Sheyenne River, in the southeast quarter of section 30, township 135, range 54, having four aboriginal mounds on its crest, 1,113 feet; top of these mounds, 1,117 feet, very nearly. Highest portions of the area of undulating till seen westward from this section 30, 3 or 4 miles distant, 1,125 to 1,150 feet.

Surface at Charles G. Froemke's house, in the northwest quarter of section 29, township 135, range 54, 1,075 feet; bottom land of the Sheyenne River close west, 1,039 to 1,029 feet; ordinary low water of the river, 1,021 feet.

Portion of area of Lake Agassiz, a strip a fourth to a third of a mile wide, west of the Sheyenne River, in sections 32 and 5, a half mile to 2 miles south of Mr. Froemke's, 1,065 to 1,075 feet. Herman beach one-fourth to two-thirds of a mile east of the Sheyenne River here and extending southeasterly toward the western limit of dunes in the east part of township 134, range 54, 1,073 to 1,079 feet. Crest of this beach, a low ridge of sand and fine gravel, at J. Altmann's house, near the middle of section 20, township 135, range 54, 1,073 feet. Within 10 or 15 rods east there is a descent of about 10 feet. This beach ridge runs north and northeasterly to near the northeast corner of this section 20, and thence it passes eastward about 3 miles, having an elevation of 1,075 to 1,065 feet to where it is intersected by the Sheyenne River, near the northeast corner of section 14. North of the river it continues about a half mile in section 12, its elevation being 1,065 to 1,070 feet, to the west end of a tract of dunes 25 to 100 feet above their vicinity, with summits at 1,100 to 1,150 feet, which extends thence about 15 miles eastward. This Herman beach was sufficient to turn the course of the Sheyenne River along its west and north side for a distance of 8 miles, from section 9, township 134, range 54, north and east to section 14, township 135, range 54, though it is only a ridge of sand and gravel 5 to 10 feet higher than the smoothed area of till, occasionally covered by 1 to 3 feet of sand, which lies west of it and in which the river has now cut its channel 50 to 60 feet deep.

Rolling surface of till in the south edge of section 9, township 135, range 54, 25 to 40 rods north of the Sheyenne River, 1,080 to 1,090 feet. Most of this section 9 is nearly level till at 1,080 to 1,085 feet, with occasional large hollows 20 feet lower. It seems to have been smoothed by Lake Agassiz at the time of the Milnor beach. Westward is slightly undulating till, having an elevation of 1,085 to 1,125 feet for 2 or 3 miles, as far as the surface lies within view.

Herman beach in the northwest quarter of section 10, township 135, range 54, 1,075 to 1,080 feet. This is a deposit of gravel and sand extending along the verge of the plateau of till just described in section 9. Fifteen or 20 rods to the east the elevation is 1,065 feet, and it sinks slowly thence eastward to about 1,050 feet at the west base of the dunes in sections 12 and 1 of this township.

Lakelet back of this beach, situated in the east edge of the southeast quarter of section 4, township 135, range 54, about 50 rods long from south to north, 1,060 feet, being 25 feet below the average of the adjacent undulating till. Shallow lakelet 40 rods across, close east of the beach, a quarter of a mile east from the northwest corner of section 3, also 1,060 feet; adjoining land, 1,065 to 1,070 feet, excepting on the west, where the Herman beach has an elevation of 1,080 feet, with undulating till beyond it a few feet higher.

Herman beach at the middle of the west side of section 34, township 136, range 54, Sheldon, 1,082 feet; surface 25 rods east, 1,070 feet, thence descending slowly eastward. Here and for $1\frac{1}{2}$ miles south, through section 3, this beach is a flattened ridge of sand and fine gravel, 25 or 30 rods wide, with a depression 3 to 6 feet deep along its west side. In the northwest quarter of section 28 its elevation is 1,080 feet.

Fargo and Southwestern Railroad track at Sheldon, 1,080 feet. Wells in Sheldon village are 10 to 15 feet deep; in sandy clay, free from gravel or boulders, 6 to 10 feet, with sand below. These deposits belong to the Herman beach, which is here spread upon a width of about a half mile.

DELTA OF THE SHEYENNE RIVER.

(PLATE XXVII.)

The delta deposited by the Sheyenne River in Lake Agassiz reaches from the Lightnings Nest 50 miles northwest to the south bend of the Maple River, and has a maximum width of nearly 30 miles to the northeast from the south bend of the Sheyenne. It probably covers an area of 800 square miles to an average depth of 40 feet, its volume being, therefore, about 6 cubic miles. Large tracts of this delta are channeled by the winds and heaped up in dunes, as before noted, which rise to heights of 25 to 100 feet

or more above the average height of its expanse. Fig. 13 presents a section crossing this delta from east to west.

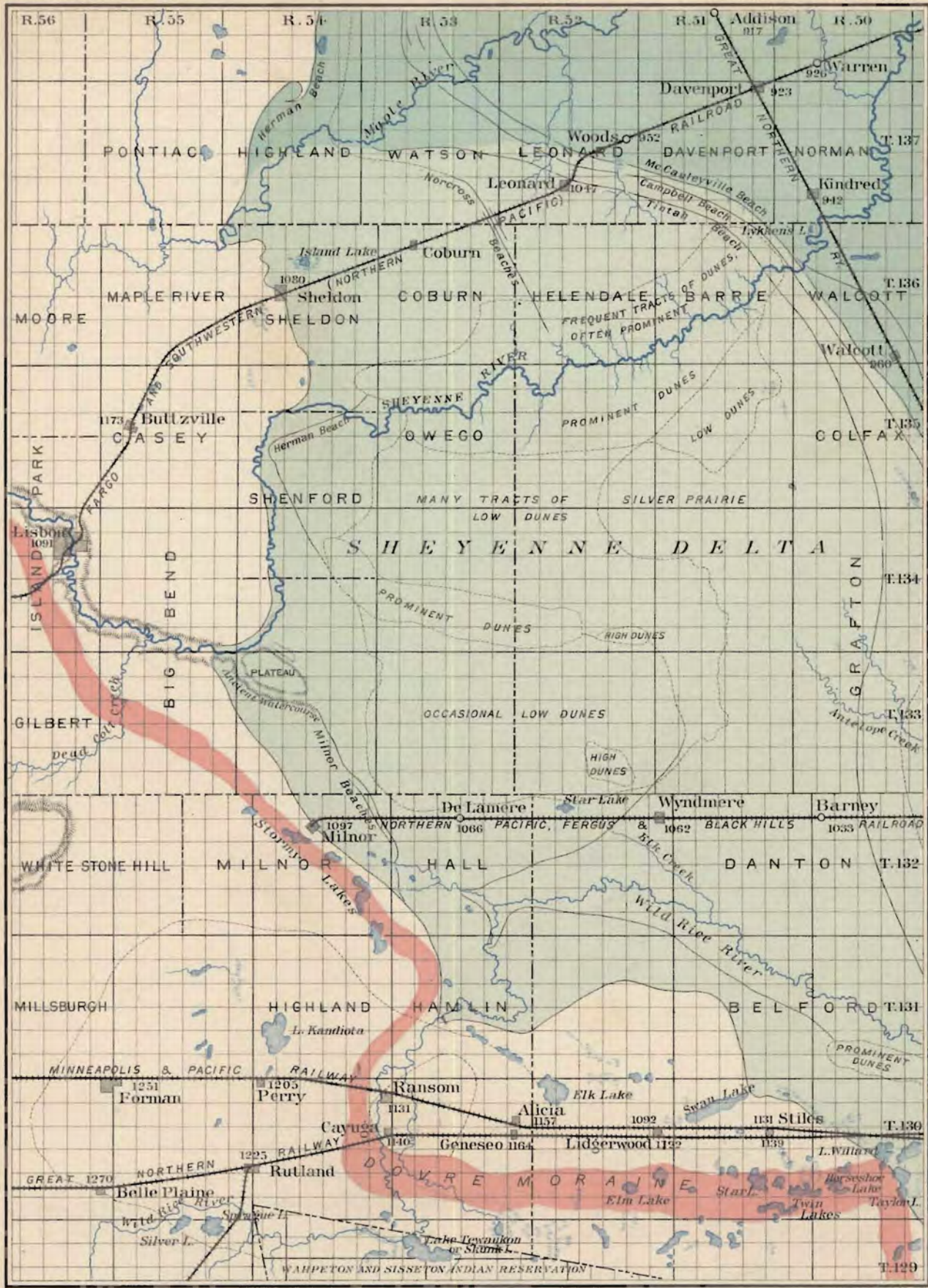
The deposition of the delta proper, and also of the fine lacustrine silt extending beyond its plateau to the Red River, took place mainly during the upper Herman stages. The plateau, gently descending eastward, is crossed by the Herman and Norcross shore-lines, and in part by the Tintah and Campbell shores on its eastern and southeastern border. From the Maple River 8 miles east to Leonard, however, and thence southeasterly about 25 miles, its margin has been eroded and changed to an abrupt escarpment, or at least a somewhat steep slope, by the lake waves during the Tintah, Campbell, and McCauleyville stages. This front of the delta, 75 to 25 feet above the flat low land of the Red River Valley adjoining its base, decreases in prominence as it is followed southward. It passes close



FIG. 13.—Section across the delta of the Sheyenne River. Horizontal scale, 6 miles to an inch.

north of Leonard and within a few miles west of Kindred, Walcott, Colfax, and Barrett, gradually ceasing as a notable feature farther south.

A great portion, probably exceeding a half, of the Sheyenne delta, as of all the other large deltas of this glacial lake, is modified drift, which was brought down by glacial streams from the melting surface of the ice-sheet. The coarser gravel and much sand that were supplied from the ice to the head streams of the Sheyenne during the time of formation of its delta were deposited along the outer side of the great moraines south of Devils Lake; the finer gravel and a great volume of sand were carried by the Sheyenne to this delta; and the finest silt and clay of the great glacial river were spread in the quiet water of the lake, over a much larger adjoining area of its bed, from near Breckenridge northward beyond the mouth of the Sheyenne.



MAP SHOWING THE GREATER PART OF THE SHEYENNE DELTA OF LAKE AGASSIZ AND CONTIGUOUS BEACHES, NORTH DAKOTA.

Scale, 6 miles to an inch.

Lake Area Delta Moraine
 Altitudes of railway stations are noted in feet above the sea.

Much alluvium was also supplied from the erosion of the Sheyenne Valley, which, with that of the Big Coulee (the avenue of discharge from the glacial Lake Souris to the Sheyenne and Lake Agassiz), probably averages three-fourths of a mile in width and 150 feet in depth along a distance of 200 miles. This channel is cut in the drift sheet, mainly till, and in the underlying, easily eroded Cretaceous shales. The volume of the material supplied from it would be equal, according to these estimates, to about three-fourths of the Sheyenne delta, or perhaps three-eighths of both the delta and the finer clayey sediments that were deposited farther out in the lake. But the valley of the Sheyenne, in considerable portions of its extent, was also a preglacial valley. If it retained in a considerable degree its trough-like form beneath the ice-sheet, as was evidently true of the Minnesota Valley,¹ its erosion and its tribute to the Sheyenne delta would be less than the proportion estimated.

FROM SHELDON NORTH TO THE NORTHERN PACIFIC RAILROAD.

(PLATES XXVII AND XXVIII.)

The Herman beach, terrace-like, at Hugh McIntosh's house, in the south edge of the northwest quarter of section 8, Sheldon, has its crest 1,083 to 1,084 feet above the sea. His well, near the top of the beach, 22 feet deep, is soil and sandy clay to a depth of 7 feet, then sand 15 feet to water. Till rises to the surface 20 rods farther west. About 30 rods east, on land 10 feet lower, a well 10 feet deep is all caving sand below the black soil, which is 1 or 2 feet deep.

Maple River in section 32, Highland, about 2 miles northeast from its most southern bend, 1,019 feet. It is 20 to 40 feet wide and 1 to 3 feet deep, with cobbles and bowlders in many portions of its channel. Herman beach, a sand and gravel deposit, extending a quarter of a mile from south to north on the verge of the bluff of till west of Maple River in the northwest part of this section 22, 1,072 to 1,077 feet. In the north edge of the northwest quarter of this section, the northeast corner of section 31, and the east edge of section 30, it is a plateau-like tract a fourth of a mile wide, with a subsoil of sand and fine gravel, 1,086 feet, from which both east and

¹"The Minnesota Valley in the Ice age," Proc., A. A. A. S., Vol. XXXII, for 1883, pp. 213-231. *Geology of Minnesota*, Vol. I, 1884, pp. 479-485, 581; Vol. II, 1888, p. 134.

west a gentle slope falls 5 feet within 20 or 30 rods. In the northwest quarter of section 20 and the west half of section 17, Highland, it is a gracefully rounded ridge, 1,085 to 1,087 feet, with descent of about 5 feet on its west side and 10 to 15 feet within as many rods on the east. The surface east of the Maple River in this township has an elevation of 1,075 to 1,065 feet, declining toward the north and east. In the east half of Pontiac, the next township on the west, a surface of till, moderately undulating near the beach of Lake Agassiz, but prominently rolling at a distance of 3 miles to the west, rises to 1,150 and 1,175 feet in the vicinity of the Maple River above its south bend.

The Herman beach, a broad, flattened ridge of sand and gravel, passes in a north-northeast course through the center of section 8, Highland, its elevation being 1,083 feet. A smoothed surface of till, 1,082 to 1,087 feet, with occasional sloughs in depressions 15 to 20 feet deep, occupies the west half of this section 8; and close east of the beach a flat of till on the east line of the section, at 1,065 to 1,070 feet, was the bed of the lake.

Continuing northeastward, the beach is offset a mile to the east, in sections 4 and 3, Highland, so that the greater part of section 4 was a bay of Lake Agassiz during its Herman stage, with bottom at 1,080 to 1,065 feet, inclosed on the west, north, and east by beach deposits. The highest portion of the hook or spit east of this bay is in the southwest quarter of section 3, 1,093 to 1,096 feet. It is composed of sand and fine gravel, with pebbles mostly less than an inch, but occasionally 2 inches in diameter, forming a smoothly rounded swell 30 to 40 rods wide. This cape, projecting south and west a mile into the lake, was accumulated by the southward drift of the beach material along the shore, caused by northern winds, as is also observable at various other places on both the east and west shores of this glacial lake and on both sides of Lake Michigan at the present time.

Herman beach in the west edge of section 26, Eldred, 1,094 feet. On the east side of the beach here, near the center of this section, is a slough filled with rushes and containing water all the year; its elevation is about 1,065 feet, that of the land on its east side, in the east part of this section, being about 1,075 feet. In the northeast quarter of section 34 the beach is intersected by a sluggish creek, apparently formed by springs within a

half mile northwest, its ravine being fully 40 feet below the general level of the beach and the land westward. Again, in the southwest quarter of section 26 the beach is cut by a dry channel, the outlet in rainy weather from a small slough.

Through the west half of section 23, Eldred, the beach is a low, smoothly rounded ridge of sand and fine gravel, about half of which is limestone and the rest granite or other Archean rocks. As in the 3 miles next southward, it is largely composed of fine gravel, and pebbles abound, often covering half the surface of the knolls made by gophers. Most of the pebbles are less than an inch in diameter, but some measure 2 and a few 3 inches. The elevation of this beach ridge is 1,092 to 1,100 feet; on the north line of this section its height is 1,099 feet. A broad depression 3 to 5 feet below the beach borders its west side. Toward the east there is a descent of about 10 feet in 25 or 30 rods, and thence a gradual slope sinks to 1,060 or 1,050 feet within 1 to $1\frac{1}{2}$ miles.

Undulating till in sections 22 and 15, Eldred, 1,095 to 1,110 feet; crests of prominently rolling till in the west edge of section 11 and the south part of section 10, 1,115 to 1,125 feet; thence northwestward lower undulating till has an elevation of only 1,090 to 1,100 feet for nearly 2 miles, and rises quite slowly beyond. This somewhat irregular contour has caused considerable diversity in the development of the beach, so that its deposits are massed in unusual amount in some places, while elsewhere they are deficient or wholly wanting. In the southwest quarter of the southwest quarter of section 14, Eldred, a swell of gravel, with pebbles up to 2 inches or rarely 3 inches in diameter, rises to 1,105 feet, extending about 40 rods from south to north; and similar gravel, at 1,095 to 1,105 feet, occurs in the west part of the northwest quarter of section 23, west of the distinct beach ridge. The northwest part of section 14 is a nearly flat tract, having a subsoil of sand and fine gravel, with an elevation of 1,090 to 1,095 feet. A beach ridge extending south from the east side of a prominent swell of till in the southwest quarter of section 11, at 1,086 to 1,089 feet, has a continuous depression of about 5 feet on its west side and is bordered eastward by land 6 to 10 feet below its crest. In the northwest part of this section 11 and the southeast part of section 3 the shore of Lake

Agassiz is marked by slight erosion in the rolling and undulating surface of till rather than by the usual beach deposits of gravel and sand.

Beyond this, a conspicuous beach ridge 25 to 40 rods wide, elevated 10 feet above the undulating till on its west side and bordered by a still lower surface on the east, extends from the middle of the southwest quarter of the southeast quarter of section 3, Eldred, northwestward to near the middle of the north line of the northwest quarter of this section, where it is interrupted by a drainage gap about 20 feet below its crest. Thence this massive beach ridge continues in a north-northeast course through section 34, Howes, to near the middle of its north line. Its material is sand and gravel, with pebbles up to $1\frac{1}{2}$ inches in diameter. In section 3 its elevation is 1,095 to 1,090 feet, and in section 34, 1,089 to 1,094 feet. It passes onward as a very distinct and typical beach ridge, with the same north-northeast course, through sections 27 and 22, Howes, having an elevation of 1,087 to 1,095 feet in section 27 and 1,089 to 1,096 feet in section 22. Its eastern slope in these sections descends 15 to 20 feet.

About a half mile west from this great beach ridge the east edge of section 4 has irregular deposits of beach gravel and sand in swells and bars 5 feet above the general level, and in the east edge of section 33, Howes, a well-defined parallel beach begins, having a width of 20 to 25 rods and elevation of 1,092 to 1,094 feet, with a depression 2 to 4 feet lower on the west and descent of about 5 feet on the east. This western Herman beach extends as a continuous ridge 2 miles to the north-northeast, excepting a gap where it is intersected by a small stream in the northwest quarter of section 27. Its material is sand and gravel, with pebbles up to 2 inches in diameter, about half being limestone. Both this and the east beach have a black soil a foot or more in depth, and are scarcely inferior to the adjoining areas of till in productiveness. Farther west a slightly undulating or nearly flat surface of till extends from a half mile to $1\frac{1}{2}$ miles before it rises above 1,095 feet, and the highest of its swells, seen 3 to 6 miles away to the west and northwest, do not exceed 1,150 or 1,175 feet. The western Herman beach on the north line of the northwest quarter of section 27 has a height of 1,095 feet; about 6 rods to the south, 1,097 feet; and northeast-

ward, in section 22, 1,092 to 1,095 feet, to its junction with the eastern or main beach in the east part of this section.

A lower Herman beach, formed after the lake level here had fallen slightly, appears in the northwest edge of section 26, Howes, having its crest at 1,072 to 1,075 feet; passing north-northeastward through the west half of section 23, its elevation is 1,075 to 1,080 feet; through section 14, 1,080 to 1,087 feet, being highest near the center of this section; and in the east part of sections 11 and 2 and onward to the southwest quarter of section 36, Buffalo, 1,083 to 1,080 and 1,075 feet. Its maximum development is in section 14, where it is a massive, smoothly rounded ridge of sand and fine gravel, 30 rods wide, with a descent of 15 feet on each side. In sections 26 and 23 it is bordered on the west by a continuous depression 4 to 8 feet below it; and through sections 14, 11, and 2, and in the southwest quarter of section 36, a slough $3\frac{1}{2}$ miles long, mown for its luxuriant marsh hay, having an elevation of 1,067 to 1,072 feet, lies between this and the main beach, a half mile farther west.

Floor of S. P. Gardner's house, in the northwest corner of section 27, Howes, 1,096 feet.

Main Herman beach through the west edge of section 14, Howes, 1,096 to 1,093 feet, declining northward; in the west part of section 11, 1,093 to 1,095 feet; in section 2, 1,092 to 1,095 feet, changing from a north to a north-northeast course; in the southeast edge of section 35 and the northwest edge of section 36, Buffalo, 1,092 to 1,096 feet; and in the west part of section 25, where it is cut by the Northern Pacific Railroad, 1,095 to 1,101 feet. At the railroad cut its crest is 1,099 to 1,101 feet, and the track is 1,092 feet above the sea. Along this distance of 5 miles it is a typical beach ridge of sand and gravel, with pebbles up to 2 inches and occasionally 3 to 6 inches in diameter, about 30 rods wide, rising nearly 25 feet above the slough on the east, and bordered on the west by a continuous depression, mostly about an eighth of a mile wide, 3 to 7 feet below its crest. Slightly undulating till rises beyond to 1,125 and 1,140 feet within 1 or $1\frac{1}{2}$ miles west, which is as far as the surface lies within view.

Northern Pacific Railroad track at Wheatland, 993 feet; on bridge over creek in the east edge of section 25, Buffalo, 4 miles west of Wheat-

land and three-fifths of a mile east of the Herman beach, 1,076 feet; bed of the creek, 1,057 feet; track at summit, $4\frac{1}{2}$ miles west from the Herman beach, same as the natural surface, 1,208 feet; and at Buffalo, a half mile farther west, 1,202 feet.

