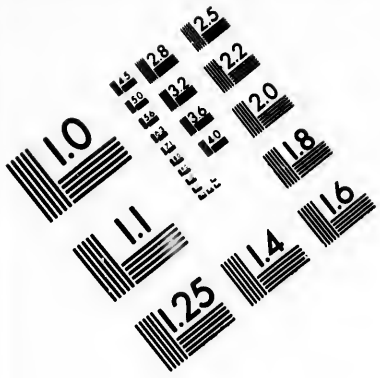

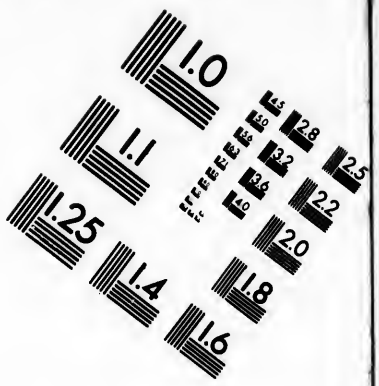

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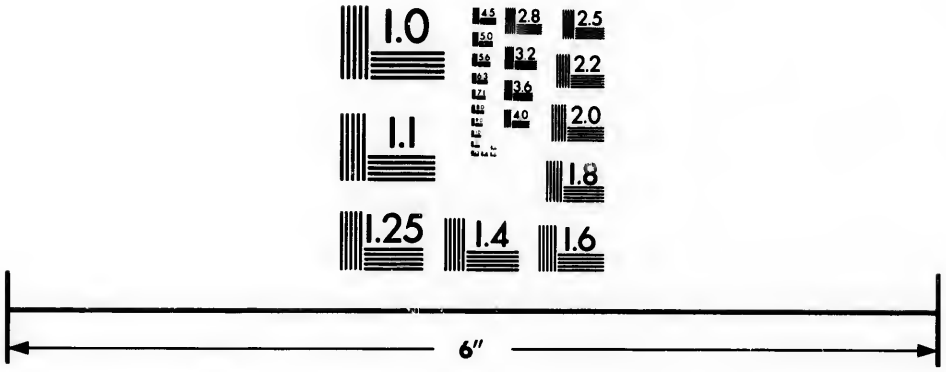

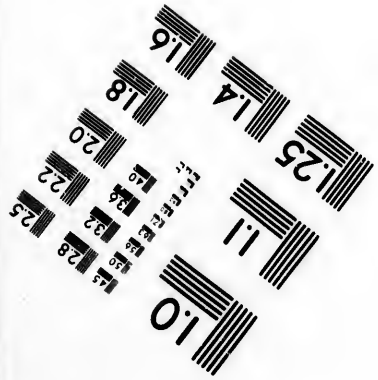

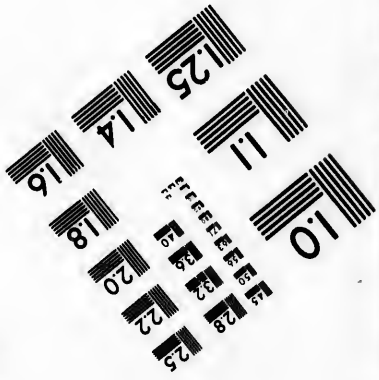

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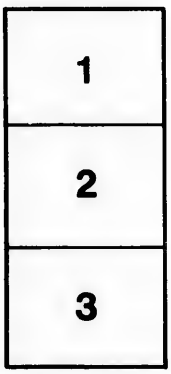

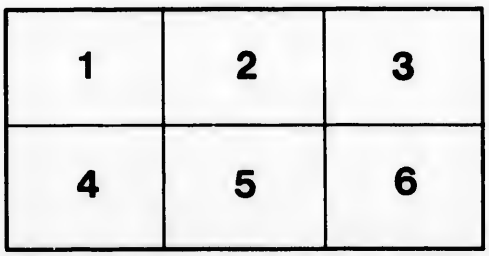

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GEOLOGICAL AND NATURAL HISTORY SURVEY OF CANADA.
ALFRED R. C. SELWYN, C.M.G., LL.D., F.R.S., DIRECTOR.

REPORT

OF EXPLORATION OF THE

GLACIAL LAKE AGASSIZ IN MANITOBA.

BY

WARREN UPHAM.

PUBLISHED BY AUTHORITY OF PARLIAMENT.

MONTREAL:
WILLIAM FOSTER BROWN & CO.
1890.

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Somerville, Mas

To A. R. C. Selwyn, C.M.G., LL.D., F.R.S.,

Director of the Geological and Natural History Survey of Canada.

Sir,—I herewith submit to you my report of observations on the area of the glacial Lake Agassiz in Manitoba. This exploration was performed in May, June and July, 1887, for the Geological Survey of Canada and for that of the United States, under which latter, in accordance with instructions from President T. C. Chamberlin in charge of the Glacial Division of that Survey, the southern portion of this lacustrine area, lying in Minnesota and North Dakota, had been examined by me during the two preceding summers. It was deemed very desirable to continue the exact mapping and levelling along its beaches northward into Manitoba for the purpose of making the final report on this subject for the United States Geological Survey as complete as possible; and arrangements providing for this were made by the Director of that Survey and yourself, enabling me to include within my examination all the prairie region that was occupied by Lake Agassiz.

Besides the prairie district thus examined, this glacial lake is believed to have included a much larger wooded region on the north and east, together with the present lakes Winnipeg, Manitoba, and Winnipegosis, its whole area being probably somewhat more than the combined areas of the five great Laurentian lakes. One of the two maps accompanying this report shows this probable extent of Lake Agassiz; and the other shows its portion examined in Manitoba, with the course of its beaches, marking the successive stages of the lake, and the Pembina and Assiniboine deltas.

Elevations determined by railway surveys have been taken as the basis of my levelling along the beaches. For opportunity to examine railway profiles and for manuscript notes of them, my grateful acknowledgments are due to Mr. P. A. Peterson of Montreal and Mr. R. M. Pratt of Winnipeg, engineers of the Canadian Pacific Railway, to Mr. George H. Webster of Portage la Prairie, engineer of the Manitoba and Northwestern Railway, to Mr. Collingwood Schreiber of Ottawa, in charge of government railways, and to Dr. George M. Dawson and Dr. Robert Bell, your associates in this survey.

I have the honor to be,

Sir,

Your obedient servant,

WARREN UPHAM.

Somerville, Mass., June, 1889.

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REPORT

OF EXPLORATION OF THE

GLACIAL LAKE AGASSIZ IN MANITOBA.

INTRODUCTION.

Among the most important geologic records of the Quaternary period in America are the sediments and shore lines of former lakes of great extent, which are now represented by lakes that occupy, excepting within the basin of the Saint Lawrence, only a small part of their ancient area. Lake Bonneville in the basin of Great Salt Lake, Utah, and Lake Lahontan in the basin of the Humboldt River and Pyramid Lake, Nevada, are conspicuous examples of one class of these Quaternary lakes, formed by increased rain-fall where now an arid climate limits the lakes to small areas, with their surface far below the water-sheds across which they would outflow to the sea. These are south of the glaciated area of the continent, but they appear to have owed their existence to the changes of climate by which the supposed ice-sheets of the glacial epochs were formed. Lake Agassiz, which occupied the basin of the Red River of the North and Lake Winnipeg, belongs to another class of these lakes, caused directly by the supposed barrier of the ice-sheet where this was accumulated on a northwardly sloping land surface. Such glacial lakes were developed on a vast scale in the basins of Lake Winnipeg and the Laurentian lakes during the recession of the ice-border, when it was being gradually melted away by a warmer climate; and it is also evident that many small lakes of the same kind then flowed southward over the lowest points of the present water-sheds. Examples of this class now existing are the little Merjelen See, pent up in a tributary valley on the east side of the Great Aletsch glacier in the Alps, and similar ice-dammed lakelets in Greenland.

Two classes of Quaternary lakes.

On the western boundary of Minnesota a remarkable valley is eroded in the glacial drift to the depth of 125 to 150 feet with a width of about one mile and a half, extending from north to south across the lowest

Channel of outlet from Lake Agassiz.

part of the water-shed that divides the basin of the Red River of the North from that of the Mississippi. This channel has been evidently the course of a great river since the drift was deposited. After the river ceased to flow here, portions of the bottom of the valley have become filled to the slight depths of ten or twenty feet by alluvial beds brought in by tributary streams, and the intervening portions of the old valley are occupied by the long, narrow and shallow Lakes Traverse and Big Stone, the former outflowing northward by the Bois des Sioux to the Red River, and the latter southward by the Minnesota River to the Mississippi. The general level of the land on each side of this water-course is about 1,100 feet above the sea; the heights of Lakes Traverse and Big Stone are respectively 971 and 963 feet above the sea; and the lowest point of the divide between them, in Brown's Valley, is only three feet above Lake Traverse. A valley of similar size extends all along the course of the Minnesota River; but toward the north the broad water-course, with the adjoining highland on each side, ends within a few miles.

The country north of Lake Traverse sinks gradually to a level not much above the small Bois des Sioux River, which flows north 35 miles, emptying into the Red River of the North at Breckenridge and Wahpeton. The Red River, here turning abruptly from its western course, flows thence north to Lake Winnipeg, 285 miles. These streams occupy

The Red River Valley.

the axial depression of a vast plain of glacial drift and lacustrine and fluvial deposits, forty to fifty miles wide and more than 300 miles long, stretching from Lake Traverse to Lake Winnipeg. This expanse, widely famed for the large harvests and superior quality of its wheat, is commonly called the Red River Valley. It has a very uniform continuous descent northward, averaging a little less than one foot per mile. So slight an inclination is imperceptible to the eye, as is also the more considerable ascent, usually two or three feet per mile, for the first ten or fifteen miles to the east and west from the Red River. This river flows along the lowest portion of the plain, somewhat east of its central line, in a quite direct general course from south to north, but meanders almost everywhere with minor bends which carry it alternately a half mile or one mile to each side of its main course. It has cut a channel twenty to fifty feet deep and is bordered by only few and narrow areas of bottomland, instead of which its banks usually rise steeply on one side and by moderate slopes on the other, to the lacustrine plain which thence reaches nearly level ten to thirty miles from the river.

Where the surface rises on each side of this expanse, definite and continuous beach deposits are found marking the shore lines of a vast lake which formerly covered the Red River Valley and by its outflow

eroded the deep channel extending thence southward as already described. This lake is believed by the writer to have owed its existence to glacial conditions during the final melting and gradual recession of an ice-sheet which overspread the northern half of North America. When this continental glacier, subdued by a more temperate climate, was yielding its ground between Lake Traverse and Hudson Bay, free drainage from its south side could not take place, because the descent of the land is northward. As soon as the border of the ice had receded beyond the water-shed dividing the basins of the Minnesota and Red Rivers, it is evident that a lake, fed by the glacial melting, stood at the foot of the ice fields and extended northward as they withdrew along the Red River Valley to Lake Winnipeg, filling this valley to the height of the lowest point over which an outlet could be found. Until the ice barrier was so far melted upon the area between Lake Winnipeg and Hudson Bay that this glacial lake began to be discharged northward, its outlet was along the present course of the Minnesota River. Because of its relation to the retreating continental ice-sheet, this lake has been named in memory of Professor Louis Agassiz, the first prominent advocate of the theory that the drift was produced by land ice.[1] Within the past fifteen years the truth of this explanation of the drift has been demonstrated by the recognition and detailed study of the morainic deposits that were accumulated along the southern boundary of the ice-sheet, extending from Nantucket, Martha's Vineyard, Cape Cod, and Long Island, across New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa, and South and North Dakota. The characters of other drift deposits, as the till and the kames and eskers, also the glacial striæ, point with equal certainty to a vast sheet of land ice as their cause; and the explanation accounts for this lake in the Red River Valley, for similar lakes that were tributary to it from the basins of the Souris and South Saskatchewan Rivers, and for the contemporaneous higher levels of the great lakes now discharged by the River St. Lawrence.

Lake Agassiz caused by the receding ice-sheet.

The evidences of the former existence of a great lake in the Red River Valley were observed in 1823 by Keating, the geologist of the first scientific expedition to this district,[2] in 1848 by Owen,[3] in 1857 by Palliser,[4] in 1858 by Hind,[5] and in 1873 by Dr. G. M. Dawson.[6] The

Earlier observers.

[1] Geological and Natural History Survey of Minnesota, Eighth annual report, for the year 1879, pp. 81, 85.

[2] Narrative of an Expedition to the source of St. Peter's River, Lake Winnepeek, Lake of the Woods, &c., performed in the year 1823, ... under the command of Stephen H. Long, U. S. Topographical Engineer. London, 1825. Vol. ii, p. 3.

[3] Report of a Geological Survey of Wisconsin, Iowa, and Minnesota. Philadelphia, 1852. p. 178.

[4] Journals, detailed reports, &c., presented to Parliament, 19th May, 1863, p. 41.

[5] Report of the Assiniboine and Saskatchewan Exploring Expedition. Toronto, 1859. pp. 39, 166, 168.

[6] Report on the Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel, from the Lake of the Woods to the Rocky Mountains. Montreal, 1875. p. 248.

excavation of the valley occupied by Lakes Traverse and Big Stone and the Minnesota river was first explained in 1868 by Gen. G. K. Warren, who attributed it to the outflow from this ancient lake. He made a careful survey of this valley, and his maps and descriptions, with the accompanying discussion of geologic questions, are most valuable contributions to science.[1] After his death, in commemoration of this work, the glacial river that was the outlet of Lake Agassiz was named River Warren.[2] That this lake existed because of the barrier of the receding ice-sheet was first pointed out in 1872 by Prof. N. H. Winchell.

Previous work in the United States.

The part of the area of Lake Agassiz which lies in Minnesota, so far as it is prairie, was explored by the writer in 1879 and 1881, under the direction of Prof. N. H. Winchell, State Geologist, with the assistance in 1881 of Horace V. Winchell as rod-man in levelling.[3] Further exploration of this lake was carried forward in 1885 and 1886 for the United States Geological Survey by the writer, under the direction of Pres. T. C. Chamberlin, with Robert H. Young as assistant, mapping the upper or Herman beaches in North Dakota from Lake Traverse to the international boundary, besides portions of the lower shore lines both in North Dakota and Minnesota, with exact determinations of their elevation by levelling. A preliminary report of part of these observations was published in 1887.[4]

Continuation in Manitoba.

By co-operation of the Geological Surveys of the United States and Canada, a portion of my field-work in 1887 was devoted to the examination of the northward extension of the beaches of Lake Agassiz in Manitoba. Travelling with horse and wagon, and assisted by Mr. Young as in the two preceding years, a somewhat detailed exploration of this lacustrine area was continued about a hundred miles north from the international boundary, the most northern points reached being

[1] "On certain physical features of the Upper Mississippi River," American Naturalist, vol. pp. 497-502, November, 1868. Annual Report of the Chief of Engineers, United States Army, 1868, pp. 307-314. "An essay concerning important physical features exhibited in the valley the Minnesota River, and upon their signification," with maps, Report of Chief of Engineers 1873. "Valley of the Minnesota River and of the Mississippi River to the junction of the two Its origin considered—depth of the bed rock," with maps, Report of Chief of Engineers, 18 and American Journal of Science, III, vol. xvi, pp. 417-431, December, 1878. (General Warren died August 8, 1882.)

[2] Proceedings of the American Association for the Advancement of Science, vol. xxxii, 1883, pp. 213-231; also in American Journal of Science, III, vol. xxvii, Jan. and Feb., 1884; and Geology of Minnesota, vol. i, p. 622.

[3] First Annual Report of the Geological and Natural History Survey of Minnesota, for 1872, p. 63; and Sixth Annual Report, for 1877, p. 31. Professor Winchell also explained in the manner the formerly higher levels of the Laurentian lakes, Popular Science Monthly, June, 1873; and the same view is stated by Prof. J. S. Newberry in the Report of the Geological Survey of Ohio, vol. ii, 1874, pp. 6, 8, and 51.

[4] Geological and Natural History Survey of Minnesota, Eighth Annual Report, for 1879, pp. 87; Eleventh Annual Report, for 1882, pp. 137-153, with map; and Final Report, vols. i and ii.

[5] United States Geological Survey, Bulletin No. 39. The Upper Beaches and Deltas of the Glacial Lake Agassiz. pp. 84, with map.

Shoal Lake, between Lakes Winnipeg and Manitoba, and Orange Ridge post-office, near the southeast end of Riding Mountain. The wooded character of the country further north makes continuous levelling and tracing the beaches of this lake impracticable; and the same condition limited my examination on the east to a narrow belt adjoining the Red River. The western border of this portion of Lake Agassiz is formed by the Pembina Mountain, the Tiger Hills, the Brandon Hills, and Riding Mountain; and the mouth of the Assiniboine was at Brandon during the highest stage of the lake. In this direction my observations were extended west of the shore line of Lake Agassiz to include the vicinity of the Assiniboine and the Canadian Pacific Railway to Griswold, the course of the Souris River below Plum Creek, Lang's Valley, a glacial water-course extending from the Elbow of the Souris southeast to Pelican Lake and the Pembina River, and the lower course of that river, by which a large delta was deposited in the west margin of Lake Agassiz a few miles south of the international boundary. The breadth of the country thus traversed from east to west is about a hundred and fifty miles.

The upper or Herman beach of Lake Agassiz was traced and its height determined in Minnesota by continuous levelling from Lake Traverse east to Herman and thence north to Maple Lake, twenty miles east-southeast of Crookston, a total distance of about 175 miles, including an extent of 140 miles from south to north. Through North Dakota this shore was thus followed continuously along the west side of the Red River Valley about 250 miles, extending northwesterly from Lake Traverse to the vicinity of Wyndmere, Milnor, and Sheldon, and thence in a nearly direct course slightly west of north to the international boundary. Profiles of the numerous railway lines crossing this district supplied reliable elevations above the sea level at their stations; and in many instances they also show distinctly their intersections of the beaches of this lake. These elevations were taken as the data and reference points of my levelling, which was proved throughout its entire extent to be accurate within close approximation by its agreement with the railway surveys, the comparisons being made at intervals varying from twenty to forty or fifty miles apart. The same methods were employed in this survey in Manitoba, where the profiles of the Canadian Pacific Railway and its branches and of the Manitoba & Northwestern Railway, kindly supplied for my examination by the engineers of these roads, were similarly the basis of my determinations of the elevations of the beaches. All these heights, as stated in this report and in the annexed notes of railway profiles, are referred to the sea level at mean tide; and the close agreements of several independent surveys from the sea to this district and of the profiles of the many

Methods of survey.

Reference of elevations to the sea level.

intersecting lines of railway in Minnesota, South and North Dakota and Manitoba, give complete assurance that these heights are not only consistent together but also absolutely true within limits of error probably nowhere exceeding five feet. Such exact determinations of the elevations of the beaches of this lake seem very important because these deposits which were formed along the level shores of the lake in its successive stages are found at the present time to have a gradual ascent from south to north, amounting to about a foot per mile in the highest and oldest beach and gradually diminishing to a quarter or even an eighth part of this amount in the lowest and latest of the beaches. The general topographic features of the region traversed, the character of the drift deposits, its underlying geologic formations, and numerous records of the sections passed through by wells, were also noted.

Plan of this report.

In this report are successively presented a brief description of the topography of the basin of Lake Agassiz, an account of the drift formations in Manitoba, and the history of this glacial lake in its relationship to the recession of the ice-sheet as shown by terminal moraines. The beaches and delta deposits of Lake Agassiz observed in Manitoba are described in detail, including their changes of levels from the time of the highest and earliest to that of the lowest and latest beaches. Next follow notes of wells, and remarks on the soil, the agricultural capabilities of the district, and its economic geology. Finally, in Appendices I and II the courses of glacial striæ in and about the area of Lake Agassiz, and tables of altitudes in Manitoba, Assiniboia and Alberta, are given.

Accompanying maps.

A map showing the whole extent of Lake Agassiz and for comparison with it the upper great lakes that outflow by the Saint Lawrence, and another map showing the beaches of this lake in Manitoba and its deltas brought in by the Assiniboine and Pembina Rivers, accompany this report. The courses of glacial striæ and the terminal moraines of the ice-sheet are noted on each. It should be remarked, however, respecting the first of these maps, that the northern and northeastern boundaries of this glacial lake probably can never be exactly determined, and must be laid down in any attempt of this kind, by estimation; for they were formed by the receding ice-sheet instead of a land surface on which beaches would be discoverable. During the formation of its highest continuous and well marked beach, this lake extended north in Minnesota at least to Maple Lake, and in Manitoba to Thorhill. The continued recession of the ice-sheet during the time of formation of the sixteen beaches made at lower levels while the lake outflowed southward probably caused it to attain nearly the area shown on this map before it began to be discharged into Hudson Bay. Afterward,

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eleven beaches were formed while the lake stood nearly stationary at various stages, interrupting the further descent of its surface to its present representative, Lake Winnipeg, its northward outflow having passed during a considerable time along the southern border of the waning ice-sheet before it was melted from the present course of the Nelson River. The lacustrine area therefore was not wholly covered by water at any one time; for when the lake reached its maximum extent on the north and northeast, it had receded below that portion of its earlier area which lies above the beaches marking its stages tributary to Hudson Bay.

TOPOGRAPHY OF THE BASIN OF LAKE AGASSIZ.

Area of Lake Agassiz.

The area that was covered by Lake Agassiz occupies the geographic center of the North American continent. Its extent is approximately from 45° 30′ to 55° of north latitude, and from 92° 30′ to 100° at Brandon, and to 106° on the Saskatchewan, of west longitude. It thus measures from south to north, and likewise from east to west, nearly seven hundred miles, or about twice the length of Lake Superior. The central and deepest portion of Lake Agassiz covered the broad, flat expanse of the Red River Valley and of the lake region farther north; and in its highest stage it reached on the international boundary from Rainy Lake to the Pembina Mountain. It was separated from Lake Superior, Lake Nipigon, and James Bay by a moderately undulating or in part hilly plateau, which rises 300 to 500 feet above the highest shore of Lake Agassiz and holds nearly this elevation southward to its termination in the highlands bordering Lake Superior, but from which toward the east and northeast a gradual slope descends to the sea level of James and Hudson Bays. On the west this glacial lake washed the base of the great range of highlands named in its successive portions from south to north the Coteau des Prairies, Pembina Mountain, Riding and Duck Mountains, and the Porcupine Mountain, and Pasquia Hills; and on the northwest it extended beyond the fork of the South and North Saskatchewan. Northward it reached beyond Lake Winnipeg and covered the upper part of the course of the Nelson. When finally the receding ice-sheet gave place for this river, the glacial lake, no longer ice-dammed, was reduced to Lake Winnipeg.

Comparison with the areas of the Laurentian lakes and the lakes of Manitoba.

Measured on the accompanying map, the probable area of Lake Agassiz is about 110,000 square miles. It thus exceeded the total area of the five great lakes, namely, Superior, 31,200 square miles; Michigan, 22,450; Huron, with Georgian Bay, 23,800; Erie, 9,960; and Ontario, 7,240; amounting together to 94,650 square miles.[1] The

[1] According to measurements on the U. S. Lake Survey charts, as stated in "Physical characteristics of the Northern and Northwestern Lakes," by L. Y. Schermerhorn, Am. Jour. Science, III, vol. xxxiii, p. 279, April, 1887.

areas of the three great lakes of Manitoba, remaining where shallow depressions prevented the complete drainage of Lake Agassiz, are approximately as follows: Lake Winnipeg, 8,500 square miles; and Lakes Manitoba and Winnipegosis, each 2,000 square miles.

Depth of Lake Agassiz.

At the time of the formation of its highest beach the depth of Lake Agassiz above Fargo and Moorhead was nearly 200 feet; above Grand Forks and Crookston, a little more than 300 feet; above Pembina, Saint Vincent, and Emerson, on the international boundary, about 450 feet; and above Lakes Manitoba and Winnipeg, respectively about 500 and 600 feet. The northward ascent of the beaches of this glacial lake as compared with the level of the present time, and its successive stages during its fall to Lake Winnipeg, will be considered in a later part of this report.

Shore Lines, Deltas, and Dunes.

Beach ridges.

Viewed in their relation to the general topography, the shore lines of Lake Agassiz are inconspicuous, though they are very distinctly traceable. They are usually marked by a deposit of beach gravel and sand, forming a continuous, smoothly rounded ridge, such as is found along the shores of the ocean or of our great lakes wherever the land sinks in a gently descending slope beneath the water-level. The beaches of Lake Agassiz commonly rise three to ten feet above the adjoining land on the side that was away from the lake, and ten to twenty feet above the adjoining land on the side where the lake lay. In breadth these beach ridges vary from ten to twenty-five or thirty rods. In some places they have been cut through and carried away by streams, and occasionally they are interrupted for a quarter or a half of a mile or even two or three miles, where the outline of the lake shore and the direction of the shore currents prevented such accumulation.

Another type of shore lines is developed where the lake has formed a terrace in the till, with no definite beach deposit, the work of the waves having been to erode and carry away rather than to accumulate. The height of these steep, wave-cut slopes varies from ten to thirty feet, which is indeed a very slight elevation in comparison with the cliffs of till of similar origin on some parts of the shores of Lake Michigan and others of the Laurentain lakes. No portions of the beach ridges nor of these low eroded escarpments, marking the margin of

Eroded shores.

Lake Agassiz, are noteworthy objects in the view from points so far away as two or three miles; but nearer at hand they appear sufficiently impressive, when the mind reverts to the receding ice-sheet and this great glacial lake by which they were made.

Delta deposits of sand and gravel, so extensive as to be important features in the topography, were formed in the edge of Lake Agassiz

by several of its tributary streams. Such deltas were brought into the east side of the lake by the Buffalo and Sand Hill Rivers; and into the west side by the Sheyenne, Pembina, and Assiniboine Rivers. The Pembina formed a delta that reaches twelve miles from north to south and has a maximum width of seven miles. The "First Pembina Mountain," which rises very conspicuously near Walhalla, North Dakota, a few miles south of the international boundary, as a steep wooded escarpment about 175 feet above the flat prairie of the Red River Valley at its base, with its crest 1,150 to 1,200 feet above the sea, is the eroded front of this Pembina delta. The sand and gravel beds brought into Lake Agassiz by the Sheyenne River reach fifty miles from northwest to southeast, and their maximum width is nearly thirty miles. But the largest of all these deltas is that of the Assiniboine in Manitoba, which extends from Brandon seventy-five miles east to Portage la Prairie, and from Treherne, Glenboro and Milford forty miles north to Gladstone and Neepawa. Its area is fully 2,000 square miles, and its depth probably averages 50 feet, with a maximum of about 200 feet. Deltas.

Extensive tracts of the deltas formed by the Sand Hill, Sheyenne, and Assiniboine Rivers have been heaped up by the wind in dunes, or drifting sand hills, which vary in height from twenty-five to one hundred feet. Their extremely uneven contour, and their singular aspect, being partly covered by small trees and bushes but in many places wholly destitute of vegetation where they are now gullied and drifted by the wind, make these hills a unique element in the topography of the Red River basin. The worthlessness of the dunes for agriculture is also in marked contrast with the fertility of the surrounding prairie, but they frequently include patches of good pasturage in the intervening hollows. The time of formation of these dunes was probably soon after the withdrawal of Lake Agassiz, before vegetation had spread over the surface. The winds could then erode more rapidly than now, and heaped up these hills of sand in nearly their present size and height; but it is evident also that their forms have been constantly undergoing slight changes since that time. Dunes.

Country adjoining Lake Agassiz.

East from the flat prairie of the Red River Valley is the undulating and in part rolling and hilly wooded region of northern Minnesota and eastern Manitoba. Through this district the outline of Lake Agassiz is mapped approximately. It extends farthest east on the international boundary, where it reaches beyond Rainy Lake. The general level of the country adjoining Rainy Lake and the Lake of the Woods is 50 to Wooded region of eastern Manitoba.

150 feet below the highest stage of Lake Agassiz; but the northern and eastern part of this district may have been still covered by the waning ice-sheet when the lake stood at that height. On account of the impracticability of tracing the shores of Lake Agassiz through this wooded and uninhabited region, the northeastern limits of this glacial lake, where the shore in its successive stages passed from the land surface to the barrier of the receding ice-sheet, remain undetermined.

Plain sloping from Lake Winnipeg to Hudson Bay, described by Dr. Bell.

The country north and northeast of Lake Winnipeg presents no considerable elevations, but is mainly a broad, nearly flat expanse, similar to the Red River Valley and the lake district of Manitoba, slowly declining to the sea level. Dr. Robert Bell writes of it as follows:—"The region through which the upper two thirds of the Nelson River flows may be described as a tolerably even Laurentian plain, sloping towards the sea at the rate of about two feet in the mile. The river, for the first hundred miles from Great Playgreen Lake, does not flow in a valley, but spreads itself by many channels over a considerable breadth of country. This tendency to give off 'stray' channels is characteristic of numerous rivers throughout the northern and comparatively level Laurentian regions, but it is perhaps more strongly marked in the Nelson than in any other. In the above section of this stream the straggling channels are of all sizes, from mere brooks up to large rivers. . . . The general aspect of the country is even, or slightly undulating, the highest points seldom rising more than thirty or forty feet above the general level." The country adjoining the lower part of this river, according to the same explorer, has a similar contour, only moderately uneven; but the channel of the river, excepting in the ten miles next to its mouth, is deeply eroded. Its enclosing bluffs vary in height from one hundred to two hundred feet between Broad Rapid, where the river is approximately 125 feet above the sea, and Gillam's or Lower Seal Island, which is at the head of the tide, about twenty miles from Hudson Bay.[1]

Ascent westward from Lake Agassiz.

Along the west side of the basin of the Minnesota River, of the Red River Valley, and of Lakes Manitoba and Winnipegosis, the surface rises from two or three hundred to one thousand feet above their slightly undulating or quite flat belt of lowland. No other feature in the contour of the Northwestern States and adjoining British territory is more noteworthy, extended and prominent, than this, excepting perhaps the ascent along the similar and parallel Coteau du Missouri. The latter, however, lacks the accompaniment of such a continuous broad depression beside it. This wide valley, occupied by Lakes Winnipeg, Manitoba and others, and by the Red and Minnesota Rivers,

[1] Geological Survey, Reports of Progress for 1877 to 1879.

varying in elevation from 710 to 1,100 feet above the sea, is the base of the slowly ascending expanse of the great plains which rise thence westward to a height somewhat exceeding 4,000 feet above sea level at the foot of the Rocky Mountains on the international boundary. Most of this elevation is attained by a gradual slope, averaging four or five feet per mile throughout the distance of 730 miles from the Red River to the Rocky Mountains; but at two lines, extending approximately from south to north, first on the west side of this valley, and again in the Coteau du Missouri, 100 to 200 miles farther west, the surface rises more rapidly several hundred feet within a few miles by a terrace-like ascent. The first was the western shore of Lake Agassiz, and continuing south and southeast held the same relation to an earlier glacial lake which occupied the basin of the Minnesota and Blue Earth Rivers.

The southern portion of this line of elevation is the massive and high Coteau des Prairies of southwestern Minnesota and the east part of South Dakota. Its lower continuation from the Head of the Coteau des Prairies, west of Lake Traverse, for the next one hundred and seventy-five miles northward, bears no name, and is scarcely more conspicuous, or in some parts even less so, than the moderate ascent that forms the opposite border of the Red River Valley in Minnesota. Farther north this line of higher land rises abruptly 300 to 500 feet in Pembina Mountain, and from 500 to 1,030 feet in Riding and Duck Mountains and the Porcupine and Pasquia Hills. All of these are successive parts of a very remarkable terrace-like escarpment, stretching from North Dakota, by the west side of Lakes Manitoba and Winnipegosis to the Saskatchewan River. Its portions thus differently named are divided by deep and broad valleys eroded by intersecting streams. Coteau des Prairies, and highland continuing thence north.

Pembina Mountain is a distinct and conspicuous topographic feature for a distance of about seventy-five miles, of which two thirds lie north of the international boundary. Its southern end is in the southwest part of T. 158, R. 56, in Walsh county, North Dakota, between the South and Middle branches of Park River; and its northern end is about six miles east-southeast from Treherne, where the course of this highland turns to the west and its more uneven continuation takes the name Tiger Hills. It is a prominent, wooded escarpment, mostly 300 to 400 feet high, extending in a very direct course from south to north or a few degrees west of north. The width occupied by its slope varies from a half of a mile to two or three miles, and from its crest the plateau, having a moderately rolling surface, stretches nearly level or with slow ascent westward. Its crest north of the international boundary averages about 400 feet above its base, or 1,400 feet above Pembina Mountain.

the sea; but within a few miles further west the rolling surface of the highland rises 100 to 200 feet higher.

Assiniboine Valley.

Northwestward from Treherne the plateau of which Pembina Mountain forms the eastern edge, is interrupted across a distance of sixty-five miles, to Riding Mountain. This broad depression is occupied by the Assiniboine and its tributaries, and by small streams on the northeast which send their waters to Lake Manitoba. The plateau, indeed, loses its regularity of surface upon all the country farther north and west, because it has been eroded to the depth of several hundred feet on the greater part of the basin of the Assiniboine.

Tiger Hills.

The border of the plateau south of this river, reaching from close south of Treherne westerly fifty miles to the Elbow of the Souris River, is called the Tiger Hills.[1] It is irregularly sculptured in steep, rounded, massive hills, and is overspread by drift deposits consisting partly of morainic accumulations. For a distance of forty miles west from the Pembina Mountain this belt occupies a width of five to eight miles, upon which the surface falls from south to north 300 to 400 feet. The country on the south has an average elevation nearly the same as the summits of the hills, which yet rise very prominently as seen from the lower region on the north. The western part of the Tiger Hills, extending ten or twelve miles east and an equal distance west from the gorge that is cut through the range by the Souris, rises considerably above the adjoining nearly flat surface on each side. The foot of the belt of hills there is 100 to 150 feet lower on the north than on the south; and the Souris flows through it in a gorge 350 feet deep. From this vicinity Hind applied the name Blue Hills of the Souris to this belt, but that name is not used by the people of the district.

Riding and Duck Mountains.

North of the Assiniboine the eastern outline of the continuation of this plateau is preserved in the prominent elevations of Riding and Duck Mountains, two remarkable wooded highlands, much alike in their general features and extent. The steep eastern escarpment of each is about fifty miles long, that of Riding Mountain trending from southeast to northwest, and that of Duck Mountain having a course a few degrees west of north. These elevations rise above the country adjoining the Assiniboine by a somewhat gradual slope, but they are abruptly cut off on their northeast side by a precipitous descent. This takes place on a line approximately parallel with Lakes Manitoba and Winnipegosis, the former of these lakes being about forty miles east of Riding Mountain, while the south end of the latter is twenty-five miles east of Duck Mountain. The crests of these highlands, according to Mr. J. B. Tyrrell's measurements, are respectively about 2,000 and

[1] From the aboriginal name, which doubtless refers to the cougar or American Panther (Felis concolor, L.).

2,300 to 2,700 feet above the sea, the latter being the highest land in Manitoba; and the bases of their escarpments are about 1,200 to 1,500 feet above the sea, being four hundred to seven hundred feet above the lakes on the east, whose height slightly exceeds 800 feet.

The reader is referred to Mr. Tyrrell's maps and descriptions of the district of Riding and Duck Mountains, to be published in the annual reports of this Survey, for details of its topography and geology and of the shore lines of Lake Agassiz north of the limit of my exploration. Maps and reports of Mr. Tyrrell.

Beyond Duck Mountain, after an interruption of about thirty miles across the basins of Swan and Woody Rivers, this line of highlands is continued in the Porcupine Mountain or Hills, which reach about twenty-five miles from south to north. These form a somewhat broken plateau, similar with the preceding in its general features of steep acclivity on the east and gentle descent westward. On their north side another gap about twenty miles wide is occupied by the Red Deer and Overflowing Rivers. Porcupine Hills.

Next are the Pasquia Hills, whose eastern end is in line with Pembina, Riding and Duck Mountains, and the Porcupine Hills, being about a hundred miles west from the mouth of the Saskatchewan. The Pasquia Hills extend thence a hundred and fifty miles westward, where they formed the southern shore of the northwestern arm of Lake Agassiz, lying about twenty-five miles south of the Saskatchewan River and parallel with it, to the Birch Hills and the South Saskatchewan River. They are the northern escarpment limiting the irregularly eroded country which is here considered as an extension of the great plateau of North Dakota and southern Manitoba and Assiniboia, thus holding the same relation to the valley of the Saskatchewan that the Tiger Hills sustain to the Assiniboine Valley. Pasquia Hills.

Existing Lakes within the area of Lake Agassiz.

The glacial Lake Agassiz was gradually reduced in size, first by the erosion and lowering of its southward outlet, and afterward by finding successively lower outlets to the northeast, until with the complete departure of the ice-sheet it sank to its present representatives, the great lakes of Manitoba. These are three in number, Lakes Winnipeg, Manitoba, and Winnipegosis. With them are associated several others, comparatively small, as Cedar Lake, through which the Saskatchewan flows near its mouth, Lake Dauphin, south of Lake Winnipegosis and tributary to it, and Lake Saint Martin on the Fairford or Little Saskatchewan River, the outlet of Lakes Manitoba and Winnipegosis. The great lakes of Manitoba.

Lake Winnipeg is two hundred and fifty miles long, trending from south-southeast to north-northwest. The maximum width of its southern

part is about twenty-five miles, and of its northern part sixty miles. Its area is approximately 8,500 square miles, being intermediate in extent between Lakes Ontario and [illegible]. Eighty-five miles from its south end, Lake Winnipeg is reduced [illegible] strait two to four miles wide, which extends northwesterly two [illegible] miles, terminating at the cape called Dog's Head. The narrowest part of the strait, scarcely exceeding a mile in width, is at this cape. Here the strait opens into the northern and main portion of the lake, which includes five-sixths of its area. The elevation of Lake Winnipeg, determined by the surveys for the Canadian Pacific Railway, is 710 feet above the sea. Its depth, according to Mr. J. Hoyes Panton, nowhere exceeds sixty-five feet. "The shallowness of this comparatively large body of water," as Mr. Panton writes, "accounts for its treacherous nature and explains how on many occasions it has proved a disastrous water-way to the freighting boats of by-gone days. As you sit upon the deck of the steamer threading its way among the islands, you are surprised at the tortuous course made, when water seems on every side and no shore near. So shallow is the lake that many places miles from land are not covered with more than six or seven feet of water. It is only safe to experienced captains, thoroughly acquainted with the concealed channels that afford a safe course at a distance from the shore."[1] On account of this slight depth, the mud brought in by the Red River is held in suspension, being almost constantly stirred up from the bottom by the waves of the lake, throughout its southern half; but in the broad northern half of its length, beyond Beren's River and Island, the water is comparatively clear.[2] Low land borders this lake along nearly its whole extent, and the highest points on the shore or visible from it rarely attain an elevation of fifty feet.

Lake Winnipeg.

Lake Manitoba,[3] from which comes the name of the province of Manitoba, lies about forty miles west of the south half of Lake Winnipeg; and Lake Winnipegosis,[4] separated only about two miles from the north end of Lake Manitoba, lies mostly forty to fifty miles west of the north half of Lake Winnipeg, but its most northeast part is only twenty miles southwest from that lake. The length of each of these lakes

Lakes Manitoba and Winnipegosis.

[1] "Notes on the Geology of some islands in Lake Winnipeg," Transactions of the Historical and Scientific Society of Manitoba, Jan. 28, 1886.

[2] "Lake Winnipeg receives its name from the muddy or sallow appearance of its waters. [illegible] signifies muddy, and *Nope* water, in Chippewa."—Keating's Narrative of Long's Expedition, vol. ii, p. 77.

[3] Meaning the "Narrows or Strait of the Manitou or Great Spirit," as I am informed by letters from Prof. George Bryce and Mr. J. B. Tyrrell. This name was originally pronounced by white inhabitants, nearly as by the Indians, with accents on the initial and final syllables; but [illegible] the past ten years or more its almost universal pronunciation in English has been with only the accent, which is laid on the next to the last syllable.

[4] Meaning "Little Winnipeg."—Hind's Narative of the Canadian Exploring Expedition, vol. ii, p. 42.

measured in a straight line, is about a hundred and twenty miles, trending in parallelism with Lake Winnipeg; and each of them covers an area of nearly 2,000 square miles. Both are shallow in proportion to their size, and are surrounded by low shores. The maximum width of Lake Manitoba, about twenty-eight miles, is at its south end. Near its middle, it is narrowed to a strait about half a mile wide and two miles long. Its northern part is of quite irregular form, and is nearly intersected from the north by a long peninsula. This lake, according to levelling by Mr. H. S. Treherne, is 809 feet above the sea, being thus almost exactly a hundred feet higher than Lake Winnipeg. The country between these lakes and from Lake Manitoba west to Lake Dauphin and to Riding and Duck Mountains is low and approximately level, but has a general westward ascent, averaging a few feet per mile. The width of Lake Winnipegosis varies from five to fifteen miles. Its northern portion is bent to the west, so that its length, following this curve, is nearly a hundred and fifty miles. Its outlines, moreover, are very irregular, presenting a constantly varying succession of bays, capes, and islands. This lake outflows by the Water Hen Lake and River to Lake Manitoba, and has an elevation of nineteen feet above the latter, as determined by surveys for the Canadian Pacific Railway, or 828 feet above the sea.

Rainy Lake and the Lake of the Woods, on the international boundary, are bodies of water of considerable size, lying within the eastern part of the area of Lake Agassiz. The length of Rainy Lake is nearly fifty miles, trending from east-southeast to west-northwest, and its average width is about five miles, giving it an area of 250 square miles, approximately. It is much diversified by projecting points, numerous bays and narrow arms, and plentiful islands. Its height above the sea is about 1,117 feet; and its maximum depth, according to soundings by Dr. A. C. Lawson, is a hundred and ten feet. Rainy Lake.

The Lake of the Woods has a very irregular form, nearly surrounding a large peninsula in its northern part, and including many bays on the north and east, some of them connected with the main lake only by narrow channels. A multitude of islands, large and small, dot its surface, excepting in its southwest part, called Sand Hill Lake, where it adjoins Minnesota. Measured from north to south or from east to west, its maximum extent in either direction is sixty miles, approximately; and its area is about 1,500 square miles. Its elevation, determined by the Canadian Pacific Railway survey, is 1,060 feet above the sea; and the maximum depth of its northern part, called Clear Water Lake, is stated by Dr. Dawson to be eighty-four feet. Lake of the Woods.

Rivers tributary to Lake Agassiz and draining its area.

Present drainage of the area of Lake Agassiz.

The area of Lake Agassiz is drained to Lake Winnipeg, chiefly by the Winnipeg, Red, and Little Saskatchewan or Fairford Rivers. On the northwest this glacial lake also included the region crossed by the lower part of the Saskatchewan. Flowing out from Lake Winnipeg, the united waters of all these river systems are carried by the Nelson to Hudson Bay.

It seems probable that the recession of the ice-sheet uncovered the entire course of the Rainy and Winnipeg Rivers before Lake Agassiz had fallen below the level of Rainy Lake. These are upper and lower portions of the main trunk of the same river system. East of Rainy Lake a large tract tributary to it reaches nearly a hundred miles on the international boundary, including almost countless lakes and small streams. The Rainy River, about eighty miles long, connecting Rainy Lake and the Lake of the Woods, is a broad and majestic, deep stream, with an average width of a sixth of a mile, flowing in general in a somewhat direct west-northwest course. At the mouth of Rainy Lake

Rainy River.

it has rapids that fall about three feet. Its principal falls are at Fort Francis, a little more than two miles from Rainy Lake, where it descends twenty-three feet in about a tenth of a mile. Manitou Rapids, about thirty-five miles from Rainy Lake, are a short descent of about two feet, with outcropping rock in the channel and banks. Six miles below these is the Long Sault, a mile in length, estimated by Major Long to have "an aggregate descent of about ten feet." Excepting these rapids, Rainy River has an average descent of only about three inches per mile, giving to the ordinary low stage of water a very gentle current. It is navigable for large steamboats from the Lake of the Woods to the foot of the Long Sault; and thence to Rainy Lake it is navigated by a tug or propeller, towing Mackinaw boats. The banks of the river are only ten to twenty feet high, and are fertile and heavily wooded, having commonly a clayey soil.

Winnipeg River.

Winnipeg River, the outlet of the Lake of the Woods, has a length of about a hundred and sixty miles, flowing in a winding course to the northwest. Its total descent is 350 feet, four-fifths of this being in the many falls and rapids which occur along nearly its entire extent. These falls are divided by portions with only a strong or gentle current, or by lake-like expansions of the river where no current is perceptible. On each side the country rises to a moderate elevation in low hills and ridges, with frequent outcrops of the bed-rocks. The highest land crossed by the Canadian Pacific Railway south of the Winnipeg River, from eighteen to twenty-eight miles west of Rat Portage, is about 200 feet above the Lake of the Woods and about 5

feet above Lake Winnipeg, rising thus nearly to the highest level of Lake Agassiz. English River, which flows through Lac Seul or Lonely Lake, is a large tributary of the Winnipeg from the east. The only important affluent from the south is the Whitemouth, draining a considerable area west of the Lake of the Woods. The water of Winnipeg River is very clear, and is strongly contrasted with the muddy water of Lake Winnipeg with which it mingles at its mouth.

The Red River of the North, so named to distinguish it from the Red River of Louisiana, has its source in a small lake about 1,600 feet above the sea, thirteen miles west of Lake Itasca. It first flows south about sixty miles, measured in a direct line, passing through Elbow, Many Point, Round, Height of Land, Little Pine, Pine, and Rush Lakes, to Otter Tail Lake, this portion being commonly called Otter Tail River. In this distance it descends to 1,315 feet above the sea. The contour of the adjoining country is rolling or hilly northward and undulating or flat southward. Below Otter Tail Lake this stream is called the Red River by this report, following the example of Owen and the prevailing popular usage; but it is still occasionally spoken of as Otter Tail River to its junction with the Bois des Sioux, forty-two miles west of Otter Tail Lake. The descent in this distance is 372 feet, or about five feet per mile, following the course of the stream. Because of the numerous large lakes on the upper part of its course, its volume along this descent to Breckenridge is not greatly affected by either heavy rains and snow-melting or dry seasons. From its bend at Breckenridge and Wahpeton the Red River flows north 285 miles, measured in a direct line, to Lake Winnipeg. The entire length of the Red River, measured thus in straight lines successively to the south, west, and north, is about 390 miles; but in its meanderings, nowhere diverging far from these lines, it flows nearly seven hundred miles. Its descent below Breckenridge is 233 feet, and in total from its source to its mouth approximately 900 feet. All the way below McCauleyville and Fort Abercrombie, fifteen miles north of Breckenridge, it is navigated by steamboats, barges, and flat-boats; but along the Goose Rapids, extending about twelve miles next below the mouth of Goose River as measured in the meandering course of the stream, the channel is obstructed by boulders which forbid navigation during low stages of water. The width of this river in the United States varies from six to twenty rods, being in some places less than the length of the steamboats; but north of the international boundary it is commonly twenty rods wide. The range between its lowest and highest stages increases rapidly north of Breckenridge, becoming thirty-two feet at Moorhead and Fargo, and attaining its maximum of fifty feet at Belmont. It continues nearly at forty feet from Grand

Red River of the North.

Length, and descent.

Navigation.

Forks to the international boundary and to Winnipeg. At Lower Fort Garry, sixteen miles north of Winnipeg and about twenty miles from the mouth of the river, it is thirty-five feet; but beyond that point it rapidly diminishes in approaching Lake Winnipeg. Floods rising nearly or quite to the high water line thus noted have been rare, occurring in 1826, 1852, 1860, 1861, and 1882. They are caused in the spring by the melting of unusual supplies of snow and by accompanying heavy rains, and often are increased by gorges of ice. These floods attain a height only a few feet below the level of the adjoining prairie where that is highest, and along the greater part of the distance between Grand Forks and Lower Fort Garry the banks are overflowed and the flat land on each side of the river to a distance of two to four or five miles from it is covered with water one to five feet or more in depth.

Higher floods.

Excepting the Red Lake River and the Sheyenne, Pembina, and Assiniboine, all the tributaries of the Red River are small, the length of their areas of drainage varying from forty to seventy-five miles. In summer droughts several of them, including the Bois des Sioux, are dried up along the greater part of their course, containing only here and there pools in the deeper hollows of their channels.

Tributaries of Red River.

Sheyenne River, having its sources near the great southeastern bend of the Souris River in North Dakota, first flows to the east nearly a hundred miles, passing ten miles south of Devil's Lake; next it flows south about a hundred miles, to where it enters the area of Lake Agassiz; and thence its course is eastward and northward, uniting with the Red River ten miles north of Fargo and Moorhead. The large valley of the upper part of this river, and its extensive delta deposited in Lake Agassiz, are probably attributable to a stream much larger than the present Sheyenne, formed by drainage from the ice-sheet when it terminated near Devil's Lake. At that time, also, a glacial lake in the basin of the Souris outflowed southeastward to the Sheyenne and James Rivers.

Sheyenne River.

During a later stage in the recession of the ice-sheet, this glacial lake in the Souris basin was extended west and north of Turtle Mountain and finally found a lower outlet in southern Manitoba. Its outflowing river ran southeasterly from the Elbow of the Souris, eighteen miles southwest of its mouth, to the Pembina River. Pelican Lake, eleven miles long from northwest to southeast and about a mile wide, occupies a part of the channel of this stream; and a distinct watercourse of similar width, called Lang's Valley,[1] eroded 110 to 150 feet below the general level, extends eleven miles between this lake and

Lang's Valley.

[1] Named for James Lang, who was the first immigrant here, coming in 1880.

the Souris. The highest portion of Lang's Valley is 1,364 feet above the sea and about 100 feet above the Souris at its Elbow, and it is enclosed by bluffs 110 feet high. It is a channel similar to that of Lakes Traverse and Big Stone and Brown's Valley, eroded by the River Warren outflowing from Lake Agassiz.

Pembina River[1] flows from the northern part of Turtle Mountain in a rather crooked easterly course through southern Manitoba and the edge of North Dakota about one hundred and thirty miles, measured in a direct line, to its mouth at Pembina and Saint Vincent. From its junction with the outlet of Pelican Lake to Walhalla at the base of the First Pembina Mountain, its valley varies from 175 to 450 feet in depth. Rock Lake and Swan Lake on this part of the river, each several miles long and from a half mile to one mile wide, are due to deposits brought into this valley by tributaries after it ceased to be the avenue of drainage from the Souris basin. In crossing the Red River Valley the Pembina runs in a channel only twenty to forty feet deep. Its descent from the northern base of Turtle Mountain to Walhalla is about 700 feet, and thence to its mouth 186 feet, its junction with the Red River being 748 feet above the sea. Long or White Mud River, Clearwater or Cypress River, and Tongue River, are its chief tributaries, all from the south side. Pembina River.

The Assiniboine, the largest tributary of the Red River, drains a basin three hundred miles wide from south to north and four hundred miles long from west to east. From its sources, fifty miles southwest of the Porcupine Hills, the Assiniboine flows south-southeasterly two hundred miles, to a point about fifty miles below the mouth of the Qu'Appelle and forty miles west of Brandon; thence it flows easterly about a hundred and fifty miles to its mouth. Its height above sea level at the mouth of the Qu'Appelle is 1,264 feet; at the bridge of the Canadian Pacific Railway near Brandon, 1,161 feet; at the mouth of the Souris, about 1,100 feet; at Portage la Prairie, 842 feet; and at its junction with the Red River in Winnipeg, 724 feet. During its high stages of water, the Assiniboine has been navigated by steamboats to Fort Ellice at the mouth of the Qu'Appelle. Along this portion it varies from ten to twenty-five rods in width. Assiniboine River.

The highest floods of the Assiniboine at Portage la Prairie and along a considerable distance eastward rise only twelve to fifteen feet above its lowest stage, but they then attain a height only a few feet below the highest portions of the adjoining country, much of which is submerged. At this extreme height, which the river reached and main- Overflow from the Assiniboine to Lake Manitoba.

[1] This name is stated by Keating to be from the Ojibway word "*onipeminan*, which name has been shortened and corrupted into Pembina," meaning the fruit of the bush cranberry (Viburnum Opulus, L.).—Narrative of Long's Expedition, vol. ii, p. 58.

tained from the 3rd to the 15th of May, 1882, the only time of such high water since 1860 or 1861, it overflowed near the former site of the fort of the Hudson's Bay Company two miles southwest of Portage la Prairie, and a portion of its flood passed north in shallow, winding water-courses to Lake Manitoba, making a descent of about forty feet in the distance of fifteen miles between the river and the lake. Near the same time Lake Manitoba also reached its highest stage, about eight feet above its lowest level, rising until it overflowed southward across the east part of T. 13, R. 6, and thence eastward through the southern row of sections in T. 13, R. 5, falling ten feet in fifteen miles to Long Lake, through which old channel of the Assiniboine its waters were discharged into this river twenty miles east of Portage la Prairie.[1]

Overflow from Lake Manitoba to Long Lake and the Assiniboine.

Qu'Appelle or Calling River and the Souris or Mouse River are the largest tributaries of the Assiniboine. Each of these streams has an interesting glacial history, which is recorded in the topographic features of their valleys and areas of drainage. The Qu'Appelle valley was the outlet of a glacial lake in the basin of the South Saskatchewan. The description, map and sections given by Hind,[2] show that this valley is quite uniformly about one mile wide, and is from 110 to 350 feet below the general level of the region through which it lies, this height being reached by steep bluffs on each side. Its length, from the Elbow of the South Saskatchewan to its junction with the Assiniboine is about two hundred and seventy miles, the general course being a little to the south of east. Of this extent the west end of the valley for about twelve miles is occupied by the River that Turns, and the remainder by the Qu'Appelle, the summit or height of land in this channel at the divide between these rivers being approximately 85 feet above the South Saskatchewan, 440 feet above the mouth of the Qu'Appelle, and 1,700 feet above the sea. The enclosing bluffs are composed mainly of glacial drift, with only a few exposures of the underlying Cretaceous rocks. The alluvial bottomland of the Qu'Appelle is generally from a half mile to one mile wide, and through it the river flows in a winding course, here and there passing through long lakes. Like the similar lakes of the Pembina and Minnesota Rivers, these owe their existence to the recent deposits of tributaries, and show that the bed of the glacial river was considerably lower than that of the present stream. The outflow of the Saskatchewan glacial lake, fed by the melting ice-fields of an immense area reaching west to

Qu'Appelle Valley, the outlet of the Saskatchewan glacial lake.

[1] Compare H. S. Treherne's description of this vicinity, "An ancient outlet of Lake Manitoba," Ninth Annual Report of the Geological and Natural History Survey of Minnesota (for the year 1880), pp. 388-392.

[2] Report of the Assiniboine and Saskatchewan Exploring Expedition, Toronto, 1859, by Henry Youle Hind.

the Rocky Mountains, took its course east by this trough-like channel or valley, entering the Assiniboine at Fort Ellice and reaching the border of Lake Agassiz at Brandon.

Long or Last Mountain Lake, about fifty miles long from south to north and one or two miles wide, lying north of the upper part of the Qu'Appelle and tributary to it, occupies a similar glacial water-course. The elevation of Long Lake is 1,598 feet, being about a hundred feet lower than the divide in the channel from the Elbow of the South Saskatchewan to the Qu'Appelle. It seems probable that when the ice-sheet had receded so far north as to allow the Saskatchewan lake to extend to the district northwest and north of Long Lake, it there obtained some lower point of discharge and outflowed along the course of this lake, forsaking its former outlet.[1] Owing to the changes in relati elevation which have taken place in the region of Lake Agassiz since that time, this new outlet, or the earliest and highest one of several successive outlets, across the water-shed between the Saskatchewan basin and Long Lake may now be found fifty or perhaps even a hundred feet higher than the old channel to the head of the Qu'Appelle, that is, 1,750 or 1,800 feet above the sea, the possible difference being probably as much as a foot to each mile of the distance between the old and new outlets.

Long Lake, probably the later glacial outlet from the Saskatchewan basin.

Souris River, flowing circuitously southwestward from Assiniboia into North Dakota and thence northeastward into Manitoba, became tributary to the Assiniboine after the waters of the glacial lake in its own basin, at first flowing to the James and Sheyenne, had been wholly drained away by its outlet through Lang's Valley and the Pembina River. The length of the Souris is nearly four hundred miles, but it is only five to ten rods wide along its lower portion. In North Dakota its descent is approximately from 1,650 to 1,400 feet above the sea, and thence to its mouth it falls about three hundred feet.

Souris River

Little Saskatchewan or Fairford River drains an area that extends more than two hundred miles west from Lake Winnipeg and includes an equal distance in latitude, from the most northern part of Lake Winnipegosis to the south end of Lake Manitoba. The latter lake receives several small streams at its south end; and the Water Hen River, the outlet of Lake Winnipegosis, flows into its north end. Four considerable streams are tributary to Lake Winnipegosis, namely, the Mossy River, the outlet of Lake Dauphin, flowing into its south end, and the Swan, Red Deer, and Overflowing Rivers at its northwest end. Riding and Duck Mountains form the southwestern boundary of

Little Saskatchewan River.

[1] Report of the Assiniboine and Saskatchewan Exploring Expedition, 1859, pp. 28 and 35.

this basin; but the Porcupine Hills are entirely enclosed between the Swan and Red Deer Rivers, and the latter drains much of the plateau bordered by the Pasquia Hills.

The lower part of the basin of the Saskatchewan, next to its mouth, was latest occupied by the ice-sheet; but that area was relinquished by it, allowing this great river to take its present course, long before Lake Agassiz began to be drained northward. From the most western sources of the Saskatchewan in the Rocky Mountains to its mouth is a distance of more than seven hundred miles; and the maximum width of its basin is about three hundred and fifty miles. Its two branches, of nearly equal size, the North and South Saskatchewan Rivers, unite two hundred and thirty miles west of Lake Winnipeg. The elevation of the South Saskatchewan at Medicine Hat, where it is crossed by the Canadian Pacific Railway, is 2,137 feet; at its Elbow, 1,619 feet, approximately; and at its junction with the North Saskatchewan about 1,200 feet. Cedar and Cross Lakes, through which the Saskatchewan flows near its mouth, are approximately 114 and 108 feet above Lake Winnipeg, or 824 and 818 feet above the sea. Hind informs us that the name Saskatchewan means "the river that runs swiftly;" and he states that in the Grand Rapids, between Cross Lake and its mouth, it falls forty-three feet in two and a half miles.[1] Its average descent per mile from Medicine Hat eastward is about two feet. The Saskatchewan and both its North and South branches for several hundred miles above their junction vary commonly from a sixth to a third of a mile in width, and during favorable stages of water are navigable by steamboats from Cedar Lake to the Rocky Mountain House on the North Saskatchewan, about 3,000 feet above the sea, and beyond the confluence of the Bow and Belly Rivers, which form the South Saskatchewan, fifty miles west of Medicine Hat, at an elevation exceeding 2,200 feet. The chief hindrances to their navigation in low stages are shifting sand-bars, over which they expand in some places to widths of a half mile to one mile, being very shallow and divided by low sandy islands. The adjoining country rises within a few miles from these rivers, or at the farthest ten or twenty miles, to an elevation three hundred to six hundred feet or more above them, excepting along the last hundred miles of the Saskatchewan, where it flows through a broad lowland region. There the highest parts of the country are only fifty to a hundred feet above the river, and its shores are generally low and in many portions swampy.

Saskatchewan River.

Grand Rapids.

Navigation.

Adjoining country.

Besides the great tributaries of Lake Winnipeg, namely, the Winnipeg, Red, Little Saskatchewan and Saskatchewan Rivers, about a dozen

[1] Report of the Assiniboine and Saskatchewan Exploring Expedition, 1859.

streams varying in length from ten to forty miles enter its west side, and twenty or more of similar or somewhat greater length enter its east side. Of the latter the largest are Beren's and Poplar Rivers, each about a hundred miles long. The recession of the ice-sheet from southwest to northeast uncovered the entire region west of Lake Winnipeg, and probably the whole of the country traversed by these streams on the east, before its melting finally permitted the waters of the glacial Lake Aga-siz to be drained to the level of this lake. Smaller tributaries of Lake Winnipeg.

The Nelson, as before noted, is bordered by no areas of highland along its course of about four hundred miles from Lake Winnipeg to Hudson Bay. The upper half of this river flows in a general direction only a few degrees east of north, passing through Great and Little Playgreen, Pipestone, Cross and Sipi-wesk Lakes, to Split Lake; thence it turns to the east for about a hundred miles, passing through Gull Lake; and finally takes a northeastward course along its lower one hundred miles. According to Dr. Bell's observations, Sipi-wesk Lake is approximately 570 feet above the sea, or a hundred and forty feet below Lake Winnipeg; Split and Gull Lakes are respectively about 440 and 420 feet above the sea; and the descent in the next forty-eight miles, to the foot of Broad Rapid, is nearly three hundred feet. The Nelson is navigable from the sea about ninety miles to the First Limestone Rapid, where the elevation is probably about fifty feet above the sea level. Nelson River.

About four fifths of the area drained by the Nelson, including the basins of the Red River of the North, the Little Saskatchewan and the Saskatchewan, and the greater part or possibly all of the basin of the Rainy and Winnipeg river system, were uncovered from the ice-sheet and were tributary to Lake Agassiz while it still had its southward outlet. The waters of a large part of British America were thus carried along the course of the Minnesota and the Mississippi to the Gulf of Mexico. The basin of Lake Agassiz then included approximately 350,000 square miles, of which nearly a third was covered by the lake itself. In the later stages of this glacial lake, when it flowed northeastward by outlets higher than the Nelson, its basin probably extended north beyond the present water-shed of Lake Winnipeg and the Nelson to include the upper portion of the basins of the Churchill and the Mackenzie, the lower course of these rivers being obstructed by the waning ice-sheet. It seems probable that with this addition the area of the glacial lake basin was not less than 500,000 square miles. Area of the basin of Lake Agassiz.

DRIFT FORMATIONS IN MANITOBA.

Thickness of the drift in Manitoba.

The thickness of the sheet of superficial deposits overlying the bed-rock in West Selkirk is 65 feet; in Winnipeg and Saint Boniface it varies from 30 to 80 feet; near Niverville it is from 65 to 100 feet; in Dominion City, near Letellier, and on the Low farm west of Morris, it is at least 170 to 250 feet, and in West Lynne at least 108 feet; at Rosenfeld it is 143 feet; near Carman it is about 100 feet; and seven miles west of Portage la Prairie, 158 feet. From these records it seems probable that the thickness of these deposits upon the flat plain of the Red River Valley in Manitoba averages about a hundred feet, considerably exceeding this, to a maximum of 150 to 250 feet, along the central part of this area south of the Assiniboine, but not probably averaging more than 50 feet in the lower part of the valley between Winnipeg and Lake Winnipeg, where the higher portions of the bed-rock rise to the surface. On the Archæan area of the east part of Lake Agassiz plentiful rock-outcrops occur about Rainy Lake and the Lake of the Woods, westward along the Canadian Pacific Railway nearly to the Whitemouth River, and in the country east of Lake Winnipeg; and it is probable that the average thickness of the superficial deposits in that extensive district is not more than 30 to 50 feet. West of Lake Agassiz, many portions of the plateau bordered by the Pembina Mountain and the Tiger Hills have only a small depth of drift, ranging from a few feet to 20 or 30 feet, but in some places the drift appears to extend deeper, as shown by stream valleys, and its average thickness may be 40 feet or more.

Distribution of the till.

Till, also called boulder-clay, constitutes the greater part of the entire sheet of superficial deposits, both within the area of Lake Agassiz and upon the adjoining country. It usually lies on the striated bed-rock, and upon large areas it reaches thence upward to the surface; but elsewhere this unmodified glacial drift is covered by modified drift, the stratified gravel, sand and clay deposited by streams which flowed down from the ice-sheet during its melting, or by lacustrine and fluvial sediments. Fully half of the area of Lake Agassiz in Minnesota and North Dakota has a surface of till; but in the part of this lake area examined in Manitoba its proportion is less, because much of this district is covered by the Assiniboine delta and its associated lacustrine beds. Extensive tracts of till, however, occupy the surface on the north and east portions of this area, as north of Neepawa, on the east side of the Big Grass Marsh, from the south end of Lake Manitoba eastward by Shoal Lake nearly to the Red River and Winnipeg and south to the Canadian Pacific Railway, from East Selkirk eastward along this railway, and ten miles east of Emerson, where the flat plain

Tracts of till forming the surface within the area of Lake Agassiz.

of the Red River Valley is bordered by slightly higher land. Till also forms the surface of the terrace along the foot of the Pembina Mountain escarpment between the international boundary and Thornhill. Beneath the delta deposits of gravel and sand, and on the central portion of the flat plain of the Red River Valley, where the surface is commonly fine silt or clay, a sheet of till lies between these sediments and the bed-rock.

Characters of the till.

The till is the direct deposit of the ice-sheet, as is shown by its consisting of clay, sand, gravel, and boulders, mingled indiscriminately in an unstratified mass, without assortment or transportation by water. Very finely pulverized rock, forming a stiff, compact, unctuous clay, is its principal ingredient, whether at great depths or near the surface. It has a dark bluish gray color, except in its upper portion, which is yellowish to a depth that varies from five to fifty feet, but is most commonly between fifteen and thirty feet. This difference in color is due to the influence of air and water upon the iron contained in this deposit, changing it in the upper part of the till from protoxide combinations to hydrous sesquioxide. Another important difference in the till is that its upper portion is commonly softer and easily dug, while below there is a sudden change to a hard and compact deposit, which must be picked and is far more expensive in excavating. The probable cause of this difference in hardness was the pressure of the vast weight of the ice-sheet upon the lower and older till, while the upper till was contained in the ice and dropped loosely at its melting. Upon each side of Lake Agassiz the till has a moderately undulating and rolling surface. Within the area that was covered by this lake it has a much smoother and more even contour, and its upper portion, owing to its manner of deposition in this body of water, sometimes shows an imperfect stratification, with a scantier intermixture of boulders and gravel. Yet even where it has distinct lamination, it usually is more like till than like ordinary modified drift, and contains stones and gravel though its entire mass.

Boulders and gravel from Archæan and Palæozoic formations.

Boulders are frequent or plentiful in the till throughout Manitoba, their abundance being nearly the same as in northeastern Minnesota and in the least rocky parts of New England. Their usual range in size extends up to a diameter of four or five feet; but in a few localities, especially in the course of morainic belts, they were observed of all sizes up to ten or twelve feet cubes. Generally as large a proportion as ninety-nine per cent. of the boulders exceeding one foot in diameter consists of Archæan granite, gneiss and schists, being derived from the Archæan area on the northeast and north. With these are occasional limestone blocks, derived from the belt of Palæozoic limestones, constituting on the average perhaps nearly one per cent. of the

large rock fragments of the drift. The bedded and jointed character of the limestones has prevented their supplying many large boulders in comparison with the more massive crystalline Archæan rocks, while yet usually about half of the smaller cobbles and pebbles in the till and in gravel and sand deposits are from these Paleozoic limestones. But east of Lake Winnipeg and northeast of a line drawn from this lake southeastward across the Lake of the Woods to the west end of Rainy Lake, both boulders and gravel of limestone are absent or exceedingly rare. This line probably marks the eastern limit of the glacial currents that moved south-southeast in the vicinity of Winnipeg and at Black Bear Island near the Narrows of Lake Winnipeg, carrying débris from the limestone region of the Manitoba lakes. Upon the Cretaceous area a considerable proportion of the gravel and cobbles is derived from the Fort Pierre shale, but this formation supplies no large boulders.

Northeastern limit of limestone drift.

Localities of abundant and large boulders.

The following localities may be mentioned as having especially abundant boulders. On the slope of the Pembina Mountain, in T. 2, R. 6, between Morden and Thornhill, very plentiful and large boulders are spread upon an area of several square miles, as noted in the description of the Tintah beaches. The sides of Star Mound, especially those facing the north and northeast, are strewn with a multitude of boulders, nearly all granitic, of all sizes up to five feet in diameter or rarely larger. These were probably combed out of the ice-sheet in its passage over this hill. Comparatively few boulders occur on the small flat area at its top. Pilot Mound, an equally prominent hill seen from this looking toward the northwest, is like Star Mound a knob of Cretaceous shale with thin covering of drift, but it has no such unusual profusion of boulders on its slopes. Rock Lake, through which the Pembina flows, derives its name from the remarkable abundance of boulders, mostly granitic, up to six feet or more in diameter, bordering its shores; and along a distance of one or two miles west from this lake the Pembina Valley is much encumbered with boulders, which in some places are accumulated upon small morainic ridges and knolls. The largest boulder noted in this exploration, having nearly twice the size of any other observed, is a block of dark gray granitoid gneiss, 22 feet long, 8 to 14 feet wide, and projecting 2 to 5 feet above the surface, in the N. W. ¼ of sec. 9, T. 1, R. 4 E., on the low ridge ten miles east of Emerson. Among the other plentiful boulders of that vicinity, none were seen exceeding seven or eight feet in dimension. Like many of the smaller boulders throughout this prairie region, this block is surrounded by a slight depression, one to three feet below the adjoining ground; and a careful examination shows that some of its projecting corners and edges are smoothly polished. These depressions were formed by the trampling and pawing of buffaloes in rubbing upon the

Star Mound.

Pilot Mound.

Rock Lake.

East of Emerson.

boulders, which were thereby sometimes worn and polished as perfectly as could be done by art.

Boulders polished by buffaloes.

A belt of morainic drift deposits, accumulated along the border of the ice-sheet during one or more pauses or times of re-advance interrupting its retreat, was observed upon the country that adjoins Lake Agassiz on the west and is crossed by the Assiniboine, Souris and Pembina Rivers. Though sufficient time was not available in this exploration for tracing the entire course of this recessional moraine, I have attempted to correlate it provisionally with the moraines of North Dakota and of Minnesota, thus indicating the probable course of the boundary of the ice-sheet at the time of the formation of the highest or Herman beach of Lake Agassiz.

Recessional moraine in southwestern Manitoba.

Evidence which is more fully detailed in the ensuing parts of this report, in treating of the modified drift and the history of this glacial lake, leads me to believe that the Red River Valley was uncovered by the recession of the ice-sheet and was occupied by this lake as far north as the latitude of Winnipeg and the south end of Lakes Winnipeg and Manitoba, while the ice still extended south on the west side of this valley to Devil's Lake and Turtle Mountain. The very abundant boulders noted on the east slope of the Pembina Mountain between Morden and Thornhill were probably deposited at this time on the east margin of this ice-lobe that reached south to Devil's Lake; and remarkable crescent-shaped moraines observed on the highest shore of Lake Agassiz in the southwest part of Walsh County, North Dakota, seem referable to the same time and manner of deposition.[1]

On the east slope of Pembina Mountain and southward.

The west side of this Dakota lobe of the ice-sheet during this and two or three earlier stages of its recession rested on Turtle Mountain, of which Dr. G. M. Dawson writes:—"It is a broken, hilly, wooded region, with an area of perhaps about twenty miles square, and slopes gradually upward from the plain around it, above which it is elevated, at its highest points, about 500 feet. . . . . Nearly all the abrupt slopes and ridges—of which there are many—show boulders in abundance, and these appear to be chiefly of Laurentian rocks. . . . The western is more abruptly hilly than the eastern side, and the more prominent ridges have a general northerly and southerly direction, with the intervening valleys characterized by swamps and lakes. Large areas of comparatively level or only gently undulated ground are however, found in some places. The surface of the 'mountain' appears to be that of the drift, as deposited, and has been but little modified by subsequent sub-aerial action. The lakes lie in basin-like

Morainic drift on Turtle Mountain described by Dr. Dawson.

[1] Bulletin No. 39, U. S. Geological Survey, p. 61.

hollows, and notwithstanding their great number, drainage valleys and stream courses are few and unimportant."[1]

Stages in the recession of the ice-sheet west and north of Turtle Mountain.

The outermost moraine marking the farthest advance of the ice-sheet in the last glacial epoch passes along the Coteau du Missouri, crossing the international boundary in its northwestward course about a hundred and fifty miles west of Turtle Mountain. Between this Altamont moraine and the Fergus Falls and Leaf Hills moraines, which are probably contemporaneous with the great moraines close south of Devil's Lake and on Turtle Mountain, several distinct stages in the recession of the ice-sheet are recognizable by morainic deposits in Iowa, Minnesota, and South and North Dakota. The morainic drift of Turtle Mountain apparently represents two or three stages in the glacial recession, and in the country lying on the west and northwest numerous morainic belts will doubtless be found beyond the limits of my exploration.

The moraine observed by me in southwestern Manitoba belongs to a time somewhat later than the great moraines of the Leaf Hills, the south side of Devil's Lake and Turtle Mountain; but it is believed to be contemporaneous with the accumulation of the boulders east of Thornhill and the moraines of southwestern Walsh County before mentioned, and with morainic hills on the north side of Devil's Lake. The most southern part of its observed course extends northerly from the east end of Turtle Mountain by Killarney to the northern part of Pelican Lake, a distance of about twenty-five miles. Thence it extends west-northwest twenty miles, forming the west part of the Tiger Hills in their extent along the north side of Lang's Valley and the Souris to T. 7, R. 19, where it again bends to the north and holds that course ten or twelve miles to the prominent Brandon Hills. Here again it turns to the west, making a sharp angle, but within a few miles it sinks to the general level of the adjoining country and loses its distinctive character. Proceeding onward to the west about twenty miles this moraine is next found on the north side of the Assiniboine a few miles northwest of Griswold, and thence it takes a northwest course lying mostly from five to eight or ten miles northeast of the Assiniboine and approximately parallel with it to the Arrow River and Bird Tail Creek, beyond which I have no definite information of its farther course. On both sides of the Arrow River it rises in prominent elevations, with characteristically rough contour and plentiful boulders, and this portion is called the Arrow Hills. The ascertained extent of this moraine, known in successive parts as the Tiger, Brandon and Arrow Hills, is about a hundred and twenty-five miles. Its general course

Moraine of the Tiger, Brandon and Arrow Hills.

[1] Report on the Geology and Resources of the region in the vicinity of the Forty-ninth Parallel, pp. 223, 224.

northwest, but within the Souris basin and that of the head streams of the Pembina, on the north side of Turtle Mountain, it is deflected about twenty-five miles to the northeast. The ice-sheet was there indented by two re-entrant angles, one having its apex in the range of the Tiger Hills near Poor's Lake, a few miles north of the north end of Pelican Lake, and the other in the Brandon Hills. A glacial lake, dammed by the ice-sheet and probably causing its indentations along the course of this moraine, then filled the Souris basin and outflowed around the south side of Turtle Mountain and Devil's Lake, being tributary to Lake Agassiz by the Sheyenne.