FROM THE NORTHERN PACIFIC RAILROAD NORTH TO GALESBURG.

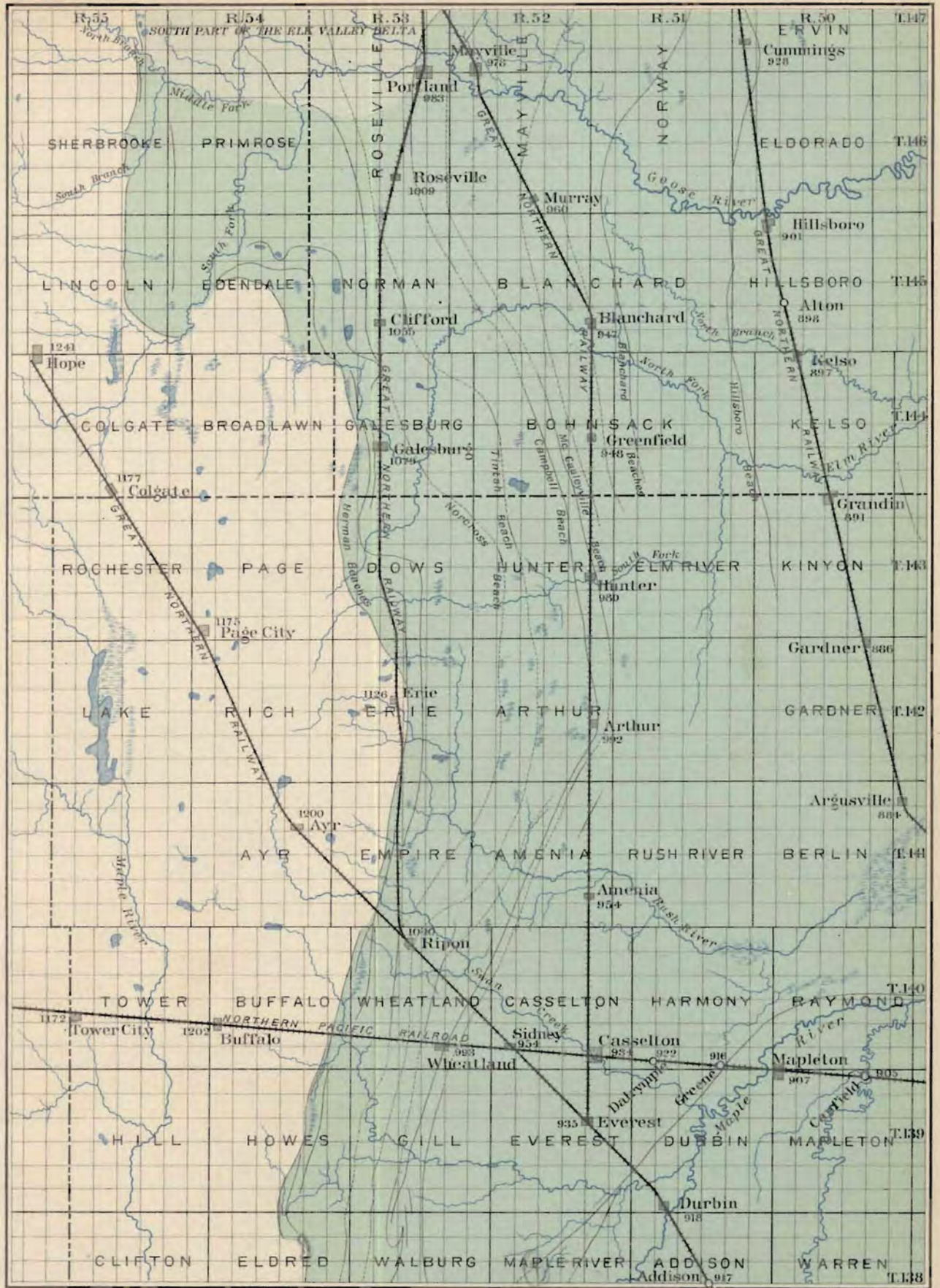
(PLATE XXVIII.)

The Herman beach, a broad, smoothly rounded, continuous ridge of the same material and contour as southward, runs to the north-northeast for the next 4 miles north from the Northern Pacific Railroad, with its crest at 1,097 to 1,100 feet, very constant in elevation. The descent of its east slope is 15 or 20 feet in about 20 rods, and of its west slope about 5 feet. Thence westward the surface is undulating till, in swells 10 to 15 feet above the depressions, rising gradually to 1,150 and 1,200 feet above the sea at a distance of 3 to 5 miles, the farthest seen in that direction. In a broad view this area seems an almost flat plain.

Where this beach is cut by the branch of the Great Northern Railway from Ripon to Hope, near the middle of the line between sections 32 and 33, Empire, its crest was 1,096 to 1,099 feet above the sea. It has been excavated here for ballast to a distance of about 30 rods south from the railway. It is mostly gravel; the pebbles seldom exceed 2 inches in diameter; about half is limestone, and the remainder granitic. The thickness of this beach deposit is only 8 to 10 feet; its east slope falls 12 or 15 feet, and its west slope 5 to 7 feet.

On the floor of this excavation, about 10 rods south from the railway, in the upper foot of the till or boulder-clay, under the gravel, numerous bones of a mammoth were found in the year 1884. These included a tusk 11 feet long and 9 inches in diameter (tapering to 6 inches at the smaller end, where it was broken off), three teeth, two vertebræ, and several other bones. They were embedded in the top of the till, and the overlying beach formation has yielded no bones, shells, or other fossils.

Southward from this locality the Herman beach is double for a distance of about 4 miles. The secondary beach ridge east of that already described is similar in size and material. Its south end is in the west part



MAP OF THE WESTERN SHORES OF LAKE AGASSIZ, FROM THE VICINITY OF WHEATLAND, CASS COUNTY, NORTH TO PORTLAND AND MAYVILLE, TRAILL COUNTY, NORTH DAKOTA.

Scale, 6 miles to an inch.

Lake Area Delta

Altitudes of railway stations are noted in feet above the sea.

of section 19, Wheatland, a half mile east from the main beach, and it passes thence north-northeastward through sections 18, 7, and the east edge of section 6, having an elevation of 1,081 to 1,084 feet. It becomes merged with the main beach in the southeast quarter of section 32, Empire. Between these beach ridges is a depression, approximately 1,075 feet, partly occupied by a grassy slough, which is all used as mowing land, having no area of water or bog.

The Herman beach in the southwest quarter of section 28, Empire, at a height of 1,094 to 1,096 feet, is not so distinct as usual, being intersected by Swan Creek and having no well-marked depression along its west side. Farther north in this section it is a ridge of the ordinary type, with its crest at 1,096 to 1,098 feet. In section 21 it is narrowed to 8 or 10 rods in width, but continues as a very distinct ridge with a slight ascent northward, from 1,097 to 1,101 feet. Its east slope falls 15 to 20 feet in about 20 rods, and there is a depression of 3 to 6 feet on the west. Thence a surface of undulating till, seeming nearly flat in a general view, rises gradually westward to about 1,150 feet at a distance of 2 or 3 miles.

This beach ridge passes onward through section 16 and the south part of section 9, Empire, with an elevation of 1,095 to 1,100 feet; but, having been followed thus continuously in a north-northeast course for more than 15 miles, it ceases in the east part of this section 9. Its north end abuts at 1,100 to 1,105 feet upon a terrace slope of till, which rises about 10 feet higher. This forms the east boundary of a slightly undulating expanse of till, which thence gradually rises to 1,150 and 1,200 feet in 2 to 5 miles west and northwest. From section 9 northward through the east part of section 4, and in the west edge of section 34 and the west part of sections 27, 22, and 15, Erie, passing close east of Erie railway station, the Herman shore of Lake Agassiz is marked by such a terrace or escarpment formed by wave erosion, and the usual deposit of beach gravel and sand is absent. The base of the escarpment is at 1,095 feet, approximately, and it rises with a moderate slope 25 to 40 feet.

About a half mile east of this escarpment, however, lies a broad, low ridge of beach sand and fine gravel, having an elevation of 1,085 to 1,090 feet. Its course is from the west part of section 10 north-northeast through

sections 3 and 34, and nearly due north through the east edge of sections 27, 22, and 15. The descent eastward is more gentle than usual, falling only 6 to 10 feet in a quarter of a mile, beyond which is a flat area of till. On the west a depression 3 to 5 feet deep, partly occupied by a grassy slough, intervenes between this beach ridge and the wave-cut escarpment. On the north line of section 15 the crest of the ridge is at 1,092 feet; the depression west, 1,088; the base of the escarpment, 1,092, and its top, about 1,115 feet.

Great Northern Railway from Ripon to Portland, track at tank and section house close south of Rush River, 1,094 feet; at Erie, 2 miles farther north, 1,126 feet; summit about 1 mile north of Erie, 1,131 feet; South Branch of the North Fork of Elm River, bridge, 1,081 feet; bed of creek, 1,062 feet; track at summit 1 mile north, 1,089 feet; at Galesburg, 1,079 feet; North Branch of the North Fork of Elm River, bridge, 1,076 feet; bed of creek, 1,063 feet; track at Clifford, 1,055 feet. At Erie and westward the surface is prominently rolling till, which rises within 3 miles to a height of 100 feet above the shore of Lake Agassiz.

In sections 10 and 3, Erie, the Herman beach is again well exhibited in its usual character. On the north line of section 10 it is a gently rounded ridge of sand and gravel, with pebbles up to 2 inches and rarely 3 or 4 inches in diameter, half being limestone; its width is about 20 rods; the elevation of its crest is 1,106 feet, and the slopes fall 10 feet on the east and 3 feet on the west. For the next mile northward, through the west part of section 3, this beach ridge has a width of 10 to 15 rods; its elevation is mostly 1,105 to 1,108 feet, with a depression 5 to 7 feet deep along its west side; but in a few places the ridge itself is depressed to 1,099 feet. Passing northward, this beach in the west half of section 34, Dows, is a very smooth, gracefully rounded, wave-like swell, 30 to 40 rods wide, 1,108 to 1,112 feet in elevation, rising 15 feet above its east base and having a depression of 3 to 5 feet on the west. A well in the northeast quarter of the southwest quarter of section 34, on the top of this beach, went through 12 feet of sand and gravel, going into till below. In the southwest quarter of section 27 the beach continues with the same massive development and nearly north course, its elevation being 1,111 to 1,115

feet. In the northwest quarter of this section it becomes a still broader deposit of gravel and sand, a fourth to a third of a mile wide, with no depression on its west side. Here its course is turned northwestward, entering the southeast quarter of section 21 with an elevation of 1,109 feet; but it seems not to be distinctly traceable farther. About a half mile west of this beach a plateau of till, 1,125 to 1,128 feet above the sea, extends a third of a mile from southeast to northwest in the southeast quarter of section 28; but for a mile south and west of this plateau, and for 3 miles northwest, the surface of slightly undulating till averages only 1,105 to 1,120 feet.

The secondary Herman beach, already described in its course east of the Erie escarpment of till, continues northward with an elevation of 1,095 feet, approximately, through the east half of sections 10 and 3, Erie, and sections 34 and 27, Dows. In sections 22 and 16 this beach turns in a gradual curve to the northwest and west, and its crest varies in height from 1,095 to 1,104 feet, being highest in or near the southeast corner of section 16. There it is a ridge of gravel and sand about 30 rods wide, rising 10 to 15 feet above its northeastern base and descending 6 to 10 feet on the southwest to a nearly flat tract of moist mowing land fully a mile wide, with a height of 1,090 to 1,095 feet. Through sections 17, 8, and 5 it again curves to the northwest, north, and north-northeast, having an elevation of about 1,095 feet. In the north half of sections 5 and 4, Dows, a smooth plain with sand subsoil extends a mile eastward from the east base of this beach ridge, descending in this distance from 1,090 to 1,075 feet.

Continuation of this beach northward nearly through the middle of section 32, Galesburg, 1,096 to 1,099 feet. It is a typical beach ridge of fine gravel and sand, 8 to 10 feet above the land on its east side and having a descent of about 5 feet westward, beyond which the surface of undulating till rises in 1 or $1\frac{1}{2}$ miles to 1,125 feet and in the next 2 miles to 1,175 or 1,200 feet. A half mile east from this beach, and only 20 to 30 rods west of the railroad, there is a parallel beach ridge of similar size and material, at 1,090 to 1,092 feet. The former of these beaches, where it crosses the south line of section 20, a fourth to a half mile west of Galesburg, is spread in a broad, nearly flat deposit which rises westward from 1,096 to 1,101 feet. On the west it is bordered by a depression about 8 feet lower.

FROM GALESBURG NORTH TO LARIMORE.

(PLATES XXVIII AND XXIX.)

In section 20, Galesburg, the beach is about a third of a mile wide, its higher western margin being at 1,097 to 1,102 feet. From its crest a slope descends first somewhat steeply and then slowly to the amount of 20 or 25 feet in two-thirds of a mile eastward, having a subsoil of sand and very fine gravel to a depth of 5 to 10 feet, underlain by till, as is shown by wells at Galesburg. Crest of this beach through the west half of section 17, 1,102 to 1,107 feet; in section 6, Galesburg, and in sections 32 and 29, Norman, 1,115 to 1,125 feet, being 10 to 15 feet higher than on the south and north; in sections 20 and 17, about 1,110 feet; in the southwest part of section 8, 1,117 feet; westward through section 7 of this township, and through the northeast part of section 12, township 145, range 54, 1,112 to 1,117 feet. On the line between Traill and Steele counties, where the top of the ridge is at 1,114 feet, it is a typical beach deposit about 25 rods wide, composed of sand and gravel, with pebbles up to 2 or 3 inches in diameter. Its course is due west, and the descent from crest to base on the south is 6 or 8 feet, and northward 12 or 15 feet, beyond which a very gentle slope sinks toward the northeast. A well on this beach, in the east edge of the northwest quarter of section 12, township 145, range 54, went through sand and fine gravel 13 feet, finding till below. Within a few hundred feet farther west the beach is interrupted for a distance of about 1 mile by an area of till some 15 feet lower, with no beach deposits. It reappears, however, as a typical beach ridge of gravel and sand for a distance of three-fourths of a mile in the northwest quarter of section 11 and the northeast quarter of section 10, having an elevation of 1,114 to 1,112 feet, with a slough on its south side 6 to 8 feet lower.

Returning to the vicinity of Galesburg, a slightly higher beach, approximately parallel with the foregoing, remains to be traced. It becomes recognizable in the west edge of section 20, Galesburg, where the border of the area of rolling till that extends thence westward bears occasional deposits of gravel at 1,115 to 1,120 feet. In the east part of section 18 it is a well-developed beach ridge of sand and fine gravel 30 to 50 rods wide,

with a depression on the west 4 to 6 feet below its top, which has an elevation of 1,120 to 1,123 feet. Northward in section 7, this beach, continuing at 1,120 to 1,123 feet, is quite broad, without a distinctly ridged form, and is indented from the east by a large slough, whose elevation is approximately 1,100 feet, including several acres of water free from grass and rushes. Crest of beach in the southwest quarter of section 6, Galesburg, 1,122 to 1,126 feet; through sections 31 and 30, Norman, 1,125 to 1,129 feet; and in the west half of section 19, 1,127 to 1,124 feet, sinking slightly from south to north. The farther course of this shore is not marked by continuous beach deposits; but, following the contour line of 1,125 feet, it must turn west in the southwest quarter of section 18, Norman, and extend through sections 13 to 6, township 145, range 54, to the South Branch of Goose River.

Natural surface at the southwest corner of section 3, township 145, range 54, a dozen rods west of the South Branch of Goose River, 1,104 feet. This stream, about 1,070 feet, is 8 to 20 feet wide and mostly 1 to 2 feet deep. Its bottom land, 5 to 10 feet above this stage of low water, varies from 20 to 100 rods in width and is inclosed by bluffs rising 30 to 50 feet, increasing in height southwestward. The valley has no timber, the largest wood growth being willows 5 to 8 feet high and 2½ inches or less in diameter. With the aid of these, however, beavers had constructed dams, and were living on this stream when this survey was made in 1885, one of their dams then occupied being found by my assistant, Mr. Robert H. Young, in the west edge of section 10, township 145, range 54.

Floor of Henry Bentley's barn, in the southwest corner of the southeast quarter of section 6, township 145, range 54, on the Herman shore of Lake Agassiz, 1,123 feet. This is a moderate slope, ascending 12 or 15 feet, eroded in till, which from its top stretches westward about 2 miles in a nearly level expanse. From the south side of section 6, such a low escarpment, with its top at 1,120 to 1,123 feet, extends due north, or a few degrees west of north, about 5 miles.

E. W. Palmer's house, in the northwest corner of the southwest quarter of section 2, township 145, range 55, 1,145 feet. Well here, 27 feet deep: soil and very hard gravel and sand, 2 feet; sand with occasional layers of

fine gravel, 22 feet; and darker clayey quicksand, 3 feet, with water. This is on the west part, nearly at the crest, of an unusually high beach of this glacial lake, similar in elevation with the Milnor beach farther south. Including its slopes, it has a width of 60 rods, the nearly flat crest being 40 rods across and in elevation 1,142 to 1,147 feet. The depression on the west falls about 5 feet. In the north part of section 2 this sand and gravel deposit has an irregular contour, not lying in a continuous ridge; its highest portions vary from 1,145 to 1,152 feet. Southward from section 2 it is not continuous, but is interrupted by wide depressions where the surface is till. Beach gravel and sand appear, however, in some amount at Mr. Thomas Ward's, in the southwest corner of section 11, township 145, range 55; also in the southwest part of section 23, nearly 2 miles farther south. Within 1 to 3 miles west from these sections an area of undulating and rolling till rises to 1,200 and 1,250 feet.

Near the middle of the north half of section 23, township 146, range 55, the elevation of this beach is 1,142 to 1,144 feet. It is a ridge of gravel and sand, extending a quarter of a mile from southeast to northwest, with crest 15 feet above the surface on each side. Toward the east it descends in a long slope, but more steeply westward. In section 14 this shore-line curves westerly, the crests of its somewhat irregular beach deposits being about 1,135 feet, with a descent of 10 to 15 feet in 25 rods east. Through section 11 they range from 1,135 to 1,147 feet, being highest in the southeast quarter of the section, where the descent eastward is 20 feet or more. These beach deposits are sand and gravel, with pebbles up to $1\frac{1}{2}$ or 2 inches in diameter, massed in flattened hillocks or swells, mostly ridged lengthwise with the shore and occasionally inclosing hollows without outlet. The formation has a width of a quarter of a mile or more in its northward course through the west part of the east half of section 11. An undulating surface of till rises slowly to the west, while on the east a very smooth expanse of till sinks slowly toward the Red River.

Herman beach ridge, 30 rods wide, in or near the east edge of the southeast quarter of section 2, township 146, range 55, 1,125 feet. Irregular accumulations of the higher beach a quarter of a mile farther west rise approximately to 1,140 feet. These upper deposits and those described in

the last two paragraphs indicate that this area, which was covered by a southwardly projecting lobe of the ice-sheet at the time of the accumulation of the eighth or Fergus Falls moraine, experienced an earlier uplift than adjacent tracts of the lake border, giving to this part of the earliest and highest Herman beach an altitude 15 or 20 feet above the normal and regular plane of the corresponding beach deposits on both the south and the north.

Crest of the Herman beach, a definite ridge 25 to 30 or 40 rods wide, through the east half of section 2, township 146, range 55, 1,122 to 1,135 feet, 10 to 15 feet above the land east, and with a depression of 6 to 8 feet on the west. In the south part of section 35, township 147, range 55, the beach ridge is merged in a flat eastwardly sloping area of sand and fine gravel at 1,135 to 1,120 feet, underlain by till at the depth of a few feet. The beach ridge reappears in the north part of this section 35 at 1,125 to 1,130 feet.

Through sections 26 and 23, township 147, range 55, the Herman shore is marked by swells and flattened ridges of sand and fine gravel at 1,130 to 1,143 feet, occupying a width of an eighth to a third of a mile, with a depression of several feet along their west side. Four sloughs, at the elevation of about 1,120 feet, lie within the east part of these beach deposits, or on their east border, in the southeast quarter of section 23. In the south part of section 14 this massive but irregular beach has an elevation of 1,132 feet on the east side of a large slough.

In the middle of section 14, township 147, range 55, the beach assumes a definitely ridged form and extends thus northward along the east side of Golden Lake, which owes its existence to this barrier. Crest of the beach, through the center and north part of section 14, 1,132 to 1,137 feet; in section 11, east of Golden Lake, 1,132 to 1,141 feet; and at Golden Lake post-office, in the east edge of the southwest quarter of section 2, 1,138 feet. An eighth of a mile north from the south end of this lake the action of its waves has eroded the greater part of the beach ridge. The material of the beach exposed by an excavation near the post-office is coarse gravel, with very abundant pebbles up to 3 inches and occasionally 4 to 6 inches in diameter.