A conspicuous portion of this moraine was examined in sec. 19, T. 4, R. 16, two to three miles west of the middle of Pelican Lake. Here morainic hills rise 40 to 60 feet above the general level, their tops being 1,550 to 1,575 feet above the sea. A beautiful lakelet, about a quarter of a mile long and said to have a depth of fourteen feet, is enclosed by these hills near the center of the section. Their material is very gravelly till, not water-worn, about half of the small rock fragments being granite and half limestone. It also contains frequent, but nowhere abundant, granitic boulders up to two or three feet in diameter. This till, like that of the flat country north and northwest to Lang's Valley, and of the Tiger Hills beyond, includes only a very small proportion of gravel from the Fort Pierre shale. These roughly irregular hills and hillocks occupy a width of a half mile from east to west in sec. 19, and extend more or less noticeable in a narrower belt to the south-southwest at least five miles. Toward the north-northeast, beyond an interval of one mile of the plain like that on each side, consisting of a slightly undulating sheet of till, the moraine re-appears in hillocks and short ridges 20 to 40 feet high, becoming most prominent in sec. 32 of this township, near the verge of the southwestern bluff of Pelican Lake. Sec. 19, T. 4, R. 16, west of Pelican Lake.

Within five miles northward from the north end of Pelican Lake, this moraine is typically developed around Poor's Lake, consisting of irregularly grouped hills, knolls and ridges of till, rising 50 to 100 feet above the intervening hollows, to 1,550 and 1,600 feet above the sea. Notman's Hill in sec. 15, T. 6, R. 16, is one of its outlying knobs to the north. On the southwest side of this morainic belt, Lookout Hill in sec. 2, T. 6, R. 17, affords a fine prospect of Pelican and other lakes, Lang's Valley, and the flat plain that rises thence slowly toward the Turtle Mountain. The morainic drift here spread over the western part of the Tiger Hills gives to this range more knolly and broken outlines than along most of its extent farther east, where its rounded massive hills of Cretaceous shale are only covered by a somewhat smooth sheet of till that commonly varies from a few feet to West part of the Tiger Hills.

twenty feet in thickness. In contrast with this, along the western moraine portion of the range, extending from Notman's Hill and Poor's Lake west-northwest across the Souris, the thickness of the drift probably averages 100 to 150 feet.

Between Lang's Valley and Gregory's mill.

The road from Langvale post office, in Lang's Valley, to Gregory's mill on the Souris, five miles to the north, crosses this moraine belt of the Tiger Hills, which there is three to four miles wide and has a surface of many hills and short ridges, with typical moraine contour, rising in elevations mostly 20 to 50 feet above the intervening depressions. It is a half mile east from this road to the top of the Big Tiger Hill, which is the highest point of the entire range, about 1,640 feet above the sea, being nearly 300 feet above Lang's Valley. The elevation of the road on the west is about 1,525 feet, and of its highest place one and a half miles north-northwest of this hill, about 1,570 feet. All this portion of the range is till, but it has fewer boulders than are usually found on moraine areas, though they are probably twenty times as abundant as on the plain southward. Small rock fragments, rarely water-worn, are very abundant, nearly all Archæan granitoid gneiss and Paleozoic limestone in about equal proportions, with little or no shale. Looking west-northwest from the Big Tiger Hill, this belt of rolling moraine hills is seen extending ten miles along the northeast side of the Souris at an elevation of about 1,575 feet. South of the Souris and thence southeast to the moraine west of Pelican Lake, a vast flat expanse is seen rising slowly from an elevation of about 1,475 feet at its verge bordering the Souris and Lang's Valley to about 1,700 feet at the northern base of Turtle Mountain, which rises to 2,000 feet or more in the blue distance thirty miles south-southwest.

Big Tiger Hill.

Gorge cut by the Souris through the Tiger Hills.

In the central part of T. 6, R. 18, two miles west of the Big Tiger Hill, the Souris cuts through this moraine by a very picturesque gorge that extends four miles north from its Elbow. The stream in this distance descends approximately from 1,265 to 1,210 feet above the sea, its channel being in many places obstructed by boulders but having no considerable abrupt fall. The width of the gorge is a half mile to one mile between the tops of its steep sides, which rise in their highest portion 350 feet from the river to the crest of the moraine belt. In some places along the southern part of the gorge the Fort Pierre shale is exposed by recent erosion to a height of 100 feet or more above the river; but it has only low outcrops near Gregory's mill at the northern boundary of the moraine. The Souris there and through its next five or six miles northeast to Souris City has eroded its channel to a depth of about 140 feet in a smooth sheet of till, only reaching the underlying shale in a few places, without cutting deeply into it. This expanse of till has a descent of several feet to the mile, nearly the same as the

of the Souris itself, toward the Assiniboine. Where its southern margin adjoins the moraine, in the vicinity of Gregory's mill, at an elevation of 1,350 to 1,360 feet above the sea, or 150 feet above the Souris, it is strewn with multitudes of granitic boulders up to eight or ten feet in diameter. Vicinity of Gregory's Mill.

From the west end of the Tiger Hills in the south part of T. 7, R. 19, this morainic belt curves to the north and is called the Brandon Hills, having through this township a characteristically knotty contour upon a width of four or five miles, with an elevation 1,450 to 1,500 feet above the sea. In the southeast part of T. 8, R. 19, the moraine rises to 1,550 and 1,600 feet, attaining about the same height as the most prominent cluster of these Brandon Hills, which lies a few miles farther north and northeast, in the northern part of secs. 31, 32, and 33, T. 8, R. 18. Viewed from the Souris and Assiniboine on the east and from Brandon on the north, this cluster of hills stands forth very conspicuously, having a steep ascent of about 250 feet from base to crest, which is 1,575 to 1,610 feet, approximately, above the sea. The most eastern ridge, running to the apex of the angle which the moraine makes here from a northern to a western course, is narrow and bounded by very steep slopes, having an osar-like form, with undulations of 20 to 30 feet along its crest, which extends about three fourths of a mile in a slightly crooked course to the N. or N. 10° E., having a height approximately 1,550 to 1,575 feet. The surface of this ridge consists of gravelly drift, principally not water-worn, with frequent but not very plentiful boulders up to five feet in diameter. About half of the small rock fragments are Archæan and half limestone, but nearly all the large boulders belong to the former. The highest portion of this hill cluster lies one to two miles west-northwest from the highest point of this ridge, and seen at that distance it appears as a similar ridge but with trend from east to west. Within the angle between these ridges the prospect to the southwest overlooks a very uneven tract of morainic knolls and small ridges irregularly grouped, having an elevation of 1,450 to 1,550 feet. In the northern part of T. 8, R. 19 and 20, the east to west morainic belt sinks and becomes indistinct from the adjoining country of undulating till which rises westward; and farther west, from Plum Creek to Griswold and the Assiniboine, it is concealed beneath delta deposits of sand. Brandon Hills.

On the north side of the Assiniboine this moraine again rises prominently in the west half of T. 10, R. 23, three to six miles west of Griswold. The channel eroded by the river here is about 200 feet deep, mainly or wholly in drift, the river being about 1,200 feet and the general surface on each side about 1,400 feet above the sea. In the first six miles north from the Assiniboine the moraine attains a North of the Assiniboine.

height 50 to 100 feet or more above the adjoining country, the tops of its irregular hills and ridges being 1,450 to 1,550 feet above the sea. Thence this belt of drift hills, having an average width of three or four miles, continues northwest diagonally across T. 11, R. 24, the west half of T. 12, R. 24, and the northeast part of T. 12, R. 25, the south and west parts of T. 13, R. 25, and the east half of T. 13, R. 26. In the two townships last named its hills rise 100 to 150 feet above the country on the east and west; and from the name of the river which interseets it in the north edge of T. 13, this part of the moraine is known as the Arrow Hills. Farther northwest, where its continuation crosses Bird Tail and Snake Creeks, the surface, though not prominently hilly, is rough and unusually strewn with boulders.

Arrow Hills.

Extent of the glacial recession to this moraine.

Enough of this moraine is thus known to show that at the time of its formation the ice-sheet had so far retreated from its former western boundary on the Missouri Coteau as to uncover the entire length of the Qu'Appelle and the Assiniboine for nearly sixty miles below the mouth of that river, to Oak Lake. The significance of this will appear more fully on subsequent pages relating to the Saskatchewan and Souris glacial lakes, the latter of which extended at this time from the southern bend of the Souris in North Dakota to the Assiniboine and the lower Qu'Appelle.

Modified drift bordering Rainy River and the southwest part of the Lake of the Woods.

Modified drift, consisting of stratified gravel and sand, overlies the bed-rocks and the till, and generally forms the surface on an extensive area about the southwest part of the Lake of the Woods and along the Rainy River. Southward similar deposits cover large tracts in Minnesota, reaching to the lakes at the sources of the Mississippi and to the Leaf Hills, and thence southeastward to Minneapolis and Saint Paul. The contour of the greater part of these deposits is flat or moderately undulating, and their surface varies in height from a few feet to fifty feet or rarely more above the adjoining lakes and streams. In central Minnesota these tracts of gravel and sand have an elevation that increases from south to north, being 825 to 950 feet in the vicinity of Minneapolis and Saint Paul, rising gradually to 1,200 feet in the distance of about a hundred miles northwest to Brainerd, and ranging from 1,350 to 1,500 feet between the Leaf Hills and Itasca Lake. Thence their surface sinks to 1,150 and 1,075 feet in the vicinity of Rainy River and the Lake of the Woods. West of this lake gravel and sand cover most of the country for nearly seventy-five miles in the upper part of the Roseau, Rat, and Seine Rivers, declining in this direction to about 900 feet above the sea. Northwestward these deposits continue to a remarkable group of osars and small plateaus of gravel and sand, between 750 and 875 feet above the sea, seventy-fifteen miles east-northeast of Winnipeg, of which Bird's Hill, be-

Its continuation south into Minnesota, and northwest to Bird's Hill, near Winnipeg.

the Canadian Pacific Railway, is the most western and one of the most conspicuous.

This broad belt of country, characterized by extensive gravel and sand deposits overlying the till, reaches from south-southeast to north-northwest about four hundred miles. From Red Lake in Minnesota north to the Rainy River, the Lake of the Woods, and the vicinity of Winnipeg, it lies within the area of Lake Agassiz. On each side this belt is bordered by areas of nearly the same general elevation which have mostly a surface of till; and it is to be remarked that the height of the tracts of modified drift and till are alike determined by that of the underlying rocks on which these superficial deposits are spread as a sheet of slight depth in comparison with the gradual change in their elevation. The drift sheet on this belt, including both the sand and gravel and underlying deposits of till, probably varies in its average thickness from 50 to 150 feet, while its central portion rises 400 to 600 feet above its south and north ends. Though the greater part of both the modified drift and till have only slight undulations, the former being often nearly flat and the latter moderately uneven, other portions are crossed by moraines which have a prominently knolly and hilly contour, rising usually 25 to 75 feet, or occasionally 100 to 200 feet, and in the Leaf Hills 100 to 350 feet, above the adjoining country. In some places the belts of morainic hills, consisting chiefly of till with abundant boulders, are bordered on one side by tracts of stratified gravel and sand which slope slowly downward from them and are merged in the extensive plains or moderately undulating areas of this modified drift, showing that a part of the gravel and sand was brought by streams that descended from the ice-sheet during the time of accumulation of its moraines. Besides these overwash slopes of modified drift, the morainic belts often include knolls, hillocks, and short ridges of sand and gravel, called *kames*, which seem to have been heaped up where such streams left their ice-walled channels and were spread out more widely, thereby losing their velocity and carrying power, upon the adjoining land surface. These deposits show that the lower part of the ice-sheet enclosed much drift material, denominated by Chamberlin *englacial drift*, from which the glacial streams gathered clay, sand, and gravel, and spread them beyond the border of the ice.

Adjoining areas of till and associated moraines.

Kames.

During the rapid melting of the ice in its times of retreat between successive moraines, the glacial streams attained their greatest extent and volume, and brought proportionately extensive deposits of modified drift, spreading it mainly in plains or moderately undulating tracts beyond the ice-margin, but here and there leaving prolonged ridges of gravel and sand, called *osars*, which were formed in their channels

Osars.

Deposition of the modified drift attributed to rivers flowing convergingly to this belt from the melting ice-sheet.

between walls of ice.* The distribution of the modified drift, thus found upon large tracts along a broad belt from Saint Paul to Winnipeg, while it is very scantily developed on a still wider region of Minnesota, North Dakota, and Manitoba southwest of this belt, and likewise is scanty or wanting on its northeast side in northern Minnesota and about the northeast and north portions of the Lake of the Woods, seems to be attributable to converging slopes of the surface of the ice-sheet and the consequent convergence of its currents, which brought an unusual amount of englacial drift into the ice along this belt, and by which also the streams produced in its melting were caused to flow thither from extensive areas of the ice on the east and west. The glacial striæ of these adjoining areas show that on the east the course of the motion, and the descent of the surface, of the ice-sheet were from northeast to southwest, but that on the west the glacial current moved, and the ice surface sloped, toward the southeast. On the east drift limestone is absent or very rare, because no limestone formations were crossed within several hundred miles by that part of the ice-sheet; but on the west the drift contains much fine limestone detritus, sand and gravel, and frequent boulders of limestone, borne southeastward from Manitoba over the Archæan area of the southwest part of the Lake of the Woods, of Rainy River, and of northern and central Minnesota. In the same directions with the slopes of the ice surface, which are known from the courses of the glacial striæ and the transportation of the drift, the streams of the glacial melting flowed convergently from the east and west, from the ice over northern Minnesota and eastern Manitoba on one side, and from that over the Red River Valley and western Manitoba on the other, toward this belt of plentiful superficial deposits of gravel and sand.

Group of osars northeast of Winnipeg.

Prominent osars begin at Bird's Hill, the first station of the Canadian Pacific Railway northeast of Winnipeg, from which it is seven miles distant, and extend thence seven or eight miles east-northeast and at equal distance southeast. The southern and southeastern portion of this group comprises many low ridges of gravel and sand five to fifteen feet high, trending from northwest to southeast; also somewhat rounded mounds, as Oak Hummock in the S. E. ¼ of sec. 12, T. 11, R. 4 E., which rises about thirty feet above the adjoining country, with its top approximately 810 feet above the sea; and occasionally a massive and conspicuous hill, as Moose Nose in secs. 29 and 30, T. 11

* The discrimination of the two classes of gravel and sand deposits named thus *kames* and *osars* was advocated by W. J. McGee in the Report of the International Geological Congress, second session, Boulogne, 1881, p. 621; and by T. C. Chamberlin, in the Third Annual Report of the U. S. Geological Survey, for 1881-82, p. 299, and Am. Jour. of Science, III, vol. xxv, May, 1884, p. 389. President Chamberlin shows that the latter term, in this Anglicized form, has long been in common use by Jackson, Hitchcock, Desor, Murchison, and other writers.

SECTIONS

ILLUSTRATING THE REPORT ON THE

GLACIAL LAKE AGASSIZ IN SOUTHERN MANITOBA.

BY WARREN UPHAM.

Fig. 1. Typical Section across a Beach Ridge of Lake Agassiz.

Fig. 2. Section across the Assiniboine Delta from Brandon to Portage la Prairie.

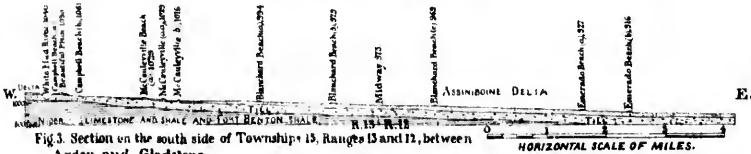

Fig. 3. Section on the south side of Township 15, Ranges 13 and 12, between Arden and Gladstone.

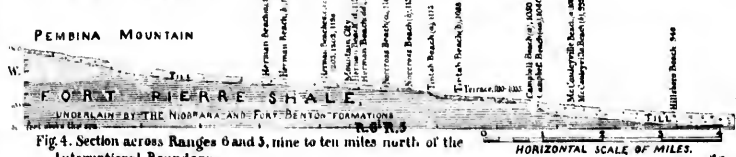

Fig. 4. Section across Ranges 6 and 5, nine to ten miles north of the International Boundary.

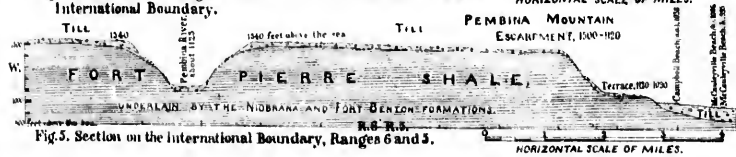

Fig. 5. Section on the International Boundary, Ranges 6 and 5.

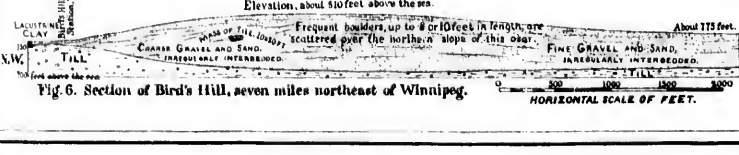

Fig. 6. Section of Bird's Hill, seven miles northeast of Winnipeg.

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R. 5 E., which projects sixty feet above the average of the nearly flat country around it, rising to about 840 feet above the sea. Toward the north, in secs. 35 and 36, T. 11, R. 4 E., and again from sec. 2, T. 12, R. 4 E., through a distance of four miles east-northeast to sec. 9, T. 12, R. 5 E., these deposits of gravel and sand form plateaus a half mile to one mile wide, trending from west to east, elevated 820 to 850 feet above the sea and 40 to 60 or 75 feet above the adjoining low land, which on the north is a spruce and tamarack swamp about a mile wide and four miles long from east to west. Next to the north, these osars again rise in plateaus, ridges, and hills in secs. 19 to 22, T. 12, R. 5 E., culminating in Griffith's Hill in the N. E. $\frac{1}{4}$ of sec. 19, about 875 feet above the sea, or a little more than a hundred feet above the railway two miles distant on the west. This whole group of elevations is composed of gravel and sand, irregularly bedded, which appear to be deposits formed near the mouths of glacial rivers where they flowed between walls of ice and were here and there divided by ice islands, whose melting left these hills, ridges and plateaus bounded by moderately steep slopes and separated by intervening depressions. With the completion of the melting of the ice about and beneath these deposits, they sank to the bottom of Lake Agassiz, here about 500 feet deep; and the infrequent boulders that are found scattered upon their surface were dropped from floating ice. Toward the north, west, and southwest, they are bounded by the flat plain of the Red River Valley, 750 to 760 feet above the sea; while toward the east and southeast they are connected with plains and undulating tracts of gravel and sand which reach with slow and gradual ascent to the Lake of the Woods and into Minnesota.

Submergence in Lake Agassiz.

An instructive section of Bird's Hill has been made in the excavation of its gravel and sand for railway ballast. This massive osar extends from the railway station about one mile east-southeast and thence a half mile southeast, beyond which it is connected by a low ridge with the plateau of secs. 35 and 36, T. 11, R. 4 E. Its width is a quarter to a half of a mile; and its maximum height, one third to two thirds of a mile from the station, is 45 to 50 feet above the railway and the flat plain that extends thence west. The elevation of Bird's Hill station is 759 feet, and of the crest of this hill 805 to 810 feet above the sea. It has a broadly rounded top, with gentle slopes on all sides. Along its northern slope an excavation reaches three fourths of a mile, varying in width from ten to twenty-five rods and in depth from ten to thirty feet. The top of the excavation is about twenty feet below the crest of the hill. As thus exposed to view, the greater part of this deposit is seen to be gravel, much of which is very coarse, containing pebbles and rock fragments of all sizes up to one and a half feet in

Bird's Hill.

diameter, many of the smaller being well rounded, but the larger mostly angular with only slight marks of water-wearing. In some portions near the west end of this section no interbedding of coarser and finer layers of the torrential osar gravel is noticeable for ten feet or more vertically, the spaces between the large stones and cobbles being filled with finer gravel and sand. Imbedded in this coarse gravel on the south side of the excavation I noted a mass of ordinary till, unstratified boulder-clay enclosing gravel and boulders in a solid matrix of somewhat sandy clay, wholly bounded by definite but irregular outlines, its dimension vertically being about ten feet and its length twenty feet. No other mass of till, either of small or large size, was observed in this entire section. It probably was derived from the drift that was contained within the ice-sheet and finally overspread its surface when the greater part of the thickness of the ice was melted. From a sheet of drift thus deposited on the ice that formed the bank of the glacial river, this mass may have fallen into its channel. The eastern half of the section includes much fine gravel and sand irregularly interbedded, and along a considerable extent there the south side of the excavation from ten to twenty feet below its top is clear sand. Palæozoic limestones make up about three quarters of the gravel, the remainder being Archæan granites, gneiss and schists. Some two hundred boulders were found scattered upon the area of the excavation; and they occur with nearly the same frequency on other portions of this northern slope of the hill, but are rarely found on its top and southern slope. They vary in size from two to eight or ten feet in length; nearly all are Archæan, but a few of Palæozoic limestone, up to five feet in length, were observed. None were seen enclosed within the gravel and sand of the osar; and the workmen informed me that they occur only on or near the surface. This hill was covered by Lake Agassiz, and its boulders were doubtless dropped or stranded from bergs and floes on this lake, before the border of the ice-sheet had retreated from the vicinity. Indeed, the occurrence of the boulders chiefly on the northern slope seems to indicate that they were mostly stranded there while ice yet remained beneath this deposit and prevented its entire submergence in the lake. The thickness of this osar is at least nearly 100 feet; for a well 45 feet deep, dug at the bottom of the excavation was wholly in the same formation of gravel and sand. It is thus known to extend considerably below the level of the Red River Valley plain, which consists of fluvial and lacustrine clay underlain at a slight depth by till. A section across the osar and plain would show till abutting upon the edge of the gravel and sand, indicating that both the stratified osar and the upper part of the till were formed from englacial drift.

Mass of till imbedded in torrential gravel.

Boulders dropped or stranded from floating ice.

Thickness of this osar and its relation to the upper part of the till.

Smaller osar deposits were observed in Ts. 12 and 13, R. 1 E., ten to twenty miles northwest of Winnipeg. Beginning about three miles east of Rosser, a narrow and occasionally interrupted belt of osar gravel and sand, with frequent boulders scattered on the surface, extends northwest diagonally across secs. 10, 16, and 20, the northeast corner of sec. 19, and the southwest part of sec. 30, T. 12, and thence westward through sec. 25 of the next township. Its highest portions rise ten to twenty-five feet above the depressions of the moderately undulating surface of till on each side, and are 800 to 810 feet above the sea. Along a distance of about a third of a mile in sec. 30 it has the form and character of an ordinary beach ridge and is destitute of boulders. A similar low osar crosses secs. 12 and 14, T. 13, trending from southeast to northwest; and others occur in the vicinity of the Grosse Isle, a name applied to poplar groves in secs. 17 and 18 of this township and in secs. 12 and 13 of the next west. Osars north-west of Winnipeg.

From the east part of the Grosse Isle a notable osar, known as Burns's Ridge, runs north-northwestward across secs. 30 and 31, T. 13, R. 1 E. Five miles west of Stonewall a section of this little beach-like ridge was made in sec. 30 by the original line of the Canadian Pacific Railway, which was abandoned for the more southern route by way of Winnipeg. The osar is cut to a depth of eight feet by the railway and to twelve feet in an excavation on the south side of the railway grade. A well in the lowest part of this excavation goes four feet deeper, that is, sixteen feet below the crest of the ridge. The entire section consists of stratified gravel and sand, extending eight feet above and at least as far below the general level of the adjoining surface, and the visible width of the deposit is about thirty rods. How much deeper it may extend, perhaps with increasing width, is undetermined. Its gravel, which is nearly all limestone, contains pebbles up to six inches in diameter. No boulders occur in this excavation, and they are rare upon the surface of this and other such comparatively broad and high portions of this osar, none being sometimes seen along a distance of several rods; but in its narrower and slightly lower portions, as traced in its somewhat crooked course northward through the next one and a half miles, it often is found to be sprinkled with frequent boulders up to three or four feet in diameter, mostly Archæan. They appear to have been stranded as at Bird's Hill, immediately after the ice-walls enclosing the osar were melted or even during that process, and before the melting of the ice under this gravel and sand allowed the water of Lake Agassiz to submerge the more massive portions of the ridge. Only a small depth of water, probably not more than thirty or fifty feet at the most, would be required for this; and afterward the melting of the underlying ice gave to the lake here a depth of fully 500 feet. Burns's Ridge. Stranded boulders.

Farther to the north the osar sinks or is merged in the moderately undulating till which there forms the surface. The crest of this peculiar ridge, approximately 800 to 805 feet above the sea, undulates three to five feet within short distances, not showing so much uniformity in elevation and directness in its course as are characteristic of beach ridges; and it is the only instance observed in all my exploration of Lake Agassiz where a gravel formation nearly resembling a beach bears boulders on its surface. Not a single boulder has been anywhere found on or within the beaches of this lake; nor have osars like the Bird's Hill group or like these of smaller size and more stream-like courses been observed by me in any other part of this lacustrine area, excepting the vicinity of Red Lake in Minnesota. But osars doubtless exist here and there throughout the belt of modified drift that extends upon this area from Red Lake by the Lake of the Woods to Bird's Hill and Barns's Ridge; and probably they continue north-northwesterly upon the country between Lake Winnipeg and Shoal Lake.

HISTORY OF LAKE AGASSIZ.

Drainage from the receding ice-sheet.

During the recession of the ice-sheets of both the earlier and later epochs of glaciation, drainage from the ice-border in many places flowed in channels from which the streams became turned by the slopes of the land into more northern courses when this was permitted by the farther retreat of the ice. Where the slope is southward, free drainage from the melting ice took place along the present valleys, and these were partially filled with modified drift, remnants of which form terraces and plains on each side of the present streams. But on areas that sloped more or less directly toward the receding ice-border, the streams of that time eroded channels which were abandoned when lower outlets were uncovered. Because of the large supply of water from the glacial melting, some of these river-courses became conspicuous topographic features, as noted by Dawson,* McConnell,† and Tyrrell‡ in various parts of the region between Lake Agassiz and the Rocky Mountains. On a slope nearly parallel with the retiring ice-border, the deserted river-courses were seldom the outlets of lakes of considerable size; but where a large area was inclined toward the ice-sheet, it was covered by an expanse of fresh water, formed by the streams that flowed down from the melting ice surface and overflowing across what is now a line of water-shed between great drainage basins.

Deserted river-courses.

* Report on the Geology and Resources of the region in the vicinity of the Forty-ninth Parallel, pp. 263-265; Geological Survey of Canada, Report of Progress for 1882-83-84, p. 15 C.

† Geological Survey of Canada, Annual Report, vol. i, for 1885, pp. 21 and 74 C.

‡ Do., Annual Report, vol. ii, for 1886, pp. 43, 45 E, and 145, 146 E.

until the continued recession of the ice allowed the lake to be discharged by the natural slope of the land. Lake Agassiz was the largest of these glacial lakes. Others existed in the basins of the James, Souris, and Saskatchewan Rivers, of which the two last named outflowed eastward into Lake Agassiz. The basins of the great Laurentian lakes, which are being studied by Mr. G. K. Gilbert of the United States Geological Survey, were also filled at this time to higher levels than now, determined by the elevations of the outlets through which they then flowed southward to the Mississippi and finally eastward to the Mohawk and Hudson.*

Glacial lakes contemporaneous with Lake Agassiz.

In tracing the history of Lake Agassiz it will be needful to review the recession of the ice-sheet which was its northern barrier, as the stages of that recession are shown by the successive terminal moraines of Iowa, Minnesota, South and North Dakota, and Manitoba; to observe the stages of the lake itself which are recorded in its successive beaches; and to note the contemporaneous history of the glacial lakes on the west, whose outflow by the Sheyenne, Pembina, and Assiniboine brought large deltas into the western edge of Lake Agassiz and spread deposits of fine silt over extensive areas of its bottom.

Summary of the history of Lake Agassiz.

When the latest North American ice-sheet attained its greatest area, its southern portion from Lake Erie to North Dakota consisted of vast lobes, one of which reached from central and western Minnesota south to central Iowa. This Minnesota lobe in its maximum extent ended near Des Moines, and its margin was marked by the Altamont moraine, the first and outermost in the series of eleven distinct marginal moraines of this epoch which are recognizable in Minnesota. When the second or Gary moraine was formed, it terminated on the south at Mineral Ridge in Boone County, Iowa. At the time of the third or Antelope moraine, it had farther retreated to Forest City and Pilot Mound in Hancock County, Iowa. The fourth or Kiester moraine was formed when the southern extremity of the ice-lobe had retreated across the south line of Minnesota and halted a few miles from it in Freeborn and Faribault Counties. The fifth or Elysian moraine, crossing southern Le Sueur County, Minnesota, marks the next halting-place of the ice. At the time of formation of the fifth moraine, the south end of the ice-lobe had been melted back a hundred and eighty miles from its farthest extent, and its southwest side, which at first rested on the crest of the Coteau des Prairies, had retired thirty to

Recession of the Minnesota lobe of the ice-sheet from Des Moines to the Leaf Hills.

* "Changes of Level of the Great Lakes," by G. K. Gilbert, in The Forum, vol. v, pp. 417-428, June, 1888. Geol. Sur. of Canada, Report of Progress to 1863, pp. 910-915. C. Whittlesey, "On the Fresh-water Glacial Drift of the Northwestern States," 1864, pp. 17-22, in Smithsonian Contributions, vol. xv. J. S. Newberry, in Report of the Geological Survey of Ohio, vol. ii, 1874, pp. 50-65, with three maps. "The Lake Age in Ohio," by E. W. Claypole, pp. 42, with four maps, Trans. of the Geol. Soc. of Edinburgh, 1887.

fifty miles to the east side of Big Stone Lake and the east part of Yellow Medicine County, Minn. During its next stage of retreat this ice-lobe was melted away from the whole of Le Sueur County, and its southeast extremity was withdrawn to Waconia in Carver County, where it again halted, forming its sixth or Waconia moraine. The seventh or Dovre moraine marks a pause in its recession when its southeast end rested on Kandiyohi County. Probably nearly all of the southern half of Minnesota was at this time divested of its ice-mantle, while nearly all of the northern half was still ice-covered. By its next recessions the glacial border was withdrawn to the eighth or Fergus Falls moraine, and the ninth or Leaf Hills moraine. These are merged together in the prominent accumulations of the Leaf Hills, which lie in southern Otter Tail County, Minnesota, reaching in a semicircle from Fergus Falls to the southeast, east, and northeast, a distance of about fifty miles, and marking the southern limits of this ice-lobe when it terminated half-way between the south and north borders of Minnesota.* The south part of Lake Agassiz probably began to be uncovered by the retreating ice-sheet between its stages marked by the Waconia and Dovre moraines; and this lake reached northward from Lake Traverse 100 to 125 miles along the Red River Valley when the Fergus Falls and Leaf Hills moraines were accumulated.

Recession of the ice-sheet in South and North Dakota from Yankton to the south side of Devil's Lake.

On the west side of Lake Agassiz the Dakota lobe of the ice-sheet, from its junction with the Minnesota lobe near the head of the the Coteau des Prairies, twenty-five miles west of Lake Traverse and Brown's Valley, at first reached about 200 miles south along the valley of the James or Dakota River to Yankton and the Missouri; but it was gradually diminished in its extent until, at the times of formation of the Kiester, Elysian, Waconia, and Dovre moraines, it no longer retained its lobate outline. While these moraines were being formed in Minnesota, the southwestern boundary of the ice-sheet in South and North Dakota passed from the vicinity of Big Stone Lake and Lake Traverse northwesterly along moraine belts that have been traced through Sargent, Ransom, Barnes, and Griggs Counties, North Dakota, and by the sources of the James and Sheyenne Rivers. During the later stages represented by the Fergus Falls and Leaf Hills moraines, the Dakota ice-front appears to have become again lobate, extending from the west shore of Lake Agassiz southward and then westward and northward, between the lake area and the Sheyenne River, to the prominent and typical moraines that are found south of Stump and Devil's Lakes, on the Big Butte, about Broken Bone Lake and north-

* For detailed descriptions of these moraines, and of the recession of the ice-sheet in this State, see Geology of Minnesota, vols. i and ii.

ward, and on Turtle Mountain. In their remarkable development these moraines are similar to the massive Leaf Hills, with which they seem to have been contemporaneous.

The course of the ice front where it formed the northern barrier of Lake Agassiz, at the time of its accumulation of these great moraines of the Leaf Hills and the south side of Devil's Lake, is marked by morainic deposits both east and west of the lake near the latitude of 47° 10′, which passes twenty miles north of Fargo; by an unusual abundance of boulders near this latitude and farther north on portions of the till forming each side of the lacustrine area; and by a tract of till which stretches across the Red River Valley at Caledonia, constituting the bed and banks of the river along the Goose Rapids. In the lake this morainic till was spread with a generally even surface, but it has many small inequalities, the higher portions being three to five feet or rarely ten feet above adjoining hollows. Boulders and gravel are plentiful on its surface, this being the only interruption of the lacustrine and alluvial clayey silt which elsewhere continuously occupies the central part of this valley plain from near Breckenridge to Winnipeg.

Tract of till crossing the Red River Valley.

Toward the east the ice-sheet at this time had receded from the southwest part of Lake Superior, which was held about 500 feet higher than now and overflowed to the Saint Croix and Mississippi Rivers by the way of the Bois Brulé River and Upper Saint Croix Lake. It seems nearly certain also that the ice-border continued across Green Bay and the north part of Lake Michigan; and further east, I think that it probably crossed southwestern Ontario and the central or northern portions of New York, Vermont, New Hampshire, and Maine. The Laurentian lakes were dammed by the retreating glacial barrier and overflowed at the lowest points on their southern water-shed.

Eastward course of the ice-border at the time of the Leaf Hills moraine.

During the formation of the tenth or Itasca moraine, crossing the lake region at the head of the Mississippi, the ice-sheet bounding Lake Agassiz probably extended thence northward, passing not far west of Red Lake and the Lake of the Woods, to the vicinity of Winnipeg, the Bird's Hill group of osars being perhaps deposited at the angle where this boundary of the ice-sheet turned back southwestward. In that course it seems to have reached across the lake area to the boulder-strewn escarpment of the Pembina Mountain east of Thornhill, and beyond to have passed south along the west shore of Lake Agassiz into North Dakota, to Pilot Knob in sec. 5, T. 154, R. 56, thence westward to the north side of Devil's Lake, and thence north northwestward by the east part of Turtle Mountain and along the moraine of the west part of the Tiger Hills and of the Brandon and Arrow Hills.

The Itasca moraine correlated with that of the Tiger, Brandon, and Arrow Hills.

The eleventh or Mesabi moraine, well developed in northeastern

Minnesota, is probably represented by morainic accumulations north of Pokegama Falls of the Mississippi, about Bowstring Lake, the head of the Big Fork of Rainy River, east of the Narrows between the south and north parts of Red Lake, and on the east part of the Tiger Hills. Lake Agassiz had contemporaneously a length of more than 300 miles, from Lake Traverse to near the south end of Lake Winnipeg. Later moraines, formed at times of halt or re-advance, interrupting the recession of the ice-sheet between northern Minnesota and Hudson Bay, have not been determined; but I believe that they exist and await discovery when the glacial drift of that wooded and very scantily inhabited region shall be fully explored.

Glacial melting on the area of Lake Agassiz during the formation of the highest Herman beach.

The highest of the Herman beaches of Lake Agassiz extends in Minnesota, as traced in this survey, to the north side of Maple Lake, twenty miles east-southeast of Crookston, and probably it continues thence into the forest region on the east, where it is impracticable to follow its course, to the vicinity of Red Lake; and on the west side of Lake Agassiz it reaches through North Dakota and at least fourteen miles into Manitoba, terminating on the northern part of the Pembina escarpment somewhere between Thornhill and its northern end, that is, between fourteen and forty miles north of the international boundary. Before the formation of this beach was completed, the ice-sheet had retired from the lake area as far north as the beach extends. During pauses of this glacial recession the Dovre, Fergus Falls, Leaf Hills, and Itasca moraines were formed, showing a northward retreat of the ice border across a distance of about 150 miles in central Minnesota and 150 to 200 miles in North Dakota and southern Manitoba, with a maximum of probably not less than 300 miles in the Red River Valley, where Lake Agassiz would doubtless cause a more rapid melting of the ice-margin. Through this time the River Warren eroded a channel about fifty feet deep, approximately from 1,100 to 1,050 feet above the sea, or perhaps it eroded only the lower half of that depth, in the moderately undulating sheet of till which reached across the present valley of Lakes Traverse and Big Stone. The shortness of the time probably occupied in the formation of the beaches of Lake Agassiz may well astonish us in what it implies concerning the rapidity of the recession of the ice-sheet, and the brevity, geologically speaking, of the stages of pause or re-advance when its moraines were accumulated.

Southwestern shore near Milnor first uncovered from the ice.

The retreat of the ice seems to have uncovered the southwest border of Lake Agassiz earlier than its shores farther north and on its east side, as is shown by the Milnor beach, a less distinct shore deposit than the Herman beach and 20 to 25 feet above it, which was observed near Milnor, North Dakota, and along a distance of about ten miles thence north-west to the Sheyenne, but was not recognized farther north nor

in Minnesota. The formation of the Sheyenne delta had begun at this time of the Milnor beach, and continued through the time of the Herman beach, with which latter the Buffalo, Sand Hill, Pembina, and Assiniboine deltas were also contemporaneous. The departure of the ice from the Red River Valley seems to have been too rapid to permit the accumulation of definite shore deposits on the borders of Lake Agassiz, excepting the scanty Milnor beach derived from the Sheyenne delta, until its outlet was cut down to the level of the Herman beach, which probably represents a time of much slower erosion of the outlet, due to diminished glacial melting and smaller volume of the outflowing stream.

Compared with the level of the present time, the highest Herman beach has a gradual ascent from south to north which averages nearly a foot per mile, amounting to about 175 feet in the 224 miles from the mouth of the lake at its southern end to the international boundary. The mouth of the lake was then about 1,055 feet, and its surface on the international boundary about 1,230 feet, above the present sea level. It is further found that in the northern part of the explored area of Lake Agassiz this upper or Herman beach, which is single along the southern part of the lake, becomes divided into numerous parallel beaches that were formed at intervals of pause in a progressing elevation of that area. A portion of these relative changes of level, however, was due to a subsidence of the lake itself toward the north, on account of the diminution of its attraction by gravitation toward the ice-sheet, proportionate with the decrease of the ice in its final melting. As many as six other Herman stages below the highest are recognizable by beach deposits, which indicate a rise of the land combined with a sinking of the lake to the amount successively of about 5, 10, 7, 15, 10, and 5 feet, or in total 55 feet, on the line between North Dakota and Manitoba, while yet the relative elevations of the lake and the adjoining land along its southern part for some seventy-five miles northward from Lake Traverse remained with only slight changes, not sufficient for the formation of any secondary beach ridge.

Northward ascent of the Herman beaches.

In a later part of this report the discussion of the causes of these changes in the height of the land and of the lake is accompanied by a table of the present elevations of the successive beaches formed by the lake on its west side through its entire existence, until it was drained to the levels of Lakes Manitoba and Winnipeg. The two highest beaches (*a* and *aa*) in the Herman series of this table were not found north of the Pembina Mountain escarpment; but the next two (*b* and *bb*) are well developed at Brandon and near Neepawa, reaching thus to the northern limit of my exploration at the south end of Riding Mountain. During the interval between these Herman beaches *a* and *b*, the

combined rise of the land and fall of the lake were only eighteen or twenty feet on the international boundary; but in this time the southern end of the ice-lobe west of the lake had been withdrawn from the east part of the Tiger Hills to Riding Mountain, and the Assiniboine delta was being rapidly deposited. The northward extent of Lake Agassiz in its subsequent Herman stages is not definitely determined, but evidently some of the upper beaches observed by Mr. Tyrrell on the foot slopes east of the escarpments of Riding and Duck Mountains belong to this series, the highest, according to information supplied by him, being in lat. 51°52′ or two hundred miles north of the international boundary, at an elevation of about 1,460 feet above the sea.

Extent of Lake Agassiz in its Herman stages north to Riding and Duck Mountains.

The foregoing observations show that the ice-sheet was melted away from at least half of the area of Lake Agassiz during its Herman stages. In the ensuing Norcross, Tintah, Campbell and McCauleyville stages, through which the lake continued to outflow southward by the River Warren, the recession of the ice doubtless permitted it to extend north and east beyond Lake Winnipeg and along the lower valley of the Saskatchewan. Each of these stages is represented by two or three beaches in northern Minnesota and North Dakota and in southern Manitoba, which, with the seven beaches of the Herman series, make seventeen shore lines recognizable in that part of the lacustrine area belonging to the time of its southern outlet. Between the Herman and Norcross beaches the channel of the River Warren was eroded about 25 feet; it was deepened 15 to 30 feet more at the time of the Tintah beaches; 10 to 20 feet farther down to the Campbell beaches; and again 10 to 20 feet to the McCauleyville beaches. In all, the mouth and southern end of the lake were lowered about 100 feet between the highest Herman beach and the lowest McCauleyville beach. Proceeding northward, the vertical distance between these beaches gradually increases to 240 feet on the international boundary, the difference of 140 feet more than the depression caused by erosion of the outlet being attributable to the northward rise of the land and subsidence of the water-level.

Later stages of the lake while it outflowed southward.

Before Lake Agassiz could obtain an outlet to the northeast, the thick ice-sheet that had filled the basin of Hudson Bay was so far melted as to admit the sea, which at first covered the land west of James Bay 350 to 500 feet above the present sea level. Eleven stages of Lake Agassiz are marked by beaches that lie below the beds of Lakes Traverse and Big Stone, which were the channel of the River Warren when the lake ceased to outflow to the south. These beaches are separated by vertical intervals that vary from 10 to 45 feet through the range of elevation between the lowest McCauleyville beach and Lake Winnipeg, which was originally twenty feet higher than now.

Stages of northeastern outflow.

As soon as the ice upon Hudson and James Bays and the adjoining country had so receded as to give to Lake Agassiz an outlet lower than the River Warren, it began to be drained in that direction, perhaps flowing at first across the water-shed between the Poplar and Severn, and later along lower courses, including the canoe route by the Hill and Hayes Rivers. Each of its successive outlets was probably eroded to a considerable depth, being occupied by the outflowing river during the time of formation of two or more beaches, until the retreat of the southeastern border of the portion of the ice-sheet remaining west of Hudson Bay finally permitted drainage to take the course of the Nelson, the ice-dammed Lake Agassiz being thus changed to Lake Winnipeg. The northeastern outflow commenced when the lake at the latitude of the south end of Lake Winnipeg stood about 1,000 feet above the present sea level, and it was gradually lowered to 730 feet when the Nelson between its successive lakes began to erode the shallow channel of the upper part of its course.

Fossils have been found in the deposits of Lake Agassiz at two localities. They are all fresh-water shells of species now living in this district, occurring in beach ridges where excavations have been made to obtain sand for masons' use. The Campbell beach, about six miles southwest of Campbell, Minnesota, at an elevation approximately 985 feet above the sea, has thus yielded shells of *Unio ellipsis*, Lea, a common species of the upper Mississippi region. In the Gladstone beach, a half mile northeast of Gladstone, Manitoba, about 875 feet above the sea and 165 feet above Lake Winnipeg, four species occur in considerable abundance from two to four feet below the surface, namely, *Unio luteolus*, Lamarck, *Sphærium striatinum*, Lam., *Sphærium sulcatum*, Lam., and *Gyraulus parvus*, Say. These species from both localities were kindly determined by Prof. R. Ellsworth Call, who states that *Unio luteolus* is one of the most widely distributed representatives of the genus, its range being from Lake Winnipeg to Texas, east to New York, and west to Montana. It is generally abundant in Minnesota. Both these species of *Sphærium* are reported by Dr. Dawson from the Lake of the Woods and Pembina River; and the first is the most common species of its genus in Minnesota, while its range northward extends at least to Great Playgreen Lake and York Factory, where it has been collected by Dr. Bell. The Campbell beach was formed in the later part of the time of the lake's southward outflow; and the Gladstone beach belongs to the middle portion of the time of its outflow toward the northeast, its south end being then about 85 miles south of the international boundary. Mollusean fauna of Lake Agassiz.

Evidences of man's presence in this region during the departure of the ice-sheet have been discovered by Miss Franc E. Babbitt at Little

Falls in central Minnesota. A stratum containing many artificially chipped fragments of quartz is enclosed there in the modified drift of the upper Mississippi Valley, which was deposited by the floods supplied from the melting ice-sheet in its retreat while it was being withdrawn from northern Minnesota and the Red River Valley.* It seems probable therefore that men lived on the shores of Lake Agassiz and witnessed the erosion of the channel of the River Warren, the gradual lowering of the lake level and reduction of its area, and its later northeastward outflow to Hudson Bay. But this is not left wholly to conjecture. Mr. Tyrrell informs me that in northwestern Manitoba, at an elevation of 1,135 feet above the sea, he has found sharp-edged fragments of quartzite, chipped by human workmanship, interbedded with the rounded gravel of one of the Campbell beaches.†

Traces of men contemporaneous with the glacial recession and Lake Agassiz.

If the question be asked how many thousand years ago did the recession of the ice-sheet take place, causing Lake Agassiz to fill the Red River Valley and the basin of Lake Winnipeg, a reply is furnished by the computations of Prof. N. H. Winchell,‡ that approximately 8,000 years have elapsed during the erosion of the postglacial gorge of the Mississippi from Fort Snelling to the Falls of Saint Anthony; of Dr. Andrews,‖ that the erosion of the shores of Lake Michigan, and the resulting accumulation of dune sand drifted to the southern end of that lake, cannot have occupied more than 7,500 years; of Professor Wright,§ that streams tributary to Lake Erie have taken a similar length of time to cut their valleys and the gorges below their water-falls; of Mr. Gilbert,** that the gorge below Niagara Falls has required only 7,000 years or less; and of Prof. B. K. Emerson,†† on the rate of deposition of modified drift in the Connecticut Valley at Northampton, Massachusetts, from which he believes that not more than 10,000 years have elapsed since the glacial period. An equally small estimate is als-

Measurements of time since the last glacial epoch.

* Proceedings of Am. Assoc. for Adv. of Science, vol. xxxii, 1883, pp. 385-390; Amer. Naturalist, vol. xviii, pp. 594-605, and 697-708, June and July, 1884; and Proc., Boston Soc. Natural History, vol. xxiii, 1888, pp. 421-449.

† Preliminary notes of this discovery, and of the northwestward continuation of the beaches of Lake Agassiz in the district of Riding and Duck Mountains, are included by Mr. Tyrrell in a paper, "On the Superficial Geology of the Central Plateau of Northwestern Canada," read before the Geological Society of London, Nov. 7, 1888, of which an abstract is given in the Geol. Mag. Magazine, III, vol. vi, pp. 37-38, Jan., 1889.

‡ Geology of Minnesota, Fifth annual report, for 1876; and Final report, vol. ii, pp. 393-4. Quart. Jour. Geol. Soc., vol. xxxiv, 1878, pp. 886-901.

‖ Transactions of the Chicago Academy of Sciences, vol. ii. James C. Southall's Epoch of the Mammoth and the Apparition of Man upon the Earth, 1878, chapters xxii and xxiii.

§ Am. Jour. Sci., III., vol. xxi, pp. 120-123, Feb., 1881; The Ice Age in North America, 2nd ed., chapter xx.

** Proceedings, Am. Assoc. for Adv. of Science, vol. xxxv., for 1886, p. 222. "The History of the Niagara River," Sixth An. Rep. of Commissioners of the State Reservation at Niagara for 1889, pp. 61-81.

†† Am. Jour. Sci., III., vol. xxxiv, pp. 404-5, Nov., 1887.

indicated by the studies of Gilbert * and Russell † for the time since the last great rise of Lakes Bonneville and Lahontan. These measures of time, surprisingly short whether we compare them on the one hand with the period of authentic human history or on the other with the long record of geology, carry us back to the date when the ice-sheet of the last glacial epoch was melting away from the basins of the upper Mississippi, of the Red River of the North, and of the Laurentian lakes.

Duration of Lake Agassiz compared with that of Lake Michigan, as indicated by shore erosion and beach deposits.

The entire departure of this ice-sheet therefore probably occupied at the most not more than two or three thousand years; and half of this time may measure the duration of Lake Agassiz, with the formation of its beaches marking more than twenty-five successive stages in the concurrent subsidence of its surface and rise of the earth's crust, which amounted together to 700 feet on the latitude of the north part of Duck Mountain and the middle of Lake Winnipeg. But even these short estimates may be too long. The shores of Lake Michigan, similar with those of Lake Agassiz in the drift of which they are formed, in their north and south trends, and in the adjoining depths of water, have suffered an amount of erosion by the lake waves during postglacial time which very far exceeds the total erosion that was effected upon the shores of Lake Agassiz during all its stages, the proportion between them being surely not less than ten to one; and Lake Michigan has a similarly greater amount of beach deposits, which upon a large area about its south end are raised by the wind in conspicuous dunes. This contrast indeed suggests that the duration of Lake Agassiz, and the recession of the ice-sheet from Lake Traverse to the lower part of the Nelson River, may have been included within less than one thousand years.

Glacial lake in the basin of the Blue Earth and Minnesota Rivers.

Before Lake Agassiz began to exist, the receding Minnesota and Dakota ice-lobes had each given place to a large lake on the central part of the area from which they withdrew. By the barrier of the Minnesota ice-lobe a lake having an elevation of about 1,150 feet above the sea was formed in southern Minnesota in the basin of the Blue Earth and Minnesota rivers, outflowing southward by way of Union Slough to the East Fork of the Des Moines. In its maximum extent this lake probably had a length of 160 miles, from Waseca to Big Stone Lake, with a width of forty miles in Blue Earth and Faribault Counties, attaining an area of more than 3,000 square miles. The continued glacial recession afterward opened lower outlets eastward to the Cannon River, and at the time of the Waconia moraine had uncovered the lower part of the Minnesota Valley, permitting the lake to

* U. S. Geological Survey, Second annual report, p. 188.
† U. S. Geological Survey, Monograph XI, Geological History of Lake Lahontan, p. 273.

be wholly drained northeastward to the Mississippi.* The modified drift from the retreating ice on the upper Minnesota basin was deposited along the lower half of this valley, filling it with stratified gravel, sand and clay, to a depth 75 to 150 feet above the present river from New Ulm to its mouth, which shows that at least this portion of the valley was excavated in the sheet of till during the interglacial epoch, and remained with nearly its present form through the later glaciation. It seems also probable that the upper part of the channel above New Ulm, occupied by the River Warren at the time of the Herman beaches, remained from such interglacial erosion, so that the first outflow from Lake Agassiz was at a level some twenty-five feet below the general surface adjoining Lakes Traverse and Big Stone and Brown's Valley, being thus approximately marked by the Milnor beach.† As long as streams poured into this valley directly from the melting ice-sheet, its modified drift, gathered from the ice in which it had been held, continued to increase in depth; but when the ice had retreated beyond the limits of the Minnesota basin, the water discharged here from Lake Agassiz brought no modified drift, and was consequently a most powerful eroding agent. By this River Warren the valley drift, so recently deposited, was mostly swept away, and the channel was excavated to a depth lower than the present river. But since Lake Agassiz began to outflow northeastward, the Minnesota Valley and that of the Mississippi below, carrying only a small fraction of their former volume of water, have become considerably filled by the alluvial gravel, sand, clay and silt, which have been brought in by tributaries, being spread for the most part somewhat evenly along these valleys by their floods.‡

Modified drift of the Minnesota Valley.

Erosion by the River Warren.

Prof. J. E. Todd supplies me the approximate outline of a lake named by him Lake Dakota, which occupied the valley of the James or Dakota River contemporaneously with the foregoing, reaching from Mitchell 170 miles north to Oakes and varying from 10 to 30 miles in width.|| It outflowed southward by the present course of the James to the Missouri. The Dakota ice-lobe, which had filled this valley and in its recession formed the northern shore of Lake Dakota, was not therefore the cause of this lake in the same way that the lake in the Blue Earth and Minnesota basin and Lake Agassiz owed their

Lake Dakota, outflowing southward to the Missouri River.

* Geology of Minnesota, vol. i, pp. 460, 622, 642.

† Compare with Geology of Minnesota, vol. i, pp. 479-485, describing the chains of lakes in Martin County, Minnesota, which are apparently due to interglacial water-courses that were not wholly filled with drift in the last glacial epoch.

‡ "The Minnesota Valley in the Ice Age," Proc. Am. Assoc. for Adv. of Science, vol. xxxii, 1883, pp. 213-231; also in Am. Jour. Sci., III, vol. xxvii, Jan. and Feb., 1884.

|| This lake is partially mapped by Prof. Todd in Proc. Am. Assoc. for Adv. of Science, vol. xxxiii, 1884, p. 393.

existence to the barrier of the ice-sheet in its retreat. The bed of Lake Dakota has a nearly uniform elevation of 1,300 feet, or is within ten feet below or above this, throughout its length; and during the glacial recession it was covered by a lake whose shores have now a height of about 1,300 to 1,350 feet, probably ascending slightly from south to north, as compared with the present sea level. Professor Todd states that the surface of this lacustrine area in its southern part, from Mitchell to Redfield, is nearly flat till, but thence northward is sand and loess-like silt, while considerable tracts of the eastern border of its north part consist of low dunes.

The outflowing James River was cutting down its channel during the retreat of the ice-lobe, and its erosion was so rapid as to prevent the northern part of Lake Dakota from retaining sufficient depth to outflow eastward into the south end of Lake Agassiz when the way was opened by the further departure of the ice, receding from the Head of the Coteau des Prairies and beginning to uncover the Red River Valley. A large tract of the sand and silt beds of Lake Dakota, and of a contiguous glacial lake formed in Sargent County, North Dakota, at the time of the Dovre moraine, now sends its drainage to the Red River by the head stream of the Wild Rice, which passes north of the Head of the Coteau and enters the area of Lake Agassiz near Wyndmere. The lowest portion of the water-shed on this lacustrine deposit, over which the James River would flow east to the Wild Rice River is scarcely ten feet above the general level of the James Valley or twenty-five feet above the present level of the James River, being at Amherst on the Aberdeen branch of the Saint Paul, Minneapolis and Manitoba Railway, 1,312 feet above the sea. The elevation of the upper portion of the lake beds in the vicinity of Oakes, and the lack of evidence that the lake waves have acted at any greater height upon the adjoining surfaces of undulating till and morainic hills, lead to the conclusion that the highest shore line of the north end of Lake Dakota is not more than 1,345 feet above the sea, showing that there was only a shallow expanse of water above the plain of lacustrine silt. On the north the depth of the channel of the inflowing James River, eroded apparently before the glacial retreat could permit an eastward outlet into Lake Agassiz, indicates that the surfaces of land and water in the James Valley had gained nearly their present relations, Lake Dakota being already drained away, when the Wild Rice River and the south end of the Red River Valley were uncovered by the recession of the ice-sheet. It is evident, therefore, that the long area of Lake Dakota has experienced only slight differential changes of level, at least in the direction from south to north, since the departure of the ice. The James River Valley is thus strongly contrasted with the northward

Less change of level on the area of Lake Dakota than of Lake Agassiz, since the departure of the ice.

uplifting that has affected the Red River Valley as shown by the beaches of Lake Agassiz, the highest of which rises from south to north about six inches per mile for 30 or 40 miles at its south end, but a foot or more per mile within 40 miles farther north, and indeed has an average northward ascent of about one foot per mile through an extent of 400 miles along the west side of this lake in North Dakota and Manitoba.

Lakes of the Saskatchewan and Souris, outflowing to Lake Agassiz by the Sheyenne.

As Lake Agassiz gradually extended to the north, following the receding ice-barrier, it received successively by three outlets the drainage of the glacial lakes of the Saskatchewan and Souris basins. These streams took the course of the Sheyenne, Pembina, and Assiniboine Rivers, each bringing an extensive delta deposit. With the first retreat of the ice from the Missouri Coteau a glacial lake began to exist in the valley of the South Saskatchewan in the vicinity of the Elbow, probably outflowing at an early time by the way of Moose Jaw Creek, and through a glacial lake in the upper Souris basin, to the Missouri near Fort Stevenson. Later the outflow from the Lake Saskatchewan may have passed to the Lake Souris by way of the Wascana River, after passing through a glacial lake which probably extended from Regina sixty miles to the west in the upper Qu'Appelle basin. When the Dakota ice-lobe was melted back to the vicinity of Devil's Lake, the drainage of Lake Souris passed southeast by the Big Coulée, one of the head streams of the Sheyenne, flowing thence for some time southward by the James River to Lake Dakota, but later eastward and southward by the Sheyenne into Lake Agassiz. A manuscript report of a reconnoissance in North Dakota by Major W. J. Twining, in 1869, describes the valley of the Big Coulée as 125 feet deep and a third of a mile wide, enclosing several shallow lakes along its course. "This great valley," he writes, "preserves its character to within twelve miles of the Mouse [Souris] River, and connects through the clay and sand ridge with the open valley of that stream."

Big Coulée.

The Sheyenne delta, reaching from the Lightning's Nest fifty miles northwest to the south bend of the Maple River, and having a maximum width of nearly thirty miles to the northeast from the south bend of the Sheyenne, probably covers an area of 800 square miles to an average depth of 40 feet. A large portion of this delta is doubtless modified drift, which was brought down by glacial streams from the melting surface of the ice-sheet, their coarser gravel with much sand being deposited in the high plains that slope southward along the outer side of the great moraines that pass south of Devil's Lake, their finer gravel and sand being carried by the Sheyenne to this delta, and their finest silt and clay being 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. Much alluvium was also supplied

The Sheyenne delta, formed partly of modified drift, and partly of alluvium from erosion of the Sheyenne Valley.

from the erosion of the Sheyenne Valley, which, with that of the Big Coulée, 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 to 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 was doubtless also both a preglacial and an interglacial valley. It was probably wholly filled with till in the first glacial epoch, then was eroded, chiefly in this drift, to nearly its present size during interglacial time, and was partially but perhaps not wholly refilled with till in the last epoch of glaciation. If it retained in considerable degree its trough-like form beneath the last ice-sheet, as was evidently true of the Minnesota Valley, its erosion and its tribute to the Sheyenne delta would be less than the proportion estimated.

When the bed of Lake Agassiz was gradually uncovered from the water of the receding lake, some parts of its central plain through which the Red River flows probably remained as broad shallow basins of water, which that river and its tributaries have since filled with their fine clayey alluvium. The similar clayey silt brought into Lake Agassiz by its delta-forming affluents, the Buffalo, Sand Hill, Sheyenne, Pembina, and Assiniboine Rivers, and others farther north, had been spread over large areas of the lake bed, but more extensive portions had a surface of till, with no such lacustrine deposit. Over these formations, much alluvium has been laid down along the avenues of drainage of the old lake bed, and it has filled depressions of the original surface, whether of lacustrine sediments or of till, being only distinguishable from the former by its containing in some places shells like those now living in the shallow lakes of the country adjoining the area of Lake Agassiz, remains of rushes and sedges and peaty deposits, as of the present marshes of the Red River Valley, and occasional branches and logs of wood, such as are floated down by streams in their stages of flood. Thus the occurrence of shells, rushes and sedges in these alluvial beds at McCauleyville, Minnesota, 32 and 45 feet below the surface, or about 7 and 20 feet below the level of the Red River, of sheets of turf, many fragments of decaying wood, and a log a foot in diameter at Glyndon, Minnesota, 13 to 35 feet below the surface, and numerous other observations of remains of vegetation elsewhere along the Red River Valley in these beds, demonstrate that Lake Agassiz had been drained away, and that the valley was a land surface, subject to overflow by the river at its stages of flood when these remains were deposited.[8] Even at the present time much of the area of stratified

Alluvium deposited along the central part of the Red River Valley after the drainage of Lake Agassiz.

[8] Geology of Minnesota, vol. ii, pp. 529, 530, 663-4, and 668-9.

clay that almost continuously forms the central part of the valley plain is covered by the highest floods, and probably no portion of it is more than ten feet above the high water line of the Red River and its tributaries. The position of the thick beds of fine silt and clay in the central depression of the Red River Valley shows that they were not mainly deposited by the waters of Lake Agassiz, which must have spread them somewhat equally over both the lower and higher parts of the lacustrine area: but instead appears to prove that at least their upper and greater part was brought by the rivers which flowed into this hollow and along it northward after the glacial lake was withdrawn.

BEACHES AND DELTAS.

Size and material of the beaches.

A brief general description of the beach ridges of Lake Agassiz has been given on page 12 E, their usual height being there stated to be from three to ten feet above the adjoining land on the side that was away from the lake, and ten to twenty feet above the adjoining land on the side where the lake lay, their varying breadth between the bases of the slopes being from ten to thirty rods. The beach ridge is thus a broad wave-like swell, with a smooth gracefully rounded surface. Like the shore accumulations of present lakes and of the sea coast, these of Lake Agassiz vary considerably in size, having in any distance of five miles some portions five or ten feet higher than others, due to the unequal power of waves and currents at these parts of the shore. The usually moderate slope of the land toward Lake Agassiz was favorable for the formation of beach ridges, and they occur at many successive levels, marking pauses in the gradual elevation of the land and subsidence of the lake. The highest distinct beach ridge of Lake Agassiz has been traced in a continuous course along a distance of more than four hundred miles in Minnesota, South and North Dakota, and Manitoba. In calling it continuous, I mean to say that whenever interrupted, as through its having been carried away by streams or where portions of the lake shore received no beach deposits, it is found a little distance farther along, beginning again at very nearly the same height. Commonly the land upon each side of the beach ridges of Lake Agassiz is till or unstratified clay, containing some intermixture of sand and gravel and occasional stones and boulders. The material of the beach ridge is remarkably in contrast with this adjoining and underlying till, for it includes no clay, but consists of stratified sand and gravel, the largest pebbles being usually from two or three to six inches in diameter.

Their formation by wave action.

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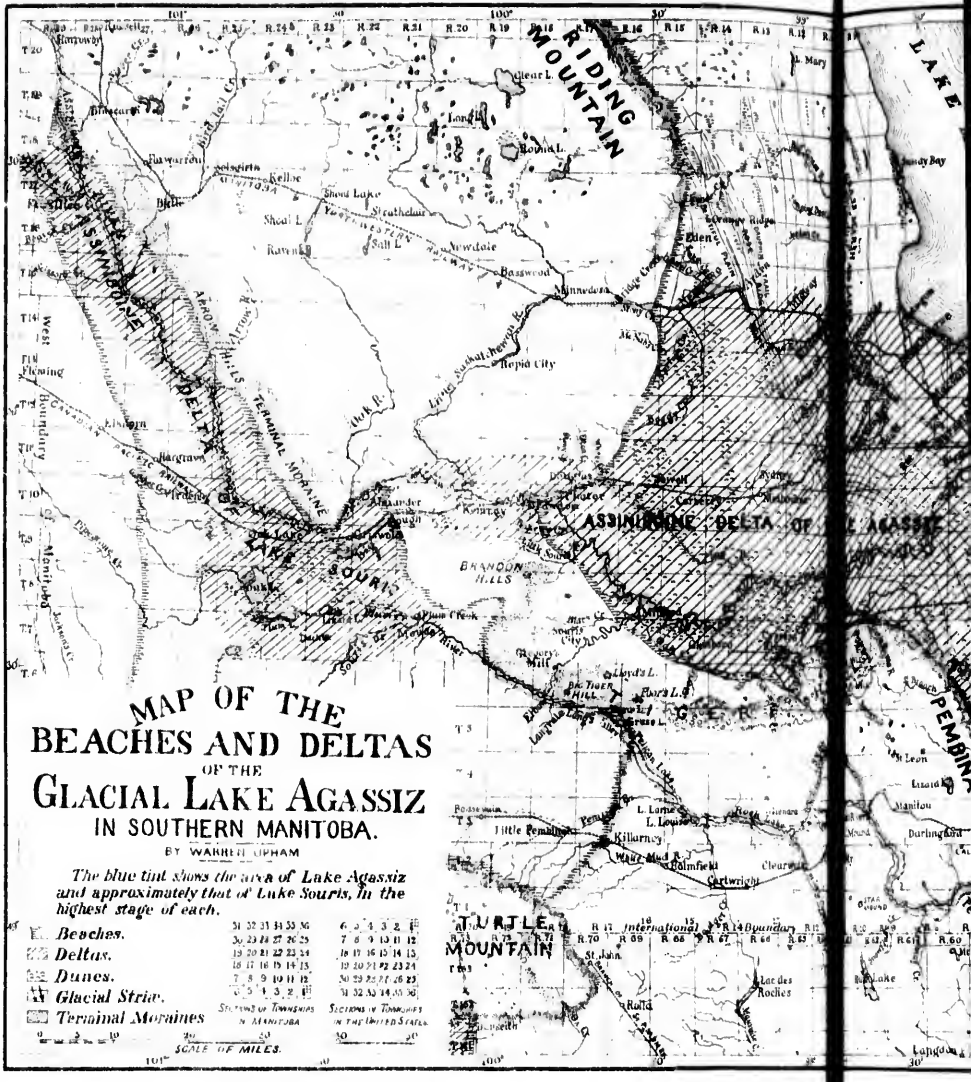
RIDING MOUNTAIN
ASSINIBOINE DELTA OF L. AGASSIZ
LAKE SOURIS
BRANDON HILLS
TURTLE MOUNTAIN
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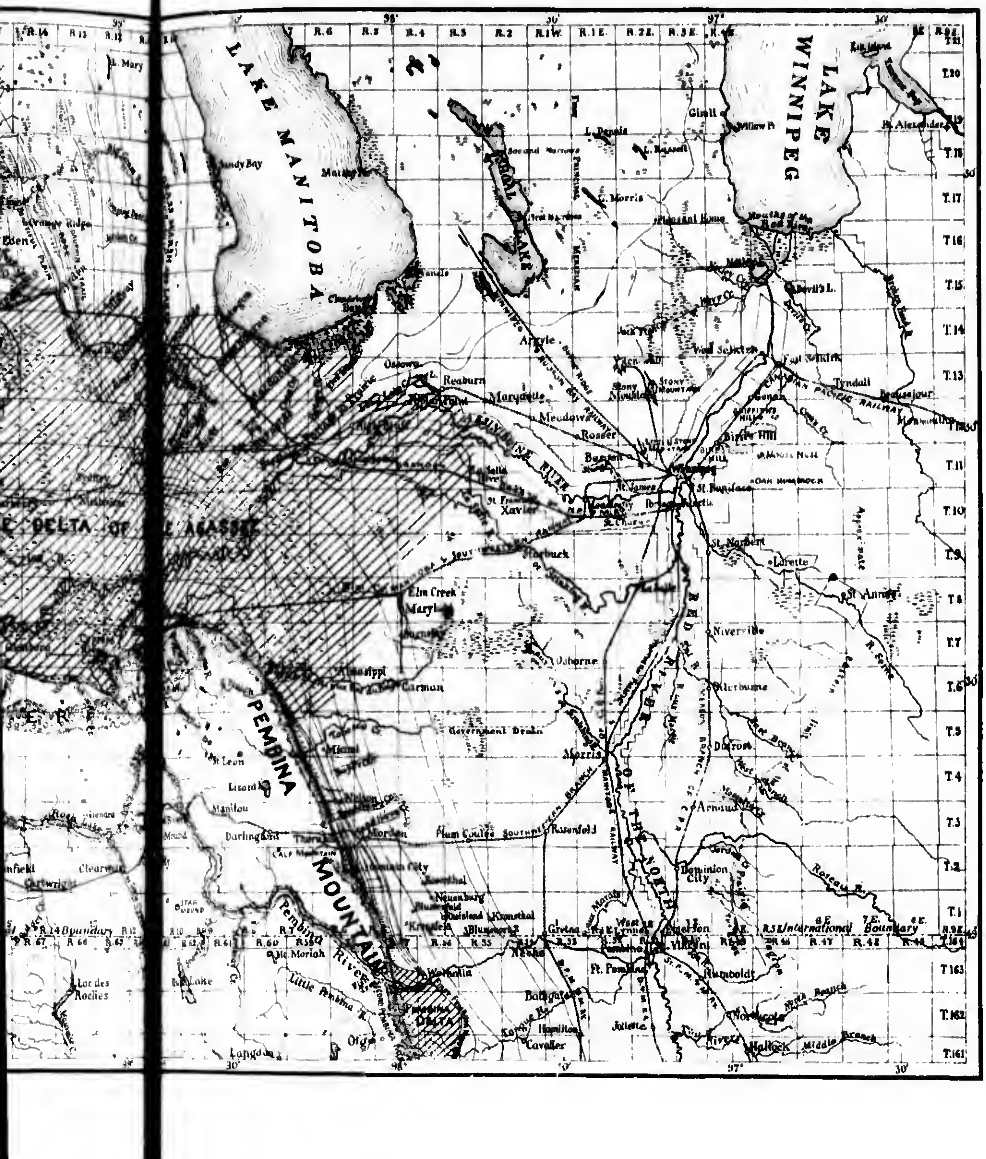
MAP OF THE
BEACHES AND DELTAS
OF THE
GLACIAL LAKE AGASSIZ
IN SOUTHERN MANITOBA.
BY WARREN UPHAM
The blue tint shows the area of Lake Agassiz and approximately that of Lake Souris, in the highest stage of each.
Beaches.
Deltas.
Dunes.
Glacial Striæ.
Terminal Moraines
SCALE OF MILES.
SECTIONS OF TOWNSHIPS IN MANITOBA
SECTIONS IN TOWNSHIPS IN THE UNITED STATES


LAKE MANITOBA
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MOUNTAIN
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Willow Pt
Ft. Alexander
Mouth of the Red River
Argyle
Reaburn
Meadows
Rosser
St. James
St. Boniface
Xavier
Starbuck
Elm Creek
Carman
Osborne
Niverville
Morris
Arnaud
Rosenfeld
Dominion City
Emerson
Humboldt
St. Norbert
St. Anne
Tyndall
Beausejour
West Selkirk
East Selkirk
Stony Mountain
Birds Hill
Manitou
Darlingford
Morden
Manitoba City
Neuenburg
Kronsthal
Gretna
Neche
Ft. Pembina
Bathgate
Hamilton
Cavalier
Walhalla
Langdon
Pembina River
Little Pembina R.
Roseau R.
St. Leon
Lizard
Clearwater
Cartwright
Lac des Roches
International Boundary
Government Drain
Plum Coulee
Tongue R.
Two Rivers
Hallock
Middle Branch
Jolliette
T.1
T.2
T.3
T.4
T.5
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deposits of stratified clay, derived from the same erosion of the till, sank in the deeper part of the lake. But these sediments were evidently of small amount and are not noticeable upon the greater part of this lacustrine area, which consists of a smoothed sheet of till. Where the beaches cross delta deposits, especially the fine silt and clay that lie in front of the delta gravel and sand, they are indistinctly developed or fail entirely. On the other hand, the most massive and typical development of beach ridges is found on areas of till that rise with a gentle slope of ten or fifteen feet per mile. No boulders referable to transportation by floating ice have been found within or upon any of the beach deposits of this lake.

Absence of boulders.

When Lake Agassiz formed its first and upper beach, its outlet was about 75 feet above the present surface of Lake Traverse, or 1,055 feet above the sea. The channel which at this time had been excavated in the drift by its outflow was 40 to 50 feet deep along the distance of about fifty miles, where are now Lake Traverse, Brown's Valley, and Big Stone Lake. This beach is crossed by the Breckenridge line of the Saint Paul, Minneapolis & Manitoba Railway at a point about one and a half miles northwest of Herman, Minnesota, from which place it is denominated the Herman beach.

The upper or Herman beach.

At the next epoch after that of the upper or Herman beach, when the lake level in its southern part was again nearly stationary long enough to form a ridge of gravel and sand upon its shore, the outlet had been eroded about 25 feet deeper than at the time of the upper beach, but was still 60 feet above the present Lake Traverse and Brown's Valley. The beach of Lake Agassiz, when it had this lower level, is crossed by the Breckenridge railway line at Norcross, Minnesota, five miles northwest of Herman; and it is therefore named the Norcross beach.

Norcross beach.

The next two series of beach deposits were formed when the outlet of Lake Agassiz had been lowered respectively, for the first, 15 to 30 feet, and for the second, 40 to 50 feet below its level at the time of the Norcross beach. These beaches take their names from Tintah and Campbell, Minnesota, the next two stations northwest of Norcross on the Breckenridge railway line.

Tintah and Campbell beaches.

The fifth and lowest beach of Lake Agassiz, while it outflowed to the south, was formed after a further erosion of 20 feet, lowering the outlet 960 feet above the sea, and completing the excavation of its channel to the present beds of Traverse and Big Stone Lakes. My first observation of this beach was three and a half miles northeast of McCauleyville, Minnesota, about fifteen miles north of Breckenridge. It is therefore named the McCauleyville beach. Five distinct series of beach ridges of gravel and sand were thus formed by Lake Agassiz at

McCauleyville beach.

successive stages of height during its process of deepening the channel by which it outflowed southward.

Northward ascent and subdivision of these beaches.

Tracing these beaches to the north, they are found to have a gradual ascent in that direction, diminishing in amount from the highest and earliest to the lowest and latest; and the single beach ridges of the south part of the lake are found to be represented northward by two or three or several parallel beaches. Accordingly, in the following descriptions of the beach ridges observed in Manitoba, those are grouped together which seem to represent the stages of the lake that southward were combined respectively in the Herman, Norcross, Tintah, Campbell and McCauleyville beaches. The Herman beach at the north is thus more or less clearly subdivided into seven, the Norcross and Tintah beaches each become double, and the Campbell and McCauleyville beaches each become threefold; so that seventeen stages are recorded in the elevation of the northern part of the area of Lake Agassiz and in the northward subsidence of the water level, belonging to the period of outflow southward by the River Warren.

Beaches formed while Lake Agassiz outflowed northeastward.

Eleven lower beaches were formed while Lake Agassiz outflowed to Hudson Bay; and these are named from localities in North Dakota and Manitoba. The first three are called the Blanchard beaches, and the next three are successively the Hillsboro, Emerado, and Ojata beaches, from towns in North Dakota near which they are well developed; while the remaining five receive their names from Manitoba, being in descending order the Gladstone, Burnside, Ossowa, Stonewall and Niverville beaches. The rate of their northward ascent is only about a sixth or an eighth as much as that of the first Herman beach. In all these stages, excepting the lowest one when the Niverville beach was formed, Lake Agassiz extended south of the international boundary.

BEACHES OF THE HERMAN STAGES.

In T. 1, R. 5.

The west shore of Lake Agassiz enters Manitoba two miles west of the east line of range five, at a distance of thirty-six miles from the Red River. On the international boundary and for the next ten 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 four miles south and two 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 S.W. ¼ of sec. 26, T. 2, R. 6. It is here a massive rounded ridge of gravel and sand, with descent of twelve to fifteen 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 N.W. ¼ 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 one to one and a half 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 twenty to thirty rods, bordered on the east by a descent of ten or fifteen feet in twenty rods, and on the west by a descent of about four 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 sec. 10, T. 2, R. 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 one or two 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 two or three 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 Laurentian rocks. Thence the highest shore continues north through the west part of secs. 16 and 21, T. 3, R. 6, and in sec. 28 comes to the steep escarpment of Pembina Mountain, with which it coincides along the next thirty 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.