Golden Lake water, July 28, 1885, 1,122 feet above the sea; highest level reached by this lake in recent years, 1,128 feet. It is a beautiful sheet of water, $1\frac{1}{4}$ miles long and a quarter to a third of a mile wide. Its west shore is moderately undulating till, with the highest swells 20 to 30 feet above the lake. In a few places its grassed bluffs rise steeply from the water's edge 10 to 20 feet. Farther west the rolling surface of till, seen for a distance of 3 or 4 miles, rises to 1,225 or 1,250 feet. This lake has no trees on its margin, excepting two small cottonwoods, each about 25 feet high, on its northwest shore; bushes grow in several places, mostly on the east; but the greater part of the lake border, like all the surrounding country, is prairie.

Beach ridge through the north part of section 2, township 147, range 55, 1,138 to 1,132 feet. In the south half of section 35, township 148, range 55, it has been mostly eroded by a lake which borders this beach on the east from the north part of section 2 to the north part of section 35, having a length of 1 mile and a width of an eighth to a fourth of a mile. The elevation of this lake is 1,104 feet. It has no trees or bushes, excepting a few willows 4 to 6 feet high, near the middle of its west side, and is wholly surrounded by hard, grassy shores. Crest of the beach west of the north part of this lake, 1,140 to 1,142 feet, and through the south half of section 26, 1,137 to 1,142 feet, similarly bordered on the east by two lakelets, which have approximately the same height as the preceding, 1,104 feet. The land east of these three lakes is flat, 1,113 to 1,117 feet near them, with a very gentle slope descending thence eastward.

More diffuse and irregular beach deposits in north-to-south swells and short, massive ridges of gravel and sand, inclosing occasional hollows with no outlets, some of which hold small ponds and sloughs, extend from the north edge of section 26 northward through the west half of section 23, township 148, range 55, with an elevation of about 1,135 feet. The depression on the west is some 5 feet lower, and on the east there is a descent of 10 feet from the crest to the base of the beach. Fingals Creek, in the northwest corner of section 23, where it intersects the beach, has a height of about 1,110 feet. Undulating and rolling till within 3 or 4 miles westward rises to 1,250 feet.

Herman beach, through the west part of section 14, township 148, range 55, 1,142 to 1,147 feet, being mainly a somewhat typical ridge, with short swells of beach gravel and sand on its east side 10 to 15 feet lower, inclosing hollows, but few or no sloughs. Two lakes at 1,110 feet, approximately, lie close east of this beach, near the center and in the northwest quarter of this section. They are bordered on the east by land 10 feet higher, from which a very gentle descent sinks toward the Red River.

Continuation of this beach ridge northward through the east edge of section 10, township 148, range 55, 1,142 to 1,146 feet, 3 to 5 feet above the depression on its west side. On the east, three lakelets at 1,120 feet, approximately, lie in the west edge of the northwest quarter of section 11, each being about 20 rods long from south to north and 15 rods wide. Crest of beach ridge, 30 to 40 rods wide, extending nearly due north through the east edge of section 3, 1,144 to 1,150 feet; east base, about 1,125 feet; depression on the west, 5 to 10 feet, nearly level upon a width of 40 rods; beyond is an ascent of undulating and rolling till to 1,250 feet within 2 or 3 miles. In the southwest quarter of section 36, township 149, range 55, Lind, this Herman shore is marked by irregular swells and massive short ridges of gravel and sand, with occasional inclosed sloughs. This is succeeded by a half mile of the ordinary continuous single ridge, 1,147 to 1,150 feet.

Magnificent beach ridge, passing north-northwest through the east part of sections 26 and 23, Lind, 1,147 to 1,150 feet. A road, which was formerly an Indian trail, runs on its top here and for several miles northward. This beach is composed of the usual sand and gravel, thickly filled with pebbles up to 2 and rarely 4 inches in diameter. It forms a broad, wave-like ridge 30 to 40 rods wide, including the slopes. On its west side is a depression of 5 to 10 feet, 20 to 60 rods wide, which is moist grass land, excepting a small reedy slough in the south edge of section 11. On the east side of this upper Herman beach there is a very smooth slope descending 25 or 30 feet in as many rods. Next is a nearly level belt 20 to 60 rods wide, increasing in width from south to north, succeeded by a lower Herman beach ridge rising 8 to 10 feet, with its crest at 1,127 to 1,130 feet, or 20 feet below the upper beach. These parallel Herman beaches are very finely developed thus for

nearly 6 miles, passing north through sections 23, 14, 11, and 2, Lind, and the southwest part of section 35, township 150, range 55. High portion of the upper beach in the south edge of section 14, 1,153 feet, and depression west, 1,142 feet; crest onward through this section, 1,153 to 1,149 feet. In the north part of section 11 and the south edge of section 2 it is a few feet lower, is irregular in height and outlines because of intersecting water-courses, and has a less continuous and shallower depression on its west side. In section 2, however, both beach ridges are finely displayed, having the same contour as southward. Crest of upper beach in sections 2 and 35, 1,152 to 1,155 feet; depression on the west, 8 to 15 feet, partly occupied by a long slough. The northwest part of section 35, in the course of these beaches, is lower smooth till, with no deposits of sand and gravel.

Goose River, near the north line of the northwest quarter of section 35, and the Little Goose River, in the north part of section 15, township 150, range 55, where they cross the ancient lake shore, are in valleys about 30 feet deep, eroded in till. Each consists of pools 5 to 7 feet deep and 10 to 20 feet wide, alternating with other portions so narrow that one may step across them.

In the east part of the west half of section 26 and the southwest corner of section 23, township 150, range 55, the upper Herman shore is offset a third of a mile east from the remainder of its course and consists of massive, irregular swells of till, partly overspread with gravel and sand, 1,152 to 1,160 feet. Among them are hollows 4 to 6 feet deep, without outlet, and their entire belt, a quarter of a mile wide, is crossed by depressions as low as 1,145 feet. Through section 22 this shore bears a typical beach ridge of sand and gravel, 40 to 50 rods wide, 1,157 feet, with depression of 10 to 15 feet on the west; descent of the eastern slope, 20 to 25 feet in 30 or 40 rods. In section 15 this upper beach, 1,152 to 1,157 feet, has a quite irregular form, chiefly due to erosion by the Little Goose River and its small tributaries. It is again exhibited in its ordinary type through section 10, being a ridge 25 or 30 rods wide, with crest at 1,155 to 1,157 feet, 15 to 20 feet above its east base and with a narrow depression of 4 to 8 feet on the west; through the west part of section 3, township 150, range 55, and the west edge of the southwest quarter of section 34, township 151, range 55, 1,157 to

1,159 feet, excepting gaps cut by small watercourses; and in the east edge of the northeast quarter of section 33, 1,154 to 1,157 feet. Thirty rods west from the northeast corner of this section 33 its elevation is 1,155 feet, with slopes descending 12 feet eastward and 8 feet westward.

Lower Herman beach, a half mile to three-fourths of a mile east of the foregoing, in the west edge of sections 14 and 11 and the east edge of section 3, township 150, range 55, 1,130 to 1,135 feet, from which there is a descent of 5 feet to its west base and 10 feet to the east. From the southeast quarter of section 34, township 151, range 55, this beach passes northeasterly to Larimore.

Upper Herman beach, a well-defined ridge, running north through the east part of section 28, township 151, range 55, 1,155 to 1,159 feet; thence north-northwesterly through sections 21 and 16, 1,157 to 1,160 feet, and through the southwest part of section 9, the northeast part of section 8, and the southeast quarter of section 5, 1,157 to 1,162 feet. Where it is crossed by the Devils Lake line of the Great Northern Railway, in the south part of the northeast quarter of section 5, about $4\frac{1}{2}$ miles west of Larimore, its crest was at 1,162 feet, 4 feet above the track, and it holds the same height for about 50 rods northeastward. Two-fifths of a mile east from this beach the railroad crosses a second beach deposit whose crest and the track are the same, 1,146 feet.

DELTA OF THE ELK VALLEY.

(PLATE XXIX.)

Nearly level land reaches 4 miles westward from Larimore along the Devils Lake railway line, averaging 1,130 feet above the sea, and varying only 2 or 3 feet above and below this level. Beneath the rich black soil here and elsewhere, all about Larimore, are stratified sand and fine silt free from gravel. The beach ridges near this town are consequently composed wholly of sand, quite in contrast with their usually coarser material.

The underlying beds consist largely of sand from the Fort Pierre shale, and were derived probably in part from erosion by the head streams of the Turtle and Goose rivers in this Cretaceous formation, which here constitutes the highland west of Lake Agassiz, thinly covered by till.

Considerable channeling of the valleys in which these streams flow appears thus to have been accomplished before the land was uplifted and the lake receded to its Norcross and lower shores. This delta accumulation, consisting partly of alluvium from stream erosion after the departure of the ice, but evidently in far larger measure of modified drift supplied by streams from the melting ice in which it had been held, occupies a width of 6 to 12 miles, and stretches about 35 miles southward from McCanna, by Larimore, Northwood, and Hatton, to the vicinity of Portland. Its thickness at Larimore, as shown in fig. 14, is 60 feet, and doubtless its average thickness is as much as 30 or 40 feet upon its area of about 300 square miles. It was deposited in the edge of Lake Agassiz during the first and second Herman stages, for these shores marked by beach ridges, are above the

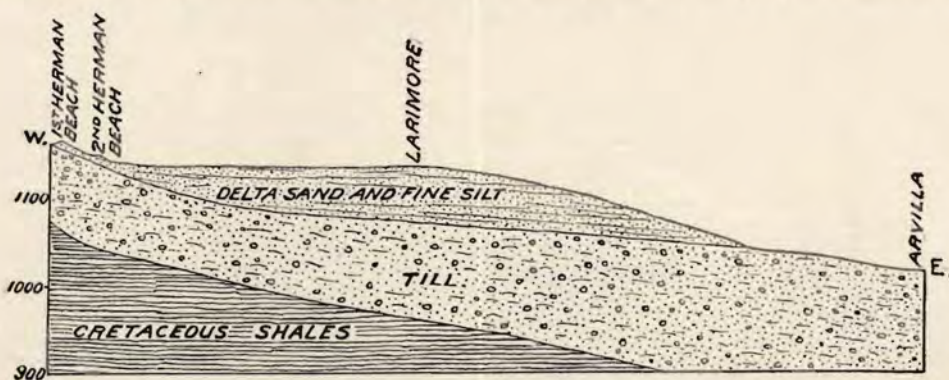
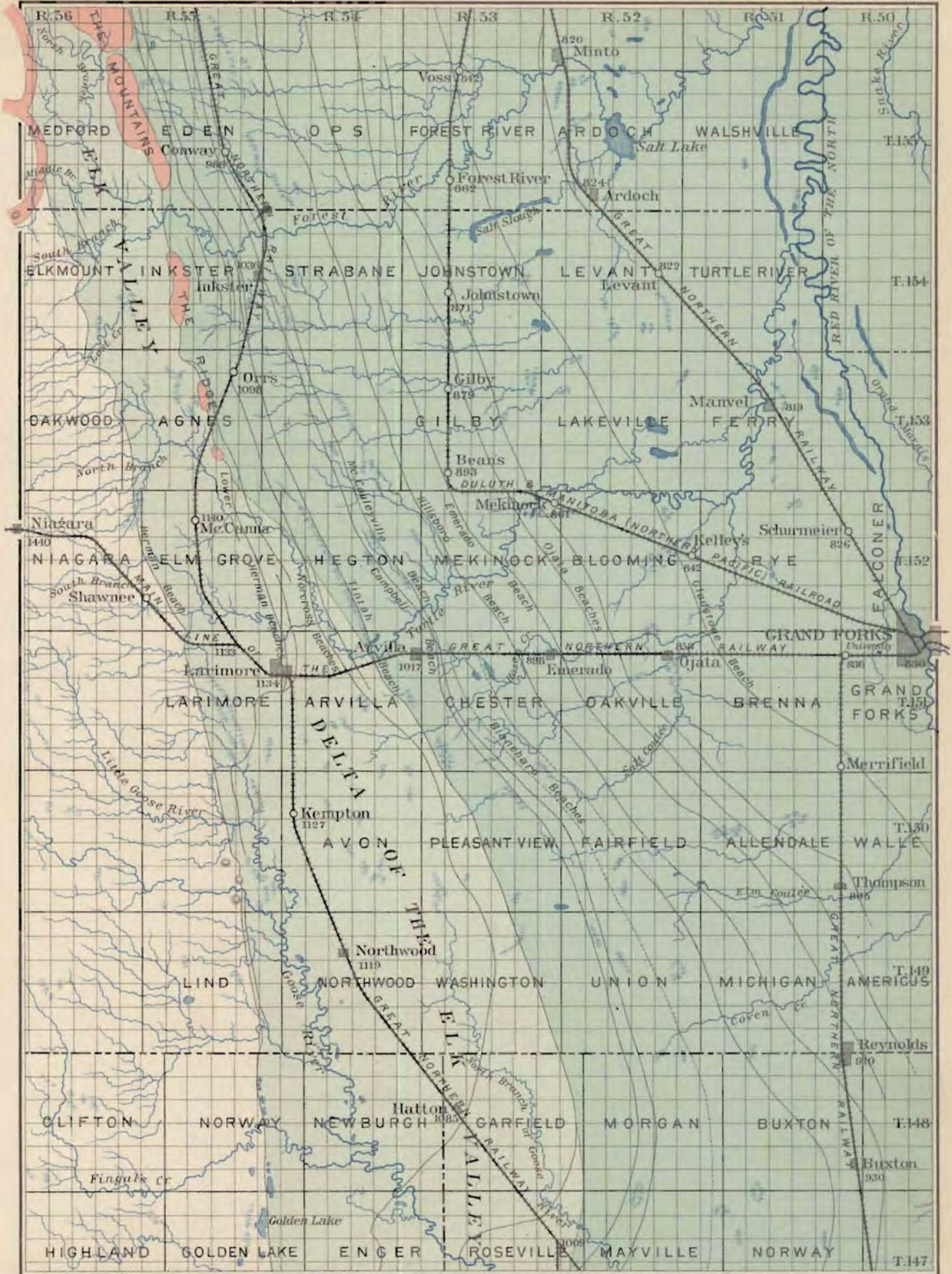


FIG. 14.—Section across the delta of the Elk Valley. Horizontal scale, 3 miles to an inch.

delta; but the third and fourth Herman beaches extend across it, passing close east of Larimore. The Norcross and Tintah shore-lines lie near its eastern boundary, for the greater part upon its edge, but it has not been conspicuously eroded. Farther east the surface is mainly till for the next 15 miles or more, descending toward the Red River, which is bordered on this latitude in North Dakota by a belt of alluvial clay and silt only a few miles wide.

A section of the beds forming this delta is furnished by the well at the Sherman House, Larimore, which was dug 20 feet and bored 40 feet, as follows: Soil, 2 feet; fine sandy and clayey silt, without coarse sand, gravel, or stones, 5 feet; fine yellowish sand, with less clay, being mainly siliceous, 13 feet; and dark sand, very soft to bore through, two-thirds



MAP OF THE WESTERN SHORES OF LAKE AGASSIZ, INCLUDING THE ELK VALLEY DELTA, IN GRAND FORKS COUNTY AND PARTS OF ADJOINING COUNTIES, NORTH DAKOTA.

Scale, 6 miles to an inch.

Lake Area Delta Moraines

Altitudes of railway stations are noted in feet above the sea.

Cretaceous shale in particles up to a twentieth of an inch in diameter, 40 feet, with much water. Hard blue till was found at the bottom. The other wells of this town are said to obtain their supply of water at a depth of about 20 feet, in the upper part of this sand derived chiefly from shale. In Northwood and Hatton, also, water is found at depths of only 10 to 20 feet before reaching the base of the delta sand.

The volume of this extensive sand and silt delta is about $1\frac{1}{2}$ or 2 cubic miles. It occupies more than thrice the area of the delta of the Pembina River, but is much shallower, so that they are nearly equal in their cubic contents, or this is the smaller; and it has nine times or perhaps twelve times the volume of either of the two deltas of this lake in Minnesota, lying on the Buffalo and Sand Hill rivers. Yet here no stream of significant size enters the lake area. There are, indeed, not less than a dozen small streams, the headwaters of the Turtle and Goose rivers, which descend to the delta from the till-covered Cretaceous highland on the west; but none of them has a large valley or extensive basin of drainage, and it would be difficult to decide which one of three or four is most worthy of consideration. The delta, however, in its position, the outlines of its extent, and the directions and rate of its slopes, seems independent of them all.

Northward from Larimore and McCanna, where the surface of this delta is highest, a very noteworthy topographic feature of the western border of the lacustrine area has received the name of Elk Valley in its southern portion, and in its northern continuation is called the Golden Valley. These are parts of one continuous belt which was at first the course of a glacial river, and afterward became a sound or strait extending about 40 miles along the coast of Lake Agassiz at its highest stage. It was divided from the main lake by a series of several small islands of knolly and hilly till, occasionally connected together by a low beach embankment or bar, formed by the lake waves. The Elk Valley is commonly regarded as beginning at Larimore, but it may more strictly be said to begin 9 miles farther north, at the most southern of its inclosing islands. It extends north from Larimore 29 miles to Ramseys Groves, on the North Branch of the Forest River, with a width of about 4 miles for the greater

part of its extent, diminishing at the north to 2 miles. The narrower prolongation of this tract, known as the Golden Valley, varies from 2 miles to only 1 mile in width along its course of 18 miles to the North Branch of Park River, 1 to 2 miles west of Gardar. Originally the whole length of this belt was called the Elk Valley, which seems to be a translation of its aboriginal name; but the name Golden Valley, proposed for its northern portion by the Ramsey brothers, living at Ramseys Groves, in Vernon Township, has come into universal use for the narrow part of the valley extending thence northward.

The Golden and Elk valleys have no river now running along their continuous depression. Instead it is crossed by numerous streams which form the Turtle, Park, and Forest rivers, descending from the highland west of Lake Agassiz and finding their way between or through the morainic islands east of the valley. But during the stage in the departure of the ice-sheet when these islands were being accumulated on the western margin of its Minnesota lobe, contemporaneous with the formation of the Leaf Hills and with the completion of the prominent compound moraine south of Devils Lake, a great river flowing from the melting ice-fields and laden with their drift ran with a strong current in this long, nearly straight valley, bringing to its debouchure into Lake Agassiz at McCanna the sand and silt of this delta. A portion of its freight was even borne 35 miles onward in the shallow water of the lake, forming the southern part of the delta, which was probably held to the western side of the lake area by the barrier of this ice-lobe. That the sand and silt were thus supplied chiefly from the englacial drift, and only in small part from erosion by the streams that now exist, is proved by the position of the axial thickest and highest portion of the delta, separated from the western shore of Lake Agassiz by a broad, shallow depression in which the numerous sources of the Goose River are diverted from their eastward course and carried to the south in a united stream. Whatever alluvium these tributaries have added to the delta, both while the lake was here and since it was withdrawn, has been insufficient to raise their channels the small amount that would give them passage across the delta in their normal course toward the east.

SHORE WEST OF THE ELK AND GOLDEN VALLEYS.

(PLATES XXIX AND XXX.)

Through section 32, Elm Grove, the upper beach runs northwesterly, its elevation being 1,160 to 1,163 feet above the sea. Its material is coarse gravel, with pebbles up to 6 inches in diameter, in part accumulated as a ridge 10 or 15 feet above the land at its base northeast and 5 to 8 feet above its southwest base, and in part lying on the flank of swells of very stony till, the crests of which are only 5 to 10 feet higher than the beach. This till or morainic drift contains a multitude of granitic and limestone boulders up to 1½ feet in diameter, but few or none of larger size. In the rolling till which rises thence westward to 1,250 or 1,300 feet within 2 or 3 miles are many granitic boulders up to 5 feet or more in diameter, exceeding the usual proportion in the till of this region.

In the north edge of section 32 and the south part of section 29, Elm Grove, this beach is the terrace-like border of a nearly level tract of sand and gravel an eighth of a mile or more in width, at an elevation of 1,171 to 1,173 feet. The bordering slope is beach gravel, with its base at 1,155 to 1,158 feet; but the slow descent thence eastward is till, somewhat eroded by wave action and having many small and large granitic boulders up to 4 or 6 feet in diameter strewn on the surface or partially covered by the soil. In the northeast quarter of section 30 this upper Herman beach is typically developed, being a gracefully rounded ridge of sand and gravel, 25 or 30 rods wide; crest, 1,165 to 1,166 feet; foot of eastern slope, 1,150 feet; depression west, usually 2 to 5 feet, beyond which is a slowly ascending area of smooth, undulating till.

Upper beach through section 19, Elm Grove, a low, rounded ridge of sand and gravel about 25 rods wide; crest, 1,166 to 1,168 feet; base of its east slope on the north line of this section, 1,158 feet. In the southwest quarter of section 18 this beach is cut by the South Branch of the Turtle River; its elevation in this section south of the stream is 1,167 to 1,168 feet. There is no considerable valley here, and the creek runs only in spring or after unusual rains, being reduced to stagnant pools during the rest of the year. Within 2 miles southeast, however, it becomes a living

stream, fed by very cold springs, and thence to the secondary Herman beach near Larimore it has cut a valley 50 to 90 feet deep.