Highest beach in Ts. 2 and 3, R. 6.

About a quarter of a mile east of the foregoing is a parallel beach fifteen to twenty feet lower, the second in the Herman series. Newton Jane'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 fifteen feet or more within an eighth of a mile to the east; but on the west the descent is only one or two feet or in part wanting, and a nearly level surface of sand and gravel reaches west to the upper beach. In sec. 10, T. 3, R. 6, at the road from Morden to Thornhill, this second Herman beach has a height

Second Herman beach, in Ts. 2 and 3, R. 6.

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.

Third Herman beach, Ts. 2 and 3, R. 6.

Three small parallel beach ridges referable to the third stage in the Herman series are crossed in the west part of sec. 24, T. 2, R. 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 sec. 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, sixteen feet deep, is gravel and sand to the depth of twelve feet, with till below. Northward these beaches are traceable through secs. 2, 11, 15, and the south part of 22, T. 3, R. 6, to Bradshaw's Creek, beyond which they pass, with the other Herman and Norcross beaches, along the Pembina Mountain escarpment.

Fourth Herman beach, Ts. 2 and 3, R. 6.

The fourth Herman beach passes through Mountain City, in sec. 24, T. 2, R. 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 school-house is a less conspicuous parallel beach, at 1,183 to 1,18[illegible] feet. Both are terrace-like in form, having a descent of three to five feet or more on the east but only one to two feet or none on the west. The continuation of this shore was also observed, like the preceding, through a distance of six miles northward.

Pembina Mountain from Thornhill to Treherne.

From sec. 28, T. 3, R. 6, the Herman shores of Lake Agassiz coincide with the prominent escarpment of the Pembina Mountain through a distance of twenty-nine miles, passing in a nearly straight course north-northwesterly to sec. 30, T. 7, R. 8, about seven 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 overshading 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 beach and those of the Norcross stage were between this and the base.

Sec. 36, T. 7, R. 9.

At the north end of the Pembina Mountain the Herman shores of Lake Agassiz turned from a northward to a westward course, and in the sharpest portion of this bend, in sec. 36, T. 7, R. 9, the current 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

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 six miles farther west the Herman beaches are well exhibited in the gradual ascent that rises to the Tiger Hills one mile south of Treherne. The highest beach here crosses the middle of the N.W. ¼ of sec. 31, T. 7, R. 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 three to five 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 T. 7, R. 9, by the road to the south from Treherne. About twenty and fifty 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 on the south edge of sec. 6, T. 8, R. 9. This is a slight terrace with crest at 1,243 and 1,244 feet and descent of four or five 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 thirty 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 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 & Southwestern Railway a mile west 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

Vicinity of Treherne.

mile farther east the railway cuts a beach ridge with its crest at 1,21[illegible] feet, also referable to the fourth Herman stage.

The Assiniboine delta occupies the western border of Lake Agassiz from Treherne westward about sixty miles to Brandon and thence northeastward about thirty-five 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 sec. 4, T. 7, R. 12, thence southwest and south to the Cypress River near Grange post-office in sec. 18, T. 6, R. 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 sec. 31, T. 7, R. 16, passes thence northwest to Brandon. Beyond the Cypress a belt of [illegible] moderately undulating or in part nearly flat, from two or three to [illegible] 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 N.E. ¼ of sec. 28, T. 8, R. 17, about fifteen 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 ten feet high, eroded in till a half mile southwest of this beach. The unusually smoothed surface of the [illegible] extending thence west and south to the Brandon and Tiger Hills, [illegible] 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 [illegible] 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.

Highest shore from Treherne to Brandon.

In the south part of the city of Brandon the second Herman beach, marking the stage *bb* of the table in a subsequent part of this report, 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 Streets. 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 of ten feet of obliquely bedded sand and gravel containing abundant pebbles up to

Second Herman beach, Brandon.

two inches and rarely cobbles three or four inches in diameter, about two-thirds being Paleozoic magnesian limestones, from one-tenth to one-fourth Cretaceous shale, and the remainder mostly Archæan granites and schists. This beach ridge varies from ten to twenty rods in width and from five to ten 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 three to four miles west of Brandon on the road to Kemnay, both of which are more fully noticed in the description of the Assiniboine delta.

Highest shore from Brandon to Neepawa.

North of the Assiniboine the highest shore of Lake Agassiz passes from Brandon east and east-northeast by Chater and Douglas, being on the 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, T. 11, R. 17. Thence its course is north-northeastward, and is indicated by an eroded escarpment, extending two or three miles with a height of ten to fifteen feet, and less distinctly observable a few miles beyond. The base of this escarpment where it crosses the south line of sec. 24 in this township is 1,269 feet above the sea; and the surface at the school-house a sixth of a mile farther west is about twenty feet higher. All the area eastward is delta sand and gravel; but the escarpment and the country rising thence slowly northwestward are till. The continuation of this line between a moderately rolling surface of till on the west, with beautiful boulders and frequent lakelets, and the slightly undulating sand and gravel delta on the east, with low dunes on many parts of its crest, passes north-northeasterly in range sixteen across the west half of T. 12 and the east half of T. 13, and thence north through the eastmost tier of sections in T. 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.

Near Neepawa.

The Manitoba & Northwestern Railway crosses two beach ridges at three and three-fourths miles and three 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 seven feet above the adjoining surface, and a width of thirty to forty 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 twelve miles to where the Herman and Norcross shores pass into the steep escarpment that forms the eastern face of Riding Mountain.

BEACHES OF THE NORCROSS STAGES.

East of Mountain City and Thornhill.

Through T. 1, R. 5, the Norcross shores of Lake Agassiz lie on the escarpment of the Pembina Mountain; and the first observations of their beaches were in secs. 7, 18 and 19, T. 2, R. 5, where the mountain wall is reduced to a gradual ascent in the vicinity of Mountain City and Thornhill. About a half mile southeast of Mountain City the upper Norcross beach is well displayed at John Borthwick's house, which is built on its crest, 1,167 feet above the sea, in the southwest corner of sec. 19. Digging for wells here shows that the gravel and sand of the beach extend only to a depth of six or eight feet, there resting on the Fort Pierre shale. From the crest of this beach ridge its slopes fall eight or ten feet within a few rods on the east and about four feet on the west. It is bordered on the west at this locality by a surface strewn with very abundant boulders up to five feet or rarely more in diameter, nearly all being Archæan granites, with perhaps a third of one per cent. magnesian limestone. Generally, however, the surface in this vicinity has few or no boulders; and a shallow depth of ordinary till or of lacustrine deposits overlies the Cretaceous shale. The second Norcross beach, also forming a distinct ridge, lies a third of a mile farther east, with its crest about 1,150 feet above the sea. A large excavation for sand to be used in plastering has been made in this ridge in the south edge of this sec. 19. A mile farther south John W. Stodders' house is built on it at an elevation of 1,148 feet. His well

twelve feet deep, passes through gravel and sand, eleven feet; and then enters the shale, the top of which, to a depth of six to twelve inches, is a hard calcareous layer, including nodules and veins of calc spar. Pieces of the hard surface of this layer, thrown out of the well, were plainly marked with glacial strie. The continuation of these beaches is traceable through the next seven miles northward across the Southwestern Branch of the Canadian Pacific Railway, passing about three miles east of Thornhill, to Bradshaw's Creek, beyond which to near Treherne they again coincide with the Pembina Mountain escarpment.

Near Treherne.

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

The next definite observations of the Norcross shores of this lake are near Neepawa, where the Manitoba & Northwestern Railway a half mile west of this station crosses small beach ridges referable to the upper Norcross stage, with their crests 1,223 to 1,225 feet above the sea. Close to the west is an eroded escarpment of till fifteen feet high,

rising from 1,225 to 1,240 feet. On the other side of the station, between a half mile and one mile east from it, the railway crosses a surface of wind-blown sand with hollows two to four feet deep, the crests of its low dunes being at 1,193 to 1,192 feet. These occupy the level belonging to the lower Norcross beach. The bed of the railway here, formed of the sand of the Assiniboine delta, further worn and redeposited by the lake waves, proves somewhat insecure because of its liability to be channelled by the wind. The road leading northward from Neepawa to Eden and Riding Mountain runs on the crest of the upper Norcross beach ridge through the east part of secs. 21 and 28, T. 15, R. 15, three to five miles north of the railway, its crest there having a nearly constant height of 1,223 feet, with a descent of five or six feet from it to the east and half as much to the west. Thence this beach ridge continues north-northeasterly to the east part of sec. 23, T. 16, R. 15, where it has an elevation of 1,225 to 1,230 feet, with width of about thirty rods and descent of ten to fifteen feet on its east side. It next runs north or slightly west of north to Thunder Creek in the south part of T. 17, beyond which its course, with that of the lower Norcross shore, is along the steep ascent of Riding Mountain. In the journey from Eden post-office (S.W. ¼ of sec. 22, T. 16, R. 15) to Orange Ridge post-office (N.W. ¼ of sec. 32, T. 16, R. 14), a nearly flat surface of till with frequent boulders is crossed upon the width of three miles between this beach and the upper Campbell beach, descending in that distance from 1,200 to 1,100 feet, approximately. Boulders are especially abundant within the first mile from the upper Norcross beach, whence the erosion of the lake bed supplied its gravel and sand. This even tract of till would seem most favorable for the accumulation of the beaches belonging to stages of Lake Agassiz between its upper Norcross and upper Campbell levels; but no beach ridge nor other deposit of gravel and sand, nor line of erosion which sometimes takes the place of these to mark a shore line, was seen in the intervening distance. It seems probable that not far south and north from this route of observation the lower Norcross and the two Tintah beaches will be found.

Neepawa and Eden road.

BEACHES OF THE TINTAH STAGES.

In proceeding northward from the international boundary the Tintah beaches were first observed near the line between Ts. 1 and 2, R. 5, lying on a terrace which forms the lower part of the Pembina Mountain. On the boundary this terrace is about three fourths of a mile wide, its eastern margin being an escarpment that rises from 1,040 to 1,090 or 1,095 feet; and from its verge it gradually rises 25 to 35 feet in its width, so that its western limit at the base of the main

Ts. 1 and 2, R. 5.

escarpment has a height of 1,120 to 1,125 feet. Its surface is till with plentiful boulders, nearly all Archæan, up to five feet in diameter, mostly embedded or only projecting a foot or less; but the slope on its east side consists of weathering and pulverized Cretaceous shale, which is thus shown to form the principal mass of the terrace, beneath a thin mantle of till. In the distance of six miles northward across T. 1, this terrace widens to two miles, and its eastern verge sinks to 1,055 feet; but it is bordered by only a slight escarpment, about fifteen feet high, the base of which is thus at the same level as on the international boundary. In its width of two miles it there rises about 90 feet, to the base of the mountain escarpment at 1,140 to 1,150 feet. A quarter to a third of a mile east of this escarpment a line of erosion rises from 1,110 to 1,125 feet, approximately, marking the upper Tintah shore. In the S.E. ¼ of sec. 5, T. 2, this shore bears scanty deposits of beach gravel and sand, with their crest at 1,110 to 1,115 feet. The lower Tintah beach lies a third of a mile farther east, and is a distinct ridge of gravel and sand with its crest at 1,083 to 1,085 feet, bordered on each side by till, the surface of which is five feet lower on the east and three feet lower on the west. Thomas Kennedy's well, fourteen feet deep in the N.E. ¼ of sec. 5, T. 2, R. 5, found the till only four feet deep, underlain by the Fort Pierre shale. This terrace doubtless owes its form, like the far more prominent Pembina Mountain, to preglacial erosion of these Cretaceous beds. It continues along the foot of the mountain, with a width of one and a half to two miles, at least to the South Branch of Tobacco Creek, which crosses it near Miami post-office, twenty-five miles north of the international boundary. Throughout its whole extent it has a considerable ascent upon its width from east to west, as in the localities noted. Much of its surface is till with many boulders, but some portions have no boulders, such tracts being overspread with lacustrine gravel and sand, or perhaps occasionally consisting of Cretaceous shale next below the soil, with no drift nor lacustrine deposits.

West of Morden.

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

Abundant boulders.

The most remarkable feature of this tract is its extraordinary abundance of boulders, nearly all Archean, usually less than five feet in diameter, but in many places ranging in size to ten feet or more. Upon an area that extends at least one to two miles both south and north of the road and railway, the surface is as thickly strewn with boulders as are the most typical terminal moraines seen by me in Minnesota and South and North Dakota. Many of these rock-masses, instead of being imbedded in the drift, as is generally the case in this region, project two to three or four feet above the surface, or lie wholly on it with no portion concealed. Here the ice-sheet probably terminated, depositing these boulders in the west margin of Lake Agassiz, during the time of its accumulation of the terminal moraine that forms the west part of the Tiger Hills and the Brandon and Arrow Hills.

Near Nelson.

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

East of Treherne

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

Northeast of Neepawa.

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

BEACHES OF THE CAMPBELL STAGES.

Upper Campbell shore from the international boundary to Treherne.

Along the course of the Cretaceous terrace which borders the base of the Pembina Mountain for at least twenty-five miles northward from the international boundary, as described in connection with the Tintah beaches, the upper Campbell shore line, there having an elevation of 1,045 to 1,050 feet, coincides with the low escarpment which forms the east margin of this terrace. A portion of the sculpturing of this escarpment was doubtless done by the waves of the lake; but the main outlines of the terrace as a bench intermediate between the expanses

the Red River Valley and the high Pembina escarpment seem clearly attributable to preglacial erosion. The first locality where I observed a distinct beach ridge of gravel and sand referable to this stage is in sec. 3, T. 4, R. 6, a half mile west of Nelson, and thence through a distance of a mile or more north-northwestward. It lies close east of the terrace escarpment, and has an estimated elevation at its crest of 1,055 feet. In T. 7, R. 8, this shore is marked by a conspicuous beach ridge, passing through sees. 22, 27, and the east edge of 33, lying an eighth to a half of a mile west of the Boyne River, with its crest about 1,055 to 1,060 feet above the sea. The descent from the crest is ten to fifteen feet on the east, and five to eight feet on the west. The lake at this stage, or at a slightly higher level, also cut an escarpment fifteen to twenty feet high, with its top at 1,075 feet, approximately, which passes northwestward across sees. 28 and 29 of this township and northward through the east part of sees. 6 and 7, T. 8, crossing the railway about seven miles east of Treherne.

Lower Campbell shore along the same distance.

The lower Campbell beach in its course northward from the international boundary lies close east of the terrace face which was the upper Campbell shore. In sees. 2 and 11, T. 1, R. 5, the elevation of its crest is 1,036 to 1,040 feet. On the west a nearly level surface extends an eighth of a mile to the terrace. On the east a slope of beach gravel and sand sinks to 1,028 feet in about twenty-five rods; and a similarly descending surface of till continues to 1,015 feet in the next twenty-five rods, beyond which there is a much slower descent eastward. The road on the line between Ts. 1 and 2, R. 5, crosses this shore about three eighths of a mile west of the northeast corner of sec. 34, T. 1, where it is marked by a typical beach ridge, with its crest at 1,034 feet, from which there is a descent of ten feet in ten rods to the east and three or four feet in ten rods to the west. This ridge was seen to hold nearly the same outline and height through a distance of one mile or more to the south and a half mile north to a small creek. About a half mile west of Morden, where it has been considerably excavated for plastering sand, it has a nearly flat top ten to twenty rods wide, with ascent on this width from 1,036 to 1,040 feet, approximately, resting on the base of the terrace escarpment. Five to six miles farther north, the road from Nelson to Miami runs along the top of this beach through the north half of sec. 3 and the S.W. ¼ of sec. 10, T. 4, R. 6. It is there a broad, low ridge of sand and gravel, twenty to thirty rods wide, the elevation of its crest being about 1,035 feet, or ten feet above Nelson. Continuing northward, it crosses the N.E. ¼ of sec. 6, T. 5, R. 6, a mile west of Miami.

The course of these shore lines was not traced across the Assiniboine delta, but their elevation shows that they lie on its eastward slope

where they are intersected by numerous ravines and are doubtless obscured in many places among its dunes. On the Canadian Pacific Railway profile three massive beach ridges, the two higher referable to the upper Campbell stage, and the third to the lower Campbell stage of the lake, are shown three miles to two and a half miles west of Austin, their crests being respectively 1,087, 1,081, and 1,066 feet above the sea. These beaches are each about thirty rods wide, with descents of ten to twenty feet from their crests to their east bases and half as much to the west.

West of Austin.

On the Manitoba & Northwestern Railway the upper Campbell beach is a very massive rounded ridge, thirty to fifty rods wide, along whose eastern slope the railway runs about three miles, from the south side of sec. 6, T. 15, R. 13, north-northwest to Arden. Before the railway was built, the old trail from Winnipeg to the Saskatchewan River passed along the top of this ridge the same distance and to a point about a mile north of Arden, there leaving it and turning to the west. This portion of the trail was a good dry road throughout the year, being thus remarkably contrasted with the deep mud along most of its extent during rainy seasons. Because of this character of the road and the beauty of the smooth beach, which is prairie, without tree or bush, but is bordered on each side by groves, this avenue-like tract received its widely known name, the Beautiful Plain. It is not flat, however, as the name seems to imply; for the crest of the beach ridge, at Arden 1,060 feet above the sea, and not varying more than a few feet above or below this elevation in its course through several miles south and north, is fifteen to twenty-five feet above the nearly straight margin of the woods an eighth to a quarter of a mile east, and seven to ten feet above the more irregular margin of bushes and woods on the west, commonly ten to thirty rods distant. The barrier of this beach ridge was sufficient to turn the White Mud River southward three miles along its west side. In a section cut six feet deep close north of Arden for the passage of the railway and in excavation of ballast, the material of this beach is mainly fine gravel with pebbles only a quarter to a third of an inch in diameter, but also includes layers of sand and coarse gravel, with pebbles up to two inches in diameter, of which about three quarters are from the Paleozoic formations of magnesian limestone that occupy the country eastward to Lake Winnipeg.

Vicinity of Arden.

Beautiful Plai

From Arden this beach extends north-northwest through the northeast part of T. 15 and nearly through the center of T. 16, R. 14. In the north half of T. 16 it has in several places a narrow terrace-like secondary beach on its eastern slope five to ten feet below the crest of the main beach; and it is closely bordered on the west by a low escarpment of till which rises five to ten feet above the beach ridge and

forms the margin of a flat or slightly uneven expanse of till that ascends slowly westward. A post-office situated close west of this beach and escarpment in sec. 32, T. 16, is named Orange Ridge, in allusion to the orange-red lilies (Lilium Philadelphicum, L.) which grow in abundance on the sandy and gravelly soil of the bench. The elevation of the Orange Ridge or Beautiful Plain beach on the north line of the N.E. ¼ of sec. 32, T. 16, is approximately 1,080 feet above the sea; and of the escarpment on the west, which was eroded during the early part of this upper Campbell stage, 1,090 feet. Orange Ridge.

The lower Campbell beach is crossed by the railway near the southeast corner of sec. 6, T. 15, R. 13, where the elevation of its crest is 1,061 feet, with a descent of eight feet in about fifteen rods to the east and five feet in a few rods to the west. Through the next fifteen miles northward it lies a half to two thirds of a mile east of the Beautiful Plain and Orange Ridge. East of the latter, on the line between Ts. 16 and 17, R. 14, the elevation of its crest is about 1,070 feet, with descent of fifteen feet to the east and ten feet to the west. Lower Campbell beach near Arden and Orange Ridge.

The northward continuations of the Campbell beaches pass through secs. 5 and 8, T. 17, R. 14, to Thunder Creek, and thence a few degrees west of north to the Big Grass River in sec. 31 of this township. Thence they traverse secs. 6, 7 and 18 in T. 18, R. 14, and the northeast part of T. 18, R. 15, where a swamp on the west about two miles wide separates them from the base of the Riding Mountain. Ts. 17 and 18, Rs. 14 and 15.

BEACHES OF THE M'CAULEYVILLE STAGES.

In the S.W. ¼ of sec. 12, T. 1, R. 5, the upper McCauleyville shore is indicated by very scanty deposits of fine gravel, 1,006 to 1,007 feet above the sea, from which there is a descent of three or four feet in twenty rods east. Through the east half of sec. 23, the middle of 26, and the west half of sec. 35 of this township, two McCauleyville beaches are developed as small parallel ridges of gravel and sand. The upper one has an elevation of 1,000 to 1,002 feet at its crest, from which there is a descent of one to two feet within two or three rods to the west and five to eight feet in ten or twelve rods to the east. Thence a nearly level surface of till with frequent boulders occupies a width of ten or twelve rods, and is succeeded on the east by the second ridge, the western slope of which rises two or three feet to its crest. This is about five feet lower than the upper beach, and has a similar descent of five feet or more on its east side. T. 1, R. 5.

About a quarter of a mile east of Nelson the upper McCauleyville shore is a line of erosion with a descent of five to ten feet within a short distance from west to east. Four miles thence to the north-northwest From Nelson to Miami.

it is a well defined beach ridge running close to the bridge over Boyd's Creek, near the northeast corner of sec. 21, T. 4, R. 6; and it continues, but is less conspicuous, through the next three miles northward to the church in the northeast corner of sec. 5, T. 5, R. 6, a quarter of a mile east of Miami post-office. Its crest at Boyd's Creek is eight to ten feet, and at Miami five feet, above the more massive second or middle McCauleyville beach, which lies a quarter to a half of a mile farther east, passing north-northwesterly through the west edge of sec. 27 and the east half of sec. 33, T. 4, in which latter it is offset nearly a quarter of a mile to the east, and through the middle of sec. 4 and the west half of sec. 9, T. 5.

East and north of Arden.

Three McCauleyville beach ridges are crossed by the Manitoba & Northwestern Railway on the north side of secs. 32 and 33, T. 14, R. 13, about four miles, four and a half, and five miles southeast of Arden, the elevations of their crests being respectively 1,039, 1,029, and 1,016 feet above the sea. Each of these rises about five feet above the surface on the east. They continue as prominent gravel ridges north-northwestward through the west half of T. 15, and the southwest part of T. 16, R. 13, and through the northeast part of T. 16, the east half of T. 17, and the west half of T. 18, R. 14, to the vicinity of Phillips' ranch. In T. 15, R. 13, next east of Arden, the most western and upper one of these beaches is called Lowdon's Ridge from Thomas Lowdon, whose house, the first built on it, is in the middle of the east edge of sec. 30. The middle beach appears to be twofold in secs. 29 and 29, Joshua Ritchie's house being built on one of its ridges and the Rose Ridge school-house a quarter of a mile farther east on the other.

Rose Ridge.

About three quarters of a mile east of the Rose Ridge is the lower McCauleyville beach, on which the trail to Lake Dauphin runs northward through Ts. 15 and 16. Lewis McGhie's house is built on the eastern slope of this beach in the N.E. ¼ of sec. 28, T. 15. Lowdon's, Ritchie's and McGhie's wells, and others in this township on these beach ridges, pass through gravel and sand five to fifteen feet and through till below to total depths of thirty to fifty feet, obtaining water in gravelly seams, from which it usually rises ten to twenty feet within a few hours, to its permanent level.

BEACHES OF LOWER STAGES WHEN LAKE AGASSIZ OUTFLOWED NORTHEASTWARD.

Blanchard beaches, T. 1, R. 4.

On the international boundary the Blanchard shore lines enter Manitoba in the west part of T. 1, R. 4, passing near Kronsfeld in sec. 7 of this township, and extending north-northwest within about a mile east of Morden, but they are not marked along this distance by distinc

beach deposits nor lines of erosion. The lowest of these shore lines crosses the Canadian Pacific Railway a mile west of McGregor, where it forms a slight swell on the gentle eastward slope of the Assiniboine delta. On the Manitoba & Northwestern Railway the three Blanchard beaches appear to be identifiable, being crossed successively two miles and three fourths of a mile west and one mile east of Midway. The upper two are nearly flat tracts of fine gravel and sand, an eighth to a quarter of a mile wide, at 994 and 979 feet above the sea, each being bordered on the west by a depression of about two feet and on the east by a gentle slope descending four or five feet. The third and lowest is a beach ridge of the usual form, about thirty rods wide, with a descent of five feet both to the east and west from its crest, which is at 969 feet. After crossing the McCauleyville beaches on the way from Arden to Gladstone, the surface is wholly silt and sand, with fine gravel, very flat, excepting these slight ridges and others at lower levels. In their continuation northward, portions of the Blanchard beaches are noted on the plats of the Dominion Land Surveys through Ts. 15 to 20, R. 13.

McGregor.

Between Arden and Gladstone.

The Hillsboro beach enters Manitoba near the middle of the south side of R. 4, and passes north-northwestward. It is not conspicuous on the international boundary, but near the west line of sec. 21, T. 1, R. 4, about a half mile east of Blumenfeld, it is a noticeable ridge with a descent of three to five feet on the east, its crest being about 940 feet above the sea. Its sand has there been excavated for use in plastering. Northward it passes about a half mile east of Oesterwick, one and a half miles east of Morden, and nearly four miles east of Miami, where Henry York's house is built on its crest at an elevation of about 950 feet. Thence its slopes descend fifteen feet in a short distance to the east and five feet or more to the west, the beach being much larger than along most of its course. Mr. York's cellar and well are in sand and fine gravel, but the lower land adjoining on each side is till. Twelve miles farther north this beach passes near Mr. Field's house in the S.E. ¼ of sec. 4, T. 7, R. 6, about three fourths of a mile west of Almasippi post-office. The road from Carman to Treherne there ascends a few feet, and in its next third of a mile northwestward crosses a tract of sand with hollows three to five feet below its highest portions, showing that it was formerly wind-blown. This beach deposit is derived from the erosion of the eastern margin of the Assiniboine delta, within a few miles to the north. On the road from Arden to Gladstone this beach was not noticed, but it seems to be traceable on the township plats northward nearly through the middle of Ts. 15, 16, and 17, and through the west part of Ts. 18, 19, and 20, in R. 12.

Hillsboro beach.

East of Blumenfeld.

East of Miami.

Almasippi.

The Emerado beach lies two to three miles east of the last. In Ts. 1

Emerado beach.

and 2, R. 4, the Mennonite villages of Rheinland, Neuenburg and Rosenthal are partly built on it. At the wind-mill in Rheinland, and

Rheinland.

thence along its course as seen for a half mile or more to the south-southeast and north-northwest, this shore is marked by an ascent of three to six feet in as many rods from east to west; and from its crest, about 905 feet above the sea, the surface extends nearly level westward. The beach consists of loamy sand, while the adjoining land is fine lacustrine silt or clay. On the Canadian Pacific Railway this beach is raised a few feet above the general slope of the Assiniboine delta, passing

Bagot.

in a west-northwest course two miles east and one mile north of Bagot.

On the M. & N. W. Railway and northward.

The Manitoba & Northwestern Railway crosses it five miles west of Gladstone, where it is a ridge about thirty rods wide, wind-blown in hollows one to two feet below the crest, which is 927 to 929 feet above the sea, with descent of five feet from it to the west and twelve to fifteen feet to the east. A lower and less conspicuous beach ridge, also belonging to this stage, lies three fourths of a mile farther east, with its crest at 916 feet. The Emerado beach continues north through the east part of Ts. 15 to 19, R. 12, and through the center of T. 20, to the east side of Lake Mary.

Ojata beach.

Along the course of the Ojata shore, lying between the Emerado and Gladstone beaches, no ridge of gravel and sand nor line of erosion was observed where it was crossed on the international boundary and elsewhere in this exploration in Manitoba, excepting a slight beach ridge, three to five feet high, which runs from Pomeroy in sec. 19, T. 5, R. 4, north-northwest through the east part of T. 6, R. 5, passing about two miles west of Carman.

Gladstone beach.

The Gladstone beach on the international boundary and for several miles thence to the north-northwest is a prominent ridge, having an ascent of ten to fifteen feet in a distance of thirty to fifty rods west from its base to its crest, which is approximately 860 feet above the sea. The slightly undulating surface of this shore deposit occupies a width of a quarter of a mile or more; and thence westward there is no noteworthy descent, but a nearly level expanse. In many shallow pits dug to obtain sand for masons' use, the material of the beach is shown to be fine sand, unmixed with gravel, excepting that very rarely a pebble is found enclosed in it, the largest being a half to two thirds of an inch in diameter. This ridge enters Manitoba about one and a half miles west

Blumenort and Kronsthal.

of Blumenort, and crosses secs. 5, 7, and 18, T. 1, R. 2, to Kronsthal, which is situated upon it. Northward it passes about a mile west of Lowestoft post-office and a mile east of Carman. George Anderson's

Carman.

house is built on its crest in the N.E. ¼ of sec. 31, T. 6, R. 4, two miles north-northeast of Carman, at an elevation of about 965 feet. It crosses the Canadian Pacific Railway near the Rat Creek bridge, and is well

developed along a distance of several miles thence to the northwest, passing through the southeast corner of sec. 12, T. 12, R. 9, where the elevation of its crest is about 875 feet, with a descent of four to six feet to the northeast and one to three feet to the southwest. Thence its course is along the southwest side of the Squirrel Creek marsh and east of the chain of Dead Lakes (a former channel of the White Mud River), which lie in sees. 17, 18 and 19, T. 14, R. 11. A half mile east of Gladstone this shore is marked by a line of erosion in the expanse of lacustrine silt, with slope in a short distance from 882 to 875 feet, and by a small beach ridge of sand with its crest at 878 feet. Continuing almost due north, this Gladstone shore line, occasionally marked by beach gravel and sand, lies a half mile to one mile west of the Big Grass Marsh through Ts. 15, 16 and 17, R. 11, the elevation of the marsh being approximately 865 fee[illegible]d of Lake Agassiz here during this stage about 875 feet above the present sea level. Gladstone.

The western Burnside shore enters Manitoba near Blumenort, nineteen miles west of the Red River, but it is not distinctly marked on the international boundary. Passing northward about a mile east of Lowestoft and three miles east of Carman, it crosses the Carman beach of the Manitoba & Southwestern Railway at Maryland, where the elevation of the crest of its beach ridge is 844 feet. About a mile northnorthwest of Maryland this ridge has been extensively excavated, its gravel and sand being used for railway ballast. One and a half miles farther north it crosses the main line of this railway about a mile west of Elm Creek station (the junction of the branch), its crest there being at 845 feet, from which its slopes fall ten feet in twenty-five rods east and seven feet in an equal distance west. The Canadian Pacific Railway crosses this shore about half-way between Portage la Prairie and Burnside, and in the next ten miles of its course, passing northwest nearly through the center of T. 12, R. 8, it is marked by a large gravel ridge, the crest of which in the south part of sec. 11, one and a half to two miles north of Burnside, has an elevation of 858 to 860 feet, with descent from it of six to ten feet northeastward and half as much to the southwest. This beach is similarly prominent on the Manitoba & Northwestern Railway, by which it is crossed and excavated for ballast half-way between Westbourne and Woodside, its crest there being 860 to 862 feet above the sea. Along the next forty miles the Burnside shore line is generally marked by a well developed beach ridge which is traceable on the plats of the Dominion Land Surveys parallel with the west shore of Lake Manitoba and four to five miles distant from it, passing about half-way between the lake and the Big Grass Marsh. It thus lies near the line between Rs. 9 and 10 as far north as to the east side of the lake in sees. 13 and 24, T. 18, R. 10, beyond which it runs north-northwest. Burnside beach. Maryland and Elm Creek. Near Burnside. On the M. & N. W. Railway and northward.

Eastern Burnside beach. "The Ridge," east of Emerson.

On the eastern side of Lake Agassiz this shore line is found at "The Ridge" about eleven miles east of the Red River and Emerson, where it is marked by a low escarpment rising from 835 to 850 feet, consisting of till with frequent boulders, nearly all Archæan, and by a deposit of gravel and sand a few feet deep, resting on the base of this slope, 835 to 840 feet above the sea.

Ts. 1 and 2, R. 4 E.

In the S.W. ¼ of sec. 15, T. 1, R. 4 E., the Burnside beach is a typical gravel and sand ridge twenty to twenty-five rods wide; its crest is 845 feet above the sea: and the descent from it to the east is about three feet and to the west six or seven feet. About a mile farther north, near the southeast corner of sec. 21, the elevation of this beach ridge is 844 feet, with a descent of one or two feet on the east and ten feet within twenty rods on the west. Another mile to the north its elevation is 846 feet, with two feet descent east and six feet west in six rods; next a surface of till, with many boulders, falls about five feet in forty rods to the west: beyond this a tract of gravel and sand continues with the same slope, falling from 835 to 830 feet, and is succeeded farther west by a slowly descending surface of till. The beach ridge continues with similar features through the east half of sec. 28, excepting a short distance in the S.E. ¼ of this section, where it is replaced by a line of erosion in the very rocky till. Through the next three miles the uneven contour causes the beach ridge to be somewhat irregular in its course and size; but it again attains its typical development in sec. 9, T. 2, R. 4 E., where it was excavated several years ago along a distance of a third of a mile for railway ballast, a branch track nearly eight miles long being laid for its transportation to Dominion City. The crest of the beach at Charles Aimé's house near the north end of this excavation is 846 to 847 feet above the sea, with a descent of two to five feet on the east and six to eight feet in eight to twelve rods west. Its width, including both slopes, is fifteen to thirty rods, and the maximum depth of the gravel and sand deposit is about eight feet, lying on till. The coarser portions of the gravel contain pebbles up to three inches or rarely six inches or more in diameter. Nine tenths or a larger proportion of them are magnesian limestone, the remainder being almost wholly Archæan granite and gneiss. This shore line continues north and north-northeast by Green Ridge post-office and through the east part of Ts. 3 and 4, R. 4 E., beyond which it has not been traced.

Proportion of limestone gravel.

Between the south ends of Lakes Manitoba and Winnipeg the country about Shoal Lake was uncovered by the fall of Lake Agassiz from the Gladstone to the Burnside beach, which latter is crossed by the Winnipeg & Hudson Bay Railway near the southwest corner of sec. 30, T. 14, R. 2, about three miles south of Shoal Lake. The crest of the beach is 860 feet above the sea, being ten feet above Shoal Lake. Here

Burnside beach in vicinity of Shoal Lake.

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

Ossowa beach.

Ossowa post-office, near the middle of the north half of sec. 27, T. [illegible] R. 4, is situated on a well defined beach ridge which runs from west-southwest to east-northeast through this township. Its crest varies in elevation from 843 to 848 feet, with descent of three to eight feet on its north side and twelve to fifteen feet on the south. The Canadian Pacific Railway was originally constructed from Stonewall due west to this beach, which it cut through in the east edge of sec. 28. In the railway cut its material is wholly gravel, in part very coarse, containing pebbles and subangular rock-fragments up to four inches and rarely six or eight inches in diameter, of which fully nine-tenths are magnesian limestone. On each side the surface is all with plentiful boulders, mostly Archæan granite and gneiss, but including many of this limestone, which is the underlying rock of the region. In the north part of T. 13, R. 3, this beach curves to the south, east and northeast, and thence passes through the southeast part of T. 14, R. 3, and the north half of T. 14, R. 2, gradually approaching and in some places joining the Burnside beach, with which the Ossowa beach is approximately parallel, lying a half mile to one or two miles southeast of it onward to Pleasant Home. The only other locality where a beach referable to this stage was observed is on the top of Stony Mountain, which a broad smoothly rounded ridge of gravel and sand extends nearly a quarter of a mile and is the site of some of the Penitentiary buildings. Its crest is about 835 feet above the sea, and the top of the underlying limestone about 825 feet. The western Ossowa shore line crosses the international boundary a few miles east of Gretna, and the eastern enters Minnesota about three quarters of a mile west of "The

From Ossowa [illegible] to Pleasant Home.

Stony Mountain.

Ridge," but they are not there marked by noteworthy beach deposits nor erosion.

Stonewall beach.

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

Niverville beach.

The road on the east side of the Red River between Winnipeg and Emerson crosses a beach ridge about a half mile southeast of Niverville. It has a width of fifteen rods, and its crest, 777 to 778 feet above the sea, is raised about four feet above the adjoining surface of lacustrine silt on each side. Beginning near Niverville station, it extends

From Niverville to Otterburne.

southeasterly at least a mile. Another beach ridge of similar size, with its crest at 780 feet, is crossed by this road a third of a mile farther south. This also runs southeast, holding its ridged form a mile or more, beyond which it is less distinct. Again, a few miles to the south from these, a beach ridge extends along this road in a nearly due south course across the S.E. $\frac{1}{4}$ of sec. 17 and the east half of secs. 8 and 5, T. 7, R. 4 E. It rises two to four feet above the land adjoining on each side, which is partly sloughs with water throughout the year, the elevation of the beach crest being 782 to 784 feet. Other beach deposits at nearly the same elevation occur a mile southwest of Otterburne; a few miles farther to the south in the northeast part of

Morris.

T. 5, R. 3 E.; and about a mile east of the Red River opposite to Morris. At the last named locality they are excavated for masons' sand. From

West shore of Lake Agassiz in this stage

the southern end of Lake Agassiz in this stage near Morris, its western shore extended north and northwest to the vicinity of Starbuck, thence north and northeast to Little Stony Mountain five miles northwest of Winnipeg, and thence nearly due north, passing between Stonewall and Stony Mountain and onward along the west side of Lake Winnipeg at a distance of a few miles from it. Gravelly and sandy deposits at the base of Stony Mountain on its north and south sides are attributable to erosion by the lake, there only a few feet deep, at the time of formation of the Niverville beach. Its level was fifteen to twenty feet

above the surface where Winnipeg is built and about seventy feet above Lake Winnipeg.

All the beaches thus far described must be referred to the glacial Lake Agassiz, held on its northern side by the barrier of the waning ice-sheet, as is shown by Dr. Bell's description of the outlet of Lake Winnipeg and the topography of the adjoining country, which could present no barrier of land so high as the Niverville beach. The original level of Lake Winnipeg, due to the height of the land upon which the Nelson River began to cut its channel in its present course, is probably that of the well defined beach observed by Hind between the mouths of the Winnipeg and Red Rivers, having "an elevation of twenty-one feet above the present level of Lake Winnipeg."* Traces of this shore line will probably be found at nearly the same height around the whole lake. Old beach of Lake Winnipeg.

DELTA OF THE PEMBINA RIVER.

The Pembina delta lies wholly in North Dakota at a distance of four to sixteen miles south of the international boundary; but its deposition by the stream outflowing from the Lake Souris along the course of Long Valley, Pelican Lake, and the Pembina, associates it so intimately with this glacial water-course in Manitoba that it seems desirable to give some description of it here.

When the delta was deposited, the Pembina was swollen by a great affluent from the glacial Lakes Saskatchewan and Souris, and thus received the drainage from the melting ice fields of the Assiniboine and Saskatchewan region far beyond the present limits of its basin. The prominent delta of gravel and sand brought into the margin of Lake Agassiz by the Pembina extends twelve miles from north to south and has a maximum width of seven miles, with a maximum thickness exceeding 200 feet. Its average thickness is probably not less than 100 feet. About five sixths of its area of fifty square miles or more lie south of the Pembina River, reaching nearly to the Tongue River. Extent and thickness.

The most elevated point of this delta, as it now remains, is about 270 feet above the sea, near the northwest corner of sec. 11, T. 162, R. 57, east of the Little Pembina and south of the Pembina River, and is nearly 300 feet above the junction of these streams, one and a half miles distant toward the northwest. The level of Lake Agassiz in its highest stage here was 1,220 or 1,225 feet above the sea, being fifty feet below this highest part of the Pembina delta, as is shown by the beach line of this level, 1,226 feet, in the central part of sec. 7, T. 162, Highest part of the Pembina delta about fifty feet above the upper beach.

*Narrative of the Canadian Red River Exploring Expedition of 1857, and of the Assiniboine and Saskatchewan Exploring Expedition of 1858, vol. i, p. 122.

R. 56, where an eastward descent begins. This is the east verge of the nearly flat area of the delta in secs. 12 and 7. Like all of this east 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 Archæan formations of granite and gneiss.

On the road from Olga to Walhalla the crest of the east margin of this delta is crossed in the north part of sec. 33, T. 163, R. 56, about two miles southeast from Walhalla. 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 ten to thirty feet lower for a width of one to one and a half 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 two feet above or below 1,175. 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 sec. 33 the "first mountain" extends southeast to secs. 13 and 24, T. 162, R. 56, and northwest across the Pembina, passing close southwest of Walhalla and onward to secs. 10 and 3, T. 163, R. 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 crests a half mile to one mile apart. From this upper portion the delta slopes down gradually toward the southeast and toward the northeast and north, extending only two to four miles north of the Pembina.*

First Pembina Mountain.

In the gravel of this delta, as seen in the bluffs of the Pembina near Walhalla and at noteworthy springs two miles to the south on the

Sources of the gravel.

*The 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 for about five miles westward to another terrace, the summit of which I was told is level with the great buffalo plains that stretch away toward the Missouri, the hunting grounds of the Sioux and the half-breed population of the 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, &c., presented to Parliament, 16 May, 1863, p. 41.

south side of the river, 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 water-course 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 two to four 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.

Fragments of lignite.

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 fifty 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 T. 161, R. 55, about seven 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 a hundred miles southward to the belt of till that reaches across the valley at Caledonia and forms the Goose Rapids. But on the west edge of the lacustrine area this fine sediment is absent, probably because of currents trending off shore; 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 two miles north of the Pembina to the international boundary and onward.

Time and manner of deposition.

Erosion and redeposition.

Lacustrine silt and areas of till.

DELTA OF THE ASSINIBOINE RIVER.

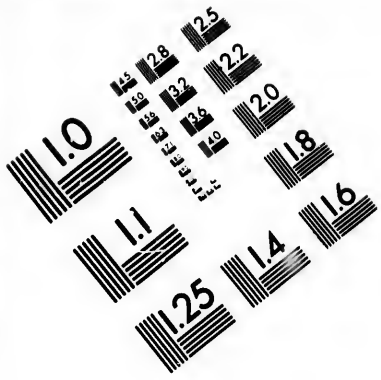
At Brandon the Assiniboine enters the area of Lake Agassiz, and thence the gravel and sand delta of this tributary extends eastward seventy-five miles to Portage la Prairie, northeastward fifty miles to Gladstone, and east-southeastward eighty miles to Almasippi post-office, nine miles west of Carman. 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 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 twenty miles in a nearly direct course toward Neepawa, then bends northward in the east part of Ts. 13 and 14, R. 16, and crosses Stony Creek a few miles west of Neepawa. Between Brandon and the mouth of the Souris the delta reaches three or four 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 twenty-five 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 five miles in width. Farther to the east the delta deposits abut directly upon the northern base of these hills from 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 stages, successively lower stages, being transported thence southward by shore currents. The same lacustrine action has doubtless extended the delta of gravel and sand generally five to fifteen 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 fifty

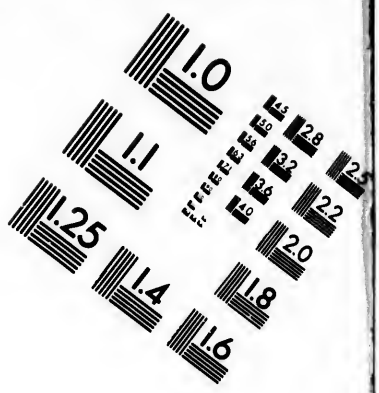
Extent and boundaries.

feet or less by the lake when it was being deposited, and was in part shoals and low islands, has an elevation 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. High plateau and eastern slope of the delta, and area of each.

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 ten to fifty 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 a hundred 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 sec. 36, T. 8, R. 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 fifty miles. The average thickness of this very extensive delta is probably between fifty and seventy five feet. Computing its volume for an average of fifty feet on an area of 2,000 square miles, it is found to be about twenty cubic miles. Thickness and volume.

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 centre of sec. 24, T. 8, R. 11. Ten to twenty 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 four miles east. Along the Canadian Pacific Elevation of the plateau of the Assiniboine delta.





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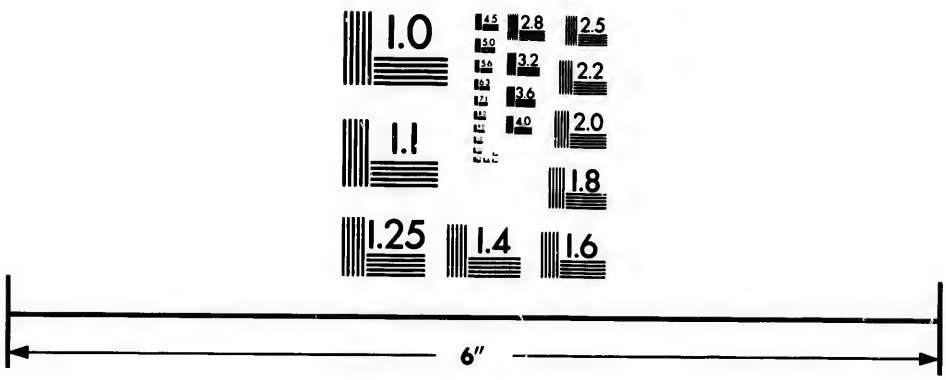

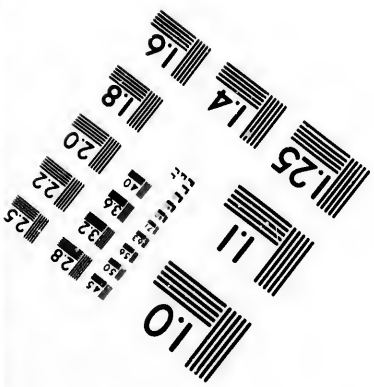

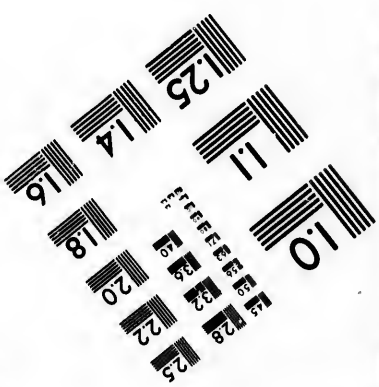

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Railway from Sydney westward by Melbourne, Carberry, and Sewell, to Douglas, twenty to twenty-five miles north of the foregoing, the undulating delta ranges in elevation from 1,230 to 1,275 feet; and it holds the same height through twenty-five miles northward, to within three 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 and sand slowly rises northward from 1,265 and 1,270 feet two to three 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 fifty 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 twelve or fifteen 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 five miles is 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 three or four miles thence northward through the south half of Ts. 11 of Rs. 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 sec. 14, T. 11, R. 17. Measured thence to its western limit on the north side of the Assiniboine half-way between Kemnay and Alexander, its length is twenty-four miles. Its width north and south of Brandon is about twelve 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.

Highest portion of this delta in the vicinity of Brandon and Kemnay.

North of the Assiniboine.

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 water-worn cobbles up to six and eight 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 one mile to the east. One and a half to three 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 five feet per mile to the east and were once continuous, a former water-course, 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 three miles, opening in sec. 7 or 8, T. 10, R. 18, upon the broad lower area eroded by the Assiniboine. The bed of this old channel is at 1,250 feet 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 four miles west of Brandon, the road to Kemnay crosses another water-course of similar character, diminishing from one and a half miles to a half mile in width within two miles from northwest to southeast, passing from the Assiniboine Valley to the head of Baker's or Stony Creek. Its bed, which is strewn with plentiful boulders, 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 three miles westward to Kemnay this delta expanse rises 50 to 60 feet, and continues to ascend more slowly in the next three and a half miles to 1,390 and 1,400 feet in secs. 1, 12, and 13, T. 10, R. 21. Thence the surface for the next six miles westward about Alexander, including nearly all of this township and the east edge of that next west, is till.

South of the Assiniboine.

Former water-courses.

Many portions of the fine sand deposits of the Assiniboine delta have been channelled 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 foot-hold 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 secs. 1 to 4, T. 7, R. 7, and are thence frequent northward upon a width of ten miles northeast of the Boyne and southeast of the Assiniboine. On the north side of the Assiniboine the most eastern dunes extend to within three 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 channelled 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 one to five miles. Their southern limit is about four miles north of Holland, three miles north of Cypress River station, and two miles north of Glenboro. One to four miles west of the mouth of the Souris, an isolated tract of dunes about three 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 secs. 12, 13, 24 and 25, T. 15, R. 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 three to five miles, reaches fifteen 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 secs. 6 and 7, T. 10, R. 20, two to three miles southwest of Kemnay; and lower hillocks of wind-blown sand continue from these two miles to the southeast.

Tracts of dunes.

Within six miles west from the dunes last noted and from the boundary of this Assiniboine delta, after crossing a belt of till that reaches about three 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 Ts. 9 and 10, R. 22, and T. 9, R. 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 seven miles southwest of Griswold this delta has been much channelled and uplifted by the wind in sand hills, which thence continue ten miles southeast along the north side of Plum Creek to sec. 11, T. 8, R. 22, four 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.

Delta and dunes of Lake Souris in the vicinity of Griswold.

An ancient water-course, now occupied by a body of water called the Big Slough, thirteen miles long and mostly twenty to fifty rods wide, but in its west part about three-fourths of a mile wide, extends from southwest to northeast nine miles through this delta of Lake Souris and thence continues four miles east through an area of till. Its west end is two miles southwest of Griswold, and its east end about half a 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 two to six or eight feet. The shores of the Big Slough rise in gentle slopes fifteen to twenty feet in twenty to thirty 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 water-course of Lang's Valley, is as follows. Lake Souris outflowed eastward by Lang's 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 Lang's 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 secs. 6 and

Connection between Lakes Souris and Agassiz by Big Slough.

7, T. 10, R. 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 Lang's Valley until the deposition of the alluvium, perhaps ten or fifteen feet thick, brought into that valley by Dunlop's Creek four 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.

History of the formation of the Assiniboine delta.

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, enclosing on its west side a lake that afterward became the bay of Lake Agassiz covering the Assiniboine delta, but was then held about a hundred feet above Lake Agassiz, to which it outflowed by the way of Lang's 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 respectively 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 water-course, which was evidently eroded after this lake became merged in Lake Agassiz, thereby falling nearly a hundred feet below its former level when outflowing through Lang's Valley, but before the Assinboine had cut its broad valley through this delta. More exactly, as before noted, this water-course seems referable to the Herman *b* stage of Lake Agassiz, and the similar water-course about twenty 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.

Channel of the Assiniboine.

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 two 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 so favorable point for this crossing exists within sixty 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. 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.

Erosion by Lake Agassiz.

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 hill from the eastern and southeastern limits of the delta, as before defined, to the low ridge first east of the Red River, about ten miles east of Emerson, while similar sediments cover the central part of the Red River Valley southward to Goose Rapids, more than a hundred 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,

Lacustrine silt of same origin with this delta.

Between Portage la Prairie and Lake Manitoba.

Portage la Prairie and High Bluff to Lake Manitoba. On this area the water-shed 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

Adjoining areas of till.

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 Ts. 13 and 14, R. 5, southeast of this lake, eastward to Shoal Lake, Stonewall, and Selkirk.

Projecting boulders.

Five to ten miles west of Portage la Prairie till with frequent boulders forms the surface, or is only overlain to the depth of a few feet by the sediments associated with this delta. Again, ten 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 two to six 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.

CHANGES IN THE LEVELS OF THE BEACHES.

Stages of Lake Agassiz during the formation of its beaches.

The successive shore lines of Lake Agassiz are not parallel with each other and with the present levels of the sea and of Lakes Winnipeg and Manitoba, but have a gradual ascent from south to north, which is greatest in the earlier and higher beaches and slowly diminishes through the lower stages of the lake, being at last only slightly different from the level of the present time. On the west side of Lake Agassiz the elevations of its beaches have been determined by continuous leveling, referred to sea level by railway surveys, through a distance of more than 300 miles from its mouth at Lake Traverse northward to near Riding Mountain in Manitoba; and the accompanying table shows approximately the stages of the lake during the formation of these shore lines, in their relations to each other and to the present level. These stages of the water surface have been assumed to coincide generally with the foot of the lakeward slope of the beach ridges, and with the base of eroded shore escarpments, the crests of the beaches having had a variable height from five to fifteen feet above the lake, corresponding with their less or more massive development, while the escarpments rose from the water's edge ten, twenty, or rarely thirty feet.

In this table the estimated stages of the lake are noted for comparison at its mouth, where it outflowed by the River Warren at the north end of Lake Traverse, and on four lines of latitude which are nearly equidistant from each other, passing through Fargo, Grand Forks, Emerson, and Gladstone, respectively 75, 150, 224, and 308 miles north of Lake Traverse. Though the fourth of these intervals is somewhat greater than the others, it may still be considered equivalent to them in the observed elevations and northward ascent of the lake shores, because, as will appear farther on, the northward rise of the land and subsidence of the lake had their maximum increase from south-southwest to north-northeast, or nearly in that direction. Therefore the more western course of these beaches in the northern part of the area examined compensates approximately for the additional distance between the third and fourth of these groups of observations.

Comparison on lines of latitude through Fargo, Grand Forks, Emerson, and Gladstone.

The letters *a*, *b*, *c*, *d*, represent successive beaches along the northern part of Lake Agassiz, which are merged in a single beach toward its south end. Several of the beaches thus noted in a preliminary report * are found to become double in some parts of their northward extent; and a correspondence in notation is here preserved by designating subordinate stages by double letters, as *aa*, *bb*. There are also added the two stages of the Tintah beaches, which were discovered after the publication of that report.

Successive stages designated by letters.

The lake shore belonging to the highest or Herman stage *a* has now a northward ascent of about 35 feet in the first 75 miles north from Lake Traverse, about 60 feet in the second 75 miles, and about 80 feet in the third distance of 74 miles to the international boundary. Its whole ascent thus in 224 miles is 175 feet, by a slope which increases from slightly less than a half of a foot per mile in its southern third to slightly more than one foot per mile in its northern third. Through six lower stages represented by separate beaches northward which seem to be united in the single Herman beach along the southern third of the lake, the northward ascent is gradually diminished to approximately 30, 40, 60, and 70 feet in the four portions of the observed course of these shore lines, amounting thus to 200 feet in about 300 miles. On the international boundary the lowest Herman stage *dd* is about 55 feet below the Herman stage *a*, while the probable erosion of the outlet and consequent lowering of the south end of the lake between these stages appears not to have exceeded ten feet.

Northward ascent of the Herman shore lines.

Between the series of the Herman beaches and that of the Norcross beaches, the River Warren eroded its channel about fifteen feet; and the upper Norcross shore ascends northward in these successive

* U. S. Geological Survey, Bulletin No. 39, p. 20.

STAGES OF THE GLACIAL LAKE AGASSIZ, WESTERN SHORE.

	Beaches.	Mouth of Lake Agassiz outflowing by the River Warren, at the north end of Lake Traverse. Feet above the sea.	On the latitude of Fargo and Wheatland, North Dakota, 75 miles north of Lake Traverse. Feet above the sea.	On the latitude of Grand Forks and Larimore, North Dakota, 150 miles north of Lake Traverse. Feet above the sea.	On the international boundary, 224 miles north of Lake Traverse. Feet above the sea.	On the latitude of Glad stone, Arden and New dale, Manitoba, 295 miles north of Lake Traverse. Feet above the sea.
Stages during outflow southward.	Herman beaches. *a*	1055	1090	1150	1230	
	Herman beaches. *aa*	1055	1090	1145	1222	
	Herman beaches. *b*	1050	1085	1135	1212	1315
	Herman beaches. *bb*	1050	1085	1132	1205	1295
	Herman beaches. *c*	1045	1080	1125	1190	1275
	Herman beaches. *d*	1045	1075	1117	1180	1255
	Herman beaches. *dd*	1045	1075	1115	1175	1245
	Norcross beaches. *a*	1030	1055	1090	1145	1215
	Norcross beaches. *b*	1025	1050	1080	1130	1185
	Tintah beaches. *a*	1015	1035	1065	1105	1156
	Tintah beaches. *b*	1000	1017	1045	1080	1120
	Campbell beaches. *c*	990	1000	1015	1045	1080
	Campbell beaches. *aa*	985	995	1010	1035	1070
	Campbell beaches. *b*	980	988	1000	1022	1055
	McCauleyville beaches. *a*	970	977	987	1007	1035
	McCauleyville beaches. *aa*	965	971	981	998	1023
	McCauleyville beaches. *b*	960	963	975	990	1012
Stages during outflow northward.	Blanchard beaches. *a*	(945)*	950	960	975	995
	Blanchard beaches. *b*	(935)	940	948	960	980
	Blanchard beaches. *c*	(925)	928	935	947	965
	Hillsboro beach	(915)	918	923	935	953
	Emerado beach	(882)		890	902	920
	Ojata beach	(860)		865	877	895
	Gladstone beach	(840)		845	857	875
	Burnside beach	(822)		827	837	855
	Ossowa beach	(810)			822	840
	Stonewall beach	(795)			805	826
	Niverville beach	(755)				775

	Beaches.	On the latitude of Fargo and Wheatland, North Dakota, 75 miles north of Lake Traverse. North ascent from Lake Traverse.	On the latitude of Grand Forks and Larimore, North Dakota, 150 miles north of Lake Traverse. North ascent from Lake Traverse.	On the international boundary, 224 miles north of Lake Traverse. North ascent from Lake Traverse.	On the latitude of Glad stone, Arden and New dale, Manitoba, 295 miles north of Lake Traverse. North ascent from Lake Traverse.
Stages during outflow southward.	Herman beaches. *a*	35	95	175	
	Herman beaches. *aa*	35	90	167	
	Herman beaches. *b*	35	85	162	135
	Herman beaches. *bb*	35	82	155	125
	Herman beaches. *c*	35	80	145	127
	Herman beaches. *d*	30	72	135	125
	Herman beaches. *dd*	30	70	130	124
	Norcross beaches. *a*	25	60	115	121
	Norcross beaches. *b*	25	55	105	118
	Tintah beaches. *a*	20	50	90	115
	Tintah beaches. *b*	17	45	80	112
	Campbell beaches. *c*	10	25	55	108
	Campbell beaches. *aa*	10	25	50	107
	Campbell beaches. *b*	8	20	42	105
	McCauleyville beaches. *a*	7	17	37	103
	McCauleyville beaches. *aa*	6	16	33	102
	McCauleyville beaches. *b*	5	15	30	101
Stages during outflow northward.	Blanchard beaches. *a*	(5)	(15)	(30)	99
	Blanchard beaches. *b*	(5)	(13)	(25)	98
	Blanchard beaches. *c*	(3)	(10)	(22)	96
	Hillsboro beach	(3)	(8)	(20)	95
	Emerado beach		(8)	(20)	92
	Ojata beach		(5)	(17)	89
	Gladstone beach		(5)	(17)	87
	Burnside beach		(5)	(15)	85
	Ossowa beach			(12)	84
	Stonewall beach			(10)	82
	Niverville beach				77

* Figures in parentheses in the first column give approximately the elevations which the stages of the lake during its outflow northward would have had at Lake Traverse, if the lake there had been low enough to permit the lake to extend south to its former outlet. From the estimated elevations the northward ascents of these stages, also in parentheses, are obtained so as to be directly compared with the northward ascents of the beaches that were formed while the lake outflowed southward, showing the changes which were gradually taking place in the levels of the beaches of Lake Agassiz during the whole time of its existence.

distances about 25, 35, 55, and 70 feet, amounting to 185 feet in the entire distance of 308 miles. In the most southern quarter its ascent is a third of a foot per mile, and this gradually increases to nearly one foot per mile in the most northern quarter. These rates of ascent are slightly reduced in the second Norcross stage, where the total ascent is 160 feet. While the outlet was being eroded probably five feet between the Norcross stages, the combined rise of the land and decline of the lake level were about 10 feet on the international boundary and 25 feet on the latitude of Gladstone. The lake shore belonging to the Tintah stage *a* ascends about 20, 30, 40, and 45 feet in the successive distances from south to north, amounting in total to 135 feet; in the same distances the Campbell *a* shore ascends about 10, 15, 30, and 35 feet, in total 90 feet; the McCauleyville *a* shore ascends about 7, 10, 20, and 28 feet, in total 65 feet; and the McCauleyville *b* shore ascends about 5, 10, 15 and 22 feet, in total 52 feet. The erosion of the River Warren from the Norcross *a* stage to the McCauleyville *b* stage, at the end of which the southward outflow ceased, was about 70 feet; but the vertical distance between the shore lines of these stages on the latitude of Gladstone is about 200 feet, the difference of 130 feet being attributable to the northward rise of the land and the fall of the lake level on account of the diminished attraction of the ice-sheet. The rate of northward ascent is reduced to less than an inch per mile along the southern part of the lowest McCauleyville shore, and to three or four inches per mile along its northern part, the average being two inches.

Northward ascent of the Norcross, Tintah, Campbell, and McCauleyville shore lines.

From the time of this lowest beach formed during the southward outflow of Lake Agassiz to the time of the first beach formed during its northeastward outflow, the lake fell only about 15 feet. Thence there is now a descent, on the latitude of Gladstone, of about 220 feet to the Niverville beach, below which Lake Agassiz, while its northern barrier of ice remained, fell about 45 feet more before it was reduced to Lake Winnipeg. The northward ascent of these shore lines of northeastward outlet decreases only very slightly in the distance of 75 or 80 miles examined north of the international boundary, the change being approximately from 20 feet to 15 feet or less, that is, to the rate of about two inches per mile. If these stages of the lake had reached south to Lake Traverse, they would probably show a decrease from about 50 feet to 25 feet or only 20 feet in their total northward ascent above the level of the present time along the distance of more than 300 miles from Lake Traverse to the south ends of Lakes Manitoba and Winnipeg. The whole descent on the latitude of Gladstone, between the lowest McCauleyville beach, where Lake Agassiz ceased to outflow southward, and the original level of Lake Winnipeg, about 20 feet above the present surface of that lake, is about 280 feet, of which

Northward ascent of the shore lines formed during the outflow to Hudson Bay.

probably 25 or 30 feet may be due to the northward rise of the land and diminution of gravitation toward the ice-sheet, while about 250 feet are due to the gradual lowering of Lake Agassiz by its successive outlets to Hudson Bay.

Successive depths of Lake Agassiz above Lake Winnipeg.

The depth of Lake Agassiz above the present surface of the south end of Lake Winnipeg was about 600 feet during its higher Herman stages, 500 feet at the upper Norcross stage, 440 feet at the upper Tintah stage, 370 feet at the upper Campbell stage, and 325 feet and 300 feet in the upper and lower McCauleyville stages, being thus reduced to half of its earlier depth before it ceased to flow to the south. During the lower stages of outflow to the northeast, the depth of Lake Agassiz above Lake Winnipeg decreased to 285 feet at the upper Blanchard stage, about 240 feet at the time of the Hillsboro beach, 210 feet in the Emerado stage, and successively about 185, 165, 145, 130, 110, and 65 feet in the Ojata, Gladstone, Burnside, Ossowa, Stonewall, and Niverville stages.

Proportionate decrease in area.

By nearly proportionate gradations the area of Lake Agassiz was diminished through these successive stages, having when the outflow to Hudson Bay began probably about half of its maximum extent attained during the formation of the Herman beaches.

Exploration of the beaches formed on the east side of Lake Agassiz has been mostly limited to Minnesota, because the eastern part of the lake area in Manitoba is covered by forest and is almost wholly without settlements or roads, so that for the present a survey of the shore lines there is impracticable. For the same reasons the upper shores in Minnesota have not been exactly traced east of Maple Lake, which lies twenty miles east-southeast of Crookston. Within the prairie area across which the highest eastern shore has been surveyed and its elevation determined by levelling, its northward ascent is about 11 feet in 140 miles, from 1,055 feet above sea at Lake Traverse to 1,17 feet at the north side of Maple Lake. As on the western shore of Lake Agassiz, the rate of ascent gradually increases from south to north, ranging from six inches to one foot per mile in its southern portion to about 75 miles, and from one foot to sixteen inches per mile farther north.

Comparison with the eastern shore lines in Minnesota.

Before the lake in Minnesota had fallen below its highest eastern beach in the south half of its explored extent, the rise of the land and diminished attraction of the waning ice-sheet had caused a slightly lower parallel beach, three fourths of a mile to one and a half miles distant, to be formed through the northern third of Clay County, and this secondary beach, sometimes double or treble, is observable at several places along the next 30 miles northward. At the northwest side of Maple Lake definite beach ridges belonging to the Herman stages of Lake Agassiz lie successively about 8, 15, 30, and 45 feet below its highest beach. Yet all these shore lines were formed while

the relative heights of the land and the lake continued stationary or with only slight change, not sufficient for the formation of any secondary beach ridge, along a distance of some 75 miles northward from Lake Traverse and Herman. The Norcross beaches in Minnesota have been explored and their height measured through the same extent of 140 miles, in which the upper Norcross beach ascends northward about 65 feet by a slope that increases slightly from south to north, averaging nearly six inches per mile. In like manner the northward ascents of the Tintah, Campbell, and McCauleyville beaches in Minnesota, and of the lower beaches formed on this east side of the lake during its outflow to the northeast, show a gradual decrease nearly as on the west in North Dakota and Manitoba. But comparison of the western and eastern shores reveals another very interesting feature of the levels of this glacial lake, namely, an ascent from west to east similar to that from south to north, but of less amount and diminishing in a similar ratio between the successive stages of the lake. On the latitude of Larimore and Grand Forks the ascent of the highest Herman stage of Lake Agassiz above a line now level is approximately 53 feet in about 70 miles from west to east, the rate per mile being very nearly half as much as from south to north; and in the later Herman stages it is diminished to about 30, 25, and 20 feet. On the Norcross shore lines this ascent toward the east is approximately 10 feet in about 60 miles, and it is reduced in the McCauleyville stages to only three or four feet in about 50 miles; yet it continues through all these stages approximately half as much per mile as the ascent toward the north. The rate of ascent eastward also increases, like that northward, in proceeding from south to north. At the latitude of Wahpeton and Breckenridge, 35 miles north from the mouth of Lake Agassiz, the ascent of its highest stage is 10 feet from west to east in 45 miles; at the latitude of Fargo and Moorhead, 75 miles north from the outlet, it is 15 feet in 50 miles; and at the latitude of Grand Forks, 150 miles north from the outlet, it is 33 feet in 70 miles.

The eastern higher than the western shore lines.

These observations, with those of the northward ascent of the west and east shores, indicate that the changes in the relations of the land and surfaces of level during the existence of Lake Agassiz and through subsequent time have given to the former levels of this glacial lake an ascent from south-southwest to north-northeast, its rate being somewhat greater than that noted in following the shores in their nearly due north course. The maximum rates of northward ascent of about one foot per mile observed in North Dakota and Manitoba, and of one foot to sixteen inches per mile in Minnesota, therefore belong to a lake level which in its northern portion differs from the present level by an ascent of approximately one and a half feet per mile toward the north-

Maximum ascent of the stages of Lake Agassiz toward the north-northeast.

northeast. Similar north-northeastward ascent continues through the successive lower stages of the lake, in which its amount north of the international boundary is reduced to about four inches per mile at the lowest stage of southward outflow; and probably it was not more than two inches per mile when the course of the Nelson River was uncovered by the receding ice-sheet.

Changes in relative elevations nearly or quite completed during the existence of Lake Agassiz.

Nearly the entire amount of the changes in the levels of the beaches of Lake Agassiz was evidently contemporaneous with the existence of this lake, taking place gradually, but apparently progressing comparatively fast between the stages marked by the formation of definite beaches, which doubtless belong to times when these changes advanced very slowly or were interrupted by intervals of repose. Great as were these modifications of the geoid surface of level, causing a differential uplift of the highest western shore of the lake in Manitoba to the extent of 175 feet at the international boundary, 265 feet at the latitude of Gladstone, and about 400 feet at latitude 51°52′ on the east side of Duck Mountain, 200 miles north of the international boundary, in the relation of the land to the water level, as compared with the vicinity of Lake Traverse, they were yet almost or perhaps quite completed before the ice-sheet was so far withdrawn that it was no longer a barrier to prevent free drainage from the basin of the Red River and Lake Winnipeg. During the subsequent postglacial epoch, to the present time, only very slight changes, or possibly none, have taken place in the relative elevations of the part of this area where the beaches of Lake Agassiz have been traced with levelling in Minnesota, North Dakota, and Manitoba; and if there have been such small postglacial changes, they were merely a continuation of the geoid movements which accompanied the recession of the ice-sheet and are recorded by the successive shore lines of this lake.

Relation to the upheaval of the Cordillera region and of the great plains.

Further important evidence is supplied by this survey of the beaches of Lake Agassiz in respect to the limitation in time and in area of the upheaval of the Cordillera region, comprising the Rocky and Sierra Nevada Mountains, and of the great plains which stretch from the Rocky Mountains east to the border of the Red River Valley. The somewhat higher elevation of the eastern than of the western shore lines of this lake proves that its area during the recession of the ice-sheet of the last glacial epoch and since then has not participated in this extensive uplift, which increases from east to west across the plains. Prof. Joseph Le Conte has shown that the Sierra Nevada range and other portions of the Cordillera region obtained a great part of their elevation within the glacial period;* and Prof.

* American Journal of Science, III, vol. xix, pp. 176-180, March, 1880; and vol. xxxii, 167-181, Sept., 1886. Compare also J. S. Diller's observations on the time of the uplifting and faulting which produced the Sierra Nevada, Eighth annual report of the U. S. Geological Survey, pp. 428-432.

Chamberlin and Salisbury conclude that the upper portion of the Mississippi basin was raised 800 or 1000 feet during the principal interglacial epoch.* Simultaneously with these movements, the plains between Lake Agassiz and the Rocky Mountains doubtless received a considerable part of their slope of ascent westward; but comparison of the opposite shores of Lake Agassiz indicates that the western uplift was probably completed before the departure of the last ice-sheet.

Consideration of the character of the changes in the levels of the beaches, resulting in a greater ascent upon the northern part of the area examined than farther south, and gradually approximating through the successive stages of the lake to parallelism with the present geoid surface of level, led me in my earlier studies to attribute these changes almost wholly to gravitation of the water of the lake toward the ice-sheet. The cause of the present relations of the old shore lines seemed to be discovered in the explanation that at first this attraction had a large effect upon the lake level because of the nearness of a great depth of ice on the east in northern Minnesota and on the north in British America, but that afterward it was gradually diminished to a comparatively small influence when the southern portion of the ice-sheet had been melted and the attracting force proceeded from the region far north between Lake Winnipeg and Hudson Bay.† Under this view the earth's crust was believed to be so rigid that it was not depressed by the vast weight of the ice nor raised when relieved of that weight, and the changes were believed to consist chiefly in the differential subsidence of the lake level, not in the differential elevation of the land basin.‡ The general uniformity of these changes in their direction and extent, and their probable completion during the departure of the ice-sheet seemed to accord with this hypothesis. The exact comparison of the shore lines observed on both the east and west sides of the lake, extending for its upper stages 440 miles from south to north in Minnesota and more than 300 miles from south to north in North Dakota and Manitoba, shows no considerable irregularity in the rates of northward and eastward ascent, that is, of north-northeastward ascent of the former lake levels, which has seem to be attributable to gravitation toward the waning ice-sheet, rather than to a progressive elevation of the land, for that would be

Gravitation of the lake toward the ice-sheet, causing part of the changes in the levels of the beaches.

* Sixth annual report of the U.S. Geological Survey, p. 314.

† Geological and Natural History Survey of Minnesota, Eleventh annual report, p. 152; U. S. Geological Survey, Bulletin No. 39, p. 18.

‡ Similar oscillations in the relative heights of sea and land, associated with glaciation, have been thus ascribed to ice attraction by Adhemar, in Révolutions de la Mer, 1840; by Croll, in Climate and Time, 1875; and by Penck, in Schwankungen des Meeresspiegels, Jahrbuch der geographischen Gesellschaft zu München, bd. vii, 1882.

expected to present noteworthy irregularities upon so large an area. It is probable, however, that close scrutiny of the shore lines will disclose small divergencies, within limits of a few feet, from the uniformity of slopes which they should have for agreement with this explanation; and it is to be noticed that the highest shores in the vicinity of Treherne, Brandon, and Neepawa have more nearly a northward than north-northeastward ascent, also that a slightly disproportionate increase in the ascent of the highest Minnesota shore line in the next ten or fifteen miles north of the Buffalo River was ascribed to the proximity of a portion of the ice-sheet on the east, where it was forming the Fergus Falls and Leaf Hills moraines. Though it now appears true that the greater part of these changes of level are due to the differential rise of the land, the gravitation of the lake toward the ice-sheet certainly operated in conjunction with that cause, contributing to the full extent of its competency in producing the results observed.

Mathematical investigation of ice attraction, by R. S. Woodward.

Mr. R. S. Woodward, of the United States Geological Survey, has worked out the mathematical problem of determining the effect of any added mass, as an ice-sheet, upon the earth's surface, to disturb the levels of the sea and of lakes.* Assuming an ice-sheet with a radial extent of 38°, or about 2,600 miles, and a central depth of 10,000 feet, from which the depth decreases at first slowly and then more rapidly to its border, he finds that the average slope within one degree of the border of the ice would be about five inches per mile, or less than one third of the north-northeastward ascent of the highest shore lines of Lake Agassiz in the north part of the area where they have been explored. Comparing the premises in this problem with the probable conditions affecting this glacial lake, it seems sure that the North American ice-sheet in its maximum extent during the last glacial epoch covered not more than one fourth so great area, its extent being equivalent to a spherical circle with radius of 1,000 miles, or at the most 1,300 miles; but, on the other hand, it is probable that the maximum depth of this ice-sheet somewhat exceeded 10,000 feet, and that the area of this great depth was a belt extending eastward from a few hundred miles north or northeast of the south part of Lake Agassiz a distance of about 1,000 miles east-northeast, lying thus much nearer than in the assumed case of Mr. Woodward's investigation. The smaller area and less total mass of the ice-sheet attracting Lake Agassiz must have been offset by the nearer position of a large part of its mass than in the assumption of the problem, so that possibly its influence might

* U. S. Geological Survey, Sixth annual report, pp. 291–300; and Bulletin No. 48, "On Form and Position of the Sea Level." Compare also Prof. Edward Hull's computations, "On the Effect of Continental Lands in altering the Level of the adjoining Oceans," Geological Magazine, Dec. III, vol. v, pp. 113-115, March, 1888.

be as great in producing an ascent of the lake level above the level of the present time; but, if this mathematical investigation is reliable, gravitation of the lake toward its ice-barrier could not give to its highest shore a northward ascent of more than a few inches per mile, at the most not so much as half a foot, whereas its observed ascent attains a maximum rate of one foot to sixteen inches per mile, and this belongs to a north-northeastward ascent of fully one and a half feet per mile. A quarter part, or perhaps less, of the changes in the levels of the beaches is therefore referable to ice attraction; while the remaining three quarters, amounting to about 130 to 300 feet, from south to north, in western Manitoba, belongs to differential elevation of the earth's crust.