Elm Grove, comprising about 5 acres, is on this creek, a third of a mile east of the upper Herman shore-line, which continues north-northwestward through the southwest part of section 18, Elm Grove Township, and the northeast edge of section 13, Niagara, to the west side of Little Elm Grove, 10 acres or more in extent, in the east part of section 12. Along this distance of $1\frac{1}{2}$ miles the surface presents a very favorable slope, from 1,150 to 1,200 feet elevation, on which a beach ridge or definite beach deposits would usually be found well developed; but the waves and currents of Lake Agassiz could not act efficiently here, because this area lay in the lee of islands and of a wave-formed bar or beach several miles to the east, which are the eastern boundary of the Elk Valley. Consequently deposits of beach sand and gravel are scanty on the upper western shore of Lake Agassiz here and for 40 miles northward along the extent of the Elk and Golden valleys, east of which a narrow chain of islands and bars rose above the surface of Lake Agassiz during its highest Herman stage. Between the South Branch of Turtle River and Little Elm Grove the beach formation consists only of a thin covering of sand and gravel spread on the sloping area of till, at an elevation from 1,160 to 1,175 feet. Several of the small grassy channels eroded here, dry excepting in spring and times of excessive rain, are almost completely paved with stones up to 1 or 2 feet in diameter, but few stones occur upon the adjoining surface of till.

From the Little Elm Grove the highest western shore of Lake Agassiz (consisting of a similar slope of till ascending gently westward, with inconspicuous deposits of beach gravel and sand, not accumulated in any distinct ridge, but probably recognizable almost continuously) extends northward through sections 12 and 1, Niagara, and sections 31 and 30, Agnes, to the central part of Bachelors Grove, which it passes through in the west half of section 30. This grove borders the head stream of Turtle River for $1\frac{1}{2}$ miles, with an average width of about a quarter of a mile, thus comprising approximately 250 acres. It is dense woods, chiefly elm and basswood in its east half, but nearly all bur oak for the west half. Much bur oak is also found along several miles of this stream next westward, but it is not

seen from the margin of Lake Agassiz, being hidden in the valley, 40 to 50 feet deep, which the stream has eroded in that area of undulating and rolling till.

Herman beach, for the first mile or more north from Bachelors Grove, passing through the northwest quarter of section 30 and the west edge of section 19, Agnes, 1,165 to 1,170 feet. This is mostly a well-defined beach ridge, 20 to 30 rods wide, composed of sand and gravel, with pebbles up to 2 inches in diameter. It rises slowly to a height of 10 or 12 feet above the flat land on the east and is bordered on the west by a depression of 1 to 3 feet, beyond which a smoothly undulating and rolling surface of till rises to an elevation of 1,200 and 1,250 feet at a distance of 3 miles. In the northwest quarter of this section 19 the beach deposit becomes complex, consisting of several irregular ridges rising 5 to 8 feet above their bases, 1,167 to 1,170 feet above sea-level, with inclosed hollows, and the depression close west occasionally sinks to 1,155 feet.

Through sections 13 and 12, the southwest part of section 1, and in section 2, Oakwood, to the grove on the north line of section 2 at the junction of the north and south branches of Lost Creek, and thence northeast and north through section 35, Elkmount, the Herman shore, between 1,160 and 1,170 feet, is not marked by any considerable deposits of gravel and sand. Farther north this shore is distinguished not only by a noticeable change in the topographic features along a nearly level line at 1,170 feet, dividing the very flat area of the glacial lake from the undulating and rolling till on the west, but also by occasional beach deposits. Through the south half of section 26, Elkmount, a somewhat typical beach ridge of sand and gravel, 15 to 25 rods wide, with a depression of 3 to 6 feet on its west side, runs north and northwest, its crest being at 1,175 to 1,170 feet, declining from south to north. On the east its slope falls 5 to 10 feet in 10 to 20 rods; and thence a more gentle descent, with surface of sand and fine gravel, sinks to 1,155 feet within an eighth of a mile. In the northwest quarter of this section 26 the beach ridge ceases and is succeeded northward by an expanse of nearly flat till, which along the north line of this section sinks eastward from 1,175 to 1,155 feet.

Elk Valley, for 12 miles from Elm Grove and McCanna north to the Forest River, is nearly constant in elevation, which is 1,155 feet on its west border and 1,135 feet near its east side, its average width being about 4 miles.

Upper Herman beach, a definite and massive ridge of sand and fine gravel, 25 to 40 rods wide, for a half mile south from the South Branch of Forest River, in the west part of the northwest quarter of section 14, Elkmount, 1,173 to 1,178 feet, passing north and northwest, with a descent of 12 to 15 feet on the east and a depression of 4 to 8 feet on the west.

Beyond this branch of the Forest River, in the north half of section 10, Elkmount, the beach ridge, similar in outline, with its crest at 1,174 to 1,179 feet, is the site of an abandoned railway grade, on account of which its material is well exhibited. It is sand and gravel, and three-fourths of the pebbles, mostly less than 2 inches in diameter, are dark-gray slaty shale. Twenty miles to the south-southeast the same shale in small grains makes fully two-thirds of a stratum of sand that extends from 20 to 60 feet in depth in the well at the Sherman House, Larimore. Pebbles of it were also observed in kame-like deposits of gravel and sand near Balaton, Lyon County, in southwestern Minnesota. During the further exploration of the western shore of Lake Agassiz this shale was discovered in place, and is found to be the bed-rock, of Cretaceous age, which forms the conspicuous escarpment of the Pembina Mountain, though even there it is generally covered and concealed by drift.

Natural surface at the northwest corner of section 3, Elkmount, on the line between Grand Forks and Walsh counties, 1,181 feet. The upper Herman shore passes north-northwesterly through this corner of section 3 and the east part of section 33, Medford, to the Middle Branch of Forest River (farther east formerly called Salt River), which it reaches near the center of the east half of section 28. It has only scanty deposits of beach gravel and sand, nowhere forming a ridge; instead, the surface is mainly till, very flat east of this shore, but undulating or rolling westward.

The South and Middle branches of Forest River occupy valleys 25 to 40 feet deep and 20 to 30 rods wide. They are bordered with groves, or at least a continuous line of trees, along the greater part of their course.

In the northwest quarter of section 28 and the west part of section 21, Medford, the highest shore-line of Lake Agassiz is very distinctly marked, at 1,183 to 1,185 feet, by being the upper edge of a flat slope of till, probably with scanty deposits of gravel and sand, which sinks 20 to 30 feet in the next half mile eastward. Farther east, for the width of 3 or 4 miles across the Elk Valley, the surface elevation is 1,160 to 1,125 feet.

Just west of this shore-line a knolly belt of morainic drift, bearing a marvelous profusion of bowlders, occupies a width of 25 to 50 rods, generally forming a single series of hillocks rising 15 to 30 or 35 feet. These are strewn with bowlders of all sizes up to 5 feet and rarely 8 feet in diameter, so plentiful that they cover a third or even half of the surface. A few masses of limestone were observed, but fully 99 per cent of the bowlders are Archean granite and gneiss. This is the most eastern portion of a semicircular moraine which appears to have been accumulated on the eastern boundary of a lobe of the ice-sheet during a pause in its retreat. From sections 21 and 28, Medford, this moraine continues, with nearly the same features, south and southwest to the southeast quarter of section 32, and thence west-southwest by Pilot Knob, in the northwest quarter of section 5, Elkmount, to the west side of section 1, township 154, range 57, and perhaps beyond. Its hills and knobs rise 25 to 75 feet above the general level of the adjoining smoothly undulating till, their tops being 1,250 to 1,300 feet above the sea. To the north, northwest, and west it reaches, with similar development, in a great curve convex to the northeast, along an extent of 5 or 6 miles, to a cluster of prominent morainic hills rising 50 to 75 feet, situated in sections 2 and 3, Cleveland. This moraine matter was doubtless englacial; among its multitude of both large and small rock fragments a half hour's search failed to discover any marked with striae or having faces planed by glaciation. On the west the area inclosed by this curving moraine is very smooth, only slightly undulating till, at 1,185 to 1,250 feet, ascending slowly westward.

Another distinct morainic series, similar in its very knolly contour, in its material (excepting a larger proportion of gravel, half of which is the Cretaceous shale before described), and in the great abundance of bowlders, nearly all granitic, branches from the preceding in the north part of

section 8, Medford, and sweeps northeast and north through the west half of section 4, and thence northwest and west through sections 32, 29, and 19, Vernon, and sections 13 to 16, Norton, to a group of morainic hills about 75 feet high, a mile northwest of Galt post-office. Between this curved moraine and the nearly parallel northern part of the preceding, 4 miles distant to the south, the surface is very smooth, undulating till, rising slowly toward the west.

These moraines, with their east base at 1,185 to 1,170 feet above the sea, formed the west shore of Lake Agassiz at its highest stage for nearly 7 miles between the Middle and North branches of the Forest River. The North Branch intersects this shore-line near the center of section 20, Vernon, close to the southwest end of Ramseys Groves, which extend thence about a mile along this watercourse in the north part of section 20 and the southeast quarter of section 17. The stream in these sections has no valley, only a channel 20 to 30 feet wide and 10 feet deep.

Golden Valley, on the north line of sections 4 and 5, Vernon, has an elevation of 1,185 to 1,195 feet, showing an ascent of 10 feet from east to west in its width of 2 miles. About the same transverse slope, raising the west side of this valley 10 or 15 feet above its east side, is found along its whole extent of 18 miles, from the North Branch of Forest River to the Middle and North branches of Park River. In the north half of Vernon, and thence northward, the width of this valley varies from $1\frac{3}{4}$ miles to only 1 mile. It is flat, and consists mainly of clay, free from gravel; but wells find gravel intermixed with the clay, probably till, at a depth of a few feet, and about 20 feet from the surface they sometimes encounter a water-bearing stratum of gravel, chiefly made up of Cretaceous shale.

Natural surface at the southwest corner of section 27, Golden, 1,191 feet. Highest part of Golden Valley south of the South Branch of Park River, along the north line of sections 27, 28, and 29, in this township, 1,199 feet on the east to 1,211 feet on the west. Surface at schoolhouse on the west side of the northwest quarter of section 21, 1,207 feet.

South Branch of Park River at the bridge near the middle of the north line of section 21, Golden, 1,170 feet, approximately; bottom land about a quarter of a mile wide, 10 to 15 feet above the stream; crest of

the south bluff rising to the flat belt of the Golden Valley, 1,191 to 1,209 feet, ascending westward; of the north bluff, 1,189 to 1,205 feet.

Golden Valley, on the north line of section 5, Golden, 1,195 to 1,205 feet; 2 miles farther north, on the north line of section 29, Lampton, 1,198 to 1,208 feet. In this northern part of the valley limited tracts of its flat area are strewn with abundant boulders up to 2 feet, and less frequently 3 or 4 feet, in diameter. They are probably where swells of till rose nearly to the surface of the water in this strait of Lake Agassiz, so that its fine portions were swept away by waves and currents, to be deposited elsewhere in the valley as clayey silt, leaving the masses of rock which could not be thus removed. Approaching the Middle Branch of Park River, the surface of the Golden Valley continues very smooth and flat, but it ceases to have a continuous ascent from east to west, some portions along the center being depressed a few feet. Such a shallow hollow holds a slough about a mile long from south to north and a half mile wide in its broadest part, at 1,193 feet, extending from the north edge of section 20 through the west part of section 17, Lampton, in which a small area of water remains throughout the year. On each side of this slough, and for miles south and north, this valley is a great hay meadow.

The west border of the Golden Valley was the most western shore of Lake Agassiz in its highest stage, but it is only very scantily marked by deposits of beach gravel and sand, because of its sheltered position on the western and leeward side of this narrow strait. From the middle of section 20, Vernon, this shore-line extends in a quite direct course a few degrees west of north 11 miles through the west part of sections 17, 8, and 5, in this township, sections 32, 29, 20, 17, 8, and 5, Golden, and the east edge of sections 31 and 30, Lampton. For the next 3 miles, in the east edge of sections 19, 18, and 7, Lampton, it runs nearly due north. Thence it turns to a northwesterly course through section 6 of this township, and through section 31, Gardar. In this vicinity the Golden Valley terminates.

Bushes and trees clothe the slope on the west side of the Golden Valley along its northern part, extending to the south line of Lampton; but this ascent farther south, also the entire extent of the Golden Valley,

the drift hills forming its east border, and the vast plain of the Red River Valley, are prairie, excepting that narrow belts of timber border the water-courses.

Smoothly undulating till rises slowly from the west side of the southern part of the Golden Valley; but in section 30, Lampton, rounded hills of till attain a height about 100 feet above the valley, or 1,300 feet above the sea. Thence northward a smooth slope ascends 50 to 60 feet, or in some portions only 30 or 40 feet, within the first quarter or half of a mile to the west, succeeded beyond by a moderately rolling surface with less ascent.

A terrace of beach sand and gravel, containing pebbles and cobbles up to 6 inches in diameter, extends a third of a mile from southeast to northwest, with a width of 5 to 30 rods, in the northwest quarter of section 33, Lampton, abutting on the west flank of the rolling and hilly deposits of till which make the east border of the Golden Valley. It was formed by currents entering this strait of Lake Agassiz from the north, eroding the bordering hills in the east edge of sections 20 and 29, and thence sweeping this sand and gravel southward. It marks the highest stage of Lake Agassiz, having an elevation of 1,213 to 1,195 feet, declining from north to south, and also sinking 1 or 2 feet from west to east in its width of 100 to 500 feet, being thus slightly higher along its verge than where it rests upon the adjoining hilly till.

Middle Branch of Park River near the middle of the south side of section 5, Lampton, about 3 miles northwest of Edinburgh station, 1,185 feet above the sea; crest of the south bank of the very small valley of this stream, rising to the flat Golden Valley, 1,192 feet on the east to 1,215 feet on the west. The Golden Valley here shows thus a transverse ascent of more than 20 feet in its width of about 1 mile. On the north line of sections 5 and 6, Lampton, the east edge of this valley has an elevation of 1,210 feet, and its west edge, 1,220 feet. About a half mile farther north the height of this belt where it is crossed by a tributary of the Middle Branch is 1,220 to 1,235 feet from east to west, being thus above the highest level of Lake Agassiz.

BEACHES AND ISLANDS EAST OF THE ELK AND GOLDEN VALLEYS.

(PLATES XXIX AND XXX.)

Returning about 45 miles south to Larimore, we have yet to describe the beaches of Lake Agassiz and its islands of rolling and hilly morainic till which divided the strait of the Elk and Golden valleys in Grand Forks and Walsh counties from the main body of the lake.

The crests of the upper or first and the second Herman beaches before described, respectively $4\frac{3}{8}$ and $4\frac{1}{8}$ miles west of Larimore, are 1,162 and 1,146 feet above the sea. The third Herman beach, a third of a mile east of Larimore depot, has its crest at 1,133 feet; and another beach belonging to the same stage of Lake Agassiz, a third of a mile farther east, rises to 1,134 feet, with descent in 30 or 40 rods east 11 feet, and in the same distance west 9 feet. The fourth Herman beach, consisting of four small beach ridges crossed by the railway $1\frac{1}{2}$ to 2 miles east of Larimore, has crests at 1,123 to 1,118 feet, with intervening hollows 3 to 5 feet deep.

The beach seen two-thirds of a mile east of Larimore passes north and north-northwesterly through the east half of sections 7 and 6, Arvilla, and the west half of sections 31 and 30, Hegton, into the southeast corner of section 24, Elm Grove. North of the South Branch of Turtle River it is not a typical ridge, but a series of massive rounded swells of sand 10 to 15 feet high, with their crests at 1,135 to 1,140 feet.

A parallel beach ridge, a third to a half mile west of the foregoing, mostly massive, with typical wave-like form, has an elevation of 1,133 feet close east of Larimore; 1,144 feet at a cemetery close north of the South Branch of Turtle River in or near the southwest corner of section 31, Hegton; chiefly 1,137 to 1,140 feet in its course thence north-northwesterly through sections 36 and 25, the west edge of section 24, and the east half of section 14, Elm Grove; 1,142 to 1,145 feet in the west half of section 11, and 1,143 to 1,147 feet in the east edge of section 3 of this township. Along the west edge of section 11, a duplication of this beach ridge, of the same massive size, lying a half mile farther west, extends a mile south from the North Branch of Turtle River, its crest being at 1,142 to 1,145 feet; but thence southward the general elevation is about 1,130 feet to the broad tract of this height crossed by the railway west of Larimore, excepting

that the South Branch of Turtle River has eroded a valley 40 to 75 feet deep. The distance of $1\frac{1}{2}$ miles from Larimore north to this stream is a gradually descending, smooth slope, but its northern bluff rises steeply to a height a few feet above that of Larimore.

Great Northern Railway at Larimore, 1,134 feet above the sea; at McCanna, 1,140 feet; on the bridge over the North Branch of Turtle River, 1,132 feet, 17 feet above the stream; at its summit, in the northeast corner of section 22, Agnes, grade and natural surface, 1,164 feet; at Orr's station, 1,098 feet.

Lower Herman beach, running northwesterly in the northeast part of section 24, Elm Grove, 1,127 to 1,128 feet, with depression of 2 to 3 feet on its west side; in section 13, 1,127 to 1,132 feet; in the west part of section 12 and the northeast part of section 11, 1,130 to 1,135 feet, being in these sections the easternmost in a succession of three beach ridges, the two others of which are 10 feet higher; at E. C. D. Shortridge's house, in the center of section 2, 1,137 feet, forming a broad, flat swell of sand and fine gravel, with a depression of 3 to 5 feet on its west side; in the west part of section 36, through sections 26 and 23, and the southwest edge of section 14, Agnes, a continuous, well-defined beach ridge, 1,140 to 1,149 feet, with a descent of 10 to 15 feet on the east and a depression of about 5 feet on the west; in the east edge of the northeast quarter of section 15 and through the southeast quarter of section 10, Agnes, a deposit of sand and fine gravel, with nearly level top 20 to 30 rods wide, 1,145 to 1,149 feet, from which a slope falls 10 or 15 feet in 20 to 30 rods eastward, while on the west it is bordered by a slough 5 to 20 rods wide, which is partly permanent water and partly mowing land. It is to be noted that the northern two-thirds of the beach here described for a distance of 8 miles corresponds in elevation with the two beaches close east of Larimore and with their continuation northward to the North Branch of Turtle River, marking the third Herman stage of Lake Agassiz; but that the southern part records a slightly lower level of the lake, when it had fallen about 10 feet, or to its fourth Herman stage.

On the west side of this beach a smoothly undulating, broad swell of till, which was an island in Lake Agassiz, lies in the west part of section 26

and the east edge of section 27, Agnes, with a nearly level top of several acres, at 1,182 to 1,190 feet. An aboriginal burial mound, raised 4 feet and having a diameter of about 50 feet, is situated on the highest part of this area. Such localities, overlooking an extensive and beautiful panorama, were frequently chosen for this use, as is shown by many mounds on hilltops and on the margin of bluffs bordering deeply eroded valleys throughout the Northwest.

North of this island the upper Herman beach is represented in the east part of the southeast quarter of section 22 and in the west half of the southwest quarter of section 23, Agnes, by a wide tract of gravel and sand deposits, in irregular ridges and swells rising 4 to 8 feet, mostly trending from north to south, with their crests at 1,164 to 1,170 feet. Next to the north it is a well-defined beach ridge, with crest rising from 1,163 to 1,168 feet in its course of a half mile from south to north through the east edge of the northeast quarter of section 22.

In the southeast quarter of section 15, Agnes, the plain that descends slowly toward the Red River on the east is divided from the Elk Valley on the west by a low swell of till, having an elevation of 1,157 to 1,160 feet, destitute of beach deposits. This is succeeded in the north part of this section and the south part of section 10 by a second island which rose above the highest level of the glacial lake, having a length of 1 mile from south to north and averaging a quarter of a mile wide, its elevation in the southwest quarter of the northeast quarter of section 15 being about 1,187 feet, on the line between these sections about 1,175 feet, and near the center of section 10, at the north end of this irregular ridge, about 1,180 feet. Its material is till, partially overspread in its south half by gravel, which seems to have been brought by the currents and waves of Lake Agassiz from the erosion of its northern portion.

The beach of Lake Agassiz during its highest stage extends north from the north end of this island into the southwest quarter of section 3, Agnes, where it is a ridge about 20 rods wide, with an elevation of 1,165 to 1,172 feet, composed of coarse gravel and sand, inclosing plentiful rock fragments, chiefly granitic, up to 6 inches in diameter, most of which are only very slightly waterworn. Its eastern slope descends 15 to 20 feet in

as many rods, and on the west an equal descent takes place within 8 or 10 rods. The steep western slope of this beach or bar, forming the east rim of the strait that filled the Elk Valley, was due to storms on the broad lake, rolling its waves upon the bar and carrying the sand and coarse gravel upward and over its crest. Turning northwestward, this beach passes into the northeast quarter of section 4, where it consists of irregular accumulations of gravel and sand, occupying a width of an eighth to a fourth of a mile, with their crests at 1,155 to 1,162 feet. In the north edge of section 4 it again becomes a definite beach ridge of the same material and contour as in section 3, and thus passes northeast and north through section 33, Inkster, with its crest mostly at 1,165 to 1,172 feet, its lowest part, about 1,162 feet, being near the center of the section. The two islands before described, this beach or bar, and the long island next northward are together commonly called "The Ridge," being the eastern limit of the Elk Valley, which averages 4 miles wide, 1,150 to 1,140 feet above the sea in its eastern and central portions, but rising with a transverse slope to 1,160 feet on its western border.

A third island above the highest stage of Lake Agassiz, 3 miles long from south to north and a quarter to a half mile wide, varying in elevation along its highest part from 1,170 to 1,223 feet, reaches through sections 28 and 21, the west half of section 16, and into the southwest corner of section 9, Inkster. It is till, with somewhat uneven surface, bearing frequent boulders. Beach deposits occur on the east flank of this island in section 21 at 1,155 to 1,165 feet, and from 1,155 feet a smooth slope of sand and fine gravel falls slowly eastward along the east side of this highland through the greater part of its extent.

In the southeast part of section 8, Inkster, irregular accumulations of beach gravel, with crests at 1,170 to 1,175 feet, 10 to 15 feet above the adjoining depressions of till, extend northward from the island just described; and in the north part of this section 8 the beach sinks within an eighth of a mile from 1,172 to 1,161 feet and changes to a broad, smooth ridge, which thence passes northward through section 5 of this township, in which it is intersected by the Forest River, and through the west half of section 32, Eden, near the center of which it has three aboriginal

mounds, 6 to 8 feet in height, on its top. The material of this beach ridge is fine gravel and sand. Its crest on the line between sections 8 and 5 has an elevation of 1,161 feet; an eighth of a mile north, at the verge of the south bluff of Forest River, 1,155 feet; for the first half mile from the bluff north of this river, 1,152 to 1,157 feet; and at the mounds in section 32, 1,156 to 1,159 feet.

Another beach ridge, 20 rods wide, with descent of 10 feet on each side in as many rods, formed during the same stage of Lake Agassiz, lies a half to three-fourths of a mile west from the foregoing, in the northeast quarter of section 6, Inkster. This is the highest land between the main Forest River and its South Branch. It consists of sand and fine gravel, of which a considerable proportion (about a sixth) is Cretaceous shale. The maximum elevation of this ridge, 1,157 to 1,164 feet, is maintained for 50 or 60 rods, from which it sinks to 1,150 feet at each end.

From the north side of section 32, Eden, an island of rolling and hilly morainic till above the highest level of Lake Agassiz, far larger than any of these already described, extends, with the exception of two short gaps, 20 miles northward, varying in width from a half mile to a little more than 1 mile in its southern quarter and from $1\frac{1}{2}$ to $2\frac{1}{2}$ miles through the remainder of its extent. This hilly tract, commonly denominated "the mountains," forms the east border of the Golden Valley. In the north part of section 36, Vernon, it has a depression to about 1,180 feet, which probably was a strait of the glacial lake in its highest stage, an eighth of a mile wide and a few feet deep. Again, in the center of Golden Township, it is intersected by the South Branch of Park River, which has a valley a quarter to a half of a mile wide and about 75 feet deep. The stream in its course of $1\frac{1}{2}$ miles through this belt descends about 50 feet, from 1,165 to 1,115 feet, approximately. It seems almost certain that a depression slightly lower than the Golden Valley on the west originally extended across this rolling and hilly area where it is cut by this stream; but the erosion of its valley has undermined and removed portions of adjoining hills and ridges, so that its inclosing bluffs now rise 50 to 100 feet, their highest points being about 1,225 feet above the sea, or 25 to 30 feet above the east edge of the Golden Valley. All these bluffs and

two plateaus left in the midst of the valley are till, yellowish near the top and dark-bluish below.

The elevation of "the mountains" in their southern and narrower portion, through the west part of Eden and the northeast corner of Medford, is 1,190 to 1,225 feet; through the east half of Vernon, 1,200 to 1,250 feet; in the south part of Golden, 1,200 to 1,260 feet, and through the north half of this township and the south half of Lampton, 1,200 to 1,275 feet, being highest in section 28 of the township last named, near the northern end of this hilly tract. These prominent accumulations of till, rising in the west edge of the lacustrine area, seem referable, as shown in Chapter IV, to the ninth or Leaf Hills moraine. They appear to have been formed on the western margin of the Minnesota lobe of the ice-sheet.

The east border of "the mountains," in section 20, Eden, falls somewhat steeply to about 1,135 feet, and thence a flat slope, with no beach ridges, sinks slowly eastward. In the northeast quarter of section 7 in this township a well-defined beach ridge 10 to 15 rods wide, composed of sand and gravel, with pebbles up to 2 or 3 inches in diameter, extends 25 rods south from an eastern spur of the hilly till; crest of this spur, about 1,195 feet; of the beach, 1,172 feet, with depression of 3 to 6 feet on the west. Irregular beach accumulations, 10 to 20 feet lower, continue southward nearly a half mile.

In section 30, Rushford, the eastern border of this rolling and hilly area falls 75 feet or more within a third of a mile, to about 1,100 feet. Its material is till, with scanty deposits of beach gravel and sand, not distinctly accumulated in ridge form. About half way down this slope it shows in some places a more abrupt escarpment, with steep descent of 15 or 20 feet. The same features continue through section 19, except that a series of distinct beach deposits is observable about 25 rods east from the crest of the slope, at 1,170 to 1,175 feet, probably formed during the second Herman stage of Lake Agassiz. A descent of 125 feet takes place within a half mile on the east side of "the mountains," near where it is cut by a large but short ravine, in the southeast quarter of section 12, Vernon, falling from 1,180 to 1,050 feet, approximately, with no well-defined shore-lines observable. A grove lies at the east base of this slope a third of a mile

south of the ravine. In the northwest quarter of this section 12 and the west edge of the southwest quarter of section 1, a well-developed beach, in part consisting of two parallel low ridges, has an elevation of 1,170 to 1,177 feet; and in the east edge of section 2, continuing northward, its elevation is 1,177 to 1,184 feet. Its eastern slope falls to 1,170 feet within 10 or 20 rods.

Great Northern Railway at Park River depot, 998 feet above the sea; natural surface at the southeast corner of section 23, Golden, on the road leading west from Park River, 1,178 feet. The crest of the upper Herman beach, crossed by this road 10 rods west from the point named, is at 1,187 feet, but 20 rods southeast and northwest from the road its height is 1,192 feet. This is a typical beach ridge of sand and gravel, with pebbles up to 2 or 3 inches in diameter, mostly limestone and granite. The Cretaceous shale before mentioned is very rare in the till of "the mountains" and in the beaches formed along their east side, indicating that the east limit of this shale is the Pembina Mountain and the western ascent of the Golden Valley, and that the glacial currents by which the drift here was deposited came only from the north and northeast, with no intermixture of currents from west of north.

Highest beach on verge of south bluff of the South Branch of Park River, in the southeast quarter of section 23, Golden, 1,188 to 1,192 feet, with a basin-shaped hollow on its west side 20 feet lower, which changes southward to a depression of about 5 feet. The river bluff is here freshly undermined, showing the depth of the beach sand and gravel to be 5 to 10 feet, lying on till. Lower beach, a quarter of a mile farther east, extending from northwest to southeast, in the southwest quarter of section 24, 1,167 to 1,170 feet.

Lower Herman beach, a massive ridge of gravel and sand, extending in a curved course convex toward the east from the northeast quarter of section 2, Golden, through the southeast part of section 35, Lampton, crest, 1,160 to 1,165 feet; through the northeast edge of section 36 and the southwest corner of section 25, 40 to 50 rods wide, with slightly undulating surface, 1,160 to 1,167 feet; near the middle of the east side of the south-

east quarter of section 26, 1,165 to 1,166 feet; and at the quarter-section stake on the north side of this section 26, 1,163 feet.

Near the west line of section 23, Lampton, two Herman beaches abut upon the east flank of the north end of "the mountains," and extend thence north-northwesterly 2 miles to the Middle Branch of Park River. The eastern one, a well-defined ridge of sand and fine gravel, passes close west of the quarter-section stake between sections 15 and 10. The elevation of its crest is 1,161 to 1,166 feet, with increase in height from south to north; the descent on the east is 15 or 20 feet in as many rods, and the depression on the west is 3 to 8 feet deep and 10 rods wide. The other beach ridge is 40 or 50 rods farther west, parallel with the preceding and similar in form and material; its crest, rising slightly northward, is at 1,173 to 1,176 feet. Another distinct beach ridge, but of smaller size, runs in a parallel course through the east part of the southwest quarter of section 9, with its crest at 1,185 to 1,187 feet. These appear to represent together the third and second Herman beaches of the series observed northwest of Maple Lake in Minnesota and east and west of Larimore. The lowest Herman beach in this vicinity passes as a well-marked ridge of gravel and sand through the west part of sections 11 and 2, Lampton, and the east part of sections 34, 27, and 22, Gardar, having a height of 1,145 to 1,150 feet, from which there is a descent of 5 to 10 feet on the east and half as much on the west.

Upper Herman beach, northward from the north end of "the mountains," forming in the northwest quarter of section 21 and the west part of section 16, Lampton, a massive broad ridge, composed of sand and gravel, with pebbles up to 4 or even 6 inches in diameter, crest, 1,197 to 1,207 feet, rising highest northward, where the beach deposit overlies the eastern slope of a wave-like swell of till that rises to 1,212 feet. Small beach ridge, belonging to this stage, in the east edge of the southeast quarter of section 8, Lampton, 1,202 to 1,207 feet. Surface at Evan Edwards's house, in the west part of the southwest quarter of section 9, 1,197 feet, consisting of sand and gravel of this beach to a depth of 10 feet, underlain by till, yellowish in its first 6 feet and dark-bluish below. Summit of a smoothly rounded hillock, probably till, but having few or no boulders, in the east edge of the northeast quarter of section 8, about 1,230 feet; train of beach

gravel and sand extending thence 30 rods southward, 1,217 feet, with descent of 15 or 20 feet on each side.

Continuing beyond the Middle Branch of Park River, this highest beach is well developed in a broad ridge running due north through the west part of section 4, Lampton, with its crest at 1,202 to 1,208 feet. On the east the surface falls 30 or 40 feet, and more slowly beyond, while toward the west a descent of 10 feet is succeeded by a flat surface of till, which rises slowly from the foot of the beach ridge to a swell at the height of 1,215 to 1,225 feet, a half mile away, forming the east boundary of the Golden Valley. This beach is sand and gravel, with pebbles up to 6 inches in diameter. About half of them are limestone; nearly all of the remainder are Archean granite, gneiss, and schists; scarcely one in two hundred is Cretaceous shale. Through the west edge of section 33, Gardar, the elevation of this excellent beach ridge is 1,202 to 1,205 feet, and in the southwest edge of section 28 and the middle of the east edge of section 29, 1,202 to 1,197 feet, decreasing in height and size northward. For a half mile through the southwest quarter of section 33, a slight secondary beach ridge, 4 to 9 feet lower, lies about 30 rods east from the foregoing; its crest is at 1,198 to 1,195 feet, sinking a few feet from south to north; it is divided from the higher beach by a continuous depression about 3 feet deep.

A very massive beach ridge, composed of sand and gravel, with pebbles and rock fragments, the largest only slightly waterworn, up to 6 inches in diameter, passes a few degrees west of north through the center of section 20, Gardar, its crest in the south half of the section being at 1,208 to 1,215 feet, and in the north half 1,215 to 1,223 feet. On the east is a descent of 20 to 30 feet within 25 to 40 rods, and on the west 10 or 12 feet from the highest part of the beach within 10 rods to a nearly level area of till, 1,211 feet, which sinks 40 rods farther west to a long slough, about 1,205 feet, parallel with the beach and a sixth of a mile wide. Beyond this an undulating surface of till, partly covered with bushes and small trees, rises to 1,250 or 1,275 feet within 2 miles, and then in smooth, massive swells to 1,450 or 1,500 feet within the next 2 to 4 miles. These are part of a plateau, thence rising more slowly westward, whose boundary

for the next 75 miles to the north-northwest is the conspicuous escarpment called Pembina Mountain.

The north end of this massive beach bears on its crest an artificial embankment 100 feet long from east to west and 20 feet wide, raised 2 feet above the natural surface, its top being 1,225 feet above the sea. This is 10 rods south from where the beach is cut to 1,210 feet by a wide gap, as of some ancient watercourse. In the south edge of the southwest quarter of section 17, Gardar, on the south bank of the North Branch of Park River, about 10 rods east from the ford of the "Half-breed road," this beach has an elevation of 1,220 feet.

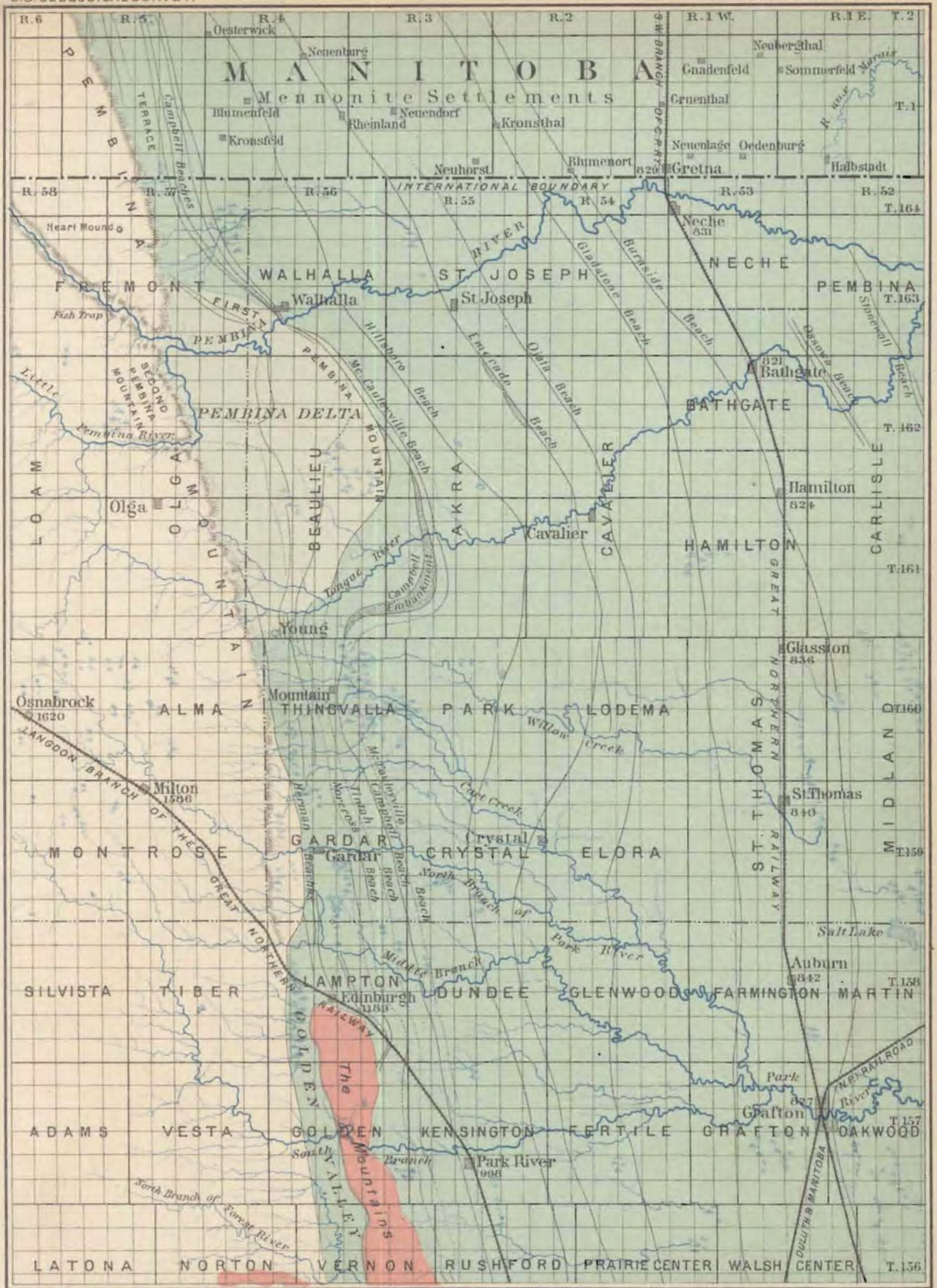
North Branch of Park River at this ford, 10 to 15 feet wide and a few inches deep, 1,203 feet. Surface at the village of Gardar, a mile east, 1,175 to 1,170 feet. Lower Herman beach, passing from south to north along the east side of sections 20 and 17, Gardar, a third of a mile west of the village, about 1,185 feet.

FROM GARDAR NORTH TO THE TONGUE RIVER.

(PLATE XXX.)

Sections 17, 8, and 5, Gardar, rise from 1,190 and 1,200 feet on their east side to 1,220 and 1,225 feet on the west, including, therefore, the upper Herman shore of Lake Agassiz; but they present no considerable deposits of beach gravel and sand. A swell of till, sprinkled with very abundant bowlders, nearly all Archean granite and gneiss, up to 5 feet in diameter, extends from south to north across the line between sections 8 and 5, having its crest at 1,215 feet, from which there is a steep descent of 10 or 12 feet to the west. Sloughs and pools of water, permanent through the year, lie in the west part of section 5, about 1,190 feet above the sea.

The South Branch of Cart Creek, in sections 31 and 32, Thingvalla, is bordered by a belt of timber a half mile wide, but it has only a small channel a few feet below the general surface, and is dry through the greater part of the year. Its alluvial gravel, like that of the Middle and North branches of Park River, is mostly Cretaceous shale, derived from the gorges eroded in this rock at the sources of these streams in the Pembina Mountain.



MAP OF THE WESTERN SHORES OF LAKE AGASSIZ, INCLUDING THE PEMBINA DELTA, FROM PARK RIVER, WALSH COUNTY, NORTH THROUGH PEMBINA AND CAVALIER COUNTIES, NORTH DAKOTA, TO THE INTERNATIONAL BOUNDARY.

Scale, 6 miles to an inch.

Lake Area Delta Moraines

Altitudes of Railway stations are noted in feet above the sea.

Along the western border of Lake Agassiz here and northward into Manitoba extends a prominent wooded bluff, the escarpment of a treeless plateau which from its crest stretches with slow ascent westward. This escarpment, commonly called the Pembina Mountain (described in pages 40-42, 93-97), is a very marked feature in the topography for about 75 miles. It is caused by the outcrop, mostly overspread by glacial drift, of a continuous belt of nearly horizontal Cretaceous shale, several hundred feet thick, usually so hard and enduring that it is popularly termed "slate." Its course coincides nearly with the west line of Gardar and Thingvalla townships. Thence it continues in an almost straight course, a few degrees west of north, to the international boundary, beyond which it runs north-northwest nearly 50 miles to the vicinity of Treherne. The base of the ascent is about 1,225 feet above the sea, and its crest approximately 1,500 feet, northward to the Pembina River, beyond which the base sinks to 1,150 and 1,100 feet and the crest to 1,400 and 1,300 feet. The width occupied by the slope varies from a quarter to a half of a mile.

Natural surface at the quarter-section stake on the north side of section 32, Thingvalla, 1,178 feet above the sea. Sections 32, 29, and 20 of this township are mostly till, smoothed by this glacial lake, the depressions having been filled by leveling down the higher portions, where many boulders partially embedded testify of considerable erosion. A broad ridge of beach sand and fine gravel 3 to 5 feet high extends from south to north through the center of section 29, its crest being at 1,180 to 1,182 feet. This is the third in the series of four Herman beaches observed near Maple Lake, near Larimore, and in Lampton. The higher beaches are probably also recognizable 1 to 1½ miles farther west, near the base of the Pembina escarpment or "second mountain," which is 1,220 to 1,230 feet above the sea; but it is impracticable to trace their course and determine their exact elevation, because woods reach from the base of this escarpment a half mile east, where these beaches belong.

Fourth Herman beach, a broad, low swell of sand and gravel, extending north-northwesterly through the east half of section 20, Thingvalla, 1,166 to 1,172 feet; through sections 17 and 8, an eighth to a quarter of a mile wide, 1,161 to 1,173 feet, having in some places a depth of at least 10 feet, as

shown by wells. On the north line of section 20, and again in the north part of section 17, it is intersected by branches of Cart Creek, which occupy valleys about 40 feet deep and an eighth to a quarter of a mile wide. Brush and scattered trees grow in these valleys and on the area between them. Toward the east a descent of 30 or 40 feet is made within the first half mile; westward there is only a slight ascent, to about 1,200 feet, in 1 mile; then a more considerable slope, covered with woods, rises 20 to 40 feet to the base of the "second mountain," on or near the township line.

In the west part of section 8, and again near the northeast corner of section 6, Thingvalla, this beach is intersected by the head streams of Willow Creek, in valleys about 35 feet deep. On the north line of sections 5 and 6 of this township the fourth and third Herman beaches are merged in an undulating tract of gravel and sand a half mile wide, which rises from 1,160 feet on the east to 1,184 feet on the west. A well on the west part of this belt found the beach deposit 6 feet thick, underlain by till, which forms the slightly ascending surface next west.

Base of the second Pembina Mountain, in the east half of section 31, township 161, range 56, 1,235 feet at the south to 1,220 feet northward, coinciding nearly with the upper Herman shore of Lake Agassiz. William Crombie's well, 24 feet deep, near the center of section 30, situated about 50 feet above the Tongue River, a few rods back from the verge of its north bluff, was soil, 2 feet; gravel, nearly all Cretaceous shale, 8 feet; underlain by gravel, nearly all granite and gneiss, with scarcely any intermixture of shale, containing pebbles and cobbles up to 4 inches in diameter, 14 feet, yielding a permanent supply of water. This well is close to the base of the "mountain," at an elevation of about 1,230 feet. Its bed of granite gravel appears to be the upper beach, the overlying shale gravel being a delta deposit brought by the Tongue River.