Among the conditions producing changes in the height and slopes of the land on which Lake Agassiz lay are the cooling and contraction of the earth's crust by the ice-sheet and glacial waters, and the subsequent warming and expansion owing to the amelioration of the climate. The superficial portion of the earth's crust in the Red River Valley has a temperature of 47° to 42° Fahrenheit, as shown by the water of artesian wells situated respectively at Ada and Donaldson, Minnesota.* But during the time when this district was covered by the ice-sheet, the temperature of the underlying land surface was reduced to the freezing point, 32° Fahrenheit, and a similar lowering of temperature may have affected the crust to a considerable depth, largely through the influence of percolating water, causing a slight depression of the isogeotherms, with consequent contraction of the rocks and lowering of the land surface. By comparison with the present mean annual temperature of the Red River Valley, ranging approximately from 41° at Lake Traverse to 33° at Winnipeg,† it is evident that the artesian waters before noted receive part of their heat from the earth's interior. In like manner probably the interior heat kept the superficial portion of the earth's crust beneath the ice-sheet as warm as 32°, at which temperature the earth's heat would be continually melting the ice, though doubtless at a very slow rate. The differences of the temperatures of the earth's crust, due to the ice-sheet and to water permeating downward from it, would not therefore probably exceed 15° from that of the present time in the southern part of the basin of Lake Agassiz, and would decrease to 10° at Donaldson in Kittson County, the most northwestern in Minnesota, and to even a less amount at Winnipeg. The extent to which these slight changes

Effect of changes in the temperature of the earth's crust, due to the ice-sheet.

* Geological and Natural History Survey of Minnesota, Eleventh annual report, pp. 147, 148.
† C. A. Schott in Smithsonian Contributions to Knowledge, vol. xxi, 1876; Atlas of the Tenth Census of the United States; Report of the Department of Agriculture and Statistics of Manitoba for 1882, p. 318.

in the crustal temperatures would depress the land while it was ice-covered and raise it when the ice was withdrawn depends on the ratios of contraction and expansion of the underlying rocks. These ratios have been experimentally determined in the case of various building stones, and computations therefrom indicate that only a very small amount of subsidence and elevation of the land could be caused in this way.* The total elevation so produced was probably not more than fifty feet in the southern part of the Red River Valley and not more than thirty feet at Winnipeg, and its slight differential effect would be in the opposite direction to that which has given to the beaches of Lake Agassiz their northward ascent. This element in the causation of the changes of elevation appears to be comparatively insignificant in itself, and its small component in the oscillation of the shore lines would be opposed to that for which we are seeking an explanation.

Probable dependence of the northward ascent of the beaches upon the departure of the ice-sheet.

It seems to be very clearly indicated, however, by the gradual diminution in the northward ascent of the beaches until the lowest and latest have nearly the level of the present time, that these progressive changes of elevation were directly dependent upon the departure of the ice-sheet, with which great geologic event they were contemporaneous. As already noted, these changes were so directly proportionate with the glacial recession that the northward ascents of the successive beaches were at first referred to the diminishing gravitation of the lake toward the ice-sheet; but, apart from the inadequacy of this cause determined by Mr. Woodward's investigations, the great extent of the highest beach and its relation to terminal moraines marking stages of the glacial recession sufficiently demonstrate that other causes contributed even more than ice attraction to produce the changes observed in the levels of the beaches. In the discussion of this subject, to be presented in the monograph of Lake Agassiz for the United States Geological Survey, there remain to be considered, as probable causes, first, the relationship between the earth's crust and its interior which may have permitted a sinking of the crust beneath the vast weight of the ice-sheet and a re-elevation when that weight was removed, and second, oscillations which may have occurred without dependence upon the glaciation. For the discrimination of these movements, it will be very instructive to notice the changes of elevation that have been going forward at the same time in other parts of the North American and European glaciated regions, and also in various areas which were never thus ice-laden. If Lake Agassiz is found to be an instance where nearly all these changes are apparently referable to glaciation there will be no lack of opportunity for comparing it with other

*T. C. Chamberlin in Sixth annual report, U.S. Geol. Survey, p. 302, and in paper read before the Philosophical Society, Washington, March 13, 1886; G. K. Gilbert, in Am. Jour. Sci., vol. xxxi, p. 297, April, 1886.

regions where the effects due to glaciation are combined with independent crustal movements. *

RECORDS OF WELLS.

The following notes of common wells in various parts of Manitoba show in considerable detail the character and order of the drift deposits, and in a few instances of the underlying rock formations. Nearly everywhere an ample supply of good water, permanent throughout the year, is found at a moderate depth. In the Red River Valley and westward it usually is hard water, as is also the water of springs and streams, containing so much dissolved carbonate of lime that it cannot be used satisfactorily for washing with soap. For this use rain water is commonly collected from the roofs. When this is stored in large cisterns, it is more desirable also for drinking and cooking than the often somewhat alkaline well water, which, however, is seldom found to be injurious to health. Hard water.

But wooden well-curbing, commonly pine, which has been often used in this region, soon contaminates the water, especially if it is notably alkaline; and when such wells are left stagnant or only drawn from slightly, the water becomes too foul in smell and taste to be drank, even by cattle, and it may be the cause of sickness before reaching this stage. If bricks, stone, or iron or cement pipe are used for lining wells, and the water in them is frequently renewed by being largely drawn from, it is entirely wholesome and palatable, and is well adapted for nearly all uses, excepting for washing with soap, as before mentioned, and for steam-boilers, in which the large amount of scale deposited from it in evaporation is objectionable. Wells often contaminated by decay of wooden curbing.

Artesian or flowing wells are obtained near the Red River, as in Winnipeg and southward, where water often rises to the surface from layers of sand and gravel in the drift. Artesian wells.

Winnipeg. About forty wells have been bored by the city authorities of Winnipeg for supplying water for domestic use. Mr. H. N. Ruttan, the city engineer, states that about a dozen of these wells go to the bed-rock, which is limestone, while the others derive their water from layers of quicksand in or beneath the till. Several of them in the west part of the city are artesian, but eastward the water rises only to five or ten feet below the surface. The water is considered of good quality for drinking and cooking, but it contains much mineral matter in solution, chiefly the sulphates of lime and magnesia. City wells.

* These Quaternary changes of level have been partly considered in a paper on the "Probable Causes of Glaciation," forming an appendix of Prof. G. F. Wright's Ice Age in North America, 553-565.

Alluvial and drift deposits.

Alluvial stratified clay extends to a depth that varies from three to ten feet or more. This is underlain by the glacial till or boulder-clay, which encloses thin veins and layers of fine gravel and sand, and frequently is underlain by sand and gravel, but in many places extends to the limestone. The upper part of the till here shows an imperfect stratification, due to its deposition in Lake Agassiz, and contains a less

Character of the till.

proportion of boulders and gravel than its lower part, which is very hard, and is therefore commonly denominated "hard pan." The depth to the limestone varies from thirty to sixty feet in the west part of the city, and increases to about seventy-five feet eastward.

Underlying limestone.

One of these wells, bored in the west edge of the city, close north of the Assiniboine and one and a half miles west of the Osborne street bridge, went 32 feet in stratified clay and till, and then 100 feet in limestone, mostly of light buff or cream color, obtaining water of good quality at 132 feet, which rose to five feet below the surface. The bed-rock is nearly like that which outcrops at Lower Fort Garry and East Selkirk.

General section of superficial deposits at Winnipeg.

A general section of the superficial deposits at Winnipeg is noted by J. Hoyes Panton as follows, from information supplied by Mr. Piper, known as having an extensive experience in well-boring through the city.

"1. Surface mould, one to four feet, dark color, and exceedingly fertile.

"2. 'Yellow gumbo,' two to three feet, a very sticky form of yellowish clay, which usually holds considerable water.

"3. Dark gray clay, thirty to fifty feet thick, with boulders scattered throughout; some of them four feet in diameter, and chiefly gneissoid and no doubt derived from Laurentian rocks.

"4. Light-colored clay, one to three feet, containing many small stones.

"5. Hard pan, two to ten feet, a very solid and compact form of clay.

"6. Sand, gravel, and boulders, five to twenty-five feet.

"7. Angular fragments, one to three feet, usually limestone, and largely derived from the solid rock which lies immediately below it.

"This loose material is far from being uniform, and varies so much in its arrangements that scarcely any two borings show the same distribution. Sometimes there is little or no hard pan, while in other parts it is several feet thick. However, as a usual thing, these several forms of strata are passed through in boring, and varying in thickness to the number of feet already mentioned."*

* Report of the Department of Agriculture and Statistics, Manitoba, for 1882, p. 176.

Saint Boniface. Wells in St. Boniface are nearly the same as in Winnipeg, on the opposite side of the river. The deepest learned of is on the Exhibition Ground, 156 feet deep, being stratified clay and till, 36 feet, its lowest 10 feet very hard and compact; sand, 44 feet, to the bedrock at 80 feet; then limestone, of light cream color or nearly white, penetrated 76 feet and extending below.

Niverville. Thomas W. Craven, hotel; well, 65 feet deep, in alluvium and till; water rises to fifteen feet below the surface. Other wells in this village have nearly the same depth or less, none coming to the bed-rock; but it was reached by a well a third of a mile east at a depth of about 100 feet.

Four miles south-southeast of Niverville, in the N. E. ¼ of sec. 5 in this same T. 7, R. 4 E., Cornelius Freesen's well, situated on the Niverville beach, passed through alluvium and glacial drift, 65 feet, and shale, 30 feet, obtaining an ample artesian flow of excellent water.

Flowing wells in the Mennonite Reserve east of the Red River.

In the S. W. ¼ of this section, a half mile from the foregoing, Adam Freesen has a similar flowing well, 107 feet deep, which went 37 feet into the shale. This is said to be the deepest of about twenty flowing wells in this Mennonite Reserve, their range of depth being from 40 to 107 feet.

Dominion City. James Spence, Victoria Flour Mills: flowing well, 170 feet deep, in alluviat clay and till, the latter very hard below the depth of 120 feet; bed-rock not reached; water brackish, flowing feebly, not used.

The common wells of this village, 12 to 16 feet deep, have good water which seeps from the alluvial clay.

Soft water of the Roseau.

The Roseau River has much softer water than the wells and most of the short streams of this region, so that the railway tank at Dominion City, taking water from the Roseau, is preferred by the locomotive engineers above any other source of water on this branch line.

Emerson. Wells in Emerson range from 10 to 25 feet in depth, in alluvial clay, and obtain water tolerably good for drinking and cooking, but it is very hard and unsuited for laundry use.

West Lynne. Hudson Bay Company's steam flouring mill: well, 108 feet deep; dug 68 feet in alluvial and lacustrine clay, and bored 40 feet lower, apparently in the same deposit. The only water found, not enough to supply the engine, is that which seeps from the clay, coming almost wholly within the first twenty feet below the surface. The ordinary wells in this village, 14 to 18 feet deep, obtain good water seeping in sufficient amount for domestic use.

Brackish artesian wells west of the Red River.

Artesian wells near Letellier and on the Low farm. An artesian well in the French Reserve at the center of T. 2, R. 1 E., near Letellier, twelve miles northwest from Emerson and West Lynne, is 250 feet

deep, not reaching the bed-rock. It supplies brackish water, which is drank by cattle. Another artesian well of similar depth is on the Low farm, about twelve miles west of Morris, the water of which is strongly saline.

West Selkirk. The well at the Lisgar House, 100 feet deep, reached the bed-rock, which is limestone, at 65 feet.

Stonewall. J. B. Rutherford's flouring mill: well, 82 feet deep, consisting of beach gravel and sand, 10 feet; till, 2 feet; and limestone, including red shaly beds, 70 feet, to the bottom, where the drill fell one foot and water rose immediately to 22 feet below the surface. Several other wells in Stonewall have had a similar experience, obtaining water which rises from hollows in the limestone.

T. 15 *R.* 2 *E.* William Andrew, S. E. ¼ of sec. 7: well, 94 feet deep; till at the surface and to a depth of 11 feet; and limestone, 83 feet, mostly hard and of light buff color, but enclosing some 25 feet of reddish shaly beds between the depths of 45 and 70 feet. There are several such wells in the same vicinity.

Between Pleasant Home and Gimli. Mr. Andrew states that, about twenty-five miles northeast from the last, a well between Pleasant Home and Gimli has been sunk 120 feet, wholly in the glacial drift, not reaching the bed-rock.

Rosser. The railway well at Rosser is 29 feet deep, in till, which forms the surface there and east to Little Stony Mountain; water rises fifteen feet from a sandy layer at the bottom.

T. 11, *R.* 1 *E.* Robert D. Bathgate, sec. 27: well, 60 feet deep: till, 24 feet, from which alkaline water seeps; and light buff, hard limestone, 36 feet, and continuing lower; water of good quality rises from the bottom to 20 feet below the surface. Other wells in this vicinity mostly get good water in veins or thin layers of sand and gravel contained in the till.

St. Francois Xavier. On Mr. Nanton's ranch, about ten miles west of Headingly and a quarter of a mile south of the Assiniboine, a well 114 feet deep passed through alluvial clay, 14 feet; till, 34 feet; limestone of light cream color, 47 feet; and reddish limestone, 19 feet. Brackish water rises from the bottom to 14 feet below the surface.

Meadow Lea, sec. 30, T. 13, R. 2. Wells in this vicinity range from 20 to 95 feet in depth, and are wholly in till, not reaching the bed-rock.

T. 13, *R.* 6. Charles Cuthbert, sec. 21, ten miles north-northeast from Portage la Prairie: well, 16 feet deep; soil and loamy silt, to water in quicksand and fine gravel. The surface here is only a few feet above the high water level of Lake Manitoba.

Portage la Prairie. The common wells are 12 to 16 feet deep, being black soil, 2 to 4 feet; then yellowish gray loamy silt, the alluvium

of the Assiniboine, in which fragments of driftwood, as small limbs of trees, are occasionally found; to water in quicksand and fine gravel. The deepest well here is that of the Manitoba and Northwestern Railway tank, which reaches 30 feet, to till at the bottom, obtaining a very large supply of water.

T. 12. *R.* 8. Kenneth McKenzie, jr., in the north edge of sec. 2, close west of Rat Creek: well, dug 86 and bored 72 feet, to a total depth of 158 feet: soil, 2 feet; sand, 4 to 5 feet; yellow till, 4 feet; blue till, 76 feet, easy to excavate, with scanty intermixture of gravel, but containing occasional stones up to one foot or more in diameter, undoubtedly true till, for the surface generally through the south part of this township has plentiful embedded boulders up to two or three feet in diameter; below was "hard pan," a more indurated deposit of till, very hard to dig or pick, bored or drilled 72 feet, and found to vary much in its hardness through this depth, some portions being much softer than where the boring began. A seam of sand and fine gravel, about an inch thick, was noticed between the upper part of the till, which was dry, and the harder lower portion. At the bottom the drill struck a harder layer, which was called rock. It was probably shale, for the drill, being dropped a few times upon it, seemed in danger of becoming stuck so that it could not be removed. Water rose from the bottom within the first day to a depth of 20 or 30 feet in the portion of the well that was dug; and within a few days it reached its permanent level about 20 feet below the surface. It does not sink below this level in dry seasons, but in wet seasons it rises to seven feet below the surface, near the bottom of the sand. It is somewhat salty, so that it is not suitable for house use; but it is drank freely, and with no ill effect, by horses and cattle during the entire winter.

A quarter of a mile south of this, Mr. McKenzie's father has a similar well as to its depth and succession of deposits passed through to rock, but it obtains a less ample supply of water. Both wells are 784 feet, approximately, above the sea; and the top of the bed-rock is accordingly about 706 feet above the sea level.

Gladstone. Wells vary from 10 to 15 feet in depth, in sandy fine silt. Water abundant and of excellent quality.

Arden. In the vicinity of Arden wells are 10 to 50 feet deep, the section being till, excepting where this is overlain by beach deposits from 5 to 15 feet thick.

Neepawa. John A. Davidson & Co., store: well, 60 feet, the deepest in the town; soil, 2 feet; gravel and sand of the Assiniboine delta, 12 feet; and till, dark bluish, with the usual proportion of gravel and boulders, 46 feet, and extending below; water good. Other wells, mostly 15 to 25 feet deep, reach till at nearly the same depth.

T. 13, *R.* 16. The deepest wells in this township go 50 to 70 feet, wholly in till; but commonly a sufficient supply of water is found within 30 feet or less.

Carberry. Wells 10 to 20 feet deep in [illegible], the Assiniboine delta; plenty of good water.

Chater. At the elevator, 42 feet, and at the hotel, 31 feet, wholly in till, yellowish above and dark bluish below; water rose several feet.

Brandon. Wells 10 to 30 feet deep, in delta gravel, underlain by till; good water.

Carman. Depths 10 to 15 feet, in alluvial clay with sandy layers; good water. Two miles south of Carman, James Stewart's and George E. Laidlaw's wells are respectively about 100 and 120 feet deep, probably passing through the alluvial and lacustrine clays and glacial drift, to underlying Cretaceous shales. The water of the deeper of these is too brackish for house use, but is drank by cattle.

Treherne. In the vicinity of Treherne wells vary from 15 to 50 feet in depth, the section being beach and delta deposits of stratified gravel and sand; excellent water.

Holland. Wells at Holland are 10 to 20 feet deep, in till to shale, which is reached at about 10 feet; water good, generally better from the shale than from the drift. Shale is not encountered by wells farther north, on the Assiniboine delta. In the adjoining Tiger Hills on the south, the depth to shale varies commonly from 2 or 3 to 10 or 15 feet.

Cypress River and Glenboro. Depths 10 to 17 feet, in fine silt, the delta of the Assiniboine; water good, issuing from quicksand.

T. 8, *R.* 18. Rounthwaite post-office, sec. 14: well, 20 feet deep; soil, 2 feet; yellowish gray till, 13 feet; harder blue till, 5 feet and lower; water seeps, plentiful and good.

T. 7, *R.* 17. Williamson, Dignum & Co., farmhouse in sec. 3: well dug 30 feet and bored 32 feet more; seen while the boring was in progress at depth of 62 feet; all till, mostly yellowish, to that depth. This is half a mile north of the northern base of the Tiger Hills, at an elevation of about 1,350 feet above the sea.

Lang's Valley. Langvale post-office, at James Lang's house, sec. 2, T. 6, R. 18: well, 18 feet deep: all gravel and sand, with quicksand at the bottom. This is on the bed of the channel of outflow to the Pembina from the glacial lake in the Souris basin.

Plum Creek. Wells in this village, at the junction of Plum Creek with the Souris, are 10 to 30 feet deep, in till, not reaching bed-rock; but outcrops of the Fort Pierre shale occur on the Souris near by.

Gretna. Common wells, 10 to 20 feet deep, in alluvial and lacustrine

clay, obtaining a scanty supply of water. A boring is said to have been made here for the railway tank, to a depth of 150 feet, without finding a supply of water, and it is now pumped from the Pembina River.

Rheinland. Wells 15 to 20 feet deep, in somewhat sandy lacustrine clay; excellent water.

T. 2. R. 5. John Johnston, sec. 3: well, 22 feet; soil, 2 feet; yellowish till, containing boulders up to five feet in diameter, 20 feet; to gravel with water which rises from it two or three feet. This is between the Campbell and Tintah beaches, on the low terrace at the foot of the Pembina Mountain escarpment. Other wells near show that this terrace consists of the Port Pierre shale, thinly covered with glacial drift.

Morden and Nelson. Wells 10 to 25 feet deep, in till; water frequently alkaline.

Thornhill. The wells of Thornhill and vicinity are 8 to 25 feet deep, their material being till, with sandy streaks from which water seeps. The till is yellowish to a depth of about 15 feet, and dark bluish below. Shallow wells, stopping in the yellow till, have better water than those that pass into the blue till.

Darlingford. David Brown, S. E. ¼ of sec. 6, T. 3, R. 7: well, 30 feet; soil, 2 feet; till, 28 feet, its lowest six feet mostly débris of the Fort Pierre shale; to quicksand at the bottom, from which water rose in a few hours to 10 feet below the surface.

Manitou. Canadian Pacific Railway well, 175 feet deep, wholly in the Fort Pierre shales, excepting about five feet of soil and drift at the surface. The common wells are 20 to 30 feet deep, going into shale at 5 to 12 feet from the surface; water good.

Saint Leon, secs. 34 and 35, T. 4, R. 9. In this village wells are 10 to 15 feet deep, being till to a depth of 6 to 12 feet, and extending into shale below; water good. Other wells in the vicinity are 10 to 30 feet deep, reaching the shale usually less than 15 feet below the surface.

Mowbray, Snowflake, and Star Mound. Wells in this district, T. 1 of Rs. 8, 9, and 10, are commonly 15 to 30 feet deep, in till, or in many cases going several feet into the underlying Fort Pierre shale; good water is found in both formations.

Pilot Mound. In the village of Pilot Mound wells are 15 to 20 feet deep, commonly passing into the shale at ten feet; water good.

West of Pelican Lake. The deepest wells within a few miles southwest of Pelican Lake, on the nearly level expanse of till about 150 feet above this lake, often reach shale at 25 to 30 or 40 feet; but many get good water at 10 or 15 feet in the overlying till.

GEOLOGIC AND AGRICULTURAL RESOURCES.

The great fertility of the soil in this district, its water-power, the value of its timber for building purposes, manufactures, and fuel, of its stone for construction and lime-burning, and of its deposits of clay for brick-making, are its chief natural resources.

Soil and subsoil.

Over nearly the entire prairie portion of Manitoba, both in the lacustrine area of Lake Agassiz and upon the higher and more undulating or rolling country that stretches thence westward, a sandy clay, often with some intermixture of gravel and occasional boulders, forms the soil, which has been colored black to a depth of one or two feet below the surface by decaying vegetation. The alluvial and lacustrine beds, or the glacial drift, the same as the soil, excepting that they are not enriched and blackened by organic decay, continue below, being usually yellowish gray to a depth of ten or fifteen feet, but darker and bluish beyond, as seen in wells. The glacial drift contains many fragments of Cretaceous shale, magnesian limestone, granites, and crystalline schists; and its fine detritus, and the silty deposits carried into Lake Agassiz by its tributaries, are mixtures of these rocks pulverized, presenting in the most advantageous proportions the mineral elements needed by growing plants.

Agricultural products.

Wheat has been the principal crop, but stock-raising and the dairy have also received much attention. A large variety of crops is profitably cultivated throughout the region, including wheat, oats, garden fruits and vegetables, potatoes, and hay. The natural prairie supplies rich pasturage for the herds of the first immigrants; but it is rapidly becoming mainly occupied by farms and brought under cultivation.

Water-power and manufactures.

Valuable water-powers are available on many of the streams, especially in the wooded northern and eastern portions of Manitoba. The rapids and waterfalls of the Winnipeg River, with its magnificent reservoirs of the Lake of the Woods and Rainy Lake, besides a multitude of smaller lakes, will doubtless some day become the sites of large manufacturing cities, where the wheat of the prairies will be made into flour, and the timber of the adjoining forests will be manufactured into lumber, furniture, and various wooden wares. While agriculture will be the leading occupation in the prairie region, more diverse industries will grow up in the wooded country on the east.

Fuel.

Even the prairie has important resources of fuel in its belts of timber, which border streams and lakes, and also extend along the escarpment of the Pembina Mountain and cover the Tiger Hills and Turtle Mountain. With the more full settlement of the prairie, however, some systematic plan may be adopted for securing coal or wood by

railway freight in large amounts, and therefore at much lower cost than now.

Quarried stone.

Quarries of magnesian limestone have been extensively worked at East Selkirk, Stonewall, Stony Mountain, and Little Stony Mountain, partly for lime-burning, but also in large amount for foundations, bridges, and buildings. The East Selkirk stone, which is beautifully mottled and banded, is easy to cut when first quarried, but hardens much when its moisture dries out. It contains so much water that newly quarried blocks in winter are damaged by freezing; but after drying no such frost fracture is observed where this rock has been used in masonry. By exposure many years the streaked contrast in color is mostly weathered out, the brown portions losing their darker color. The Volunteers' Monument in Winnipeg is a fine example of the adaptation of this stone for ornamental purposes. The quarry at Stonewall, situated close east of the village, has been opened to an average depth of six or eight feet on an area about fifteen rods square. Inexhaustible supplies of stone of the most durable quality, in many portions capable of being quarried in blocks of large dimensions, outcrop there and at Stony Mountain, and have been much used for building in Winnipeg. Similar stone has been slightly quarried on the N.E. ¼ of sec. 4, T. 15, R. 2 E., on land of Allen Bristow, nine miles north-northeast of Stonewall. The outcrop of Cretaceous limestone on the Assiniboine in sec. 36, T. 8, R. 11, has also been quarried in small amount.

Lime.

The quarry of Little Stony Mountain was actively operated several years ago for burning lime, a spur track about a mile long being laid to it from the Canadian Pacific Railway; but work had been suspended at the time of this survey in 1887. Besides the outcrops of the bed-rock which thus supply lime, it is conveniently obtained by collecting and burning limestone boulders that occur in the glacial drift throughout all the prairie district of Manitoba, having been originally derived from these rock-formations and distributed by the currents of the ice-sheet. The more abundant granitic boulders of the drift also commonly serve the immigrant for the construction of foundations of farm buildings and for the walls of cellars and wells.

Bricks.

Nearly every part of the province also has beds of brick-clay, which are utilized in proportion to the demands of settlement. Four brick-yards in Saint Boniface, on the east side of the Red River opposite to Winnipeg, produced in total in 1887 about four million bricks. This business began to be extensively developed there in 1880. The soil is stripped off to a depth of two feet, beneath which the next two or three feet of yellowish, horizontally laminated, somewhat sandy clay is used for brick-making. It requires no further admixture of sand for tempering. The bricks, which are cream-colored and very durable, are

sold at $11 to $12 per thousand, loaded on the cars or delivered in the city of Winnipeg. Another brick-yard in Saint James, close southwest of Winnipeg, makes about 1,500,000 bricks yearly. The light cream color of these bricks, like those of Milwaukee and of most brick-yards in Wisconsin, Minnesota, and North Dakota, is due, as shown by President Chamberlin, to the calcareous and magnesian ingredients of these glacial clays derived in part from magnesian limestone formations, which unite with the iron ingredient to form a light-colored silicate, instead of the ferric oxide which in other regions destitute of magnesian limestone gives to bricks their usual red color.

APPENDIX I.

COURSES OF GLACIAL STRIÆ.

The following table of glacial striæ in the region of Hudson Bay and Lake Superior and westward shows the directions of the currents of the ice-sheet within the basin of Lake Agassiz and upon the country where it lay as the barrier or dam of this lake. They are derived chiefly from the reports of the Geological and Natural History Surveys of Canada and of Minnesota, and are all reduced to refer to the true or astronomic meridians. Unless they are otherwise credited, the observations in British America are by Dr. Robert Bell, and in Minnesota by the present writer. All are in the area that is supposed to have been covered by the ice-sheet of the last glacial epoch.

Hudson Strait and Bay.

Hudson Strait, Port Burwell, ten miles southwest from Cape Chudleigh ..... S. 85° E.
do., Ashe's Inlet, on the north side of the strait, about ..... S. 65° E.
do., Cape Prince of Wales, on the south side, opposite to the last ..... E. to N. 70° E.
do., south part of Nottingham Island ..... S. 80° E.
do., Digges Island, off Cape Wolstenholme ..... N. 55°–75° E.
Ottawa Islands, in the northeast part of Hudson Bay ..... N. 75° E., N. 40°—20° E., and N. 5° W.
East coast of Hudson Bay, northern part, successively, proceeding southward ..... N. E., N. and N. W.
do., from Cape Dufferin southward to Hopewell Head and the most northern of Nastapoka Islands, in lat. 58° to 57° N., near the middle of the east side of Hudson Bay, numerous localities, S. 70°, 60° and 35° W.

It is probable that the first two of these courses record the direction of the ice-flow during the time of maximum depth and area of the ice-sheet, or during a somewhat later stage; and that the last belongs to the time of final melting of the ice.

East coast of Hudson Bay, thence southward to the entrance of Richmond Gulf, numerous localities, mostly between ..... S. 65°–75° W. and N. 75° W., but in two localities, probably a later glaciation ..... S. 35°–45° W.

East, Cairn Mountain Island, Richmond Gulf, several localities, mostly ..... N. 60°–70° W.,
but in one place varying from this to ..... S. 45° W.
do., from Richmond Gulf and Little Whale River southward to Esquimaux Harbor, many localities ..... N. 80° W. to W.
do., thence to Red Head, fifty-seven miles northeast of Cape Jones, eight localities ..... W. to S. 75° W.,
and one locality ..... S. 55° W.
do., Red Head Island ..... N. 70° W.
do., thence southward to forty miles south of Big River, many localities ..... S. 40°–60° and 70° W.;
but on the southwest extremity of Long Island, near Cape Jones, striæ bear in every direction from ..... S. 70° W., around by S. W. and S., to S. 40° E.
The two prevailing directions are about ..... S. 45° W. and S. 15° E.; the former being probably the older, but perhaps deflected to the south from the direction of the glacial current when the ice-sheet was thickest, and the latter, with further deflection southeastward, belonging to the closing stages of the glacial period. An island off the southwest point of Long Island has three sets of glacial striæ ..... S. 60° W., S. 40° W., and S. 20° E.
East coast of Hudson Bay, from forty miles south of Big River southward along the east coast of the south half of James Bay, many localities ..... S. 30°–55° W.;
but in one locality, about three miles northwest of the Paint Hills, three sets of glacial striæ occur, bearing ..... N. 75° W., S. 55° W., and S. 30° W.
The first probably records approximately the course of glaciation here when the ice attained its greatest area, belonging thus to a striation which was chiefly effaced by a later glacial movement to the southwest during the departure of the ice-sheet. Again, at the Paint Hills, two sets of glacial striæ are found, bearing ..... S. 75° W. and S. 35° W.;
and on Governor's Island, at the mouth of Eastmain River, the course is ..... S. 75° W.
Marble Island, northwest part of Hudson Bay ..... S. 15°–25° E.
West coast of Hudson Bay, east side of the mouth of Churchill River ..... S. 5° E.
do., two and a half miles east from the last ..... S. 20° W.
do., five miles east from the mouth of Churchill River ..... S. 15° E.

Region of the Churchill and Nelson Rivers, Lake Winnipeg, and southwest to the Assiniboine.

Churchill River, at Fort Churchill..... S. 30°–40° W.
do., four miles below the mouth of the Little Churchill River.....S. 20° W. and S. 80° W.
do., six and eleven miles above the mouth of the Little Churchill River..... S. 10°–15° W.
Little Churchill River, three localities, four, thirteen and eighteen miles below Was-kai-ow-a-ka Lake, respectively.....S. 40° W., S. 80° W., and N. 85° W.
do., outlet of Lower Recluse Lake, various directions from.....S. 15° W. to S. 50° W.; also, W.
do., Eagle Rapid, two miles in a straight line below the last, two sets, both distinct.....S. 20° W. and W.

The courses to the west, or nearly so, probably mark the motion of this part of the ice-sheet during the time of its greatest depth and extent; while the southerly courses show its deflected motion during the final melting.

Along the Nelson River, Third Limestone Rapid, a hundred miles by the course of the river above its mouth..... S. 30°–50° E.
do., Broad Rapid, five miles long, eleven to sixteen miles above the last, mostly..... S. 50° W.; also.....S. 15° W. and S. 55°–75° W.
do., thence to Middle Gull Rapid, numerous localities. S. 55°–80° W.
do., Upper Gull Rapid, and thence to the middle portion of Split Lake, numerous localities..... N. 85°–75° W.
do., southwestern part of Split Lake, two localities.. S. 85° W.
do., Chain-of-rocks Rapid, three miles above Split Lake, one set, probably the older..... S. 85° W., the other..... S. 10° E.
do., on Grass River, tributary to the Nelson River from the west a few miles above Split Lake, numerous localities.....S. 85° W. to W.; but in one place, at the outlet of Witchai (Stinking) Lake..... N. 75° W.
do., between Split Lake and Sipi-wesk Lake, numerous localities, mainly..... S. 55°–75° W., and occasionally..... W.
do., Sipi-wesk Lake, outlet and northeastern part, mostly..... S. 70°–75° W.; also, in numerous localities..... S. 45°–65° W.
do., Sipi-wesk Lake, average course throughout the southwestern half of the lake..... S. 55°–60° W.; but in some places..... N. 85° W.
do., southwest extremity of Sipi-wesk Lake..... S. 65° W.
do., from Sipi-wesk Lake to the outlet of Pipestone Lake, six localities..... S. 55°–65° W.
do., Pipestone and Big Reed Lakes and vicinity, five localities..... S. 40°–55° W.

Along the usual boat route from Hudson Bay by Hayes and Hill Rivers to Lake Winnipeg, six miles below the Rock, Hill River	S. 12° E.
do., the Rock, Hill River	S. 10° E.
Dr. Bell reports also at this locality another and older set of striæ	N. 79° W.
do., Borwick's Fall, and one mile above White-mud Fall, Hill River, both within a few miles southwest from the Rock, respectively, S. 18° W., and	S. 28° W.
do., Knee Lake, numerous localities	S. 35°–60° W.
do., from Knee Lake to Pine Lake, seven localities	S. 45°–60° W.
do. from Pine Lake and Molson's Lake to Great Playgreen Lake, many localities	S. 35°–60° W.
Around God's Lake, southeast of the foregoing route, 140 to 180 miles east-northeast from the north end of Lake Winnipeg, many localities (Cochrane) S. to S. 52° W., mostly	S. 15°–40° W.;
but in two localities	S. 80° W.
Between Jackson Bay, on Oxford Lake, and the southern part of God's Lake, seven localities (Cochrane)	S. 28°–40° W.
Around Island Lake, about forty miles south of God's Lake, many localities (Cochrane)	S. 16°–36° W.
Between Hudson Bay and Lake Winnipeg, along the Severn, Fawn, Poplar and Beren's Rivers, on almost all exposed rock-surfaces (A. P. Low). generally	S. W.,
varying only a few degrees from this on either side.	
Mouth of Lake Winnipeg and its vicinity, several localities	S. 40°–45° W.
East shore of Lake Winnipeg, Spider Islands, on the adjacent mainland, and at the Shoal Islands, about thirty and forty-five miles south from the north end of the lake	S. 30°–46° W.
do., Poplar Point, four miles southeast of Poplar Point, and opposite to George's Island, a few miles farther southeast	S. 30°–35° W.
do., four localities near the mouth of Beren's River, half-way from the north to the south end of the lake	S. 57°–60° W.
do., near the mouth of Beren's River (Panton)	S. W. and S. S. W.
do., east side of Beren's or Swampy Island (Panton)	S. W.
do., Rabbit Point, near the Narrows	S. 18° W.
do., Black Bear Island, also near the Narrows (Panton)	S. S. W.,
intersected by other glacial striæ, bearing	S. S. E.

The latter, agreeing in direction with striæ observed at Stonewall, Stony Mountain and Little Stony Mountain, near Winnipeg, appear to belong to

basal portion of the divergent glacial current which continued south and southeast in the Minnesota lobe of the last ice-sheet.

East shore of Lake Winnipeg, between the Narrows and the mouth of Winnipeg River, numerous localities	S. 40°–45° W.
Stonewall, in many places (Panton, Upham)	S. 20°–25° E.
Stony Mountain (Panton, Upham)	S. 20°–25° E.
Little Stony Mountain (Upham)	S. 25° E.
Assiniboine River, sec. 36, T. 8, R. 11, in three places (Upham)	S. 4°–8° W.,
and in one place	S. 10° E.

Athabasca River and Lake, Wollaston and Reindeer Lakes, and southward to Cumberland House.

Mountain Portage, Athabasca River, seven miles above the mouth of Clearwater River	S. 54° E., or more probably N. 54° W.
Fort Chipewyan, near the mouth of Lake Athabasca, also one mile west and eight miles southwest of Fort Chipewyan	S. 78°–83° W.

The following observations, to Cumberland House, are by Mr. A. S. Cochrane, and are communicated by Dr. Robert Bell, having never before been published.

North shore of Lake Athabasca, ten miles north from the Burntwood Islands	S. 81° W.
do. twenty miles west of Black Bay	S. 61° W.
do. half-way from the west to the east end of the lake	S. 43° W.
do. twenty miles west of the Hudson Bay Company's post at Fond du Lac	S. 21°, 27°, and 31° W.
do. H. B. post, Fond du Lac, fifty miles west from the east end of the lake	S. 53° W.
On the western outlet of Wollaston (Hatchet) Lake, fifteen miles east from its mouth at the east end of Athabasca Lake	S. 85° W.
Junction of Porcupine River with the western outlet of Wollaston Lake, fifty miles east of Athabasca lake	S. 75° W.
North shore of Wollaston Lake, half-way between its western and eastern outlets	S. 27° W.
Jackfish Lake, about half-way between Wollaston and Reindeer Lakes, by way of Hatchet Lake River	S. 17° W.
North end of Reindeer Lake (average of numerous observations)	S. 31° W.
do. mouth of Hatchet Lake River	S. 17° W.
East shore of Reindeer Lake, Porcupine Point	S. 24° W.
do. half-way from the north to the south end of the lake	S. 18° W.

South end of Reindeer Lake, and on its outlet	S. 18° W.
Churchill River, near Frog Portage, 110 miles north-northwest of Cumberland House	S. 40° W.
do., at a small lake ten miles east from the mouth of Isle à la Crosse Lake	S. 18° W.
On the canoe route, seventy miles north of Cumberland House	S. 16° and 26° W.
do., fifty-five miles north of Cumberland House	S. 26° W.