Surface at Young post-office, in the northeast corner of the southwest quarter of section 32, township 161, range 56, 1,192 feet. The well here, 14 feet deep, is wholly stratified gravel and sand, being a beach deposit of the second and third stages in the Herman series. Third beach, about an eighth of a mile east of Young post-office, a broad ridge of sand and fine gravel, a few feet above the land on its west side, crest, 1,187 feet. Fourth

and lowest Herman beach, of similar form with the last, but larger, running a few degrees west of north through the west edge of section 33, 1,173 to 1,175 feet, with depression of 1 to 5 feet on its west side and descent of 25 feet within 30 or 40 rods east.

Tongue River, at bridge near the center of the south half of section 28, township 161, range 56, about 1,110 feet; bottom land, 10 feet higher; top of the bluffs, about 1,150 feet. Gavins reek, in the south half of section 20, about 1,140 feet; valley, 40 feet deep, a sixth of a mile wide.

The lowest Herman beach forms a massive ridge of sand and fine gravel in the northeast quarter of section 29 and the east part of sections 20 and 17, township 161, range 56, with its crest at 1,175 to 1,180 feet.

DELTA OF THE PEMBINA RIVER.

(PLATE XXX.)

The largest tributary to the Red River in North Dakota is the Pembina River, which has cut a valley about 400 feet deep and a mile wide in the plateau of the second Pembina Mountain. During the recession of the ice-sheet this stream was much larger than now, being for a time the outlet of glacial lakes in the basins of the Souris and Saskatchewan rivers.¹ The delta deposited in the margin of the glacial Lake Agassiz by the Pembina River, swollen by a great affluent from the melting ice-fields at the northwest, beyond the present limits of its basin, extends about 16 miles from south to north and has an average width of about 5 miles, with a maximum width of $7\frac{1}{2}$ miles and a maximum thickness exceeding 200 feet. Its mean thickness is probably not less than 150 feet, giving for its volume about $2\frac{1}{3}$ cubic miles, spread upon an area of 80 square miles. Four-fifths of this delta lie south of the Pembina River, reaching nearly to the Tongue River. Fig. 15 shows a section across this delta from east to west about 3 miles south of Walhalla.

Its elevation in the northwest part of section 17, township 161, range 56, is 1,200 feet; thence northward it rises slowly in 2 miles to 1,225 feet in the east part of section 6; and in sections 31 and 30, township 162, range

¹ Pages 267-274, foregoing. Geol. and Nat. Hist. Survey of Minnesota, Ninth Annual Report, for 1880, p. 342. Hind's Report of the Assiniboine and Saskatchewan Exploring Expedition, 1859, pp. 118 and 168.

56, it varies from 1,220 to 1,227 feet. From this crest of the southern part of the delta it slopes slowly east and northeast to 1,080 and 1,090 feet at its eastern border, in sections 25, 24, and 13, which coincides nearly with the east line of this township 162, range 56. Deep valleys, with frequent tributary ravines, have been eroded in it by several small streams. Westward the delta reaches to the base of the second Pembina Mountain, the belt, a half mile to 1 mile wide, next beyond the crest, only about 5 feet lower, being a very flat, beautiful prairie, which rises slowly, like the crest, from south to north. The elevation of this belt in section 18, township 161, range 56, is 1,190 to 1,195 feet, and at Mr. Henry Goff's house, in the middle of the east edge of section 36, township 162, range 57, 1,221 feet. Farther west there is an ascent to about 1,240 feet at the base of the "sec-

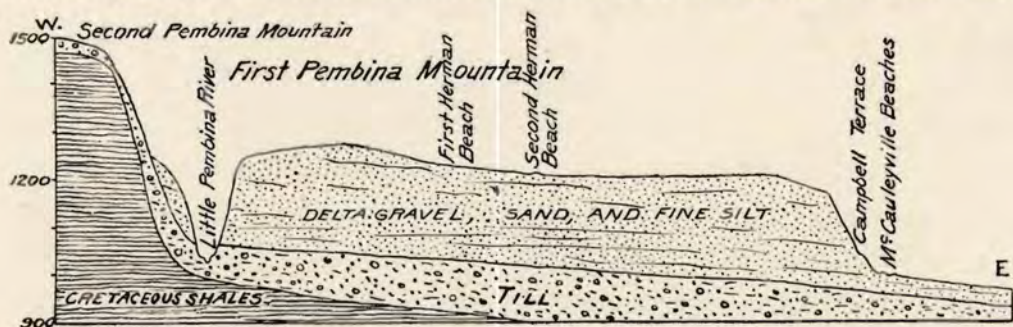


FIG. 15.—Section across the delta of the Pembina River. Horizontal scale, 2 miles to an inch.

ond mountain." Wells on this area penetrate only beds of sand and gravel, easy to dig and needing to be curbed to prevent caving. A large proportion, probably half, of the gravel is Cretaceous shale. Water is obtained at depths varying from 25 to 60 feet.

The part of the Pembina delta thus far described is divided from its central and higher part, which is crossed by the section of fig. 15, by a depression about a mile wide, through which a portion or the whole of the river flowed during much of the time while this delta was being formed. In the southwest corner of section 18, township 162, range 56, this depression is 1,205 feet above the sea, being 20 feet lower than the area on the south. It extends eastward with a slow descent and rises westward to 1,215 feet close east of the Little Pembina River, in section 15, township 162, range 57. This stream flows through the escarpment of the "second

mountain," in the southeast quarter of section 22, about a mile south from this lowest part of the divide on its east side. It here turns abruptly from its eastern course, and thence flows north-northwest along the base of the "second mountain" to its junction with the Pembina River, thus leaving the depression just described, which would seem to be its more natural course, and taking in its stead a channel that is eroded through a portion of the delta 50 feet higher.

The most elevated point of this delta, as it now remains, is about 1,270 feet above the sea, near the northwest corner of section 11, township 162, range 57, east of the Little Pembina and south of the Pembina River, and is nearly 300 feet above the junction of these streams, $1\frac{1}{2}$ miles distant toward the northwest. Section 12 of this township and the west part of section 7, township 162, range 56, slope from 1,225 feet on the south to 1,215 feet on the north; their southern part is the highest land crossed between the depression before mentioned and the Pembina River by the line dividing these townships. The level of Lake Agassiz in its highest stage here was 1,220 or 1,225 feet above the sea, being 50 feet below the top of the Pembina delta, as is shown by the beach line of this level, 1,226 feet, in the central part of this section 7, where an eastward descent begins. This is the east verge of the nearly flat area of the delta in sections 12 and 7. Like all of this delta deposit, the material here is sand and gravel, covered by a fertile soil. A small proportion of the pebbles of this gravel is limestone; a large part is Cretaceous shale; but more was derived from Archean formations of granite and gneiss.

The second Herman beach, a ridge of the usual form, is crossed by the road near the east side of the northeast quarter of section 7, township 162, range 56, descending from 1,212 feet to about 1,200 feet in a distance of a third or half of a mile from south to north.

William Roadhouse's well, 110 feet deep, in the northwest quarter of section 8, township 162, range 56, at the elevation of 1,184 feet, is all stratified sand and gravel, with pebbles up to 6 inches in diameter, fully half Cretaceous shale. Water comes in coarse sand at the bottom, filling the lowest 2 feet. Another well of the same description, but 137 feet deep,

is a mile farther east, at Wellington Stewart's house, in the southwest quarter of section 4, 1,192 feet above the sea.

On the road from Olga to Walhalla the crest of the east margin of this delta is crossed in the north part of section 33, Walhalla, about 2 miles southeast from the village of this name. Its elevation is 1,190 to 1,196 feet above the sea. This is a beach accumulation, belonging to the third Herman stage. Toward the west and southwest the undulating delta plateau, mostly covered with bushes and occasional trees, is 10 to 30 feet lower for a width of 1 to 1½ miles, averaging about 1,175 feet. Northeast from the crest of this road a short descent is made to a prairie terrace, 30 to 60 rods wide, varying in elevation from 1,182 to 1,169 feet, but mainly within 2 feet above or below 1,175 feet. In general the verge of this terrace is its lowest portion. Thence a very steep descent of 169 feet is made on the road from 1,173 to 1,004 feet, this being the very conspicuous wooded escarpment called the "first Pembina Mountain." It is the eroded front of the great Pembina delta, the eastern part of which, originally descending more moderately, has been swept away by the waves and shore currents of the lake during its Norcross, Tintah, Campbell, and McCauleyville stages. From this section 33 the "first mountain" extends southeast to sections 13 and 24, township 162, range 56, and northwest across the Pembina, passing close southwest of Walhalla and onward to sections 10 and 3, township 163, range 57. Its highest part is intersected by the Pembina River, above which it rises on each side in bluffs of gravel and sand 200 to 250 feet high, with their crest a half mile to 1 mile apart. From this upper portion the delta slopes down gradually toward the southeast and toward the northeast and north, extending only 2 to 4 miles north of the Pembina.¹

¹The first Pembina Mountain was visited by D. D. Owen in 1848. He describes it as follows: "Pembina Mountain is, in fact, no mountain at all, nor yet a hill. It is a terrace of table-land, the ancient shore of a great body of water that once filled the whole of the Red River Valley. On its summit it is quite level and extends so far about 5 miles westward to another terrace, the summit of which, I was told, is level with the great buffalo plains that stretch away towards the Missouri, the hunting grounds of the Sioux and the half-breed population of Red River."—Report of a Geological Survey of Wisconsin, Iowa, and Minnesota, 1852, p. 178.

Both the first and second Pembina mountains were examined in 1857 by Palliser, who says of the flat Red River Valley and the Pembina delta: "This plain, no doubt, had formed at one time the bed of a sheet of water, and the Pembina Hill, consisting of previously deposited materials, was its western shore."—Journals, detailed reports, etc., presented to Parliament, 19th May, 1863, p. 41.

Surface at the Bellevue Hotel, Walhalla, 994 feet above the sea; at the post-office, Mr. G. D. Loring's store, 968 feet; Pembina River at the bridge, a third of a mile east of Walhalla, low and high water, 934 to 943 feet.

Highest part of the Pembina delta north of the Pembina River in sections 25 and 26, township 163, range 57, 1,210 to 1,230 feet, rising slowly from east to west; in the west half of section 26 and the east edge of section 27 it is depressed to 1,225 and 1,220 feet; but beyond this it rises to 1,235 and 1,240 feet, next to the foot of the "second mountain."

Natural surface at the quarter-section stake on the north side of section 26, township 163, range 57, 1,191 feet. Third Herman beach, crest 5 rods south of this stake, 1,197 feet, from which there is a descent in 5 rods south to 1,192 feet and in 15 rods north to 1,180 feet. This beach curves thence to the northwest and north, and in the opposite direction runs east-southeast 2 miles to near the center of section 30, Walhalla, where its elevation is approximately 1,192 feet. Other shore-lines of the Herman group were not noticed north of the Pembina River.

In the gravel of this delta, as seen in the bluffs of the Pembina near Walhalla and at noteworthy springs 2 miles to the south, on the south side of the river, in the southwest corner of section 32, the pebbles of some beds are mainly Cretaceous shale, of others mostly limestone, and of others granite, gneiss, and dark trappean rocks. In the aggregate these three classes have a nearly equal representation, and they are more commonly intermingled in the same beds. The shale was doubtless chiefly derived from the erosion of its strata along the glacial watercourse from the Lake Souris, and was occasionally deposited in layers almost unmixed with drift materials; but the other constituents of the gravel were derived from the overlying drift and from the melting ice-sheet. White quartz and moss agate are frequent, and bits of silicified wood occur rarely; but no banded agates were found. Numerous pieces of lignite, rounded by water-wearing, from 2 to 4 inches in diameter, noticed in this delta gravel at the springs, have caused some to look for workable beds of this kind of coal in the vicinity; but the proportion of these fragments is no greater than in the glacial drift generally throughout this region and for hundreds of miles to the south.

The deposition of this delta took place during the highest Herman stage of Lake Agassiz. It seems to have been very rapid, the supply of sediments being so great that about the mouth of the Pembina Valley they were accumulated in a fan-like sloping mass to a height of more than 50 feet above the lake level. When the recession of the ice-sheet caused the cessation of its supply of modified drift, and permitted the Souris to flow, as now, to the Assiniboine, the growth of this delta ceased; and its subsequent history is that of the deep channels cut through it by the Little Pembina and the Pembina, and of the steep escarpment sculptured on its east side. From the erosion of this first Pembina Mountain large amounts of gravel and sand were swept southward, notably during the Campbell stages of the lake, when they were deposited in a very massive curving beach ridge that crosses the Tongue River in the west part of township 161, range 55, about 7 miles west of Cavalier. In the Herman stage, while the delta was being accumulated, much fine clay and silt, brought by the same glacial river, were carried farther and spread upon the lake bed along the central part of the Red River Valley, perhaps extending in appreciable amount nearly 100 miles southward to the belt of till that reaches across the valley at Caledonia and forms the Goose Rapids. But on the west side of the lacustrine area this fine sediment is absent, probably because of currents trending offshore; and the surface is till both south and north of the gravel and sand delta, as from Park River north to Gardar and Mountain and nearly to the Tongue River, and from 2 miles north of the Pembina to the international boundary and onward.

During the Glacial period the great valley of the Pembina River west of its delta was only partially filled with drift, for its reexcavation, with the channeling of Langs Valley, tributary to it from the glacial Lake Souris, would have supplied as large a tribute to Lake Agassiz as the entire Pembina delta and the fine silt and clay that are spread over the adjacent lake bed. The volume of the delta, as before stated, is approximately $2\frac{1}{3}$ cubic miles. If an equal amount of fine silt were deposited beyond the delta, both together would measure about the same as Langs Valley and the Pembina Valley from the former mouth of Lake Souris to the delta, namely, between 4 and 5 cubic miles.¹ But much of the Pembina delta and lacus-

¹ See pages 267-272, foregoing.

trine silt was doubtless supplied from the melting ice-sheet at the same time with the deposition of the tracts of modified drift that border the valley north of Rock and Swan lakes; so that the material derived from erosion in this valley was considerably less than would be required to fill it. Moreover, it seems likely that the entire erosion of Langs Valley—that is, of the portion of this watercourse extending from the Souris to Pelican Lake—together with most of the valley along the extent of that lake, was effected by the outflow from the Lake Souris during the time of formation of the Pembina delta; and this large supply from erosion in the upper part of the valley still further diminishes its probable amount along the course of the river below. Thus it is clearly indicated that the Pembina Valley, like the valleys of the Minnesota, Sheyenne, and Assiniboine rivers, was eroded during preglacial time and was not entirely filled by the drift. Comparing this delta with all the other conspicuous deltas of Lake Agassiz, it seems indeed probable that more than half of its mass was supplied directly from the englacial drift of the ice-sheet, and that less than half came from erosion of the valley, which, therefore, along the lower and deeper portion of its course appears not to have been much obstructed by the glacial drift. From this it follows that the extensive high terraces observed on the sides of the Pembina Valley in the vicinity of the Mowbray bridge and westward (page 270) are due to preglacial erosion in the Cretaceous shales, owing to the action of the ice-sheet only their minor features, together with the drift forming their surface.

THE UPPER OR HERMAN BEACHES AND DELTAS IN MANITOBA.

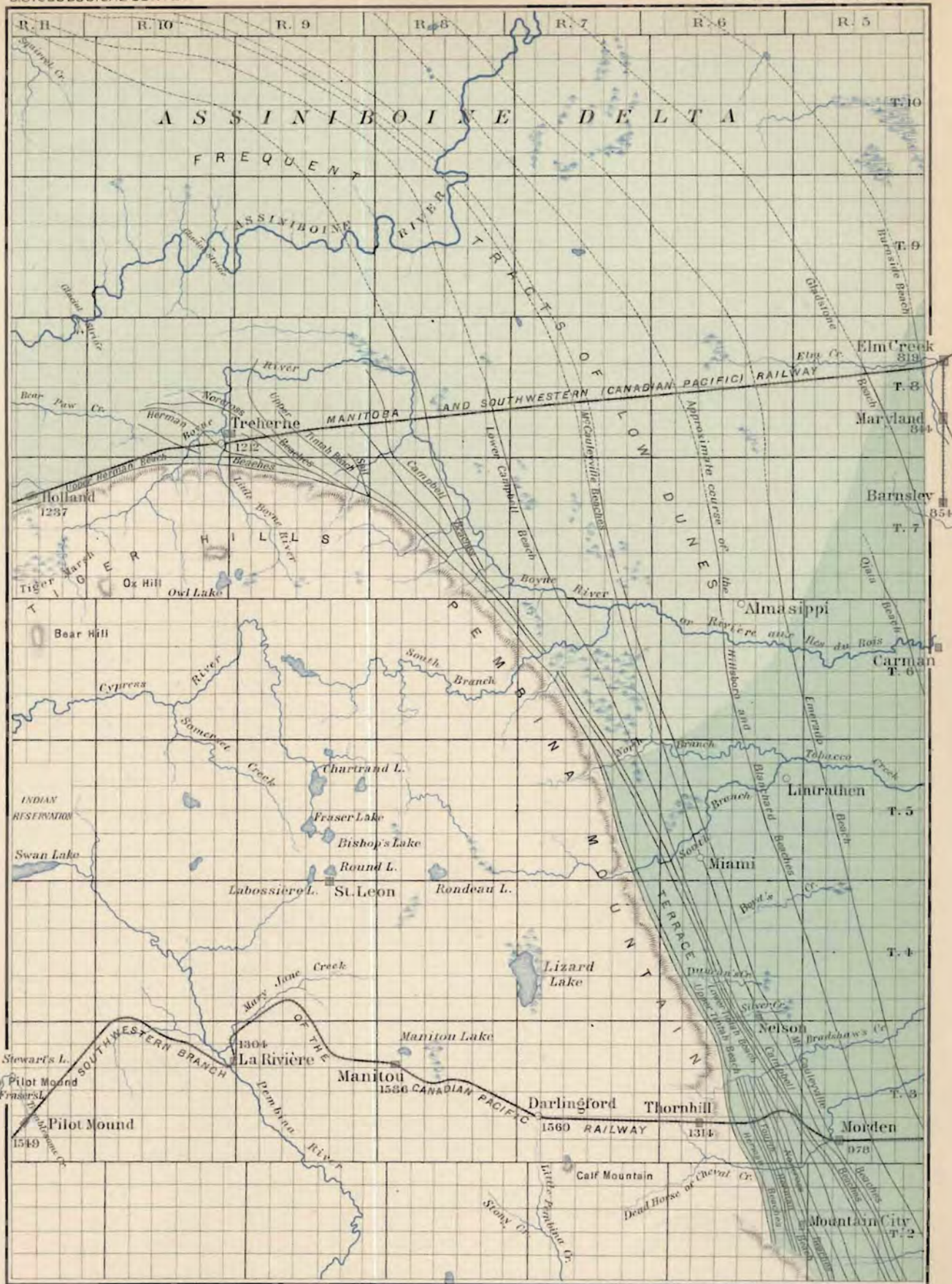
FROM THE INTERNATIONAL BOUNDARY TO THE VICINITY OF NEEPAWA.

(PLATES XXX, XXXI, AND XXXII.)

The west shore of Lake Agassiz enters Manitoba 2 miles west of the east line of range 5, at a distance of 36 miles from the Red River. On the international boundary and for the next 10 miles northward the shores of the highest stages of the lake were on the steep wooded escarpment of the Pembina Mountain, the base of which here is 1,100 to 1,150 feet above the sea, rising slightly northward, and the verge of its top, 1,300 to

1,400 feet. This ascent, forming the steep face of the Pembina Mountain, is made upon a width of about a quarter of a mile.

Where the Pembina Mountain plateau is ascended by the Southwestern Branch of the Canadian Pacific Railway, and for a distance of about 4 miles south and 2 miles north of this railway, the principal line of escarpment is replaced by a moderate slope which is chiefly prairie. Across this tract the Herman beaches of Lake Agassiz are well developed. In order proceeding northward, the first point of examination of the highest beach was near William H Oakley's house, in the south edge of the southwest quarter of section 26, township 2, range 6. It is here a massive rounded ridge of gravel and sand, with descent of 12 to 15 feet in a distance of as many rods both to the east and west from its crest, which is 1,253 feet above the sea. Northward this beach, with similar outline, extends to Francis J. Parker's house, which is built on its crest, having there also a height of 1,253 feet, in the north edge of the northwest quarter of this section. Westward from this beach is an undulating surface of till with few boulders. Half a mile farther north the beach is intersected by the deep and broad ravine of Dead Horse or Cheval Creek. Beyond this ravine the beach begins near Samuel B. Bowen's house. Its elevation 1 to $1\frac{1}{2}$ miles north-northwest of Mr. Bowen's is 1,255 to 1,259 feet, and it is there spread more broadly than usual, having a nearly flat surface on a width of 20 to 30 rods, bordered on the east by a descent of 10 or 15 feet in 20 rods, and on the west by a descent of about 4 feet. The beach is gravel and sand, with till on each side. It has nearly the same features also a third of a mile farther north, near the center of section 10, township 3, range 6, where it is crossed by the road from Morden to Thornhill, the elevation of its crest being 1,258 feet, but the depression on the west is reduced to only 1 or 2 feet. In the same section this and lower beach ridges are excavated beside the railway for ballast, and are found to consist of sand and gravel, with pebbles seldom exceeding 2 or 3 inches in diameter. About half of the pebbles are light-gray magnesian limestone and about half Cretaceous shale, such as forms the Pembina Mountain, with only a small proportion derived from Archean rocks. Thence the highest shore continues north through the east part of sections 16 and 21, township



MAP OF THE WESTERN SHORES OF LAKE AGASSIZ IN MANITOBA, FROM MORDEN AND THORNHILL NORTH TO THE ASSINIBOINE RIVER.

Scale, 6 miles to an inch.

Lake Area



Delta



Altitudes of Railway stations are noted in feet above the sea.

3, range 6, and in section 28 comes to the steep escarpment of Pembina Mountain, with which it coincides along the next 30 miles north-northwest. The elevation of this beach shows that it is the continuation of the highest in the series of Herman beaches in Minnesota and North Dakota.

About a quarter of a mile east of the foregoing is a parallel beach 15 to 20 feet lower, the second in the Herman series. Newton Lane's house, next east of Mr. Oakley's, is built on its crest, 1,237 feet above the sea. It there has a descent of 15 feet or more within an eighth of a mile to the east; but on the west the descent is only 1 or 2 feet or in part wanting, and a nearly level surface of sand and gravel reaches west to the upper beach. In section 10, township 3, range 6, at the road from Morden to Thornhill, this second Herman beach has a height of 1,241 feet, and another beach at 1,247 feet lies between this and the highest, indicating similar conditions in the fall of the lake level as on the northwest side of Maple Lake, in Minnesota, where such an intervening beach also occurs.

Three small parallel beach ridges referable to the third stage in the Herman series are crossed in the west part of section 24, township 2, range 6, by the road leading northwest from Mountain City. The elevation of their crests is 1,198, 1,202, and 1,205 feet. Two miles farther north, near the center of section 35, in the same township, William Miller's house is built on the highest of these, at an elevation of about 1,210 feet. His well, 16 feet deep, is gravel and sand to the depth of 12 feet, with till below. Northward these beaches are traceable through sections 2, 11, 15, and the south part of section 22, township 3, range 6, to Bradshaws Creek, beyond which they pass, with the other Herman and Norcross beaches, along the Pembina Mountain escarpment.

The fourth Herman beach passes through Mountain City, in section 24, township 2, range 6, the post-office and the south end of the principal street being on its crest, at 1,191 to 1,192 feet. Twenty-five rods farther east, at the schoolhouse, is a less conspicuous parallel beach, at 1,183 to 1,184 feet. Both are terrace-like in form, having a descent of 3 to 5 feet or more on the east, but only 1 to 2 feet or none on the west. The continuation of this shore was also observed, like the preceding, through a distance of 6 miles northward.

From section 28, township 3, range 6, the Herman shores of Lake Agassiz coincide with the prominent escarpment of the Pembina Mountain through a distance of 29 miles, passing in a nearly straight course north-northwesterly to section 30, township 7, range 8, about 7 miles east-southeast from Treherne. Along this distance the base of the escarpment is 1,100 to 1,125 feet above the sea, and its crest about 1,400 feet. Seen from this elevation, the great plain of the Red River Valley on the east, when overshadowing clouds give to it in the distance a dark blue or azure color, appears not unlike the vast expanse of the ocean as viewed from an equal height a few miles inland. The highest shore of the glacial lake was about half way up this ascent, and the lower Herman beaches and those of the Norcross stage were between this and the base.

At the north end of the Pembina Mountain the Herman shores of Lake Agassiz turned from a northward to a westward course, and at the sharpest portion of this bend, in section 36, township 7, range 9, the currents along the shore, caused by storms, brought a large amount of gravel and sand from their erosion on each side, and accumulated these deposits in a massive ridge which juts out north-northwesterly a mile or more from the curving line of the escarpment. This gravel and sand spit sinks from nearly 1,300 feet above the sea at its south end, where it rests on the adjoining highland, to about 1,125 feet, comprising deposits of the successive Herman, Norcross, and Tintah stages of the lake.

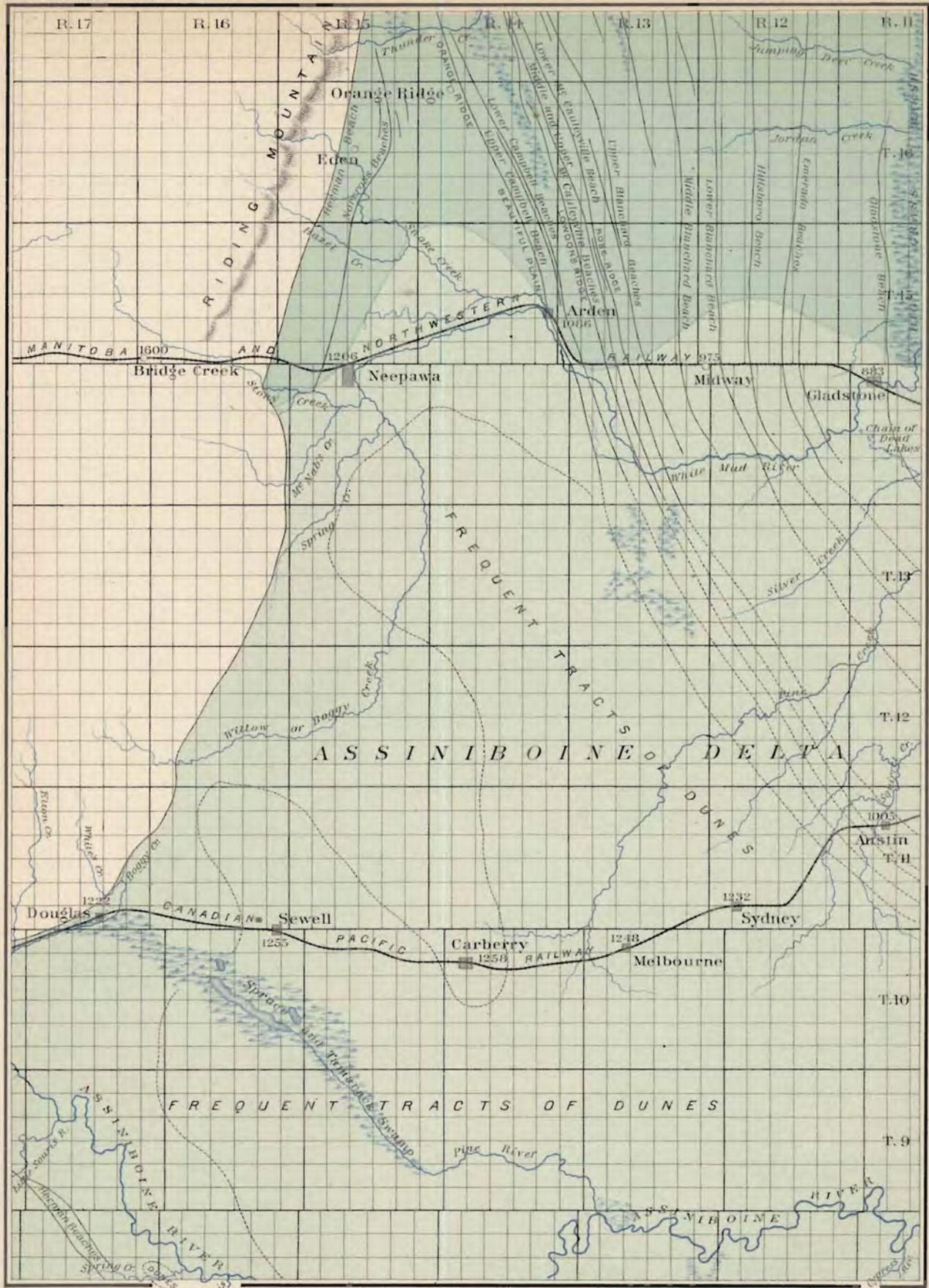
Five to 6 miles farther west the Herman beaches are well exhibited in the gradual ascent that rises to the Tiger Hills, 1 mile south of Treherne. The highest beach here crosses the middle of the northwest quarter of section 31, township 7, range 9, where it forms a swell of sand and gravel, with pebbles mostly of Cretaceous shale, having its crest 1,272 to 1,273 feet above the sea. In some portions this reaches nearly flat an eighth of a mile south to the base of the Tiger Hills, but elsewhere it is divided from them by a depression of 3 to 5 feet. This appears to be the second (*b*) in the series of Herman beaches, the first of this series (*a* and *aa*) not being found here nor farther north. At the time when that uppermost beach of Lake Agassiz was formed this locality and the country northward are believed to have been covered by the ice-sheet, its termination being at the

tract of morainic drift which overspreads the east part of the Tiger Hills, as crossed in township 7, range 9, by the road to the south from Treherne. About 20 and 50 rods north of the beach just described two inconspicuous beach lines, terrace-like sand and gravel deposits, are found at 1,266 and 1,254 feet, referable to subdivisions (*b*¹ and *bb*) of the second Herman stage. A little farther north the third Herman beach is represented at Irvine Scarrow's house, in the south edge of section 6, township 8, range 9. This is a slight terrace with crest at 1,243 and 1,244 feet and descent of 4 or 5 feet on its north side. Mr. Scarrow's well, on this beach, 31 feet deep, consists of black soil, 2 feet; interbedded sand and clay, 10 feet; very coarse shale gravel, 5 feet; beds of coarse and fine gravel and sand, 13 feet; and very hard dark bluish till at the bottom, dug into only 1 foot. This well shows an accumulation of shore drift to a depth of 30 feet, swept out by the currents of the lake from the curve where its beaches turned westward. About an eighth of a mile north of Mr. Scarrow's house another beach, also referable to the third Herman stage, descends from 1,236 and 1,238 feet at its crest to 1,230 feet at the base of its northward slope. At the summit of the Manitoba and Southwestern Railway, a mile east of the Little Boyne River, and on the slope thence eastward, very massive beach deposits are accumulated, due apparently to the same action of northwestward currents from the northern end of the Pembina Mountain. The summit of the railway is on such a beach, 1,217 to 1,220 feet above the sea, the fourth in the Herman series, forming a broad swell from which a gentle slope falls on its northeast and southwest sides. Arthur Willett's well here goes to a depth of 42 feet in beds of sand and gravel, obtaining a plentiful supply of good water from their lower portion, without reaching their bottom. A fifth of a mile farther east the railway cuts a beach ridge with its crest at 1,211 feet, also referable to the fourth Herman stage.

The Assiniboine delta occupies the western border of Lake Agassiz from Treherne westward about 60 miles to Brandon, and thence northeastward about 35 miles to Neepawa. The shore of the lake along these distances is not generally marked by a definite beach ridge, the absence of which seems to be accounted for chiefly by the extreme shallowness of the

lake upon the delta, so that powerful waves were not driven ashore by storms. The course of the highest shore between Treherne and Brandon, belonging to the time of the second Herman beach, passes first west-southwest along the foot of the Tiger Hills to the north and west side of Campbell's Hill, in section 4, township 7, range 12; thence southwest and south to the Cypress River, near Grange post-office, in section 18, township 6, range 12; thence west-northwestward to Oak Creek and along the south side of this creek, within a mile or less from it, nearly to its mouth; and, crossing the Souris in section 31, township 7, range 16, passes thence northwest to Brandon. Beyond the Cypress a belt of till, moderately undulating or in part nearly flat, from 2 or 3 to 10 miles wide, separates this lake shore from the northern border of the Tiger Hills and the eastern and northern base of the Brandon Hills. S. Martin's house, in the northeast quarter of section 28, township 8, range 17, about 15 miles southeast of Brandon, is built on a small beach ridge of sand and gravel extending from southeast to northwest, only slightly below the highest stage of the lake, which is marked by a moderately sloping parallel escarpment, about 10 feet high, eroded in till a half mile southwest of this beach. The unusually smoothed surface of the till extending thence west and south to the Brandon and Tiger Hills, on the area crossed by the Souris in its course from Gregory's mill to the mouth of Black Creek, is probably attributable to the deposition of its upper portion in a body of water held between these hills and the northwardly retreating ice-sheet before this area was drained to the level of Lake Agassiz by the retreat of the ice from the east part of the Tiger Hills and the north end of the Pembina Mountain.

In the south part of the city of Brandon the second Herman beach, marking the stage *bb* of the table in Chapter IX, is a well-defined ridge of sand and gravel along a distance of about a mile. It extends from east to west, passing an eighth of a mile north of the court-house, and thence close along the south side of Lorne avenue from First to Fourth street. Between Fourth and Sixth streets it is crossed by this avenue, and thence westward lies close on its north side. Its structure is shown by sections where it is intersected by Tenth, Eleventh, and Twelfth streets, exposing a thickness



MAP OF THE WESTERN SHORES OF LAKE AGASSIZ IN THE VICINITY OF THE CANADIAN PACIFIC RAILWAY AND NORTH TO ORANGE RIDGE, MANITOBA.

Scale, 6 miles to an inch.

Lake Area

Delta

Altitudes of Railway stations are noted in feet above the sea.

of 10 feet of obliquely bedded sand and gravel, containing abundant pebbles up to 2 inches and rarely cobbles 3 or 4 inches in diameter, about two-thirds being Paleozoic magnesian limestones, from one-tenth to one-fourth Cretaceous shale, and the remainder mostly Archean granites and schists. This beach ridge varies from 10 to 20 rods in width and from 5 to 10 feet or more in height, having a smoothly rounded, wave-like form. The elevation of its crest near the court-house ranges from 1,260 to 1,269 feet above the sea, and at Eleventh and Twelfth streets it is 1,260 to 1,261 feet. No distinct beach ridge of the slightly higher Herman *b* stage of Lake Agassiz was found in the vicinity of Brandon, but evidence of the lake level in that stage is afforded in the southeast part of Brandon by the delta plateau of coarse gravel and sand at the court-house and eastward, which is 1,270 to 1,282 feet above the sea, and by an old water-course crossed 3 to 4 miles west of Brandon on the road to Kemnay, both of which are more fully noticed in the description of the Assiniboine delta.

North of the Assiniboine the highest shore of Lake Agassiz passes from Brandon east and east-northeast by Chater and Douglas, being on or close below the verge of the plateau of till, overspread by delta gravel and sand, which lies close north of the Canadian Pacific Railway. About a mile north of Douglas station this shore is marked by a dune hillock, nearly at the middle of the line between sections 10 and 11, township 11, range 17. Thence its course is north-northeastward, and is indicated by an eroded escarpment, extending 2 or 3 miles, with a height of 10 to 15 feet, and less distinctly observable a few miles beyond. The base of this escarpment where it crosses the south line of section 24 in this township is 1,269 feet above the sea; and the surface at the schoolhouse, a sixth of a mile farther west, is about 20 feet higher. All the area eastward is delta sand and gravel; but the escarpment and the country rising thence slowly north-westward are till. The continuation of this line between a moderately rolling surface of till on the west, with plentiful bowlders and frequent lakelets, and the slightly undulating sand and gravel delta on the east, with low dunes on many parts of its area, passes north-northeasterly in range 16 across the west half of township 12 and the east half of township 13, and thence north through the eastmost tier of sections in township 14, to Stony

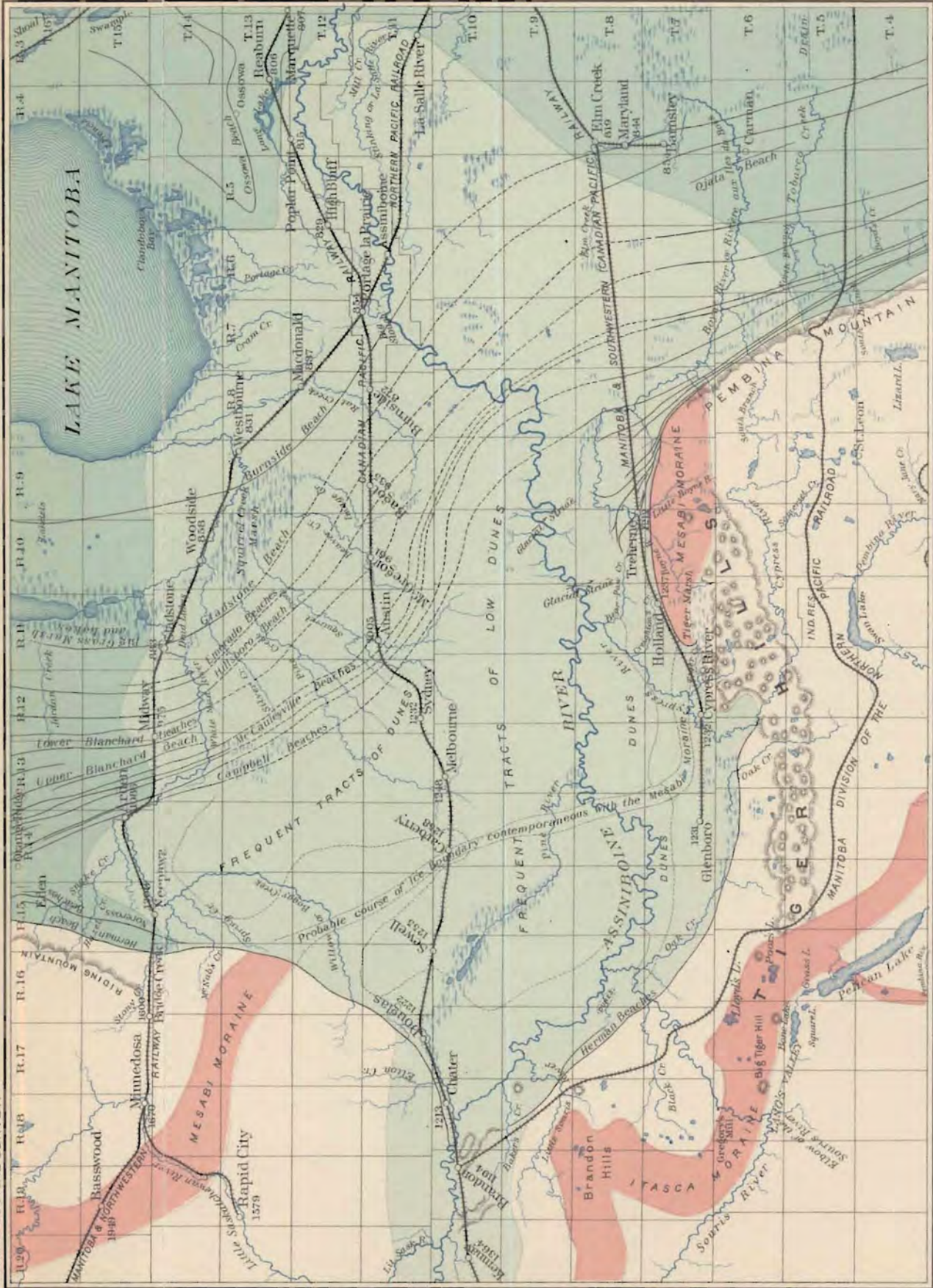
Creek. It evidently marks, at least approximately, the highest shore of the glacial lake; but it bears no distinct beach ridge nor line of erosion, partly because the lake was so shallow on the adjoining delta area, and partly because the prevailing trends of the inequalities in the till surface run nearly from east to west, transverse to the course of the shore currents and drift by which beaches would be formed, thus intercepting the scanty deposits of beach gravel and sand in their hollows, instead of permitting them to be accumulated in a distinct ridge.

The Manitoba and Northwestern Railway crosses two beach ridges at $3\frac{3}{4}$ miles and 3 miles west of Neepawa, the crests of which are respectively 1,323 and 1,304 feet above the sea. These elevations indicate that they belong to subdivisions of the second Herman stage, in the same manner that this stage is represented by three beach lines at Treherne. Each of these ridges has a height of about 7 feet above the adjoining surface and a width of 30 to 40 rods. They consist of sand and gravel, and the railway company has therefore purchased a considerable tract occupied by the lower one of them for its excavation and use as railway ballast. This lower beach probably marks the same lake level as the beach observed at Brandon, having there an elevation of 1,260 to 1,269 feet. Gravel and sand brought into Lake Agassiz by Stony Creek seem to have contributed to the conspicuous development of beach deposits here, while they are wanting or less distinct upon most of the shore southward to Brandon and also northward through the next 12 miles to where the Herman and Northcross shores pass into the steep escarpment that forms the eastern face of Riding Mountain.

DELTA OF THE ASSINIBOINE RIVER.

(PLATE XXXIII.)

At Brandon the Assiniboine enters the area of Lake Agassiz, and thence the gravel and sand delta of this tributary extends eastward 75 miles to Portage la Prairie, northeastward 50 miles to Gladstone, and east-southeastward 80 miles to Almasippi post-office, 9 miles west of Carman. On the northwest this delta is bordered by an expanse of moderately undulating or rolling till which rises slowly above the ancient lake level and



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MAP OF THE DELTA OF THE ASSINIBOINE RIVER.

Scale, 12 miles to an inch.

Lake Area
 Delta
 Moraines

Altitudes of Railway stations are noted in feet above the sea.

stretches northwestward from Brandon, Chater, and Douglas to the Little Saskatchewan and Oak rivers. From Brandon to Douglas the boundary of the delta is close north of the Assiniboine and the Canadian Pacific Railway; but at Douglas the line dividing the delta sand and gravel and the adjoining surface of till turns north-northeastward and extends about 20 miles in a nearly direct course toward Neepawa, then bends northward in the east part of townships 13 and 14, range 16, and crosses Stony Creek a few miles west of Neepawa. Between Brandon and the mouth of the Souris the delta reaches 3 or 4 miles southwest of the Assiniboine, being there also bordered by a smoothly undulating or rolling tract of till, but the morainic Brandon Hills rise prominently within a few miles farther west. From the Souris east to the Cypress, a distance of nearly 25 miles, the southern margin of the delta is similarly divided from the Tiger Hills by a belt of undulating and rolling till which averages about 5 miles in width. Farther to the east the delta deposits abut directly upon the northern base of these hills from the Cypress River, by Holland and Treherne, to the north end of the Pembina Mountain. Thence to the southeast the head streams of the Boyne, after their descent from the plateau of the Pembina Mountain, cross the southeastward extension of this delta to Almasippi. This portion, however, is not probably a part of the delta as it was at first deposited, but has been derived from the erosion of the eastern front of the original delta by the waves of the lake in its later and successively lower stages, being transported thence southward by shore currents. The same lacustrine action has doubtless extended the delta of gravel and sand generally 5 to 15 miles eastward beyond its original area, thereby giving its eastern face a more gradual slope. As thus enlarged its east boundary runs north from Almasippi to Portage la Prairie, curving eastward between these places, and thence it passes west-northwest to near Gladstone, Arden, and Neepawa. The eastern base of the delta, where it adjoins the flat expanse of the Red River Valley and the country bordering the lower Assiniboine and Lake Manitoba, has an elevation of 850 to 900 feet above the sea; while the high delta plateau, which was submerged only about 50 feet or less by the lake when it was being deposited, and was in part shoals and low islands, has an elevation of from 1,200 to 1,275 feet above the sea.

The western and southern limits of the plateau are those already noted, and on the east its boundary runs north and northwest from Treherne to Sydney and Neepawa. The area of the plateau is about 1,300 square miles, and the eastern slope adds to this fully two-thirds as much, making the total area of this delta somewhat more than 2,000 square miles.

The thickness of the Assiniboine delta is seldom shown by wells, which generally obtain a plentiful supply of water upon this area within moderate depths, ranging from 10 to 50 feet. In some localities, however, near the great valley that the Assiniboine has cut through the delta, the plane of saturation probably lies much deeper, and wells must be sunk 100 feet or more to obtain water. Better measures of the depth of these gravel and sand deposits are supplied by the valleys of the Assiniboine and other streams, which are eroded in their deeper portions 100 to 200 feet below the top of the delta plateau before reaching the underlying till. Deep ravines are especially numerous on the northern part of the delta, where many springs issue near the plane of junction between the porous gravel and sand beds and the till, giving rise to the Squirrel, Pine, and Silver creeks, which flow northeast to the White Mud River. The descent of 200 to 300 feet made within a few miles upon the eastern face of the delta is a further indication of its thickness, which reaches its maximum at the verge of the plateau. In the vicinity of the outcrop of Niobrara beds on the Assiniboine, in section 36, township 8, range 11, the thickness of the delta gravel and sand appears to be about 200 feet; and it probably ranges from 100 to 200 feet along the outer limit of the plateau through the greater part of its extent of more than 50 miles. The average thickness of this very extensive delta is probably between 50 and 75 feet. Computing its volume for an average of 50 feet on an area of 2,000 square miles, it is found to be about 20 cubic miles.

Fig. 16 presents a section crossing the central part of the Assiniboine delta, along the line of the Canadian Pacific Railway from Brandon to Portage la Prairie.

Fifty miles east-southeast from Brandon the highest portions of the surface of the delta south of the Assiniboine and east of the Cypress, where it has not been heaped in sand hills by the wind, are 1,225 to 1,240 feet

above the sea, the latter being its elevation in a broad swell near the center of section 24, township 8, range 11. Ten to 20 miles thence westward, between Cypress River and Glenboro, the elevation of the slightly undulating surface of the delta is mostly 1,235 to 1,245 feet, with frequent sloughs and permanent ponds, up to a quarter of a mile or more in extent, lying at 1,225 to 1,235 feet. These ponds abound near Glenboro and for 4 miles east. Along the Canadian Pacific Railway from Sydney westward, by Melbourne, Carberry, and Sewell, to Douglas, 20 to 25 miles north of the foregoing, the undulating delta ranges in elevation from 1,230 to 1,275 feet; and it holds the same height through 25 miles northward, to within 3 miles southeast of Neepawa. Adjoining the undulating and rolling area of till which borders this part of its area on the west, its expanse of gravel

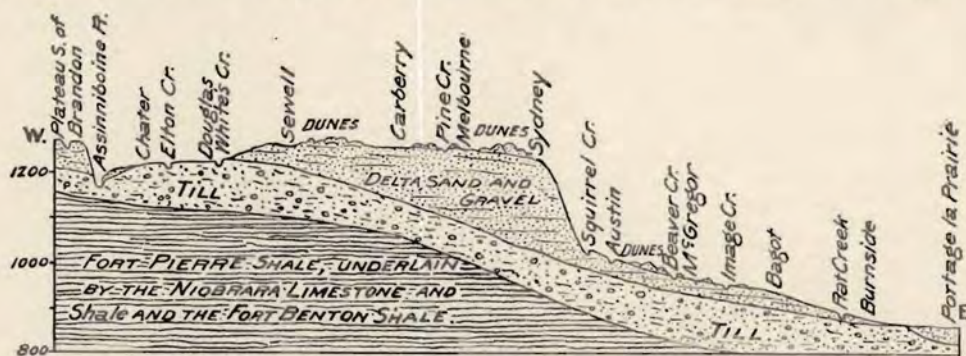


FIG. 16.—Section across the delta of the Assiniboine River. Horizontal scale, 15 miles to an inch.

and sand slowly rises northward from 1,265 and 1,270 feet 2 to 3 miles northeast of Douglas to 1,275 and 1,280 feet between Willow or Boggy and Spring creeks. These elevations represent the plateau before mentioned, which forms the greater part of this delta.

While the extensive area of this plateau, reaching 50 miles from east to west and nearly the same distance from north to south, is thus so uniform in its elevation that its deposition must be attributed to stages of the lake when its level was not much higher, probably those of the Herman beaches *b* and *bb* near Treherne and Neepawa, there is a considerable tract lying on both sides of the Assiniboine in the vicinity of Brandon and Kemnay upon which delta deposits closely associated with this plateau ascend from a few feet to 125 feet above it in a distance of 12 or 15 miles from east to

west. A mile north of Brandon the bluff on the north side of the Assiniboine rises about 140 feet above the river to 1,300 feet, approximately, above the sea. It consists of till to a height of 100 feet or more; but its crest and the surface thence northward for 5 miles are mostly undulating gravel and sand to a thickness of 10 to 20 feet, thinly covering the till, which forms the surface farther north. Eastward this bluff, eroded by the Assiniboine since the deposition of this stratified gravel and sand, extends along the north side of the railway by Chater and Douglas, having a height of about 75 and 50 feet, respectively, at these stations, but declining only slightly in the elevation of its crest, which is 1,275 to 1,290 feet. Delta gravel and sand, and on some portions fine silt, cover a width of 3 or 4 miles thence northward through the south half of townships 11 of ranges 18 and 17, having an elevation at their northern limit 1,300 to 1,290 feet above the sea, beyond which the surface, gradually ascending northward, is till. The most eastern point of this higher delta deposit is in section 14, township 11, range 17. Measured thence to its western limit on the north side of the Assiniboine, half way between Kemnay and Alexander, its length is 24 miles. Its width north and south of Brandon is about 12 miles. Through it the Assiniboine has eroded its valley, and has carried it away, cutting also into the underlying till, upon a large area from Brandon east to Chater and Douglas and thence south nearly to the Brandon Hills.

South of the river, at the court-house, in the southeast part of Brandon, very coarse gravel and sand of this higher part of the Assiniboine delta, containing waterworn cobbles up to 6 and 8 inches in diameter, form a plateau mostly 1,270 to 1,275 feet above the sea, but rising to 1,282 feet at a distance of 1 mile to the east. One and a half to 3 miles west of Brandon a similar plateau varies in height from 1,290 to 1,305 feet. Between these small plateaus or plains, which slope about 5 feet per mile to the east and were once continuous, a former watercourse, diminishing from a half to a quarter of a mile in width, passes southeast from the valley of the Assiniboine through the south part of Brandon and thence continues east nearly 3 miles, opening in section 7 or 8, township 10, range 18, upon the broad lower area eroded by the Assiniboine. The bed of this old channel is at

1,250 to 1,255 feet, and it appears to have been eroded at the time of the formation of the Herman beach *bb* in Brandon, when the level of Lake Agassiz was approximately at this height. Three to 4 miles west of Brandon the road to Kemnay crosses another watercourse of similar character, diminishing from $1\frac{1}{2}$ miles to a half mile in width within 2 miles from northwest to southeast, passing from the Assiniboine Valley to the head of Bakers or Stony Creek. Its bed, which is strewn with plentiful bowlders, showing that the erosion here extended through the stratified gravel and sand to till, is about 1,270 feet above the sea, and marks nearly the Herman *b* stage of Lake Agassiz, being about 30 and 40 feet, respectively, below the adjoining areas of delta gravel and sand on the east and west. In 3 miles westward to Kemnay this delta expanse rises 50 to 60 feet, and continues to ascend more slowly in the next $3\frac{1}{2}$ miles to 1,390 and 1,400 feet in sections 1, 12, and 13, township 10, range 21. Thence the surface for the next 6 miles westward, about Alexander, including nearly all of this township and the east edge of that next west, is till.

Many portions of the fine sand deposits of the Assiniboine delta have been channeled and piled by the wind in dunes from 10 to 75 feet high, mostly covered with bushes and a scanty growth of herbaceous plants, but in part destitute of vegetation, which is prevented from obtaining a foothold by the drifting of the sand. On the southeast part of this area these sand hills, seldom exceeding 30 or 40 feet in height, occur in sections 1 to 4, township 7, range 7, and are thence frequent northward upon a width of 10 miles northeast of the Boyne and southeast of the Assiniboine. On the north side of the Assiniboine the most eastern dunes extend to within 3 miles southwest of Portage la Prairie. Both these tracts lie on the lower part of the eastern slope of the delta, and thence westward dunes are found here and there over this entire slope. Even where no distinct hillocks and ridges have been formed, the surface is often channeled and ridged in hollows and elevations of a few feet, though now wholly grassed or covered with bushes or small poplar groves. Upon the delta plateau tracts of dunes, commonly raised 20 to 40 feet above the general level, interspersed with occasional smooth areas where the original surface remains undisturbed, extend on the south side of the Assiniboine from the Cypress to

the Souris, occupying a width that varies from 1 to 5 miles. Their southern limit is about 4 miles north of Holland, 3 miles north of Cypress River station, and 2 miles north of Glenboro. One to 4 miles west of the mouth of the Souris an isolated tract of dunes about 3 miles long from southeast to northwest is crossed by Spring Creek near its mouth. North of the Assiniboine much of its delta plateau is occupied by dunes, which extend north to the White Mud River. Their most northern area is a belt that reaches north of this stream through sections 12, 13, 24, and 25, township 15, range 15, to the junction of Hazel and Snake creeks. But the northwestern part of this plateau includes a belt of smooth and fertile land, several miles wide, extending from Carberry north and northwest to the limit of the delta. Also, from Douglas and Chater southeastward a belt of good agricultural land, free from dunes upon a width of 3 to 5 miles, reaches 15 miles along the northeast side of the Assiniboine. On the extreme western and highest part of this delta conspicuous sand hills rise 60 feet above the adjoining surface, with their crests about 1,445 feet above the sea, in sections 6 and 7, township 10, range 20, 2 to 3 miles southwest of Kemnay, and lower hillocks of wind-blown sand continue from these 2 miles to the southeast.

Within 6 miles from the dunes last noted, and from the boundary of this Assiniboine delta, after crossing a belt of till that reaches about 3 miles east and the same distance west from Alexander station, the Canadian Pacific Railway, thence west to Griswold, Oak Lake, and Virden, lies upon the delta which was brought into the Lake Souris by the Assiniboine. In townships 9 and 10, range 22, and township 9, range 23, including the vicinity of Griswold, this deposit consists of fine clayey silt and sand, having a moderately undulating or rolling surface, with broad, smooth swells elevated 10 to 30 feet above the depressions, their tops being 1,400 to 1,435 feet above the sea. Three to 7 miles southwest of Griswold this delta has been much channeled and uplifted by the wind in sand hills, which thence continue 10 miles southeast along the north side of Plum Creek to section 11, township 8, range 22, 4 miles west of Plum Creek village. The crests of these dunes are 1,420 to 1,430 feet above the sea, being 30 to 40 feet above the adjoining surface. Nearly all of them are now covered by grass and bushes.

The Assiniboine delta of Lake Souris has a length of about 85 miles, extending from the north end of this glacial lake south-southeasterly along the Assiniboine to its eastward bend and beyond to Plum Creek and the Souris River. Its width ranges from 5 to 25 miles, averaging about 12 miles. This delta is doubtless shallower than that of Lake Agassiz, but if its average thickness is 25 feet upon this area of 1,000 square miles, its volume is about 5 cubic miles.

An ancient watercourse, now occupied by a body of water called the Big Slough, 13 miles long and mostly 20 to 50 rods wide, but in its west part about three-fourths of a mile wide, extends from southwest to northeast 9 miles through this delta of Lake Souris and thence continues 4 miles east through an area of till. Its west end is 2 miles southwest of Griswold and its east end about a half mile east of Alexander, its whole extent being on the south side of the railway. Its elevation in the stages of low and high water ranges from 1,385 to 1,388 feet, and its depth at low water varies from 2 to 6 or 8 feet. The shores of the Big Slough rise in gentle slopes 15 to 20 feet in 20 to 30 rods, to the general level, not having the usual steepness of banks undermined by streams; yet it doubtless marks the course of a stream that outflowed at one time westward into Lake Souris from a small glacial lake north of the Brandon Hills, and of a later stream that flowed in the opposite direction, eastward from the basin of Lake Souris into the Brandon glacial lake, before that became merged in Lake Agassiz by the departure of the ice-sheet. The succession of events indicated by this channel, together with that of the present Souris and with the great glacial watercourse of Langs Valley, is as follows: Lake Souris outflowed eastward by Langs Valley, Pelican Lake, and the Pembina River until the receding ice formed a lake north of the Tiger Hills and east of the Brandon Hills, which, outflowing south to the Souris, cut a deep gorge through the Tiger Hills moraine, where the Souris now flows through it to the north. Similarly, north of the Brandon Hills, a lake was probably held by the barrier of the ice during its recession from Alexander east by Kemnay and Brandon, outflowing westward to the Lake Souris by the course of the Big Slough. As soon as the continued glacial recession left the Brandon Hills wholly uncovered from the ice, these lakes

on the east and north were merged in one, and the outflow from the lake so formed passed south through the Tiger Hills to Langs Valley until that channel was cut down nearly to 1,350 feet. During this stage of a continuous lake east and north of the Brandon Hills, this independent part of Lake Agassiz, before it was merged with the main body of this lake by the recession of the ice from the east end of the Tiger Hills, received an extensive delta, already described as the highest portion of the Assiniboine delta in the vicinity of Brandon and Kemnay, consisting partly of modified drift from the retreating ice and partly of fine sand and silt brought by a stream then flowing east from the Lake Souris delta along the Big Slough. The tribute of the latter is spread over an area of several square miles southwest of Kemnay, and upon it are raised the conspicuous dunes of sections 6 and 7, township 10, range 20. With the retreat of the ice northward from Treherne, the Brandon lake was lowered nearly 100 feet to the level of Lake Agassiz in its Herman *b* stage. For a short time the Souris probably continued to flow southeastward through Langs Valley until the deposition of the alluvium, perhaps 10 or 15 feet thick, brought into that valley by Dunlops Creek, 4 miles east of the elbow of the Souris, raised a barrier a few feet higher than the gap that had been cut through the Tiger Hills north of the elbow, whereby the river was turned through this gap, which it has since eroded 100 to 150 feet deeper.

The modified drift and alluvium that form the plain of coarse gravel and sand sloping eastward from Kemnay to Brandon and reach along the north side of the Assiniboine to Douglas were probably deposited mostly while the barrier of the waning ice-sheet stretched from the Tiger Hills to Riding Mountain, inclosing on its west side a lake that afterwards became the bay of Lake Agassiz covering the Assiniboine delta, but was then held about 100 feet above Lake Agassiz, to which it outflowed by the way of Langs Valley and the Pembina. The deposition of this highest part of the Assiniboine delta, lying above the Herman *bb* beach observed in Brandon, appears to have been in progress through a considerable period, beginning when this Brandon glacial lake was held at an elevation of about 1,400 feet, and continuing while it was lowered nearly 150 feet. During this time the Brandon Lake had three outlets: first, from its two parts, respec-

tively, westward by the Big Slough and southward across the Tiger Hills moraine; second, from the whole lake, when these parts became confluent, by the southward one of these outlets, namely, the gap where the Souris now flows through the Tiger Hills; and, third, by confluence with Lake Agassiz, when this was permitted by the recession of the ice. Much modified drift was probably brought into the Brandon Lake by drainage along the course of the Little Saskatchewan, and it is significant that in the line of continuation of the valley of that stream the plain between Kemnay and Brandon is crossed by a broad watercourse, which was evidently eroded after this lake became merged in Lake Agassiz, thereby falling nearly 100 feet below its former level when outflowing through Langs Valley, but before the Assiniboine had cut its broad valley through this delta. More exactly, as before noted, this watercourse seems referable to the Herman *b* stage of Lake Agassiz, and the similar watercourse about 20 feet lower, passing through the west and south parts of Brandon, was probably formed during the Herman *bb* stage. During these two stages of the lake the principal expanse of the Assiniboine delta was formed, lying only slightly below the levels which the lake then had.

At the time of formation of the Herman *bb* beach the Assiniboine had already eroded a deep and wide valley in its delta at Brandon, and as Lake Agassiz sank to successive lower levels this erosion continued, cutting at least the lower part of the great valley 200 to 300 feet deep, in which this river flows above Brandon, and wearing its channel to a nearly equal depth through its own delta. The Canadian Pacific Railway crosses the Assiniboine about 2 miles east of Brandon, near the division between the main area of its delta in Lake Agassiz and the deep portion of its upper valley. There the high land on each side of the river recedes, allowing the descent to the stream to be made by easy grades on each side and supplying upon the gradual slope south of the river the beautiful site of Brandon. No other point so favorable for this crossing exists within 60 miles to the east or west, where the river flows in a deeper and narrower valley. The greater part of this delta was modified drift derived from the melting ice-sheet on the upper part of the basin of the Assiniboine and on Riding Mountain, being carried down from the latter area by the Bird-

tail Creek and the Oak and Little Saskatchewan rivers (p. 190). It was deposited in this delta chiefly during the early Herman stages of the lake, as is indicated by the elevation of the outer part of its principal expanse; and its deposition continued until the ice-sheet was melted away on Riding Mountain and the upper Assiniboine. The erosion of the Assiniboine Valley above Brandon also supplied a considerable part of the delta. During the ensuing stages of Lake Agassiz, to those of Gladstone and Burnside, the border of this great delta was undergoing erosion by the lake waves and shore currents, by which its outer portion was spread in more gentle slopes, extending farther into the lake, and much of it was swept southward along the shore.

By this erosion of the sloping face of the delta, and especially by earlier transportation into the deep water of the lake while the gravel and sand were being deposited in its western embayment between the Tiger Hills and Riding Mountain, a large expanse of fine clayey sediment of the same origin with this delta was spread far into the lake, extending to the east beyond the Red River and to the south beyond the international boundary. This deposit of lacustrine silt covers the till from the eastern and southeastern limits of the delta, as before defined, to the low ridge first east of the Red River, about 10 miles east of Emerson, while similar sediments cover the central part of the Red River Valley southward to Goose Rapids, more than 100 miles east-southeast from this delta. Toward the north and northeast, lacustrine sediments and subsequent alluvial deposits associated with the Assiniboine delta cover the nearly flat country north from Burnside, Portage la Prairie, and High Bluff to Lake Manitoba. On this area the watershed between the Assiniboine and Lake Manitoba is very low, and the river has sometimes overflowed its low banks, sending part of its floods north to the lake, which in turn in its highest stages has occasionally become for a short time tributary to the lower part of this river. But the transportation of the silt in the lake was of less extent in this direction than to the east and south, as is shown by areas of till on both sides of the Big Grass Marsh, west of Lake Manitoba, and from townships 13 and 14, range 5, southeast of this lake, eastward to Shoal Lake, Stonewall, and Lower Fort Garry.

Five to 10 miles west of Portage la Prairie till with frequent boulders forms the surface, or is underlain only to the depth of a few feet by the sediments associated with this delta. Again, 10 miles farther west, the sandy eastern slope of the delta in the vicinity of McGregor shows very rarely projecting boulders, the size of the few noticed being from 2 to 6 feet in diameter. They probably lie on till that has been somewhat eroded by the lake waves, so that these boulders are not embedded in it as usual, while the sand and silt afterward spread there on the surface are not sufficiently thick to conceal them. No boulders were elsewhere seen on the general surface of the delta and of the great area of associated lacustrine silt, nor in any observed sections of these deposits.