As on the lower part of Churchill River, before noted, the more westerly courses of this list are believed to indicate the glacial motion when the ice had its maximum depth, or nearly that, continuing probably through the greater part of the epochs of glaciation; and the southward currents seem referable to deflection during the recession of the boundary of the ice-sheet, most of the earlier westward striæ being thereby effaced.

From Hudson Bay to Lake Superior and the Lake of the Woods.

On the route of Dr. Bell from James Bay to Lake Huron, commonly	S. 5° E. to S. 5° W.;
rarely varying to	S. 25° E.
Between James Bay and the east end of Lake Superior, from Long Portage of the Missinaibi River to Mattagami Lake, both belonging to the Moose River system, mostly	S. S. W.
do., Wasquagami Portage, Missinaibi River, two sets	S. 15° W., and S. 60° E.

The last is doubtless a local deflection, belonging to the time when the ice-sheet was being melted away.

do., Missinaibi River, east of Brunswick Lake	S. 15° E.
do., around Mattagami Lake	S. 30-65° W.
do., Lake Manitowick, on Michipicoten River	S. 30° W.
do., Long Portage of the Michipicoten River, six miles east of its mouth	S. 40° W.
North shore of Lake Superior, Falls of St. Mary, and thence twenty miles south (Agassiz)	S. S. E.
do., twenty-five miles north of the Falls of St. Mary, and thence to the northeast angle of the lake, seventy-five miles east of St. Ignace Island, many localities (Agassiz)	S.
do., fifty miles east of St. Ignace Island (Agassiz)	S. S. W.
do., St. Ignace Island, and the same twenty-five miles east (Agassiz)	S.
do., southwest side of Nipigon Bay (Agassiz)	S. S. W.
do., islands in Thunder Bay (Agassiz)	S. W.
do., between Thunder Bay and Pigeon River (Agassiz)	S.
Isle Royale, Lake Superior, numerous localities (Desor)	S. 20°-75° W.
Along the Pic River, tributary to Lake Superior	S. 20°-30° W.

Kenogami or Long Lake, at the head of the Kenogami River, tributary to Albany River, many localities ..... S. to S. 25° W.

"The grooving is as well marked on the tops of the highest hills as in the valleys."

In the country northwest of Kenogami or Long Lake, several localities ..... S. 30°–40° W.
Along the Kenogami River, mostly ..... S. 30°–50° W.; but varying to ..... S. and S. 60° W.
Lake St. Joseph, mostly ..... S. 30°–45° W.; also, in two localities ..... S. 15° W. and S. 60° W.
Albany River between Lake Saint Joseph and Maminiskа Lake, three localities ..... S. 20°, 25°, and 40° W.
Maminiska Lake ..... S. 65° W.
Patawonga Lake ..... S. 75° W.
Eabamet Lake, two localities ..... S. 75° and 80° W.
Inlet of Sturgeon Lake, Boulder River ..... S. 70° W.
Attawapishkat River, respectively 3, 13, 22, and 23 miles below the junction of the two channels from the lake of the same name ..... S. 60°, 42° 22°, and 15° W.
do., lowest exposure of Archæan rocks ..... S. to S. 10° E.
do., on limestone about 75 miles from the southern mouth of the river ..... S. 18° W.
do., on limestone nine miles below the last, two sets of striæ, the older ..... S. 8°–12° W.; and the newer ..... S. 60°–70° E.
do., on limestone at the head of Lowasky Island, about 44 miles from the southern mouth of the river ..... S. 2° W.
do., southern channel or Lowasky River, four miles below the last, the older striæ ..... S. 35° W.; and newer striæ varying in course from the foregoing to ..... S. 80° W.
Around Lake Nipigon two sets of glacial striæ are common, and are often found crossing each other on the same rock surface. The southward set, which is the older, varies from S. 18° E. to S. 25°. W.; and the westward and newer set varies from ..... S. 50° W. to due W.
Along and near Kaministiquia River ..... S. to S. W., averaging S. S. W.
Dog Lake, mean of several localities (Hector) ..... S. 10° W.
Lac des Mille Lacs, mean of several localities (Hector) S. 5° E.
Sturgeon Lake, fifty miles southeast of Lonely Lake, commonly ..... S. 20°–30° W.; but in one locality ..... S. 50° W.
Minnietakie Lake and vicinity, west of Sturgeon Lake, several localities ..... S. 20°–55° W.
Abram's Chute ..... S. 10° W.
Islands in the middle of Abram's Lake ..... S. 40° W.

Lonely Lake (Lac Seul), three localities	S. 70° W., S. 85° W., and N. 80° W.
do., three other localities, respectively 10, 13, and 16 miles east of the Hudson Bay Company's post	S. 60° W., S. 25° W., and S. 55° W.
do., east extremity of the lake	S. 45° W.
Root River, tributary to the east end of Lonely Lake, two localities	S. 50° and 45° W.
English River, below Lonely Lake, five localities	S. 30°-60° W.
and one locality	S. 80° W.
Winnipeg River, several localities	S. 20°-55° W.
Around the Lake of the Woods, observations in about 180 localities by Dr. A. C. Lawson and assistants, and in about 60 localities reported by Dr. G. M. Dawson, "the great majority," i.e., 82 per cent.	S. 35°-55° W.;
but 13 per cent. are	S. 10°-34° W.,
and 5 per cent. are	S. 56°-83° W.
Only four localities showed courses more westerly than S. 65° W.: one of these is on the southeast side of Big Island, where striæ bearing	S. 75° W.
intersect others bearing	S. 37° W.;
on the west side of Bigsby Island, which, like the preceding, lies near the middle of Sand Hill Lake (the southern and largest part of the Lake of the Woods), double sets of striæ were observed in two places, respectively	N. 80° W. and S. 20° W.,
and	N. 83° W. and S. 33° W.;
and on a point projecting from the south shore in the southwestern part of this Sand Hill Lake, striæ bear	S. 70° and 65° W.,
with others	S. 35° and 33° W.; also, S. 10° E.

Probably the bearings S. 10° E. to S. 20° or 30° W. belong to the time of maximum depth and area of the ice-sheet; the prevailing southwestern courses to later glaciation; and the more westerly deflections to the time of final melting of the ice.

Minnesota.

North shore of Lake Superior southwesterly from Pigeon Point, numerous localities (Norwood and Whittlesey)	S. 25°-45° W.
Duluth (N. H. Winchell)	W. S. W.
Otter Track, Sucker (or Carp), and Long Lakes, in northeastern Minnesota, south of Hunter's Island (Winchell)	S. W.
Vermilion Lake, two places (Winchell), about	S. 20° W.,
and in another place (Winchell)	S. 40° W.
Vermilion Lake (Whittlesey)	S. 15° W.
Pike River, tributary to Vermilion Lake, two places (Winchell)	S. 10° and 20° W.

In T. 59, R. 14, about twenty miles south-southeast of Vermilion Lake (Winchell), estimated..... S. 30° W.

The following, to Knife Lake, inclusive, are observations by Prof. N. H. Winchell, noted in his Fifteenth annual report, Minn., 1886, pp. 385-6:

Vermilion Lake, twenty localities..... S. 17°–24° W.
do., three other localities.....S. 28° W., S. 10° W., and S.
Birch Lake.....S. 12° W. and S. 22° W.
Sec. 30, T. 63, R. 8..... S. 8° E.
Sec. 35, T. 63, R. 9..... S. 12° W.
Sec. 27, T. 63, R. 10..... S. 15° W.
Basswood Lake, Northeast Cape..... S. 15° W.
Ima Lake, north shore.....S. 30° W. and S. 23° W.
Island in Thomas Lake..... S. 25° W.
Sec. 11, T. 64, R. 7..... S. 30° W.
Knife Lake..... S. 48° W.

The two following are from Prof. N. H. Winchell, in his Sixteenth annual report, for 1887, p. 114:

East end of Delta Lake, west of Ogishke Muncie Lake. S. 25° W.
Island in Pseudo-Messer Lake..... S. 40° W.

Mr. Horace V. Winchell, in the report last cited, pp. 395–478, notes the following glacial strice, to Trout Lake, inclusive, corrected by him for magnetic variation:—

Little Fork of Rainy River, five localities..... S. 10°–42° W.
Rainy River, 34 miles below Fort Francis..... S. 32° W.
Rainy Lake, nine localities..... S. 32°–64° W.
North fall on outlet from Namekan Lake to Rainy Lake..... S. 30° W.
Bowstring River (Big Fork of Rainy River), probably in T. 63, R. 26, intersecting strice, mainly..S. 10° W. and S. 30° E.
do., a short distance above the last, very distinct glaciation..... S. 60° E.
Deer River, at dam about a half mile above its junction with the Big Fork, probably in T. 62, R. 25.....S. 80° E. to due E.
Big Fork, about three miles above the mouth of Deer River..... Due E.
do., in or near sec. 35, T. 150, R. 25..... S. 52° E.

The southeastward and eastward striation on the Bowstring River or Big Fork belongs to the east part of the glacial current that moved to the south and southeast from the region of Lakes Winnipeg and Manitoba, carrying plentiful bowlders and gravel of limestone from those lakes and the lower part of the Red River Valley southeast to this stream and to the mouth of Rainy Lake.

Lower Falls of Prairie River, sec. 34, T. 56, R. 25..... S.
Elbow Lake, T. 64, R. 18, two localities.....S. 26° W. and S. 28° W.
Pelican Lake, mostly in Ts. 64 and 65, R. 20, four localities..... S. 24°–36° W.
Net Lake, in the Bois Fort Indian Reservation..... S. 20°–24° W.
Trout Lake, north of Vermilion Lake, two localities. .....S. 16° W. and S. 36° W.

Sand Point Lake and Sturgeon or Namekan Lake (Whittlesey)..... S. W. to S. 55° W.
Rainy Lake (Whittlesey)..... S. 40°–60° W., and W. S. W.
Big Fork of Rainy River, about 82 miles from its mouth (Whittlesey)..... S. 80° E.

This seems to be near the locality noted by H. V. Winchell about three miles above the mouth of Deer River.

Hinckley, Pine County..... S. and S. 5° W.
Watab, Benton County..... S. 15° W.
Sauk Rapids, Benton County, numerous places..... S. 45°–55° W.; but in one place..... S. 15° W.
Sauk Center, Stearns County, forty miles west of the last..... S. 40° E.
Minneapolis, several places..... S. 5°–28° E.
One to seven miles southeast from Big Stone Lake, numerous places..... S. E.
Granite Falls, several places..... S. 45°–50° E.
Beaver Falls..... S. 60° E.
In the valley of the Minnesota River two miles below Lac[illegible] Cooley..... S. 60° E.
One and a half miles west of Fort Ridgely..... S. 60° E.
Redstone, near New Ulm..... S. 25° E.
Jordan, at mill of Foss, Wells & Co..... S. E.
Posen, Yellow Medicine County..... S. 50° E.
Echo, Yellow Medicine County..... S. 50°–55° E.
T. 111, R. 38, Redwood County..... S. 50°–60° E.
Stately, Brown County..... S. 50°–55° E.
Germantown, Cottonwood County..S. 30° E., S. 50° E., and S. 70° E.
Amboy, Cottonwood County, mostly..... S. 35°–50° E.; but also rarely deflected to..... S. 70° E.

In one place all these courses intersect on the same surface.

Delton, Cottonwood County, numerous localities, mostly..... S. 15°–40° E.; also, in one place, all courses from..... S. to S. 80° E., intersecting on the same surface.
Selma, Cottonwood County..... S. 18°–22° E.
Amo, Cottonwood County..... S. 30°–32° E.
Dale, Cottonwood County..... S. 20°–34° E.
Adrian, Watonwan County..... S. 20°–30° E.

APPENDIX II.

TABLES OF ALTITUDES.

Much care has been taken to determine the elevations of the beaches of Lake Agassiz with the greatest possible accuracy, in their relation to each other and to the sea level. The railway surveys which have been used as the basis for my levelling along these ancient beaches are found to agree very closely with each other, giving assurance of their reliability throughout the basin of Lake Agassiz, as stated at the beginning of this report, within probable limits of error nowhere exceeding five feet. By the courtesy of the engineers of these railways, their profiles have been mostly submitted to my examination, and I have copied from them the greater part of the notes which are here tabulated; but small portions have been received in manuscript compiled from the profiles by the engineers or their assistants, who have taken much interest in this work, and to whom I desire to express my grateful acknowledgments. Altitudes compiled from railway profiles.

The plane of reference in the following tables, and for the altitudes stated throughout this report, is the mean tide sea level. Heights on railways designate the top of the rail in front of passenger stations, at summits from which the grade descends both ways, and at the middle of bridges. The lowest and highest known stages of water in rivers is noted when it is given on the profiles; but in many instances only the ordinary low stage is recorded. Reference to mean tide sea level.

Altitudes of lakes, rivers, hills, mountains, and depressions in lines of water-shed, within the basin drained to Lake Agassiz north of the international boundary, are also here tabulated for convenient consultation. Portions of these lists are compiled from former reports of this Survey, and from Hind's Narrative of the Canadian Exploring Expeditions, which was published in 1860. Wherever subsequent railway surveys have supplied means for more accurate reference of these to the sea level, the needed corrections have been made. In all cases, whether of railways or other lists, the source of observations, and the amount of change from the original, if any, with the reasons for it, are noted. Lakes, rivers, mountains, and lines of water-shed.

CANADIAN PACIFIC RAILWAY.

A published profile of this railway gives the elevation of Lake Superior as 600 feet above the sea, while on the profiles in the engineers' offices it is shown as 600 feet. Assuming the mean of these figures to represent the mean lake level, a uniform addition of three feet is here made to the eastern part of the profile, extending from Port Arthur to Eagle River station, to accord approximately with the mean elevation of Lake Superior, 601.56, determined by the United States Lake Survey.

The profile shows a discrepancy of eight feet close west of Eagle River station, 232 miles west of Port Arthur, on account of which its elevations thence west to Cross Lake require a subtraction of five feet, which is here made, to agree with the foregoing. Again at Cross Lake, 334.4 miles west from Port Arthur, a discrepancy of five feet to be added is found in the profile, so that its original elevations thence west to the Red River and south to Emerson are here copied without change, being in accord with the corrected profile on the east.

The main line from East Selkirk to the junction of the Emerson branch close east of Winnipeg, and this branch, extending from Saint Boniface to the international boundary, are supplied by Collingwood Schreiber, chief engineer and general manager of the Canadian government railways, and are on the same system of levelling with the main line from Port Arthur to East Selkirk, which, however, is subject to the slight adjustments mentioned. This whole series thus adjusted is surely correct within very close approximation, as is shown by its exact agreement at Emerson with the Saint Paul, Minneapolis & Manitoba Railway and with levelling by the United States Engineer Corps along the Red River of the North.

Two smaller discrepancies also appear in the profile, but are here neglected. At 117 miles from Port Arthur (close west of Scott's River) and thence west, a subtraction of two feet is indicated; and at 256.5 miles (close west of Parrywood) and thence west, a subtraction of one foot. If these were taken into account, the west part of this profile would be lowered three feet; but it seems more probable that it should agree with the elevation of Emerson determined by surveys of the United States.

A large discrepancy is found between the eastern system of levelling and that which begins at Winnipeg and extends west to the Rocky Mountains. The latter includes the branches west of the Red River at Winnipeg and westward also the Manitoba & Northwestern Railway and its branches, which refer their elevations to that of the Canadian Pacific profile at Portage la Prairie. The system east of the Red River is reliable, as already stated; and levelling from Saint Boniface station (754 feet) to the Louise bridge (752 feet, instead of 728, the profile extending westward) shows that the system west of the Red River requires a uniform addition of twenty-four feet, which is here made in the list of elevations at Winnipeg and thence west. With this correction, the South-western Branch from Winnipeg to Gretna agrees with the Saint Paul, Minneapolis & Manitoba Railway at the international boundary; the surface from this branch at Rosenfeld to Emerson agrees with the Emerson branch and the West Selkirk branch agrees with the main line east of the Red River.

a. Main line, from Port Arthur to Winnipeg.

Between Port Arthur and East Selkirk from profiles in the offices of P. A. Peterson, engineer, Montreal, and R. M. Pratt, engineer, Winnipeg; and between East Selkirk and Winnipeg from Collingwood Schreiber, engineer of government railways, Ottawa.

	Miles from Port Arthur.	Feet above the sea.
Lake Superior, mean surface, Nov. 1, 1870, to Jan. 31, 1888, according to U.S. Engineers' gauge, Sault Ste. Marie	0.0	601.56
Lake Superior, extreme low and high water (range, 4.9 feet), approximately	0.0	599–604
Port Arthur (a summit of grade), 993.0 miles from Montreal	0.0	628
McIntyre or Second River, water, 603; grade	6.0	610
Neebing or First River, water, 603; grade	6.2	610
Fort William	7.0	615
Kaministiquia River here, 1¼ miles above its mouth, bed, 586; low water (1879), 600; high water (1859), 612.		
Fort William West (station disused)	10.0	635
Kaministiquia River here, bed, 584; low and high water	10.0	602–614
Murillo	17.6	947
Summit, grade (three feet above natural surface)	20.6	1080
Lofoden	20.8	1078
Depression, tilling 7 feet; grade	21.8	1055
Summit, cutting 2 feet; grade	22.3	1081
Strawberry Creek, bed, 987; low and high water, 990–993; grade	27.3	1002
Kaministiquia	27.9	1013
Kaministiquia River, bed, 973; low and high water, 982–996; grade	28.2	1013
Mattawan River, bed, 1078; low and high water, 1082–1089; grade	32.4	1099
Sunshine Creek, first crossing, bed, 1106; low and high water, 1109–1113; grade	33.9	1122
Sunshine Creek, third crossing, bed, 1151; low and high water, 1158–1162; grade	35.5	1168
Finmark	37.1	1180
Sunshine Creek, bed, 1330; water, 1334; grade	41.3	1352
Buda (a summit, natural surface and grade the same)	44.4	1473
Oskondiga River, bed, 1415; water, 1421; grade	45.3	1453
Tunnel, grade, 51 feet below top of rock above	46.1	1458
Oskondiga River, bed, 1426; water, 1428; grade	52.2	1411
Nordland	55.5	1543
Summit, natural surface and grade	57.8	1584

	Miles from Port Arthur.	Feet above the sea.
Southeast branch of Savanne River, bed, 1544; water, 1545; grade	59.9	1554
Southeast branch of Savanne River, bed, 1537; water, 1538; grade	62.0	1546
Linkooping	65.2	1534
Savanne	75.8	1506
North branch of Savanne River, bed, 1487; water, 1489; grade	76.4	1506
Upsala	86.2	1579
Carlstad	93.6	1515
Fire-steel River, bed, 1500; water, 1505; grade	98.5	1513
Beaver River, bed, 1519; water, 1525; grade	102.2	1532
Bridge River station	105.6	1543
Hawk Lake, water, 1509; grade	113.6	1518
English River, bed, 1504; water, 1510; grade	115.2	1515
English River station	116.0	1517
Scott's River, bed, 1505; water, 1511; grade	116.6	1516
Summit, cutting 11 feet; grade	123.6	1558
Martin	124.0	1557
Depression, grade	127.4	1483
Summit, grade	131.6	1549
Bonheur	134.0	1520
Summit, grade	136.4	1554
South Lake, water, 1495; grade	138.3	1510
Depression, grade	139.7	1478
Gull River, bed, 1456; grade	143.7	1490
Falcon	144.8	1509
Ahgimac River, bed, 1470; grade	151.3	1490
Ignace	152.3	1487
Osaquan River, bed, 1398; grade	158.7	1420
Butler	160.5	1423
Little Wabigoon River, bed, 1398; grade	165.7	1408
Glencoe River, bed, 1398; grade	167.0	1405
Raleigh	170.4	1410
Little Wabigoon River, bed, 1350; grade	180.0	1366
Taché	180.2	1366
Burnt Stick Creek, bed, 1314; grade	182.5	1347
Kirkpatrick Creek, bed, 1320; grade	183.9	1352
Bear Creek, bed, 1333; grade	186.6	1348
Brulé	190.4	1355
McHugh's Creek, bed, 1207; grade	198.6	1235
Summit, grade	200.4–200.8	1275
Hughes River, bed, 1198; grade	202.2	1211
Wabigoon	202.6	1211
Blackwater Creek, bed, 1200; grade	204.5	1211
Thunder Creek, bed, 1205; grade	206.1	1225
Barclay	209.8	1251
Summit, cutting 10 feet; grade	211.5	1267

	Miles from Port Arthur.	Feet above the sea.
Wabigoon River, bed, 1178; grade	215.4	1219
Shoshogawae River, bed, 1151; grade	220.8	1159
Oxdrift	221.8	1162
Beaver River, first crossing, bed, 1129; grade	225.8	1149
" " second crossing, bed, 1125; grade	226.4	1139
" " third crossing, bed, 1123; grade	229.4	1153
Eagle River station	231.8	1186
Eagle River, bed, 1148; grade	232.2	1190
Summit, cutting 7 feet; grade	234.9	1278
Vermilion Bay station	242.0	1221
Grass Creek, bed, 1183; grade	242.5	1213
Eagle Lake, water about 1182; grade	246.9	1210
Gilbert	249.8	1217
Muskrat Lake, water, about 1174; grade	251.0	1206
Summit, natural surface and grade	255.4	1295
Parrywood	256.3	1292
Stewart Lake, water, 1303; grade	258.3	1328
Summit, near Forest Lake, natural surface and grade	259.8	1382
Outlet of Swan Lake, bed, 1332; grade	260.8	1362
Parrywood Lake, water, about 1362; grade (a summit)	262.1	1379
Outlet of Ulverston Lake, bed, 1318; grade	262.9	1364
Mud Lake, water, 1328; grade	263.3	1355
Feist Lake, water, 1326; grade	264.3	1347
Turtle Lake, water, 1366; grade	265.1	1376
Summit station, cutting near, 10 feet; grade	265.4	1385
Summit Lake, water, 1384; grade	265.6	1385
Clare Lake, water, 1284; grade	270.3	1295
Viaduct Lake, water, 1246; grade	271.6	1282
Hawk Lake station	272.9	1289
Outlet of Narrow Lake, bed, 1220; grade	275.1	1256
Trout Lake Creek, bed, 1213; grade	280.6	1248
Beaver (depression of grade near Beaver [illegible] Lake)	284.1	1186
Rossland	288.9	1128
Rat Portage	297.3	1087
Winnipeg River, outlet of the Lake of the Woods, low water, at same level with this lake, 1057; grade	298.1	1087
Lake of the Woods, mean, 1060; low and high water.	298.1	1057–1063
Keewatin	300.8	1075
Winnipeg Bay, water, 1043; grade	301.6	1062
Mink Bay, water, 1043; grade	302.4	1070
Winnipeg Bay, water 1043; grade	303.7	1078
War Eagle Rock Lake, water, 1082; grade	305.8	1121
Ostersund	308.3	1105
Summit, cutting 33 feet; grade	311.4	1187
Lake Bobo, water, 1138; grade	312.7	1151

	Miles from Port Arthur.	Feet above the sea.
Lake Deception, water, 1094; grade	313.1	1143
Deception	313.4	1136
Bear Lake, grade	315.2	1192
Summit, at west end of a cut 35 feet deep; grade	315.7	1218
Monument Lake, grade	318.3	1218
Red Pine Lake, grade	319.2	1226
Fellows Lake, water, 1235; grade (eleven feet lower than the lake)	319.7	1224
Kalmar	320.4	1217
Summit Lake, water, 1252; grade	322.1	1255
Kennedy Lake, water, 1245; grade (two feet lower than the lake)	323.1	1243
White Fish Lake, water, 1213; grade	323.8	1246
Summit, 30 rods west from the centre of a cut 33 feet deep; grade	325.8	1221
Ingolf	328.2	1184
Summit, cutting 30 feet; grade	328.9	1130
Cross Lake station, water, 1045; grade	334.4	1092
Depression, grade	336.2	1053
Telford	338.5	1059
Summit, grade, two feet above the natural surface. For two and a half miles east and one mile west the surface is very smooth, 1105 to 1113.	342.3	1115
River Brenton, water, 1041; grade	348.7	1059
Rennie	349.0	1053
Bog River, water, 996; grade	354.7	1007
" water, 993; grade	356.2	996
Darwin. Westward to the Red River the country is mostly swamp, bearing alders and tamaracks. The swamp is underlain by a hard bottom at depths varying commonly from 5 to 15 feet.	359.4	971
Bog River, water, 927; grade	364.0	935
Whitemouth River, water 877; grade	368.1	900
Whitemouth	368 9	907
Beaver Creek, water, 885; grade	369.8	904
Shelly	374.9	929
Monmouth	384.9	879
Bear Creek, water, 820; grade	387.4	831
Broken Head River, water, 784; grade	391.1	796
Beausejour	394.3	814
Tyndall	400.9	796
Devil's Creek, water, 770; grade	402.3	777
East Selkirk	408.9	743
Red River at West Selkirk, two miles west of East Selkirk, "ice, 1876" [probably two or three feet above extreme low water], 712; flood of 1876, 723; flood of 1875, 725; extreme high water, flood of 1826, 732; range, 22 feet	411.0	710–732

	Miles from Port Arthur.	Feet above the sea.
The railway at East Selkirk turns southward, leaving the line of its original survey, which crossed the Red River here.		
Lake Winnipeg, mean, 710; low and high water, approximately		708-713
Cook's Creek, water	409.1	728
Gonor	415.0	757
Bird's Hill station	422.1	759
Winnipeg Junction, Emerson branch	427.8	752
Red River, extreme low water, 723; highest water in ordinary years, 735–740; high water, 1882, 749; grade, Louise bridge	429.0	752
Winnipeg	429.8	757

b. Main line; from Winnipeg to the Rocky Mountains and Donald.

From profile in the office of R. M. Pratt, engineer, Winnipeg.
With uniform addition of twenty-four feet, as before explained.

	Miles from Winnipeg.	Feet above the sea.
Winnipeg, 1422.8 miles from Montreal	0.0	757
Junction of Southwestern branch	1.1	760
Junction of Manitoba & Southwestern Railway	1.2	760
Junction of West Selkirk branch	1.5	759
Point of beginning of the original profile (at 0 of distances measured thence westward)	1.8	761
Air Line Junction, of Stonewall branch	1.9	761
Colony Creek, water, 769; grade	3.3	776
" water, 772; grade	4.0	780
Junction of Winnipeg & Hudson Bay Railway	4.7	780
Bergen	7.4	784
Rosser	15.2	796
Meadows	22.3	793
Marquette	28.9	807
Reaburn	35.2	806
Long Lake, ordinary low and high water, 798–803; grade	35.7	804
Poplar Point	40.4	815
High Bluff	48.7	829
Portage la Prairie, junction of the Manitoba & Northwestern Railway	56.0	854
Dry Creek, bed, 858; grade	63.4	872
Burnside	63.5	872
Rat Creek, water, 862; grade	65.1	890
Bagot	71.1	935
Image Creek, water, 939; grade	75.6	953
McGregor	77.6	961
Austin	84.5	1005
Apparently a beach ridge (the lower Campbell beach of Lake Agassiz), crest, 1066; grade	86.9	1061

	Miles from Winnipeg.	Feet above the sea.
Again, apparently a beach ridge (the upper Campbell beach, second ridge), crest, 1081; grade....	87.2	1076
Again (the upper Campbell beach, first ridge), crest, 1087; grade.....	87.5	1085
These beach ridges are each about 30 rods wide, with descents of 10 to 20 feet from their crests to their east bases and half as much to the west.		
A very uneven profile, intersected by numerous ravines, extends from 89.3 to 92.0 miles, in which distance the grade rises from 1124 to 1232 feet.		
Sydney.....	92.6	1232
It is again very uneven from 93.7 to 95.9 miles, in which distance the grade ranges from 1234 1251 feet.		
Here and westward the profile shows frequent lakelets, but no names for them are given.		
Melbourne.....	98.0	1248
Pine Creek, water, 1199; grade.....	99.7	1224
An uneven surface of low dunes extends from 101.1 to 102.7 miles, the grade varying from 1244 to 1257 feet.		
Carberry.....	105.5	1258
Herman beach (*dd*) of Lake Agassiz, crest, 1263; grade.....	107.6	1264
Herman beach (*d*), crest, 1268; grade.....	108.9	1267
Each of these beach ridges is about 20 rods wide, with crest about five feet above the adjoining land; but west of the west beach (*d*) is a depression of 10 to 12 feet, about 50 rods wide, succeeded farther west by land slightly, only a few feet, above these beaches.		
Very rough contour of dune sand reaches from 110.2 miles (grade, 1274) to 112.7 miles (grade, 1249).		
Sewell.....	114.2	1255
Two slight summits of grade, probably crests of the Herman beach *d*, natural surface and grade the same, 1268 feet, are crossed at 116.3 and 116.8 miles.		
Douglas.....	121.5	1222
Chater.....	127.2	1213
Assiniboine River, water, 1161; grade.....	131.0	1177
Brandon.....	132.7	1194
Kemnay.....	140.9	1364
Alexander.....	148.4	1406
Griswold.....	157.4	1417

	Miles from Winnipeg.	Feet above the sea.
Flat Creek, water, 1376; grade	162.4	1391
Oak Lake station	164.7	1415
Gopher Creek, water, 1404; grade	178.9	1422
Virden	180.0	1444
Hargrave	188.1	1579
Elkhorn	196.6	1630
Fleming	210.8	1794
Moosomin	219.1	1884
Red Jacket	226.4	1917
Wapella	235.2	1930
Burrows	242.8	1948
Whitewood	249.2	1966
Percival	256.2	2038
Summit, grade	257.9	2054
Broadview	263.8	1960
Oakshela	272.0	1952
Grenfell	279.9	1957
Summerberry	287.4	1938
Wolseley	295.1	1950
Sintaluta	303.9	1984
Indian Head	314.1	1924
Qu'Appelle	323.8	2134
McLean	332.4	2284
Summit, grade	334.3	2286
Balgonie	341.5	2187
Pilot Butte	348.0	2016
Regina, junction of the Regina & Long Lake Railway	356.6	1885
Pile of Bones Creek (Wascana River), grade	358.6	1861
Grand Coulée station	366.1	1857
Grand Coulée (Creek), grade	368.7	1842
Pense	373.5	1881
Belle Plaine	381.3	1902
Pasqua	390.2	1872
Moose Jaw Creek, grade	398.1	1761
Moose Jaw	398.3	1767
Boharm	406.5	1792
Caron	414.5	1841
Mortlach	423.6	1961
Parkbeg	432.8	1982
Summit, grade	442.9	2282
Secretan (on the Missouri Coteau)	443.2	2282
Chaplin	452.0	2202
Ernfold	461.4	2288
Summit, grade	464.2	2374
Morse	471.8	2274
Herbert	480.6	2311
Summit, grade	485.2	2377

	Miles from Winnipeg.	Feet above the sea.
Rush Lake station	489.3	2301
Summit, grade	495.4	2420
Waldec	496.7	2357
Aiken's	504.8	2401
Swift Current Creek, grade	509.7	2415
Swift Current station	510.6	2423
Leven	519.6	2467
Goose Lake station	528.9	2465
Summit, grade	532.3	2586
Depression, grade	533.7	2542
Summit, grade	535.5	2590
Antelope	538.5	2556
Gull Lake station	546.3	2562
Cypress	554.8	2637
Sidewood	565.4	2478
Crane Lake station	575.5	2518
Summit, grade	583.9	2568
Colley	585.9	2569
Summit, grade	589.2	2561
Maple Creek station	596.7	2495
Maple Creek, grade	597.2	2497
Kincarth	605.9	2531
Summit, grade	608.9	2546
Forres	615.5	2428
Walsh	627.9	2430
Summit, grade	636.4	2522
Irvine	638.3	2493
Dunmore, junction of the Northwest Coal & Navigation Company's Railway	652.8	2405
Medicine Hat	660.3	2171
South Saskatchewan River, low and high water, 2137–2154; grade	660.6	2173
Stair	667.3	2431
Bowell	675.1	2582
Summit, grade	675.7	2594
Depression at tank, grade	682.6	2384
Sutfield	686.6	2455
Langevin (a summit of grade)	695.2	2496
Kininvie	704.1	2429
Tilley	713.3	2462
Summit, grade	719.3	2506
Bantry	723.1	2471
Tank four miles west of last	727.1	2473
Cassils	733.1	2517
Southesk	740.7	2560
Lathom	748.9	2559
Bassano	757.5	2589
Summit, grade	764.4	2722

	Miles from Winnipeg.	Feet above the sea.
Crowfoot	765.9	2698
Summit a half mile east of tank	768.4	2739
Crowfoot Creek, grade	770.1	2689
Cluny	776.5	2850
Gleichen	784.8	2952
Summit, grade	790.0	2997
Namaka	793.8	2971
Summit, near tank	796.2	3038
Strathmore	801.0	3032
Cheadle	809.4	3189
Summit, grade	815.0	3306
Langdon	819.5	3292
Summit, grade	824.8	3373
Depression, grade	828.2	3334
Shepard	830.1	3370
Summit, grade	832.9	3409
Bow River, grade	836.8	3377
Elbow River, water, 3394; grade	839.2	3411
Bow River at the mouth of Elbow River, water	839.2	3390
Calgary	840.1	3421
Keith	849.4	3547
Cochrane	862.9	3743
Radnor	873.1	3876
Morley	881.6	4061
Kananaskis River, bed	892.0	4149
Kananaskis	894.1	4214
The Gap, station	901.9	4225
Bow River here, at point of issue from the mountains, water, about	901.9	4215
Branch of Bow River, water	902.3	4220
Canmore	907.2	4278
Bow River, water	914.5	4359
Duthil	914.8	4380
Devil's Head Creek, water	916.1	4436
Anthracite	917.3	4484
Banff (new station)	921.8	4515
Forty Mile Creek, water	922.0	4505
Cascade	927.9	4531
Bow River, water	934.2	4586
Castle Mountain station	938.6	4653
Eblon	946.3	4804
Baker's Creek, water	948.6	4852
Lion Creek, water, 4949; grade	954.2	4970
Laggan	956.2	5029
North branch of Bow River, water	956.2	5020
South branch of Bow River, water	957.8	5049
Bath Creek, water	961.5	5263
Summit of grade crossing Rocky Mountains, Wapta or Kicking Horse pass	962.2	5323

	Miles from Winnipeg.	Feet above the sea.
Stephen	962.7	5313
Summit Lake, water	962.7	5308
Hector	965.0	5197
Kicking Horse Lake, water	965.0	5190
Kicking Horse River, first crossing, water	966.2	5184
Mount Stephen tunnel, grade	970.4	4335
Field	973.2	4058
Muskeg summit, grade	975.7	4164
Ottertail Creek, water, 3746; grade	978.4	3856
Ottertail	980.2	3689
Kicking Horse River, water	981.4	3605
Leanchoil	986.4	3570
Summit grade	988.6	3669
Kicking Horse River, fourth crossing, water	992.7	3287
Pallisor	994.2	3275
Kicking Horse River, sixth crossing, water, 2666; grade	1003.5	2682
Golden	1006.7	2570
Columbia River here, at the mouth of Kicking Horse River, water	1006.7	2557
Arm of Columbia River, water	1008.7	2558
Moberly House	1013.4	2537
Blueberry Creek, water	1016.7	2544
Donald	1023.6	2565
Columbia River, first crossing, grade	1024.4	2544

c. Main line through British Columbia, from Donald to Vancouver.

From H. Abbott, Superintendent of the Pacific Division, Vancouver, wh
figures, referred to the level of the Pacific Ocean, are given without chang
the first column of these elevations, showing at Donald a discrepancy of 30
above the preceding series from Winnipeg, Lake Superior, and the Atlan
In the second column these figures are revised by subtraction of 30 feet fr
the east end of the series for agreement at Donald; by comparison with a pr
from Donald to Sicamous, supplied by P. A. Peterson, engineer, Montreal, wh
indicates that this correction should be reduced to 30 feet at Glacier House
onward, and to 20 feet at Twin Butte and onward; and by comparison w
elevations supplied by Dr. G. M. Dawson, copied from profiles in the offic
Collingwood Schreiber, engineer of government railways, Ottawa, which sec
require the continuance of this subtraction of 20 feet west to Notch Hill
Shuswap, beyond which they indicate that the elevations received from
Abbott are probably correct. This line, however, needs verification by leve
from Donald to Lytton, about 300 miles, within which distance the discre
of 39 feet at Donald can probably be eliminated. At Lytton, and through
remaining distance of about 150 miles to Vancouver, these elevations agre
those published by Dr. Dawson in advance sheets of the second editi
Macfarlane's *American Geological Railway Guide*, and with the blue
condensed profile prepared in the engineers' office of this railway, Montrea

	Miles from Winnipeg.	Feet above the sea. (Abbott.)	Feet above the sea. (Revised.)
Donald	1023.6	2604	2565
Beaver	1035.6	2453	2414
Six Mile Creek station	1041.0	2633	2594
Bear Creek station	1050.0	3680	3641
Rogers Pass station	1055.0	4222	4183
Summit grade in Rogers Pass, crossing the Selkirk Mountains	1056.5	4366	4327
Glacier House station	1059.0	4102	4072
Ross Peak Siding	1065.5	3471	3441
Illecillewaet	1074.5	2740	2710
Albert Canyon station	1081.0	2244	2214
Twin Butte station	1091.0	1918	1898
Revelstoke (at the second crossing of the Columbia River)	1103.0	1515	1495
Summit grade in Eagle Pass, crossing the Gold range	1111.0	1848	1828
Clanwilliam	1112.0	1827	1807
Griffin Lake station	1120.0	1537	1517
Craigellachie	1130.5	1259	1239
Sicamous bridge crossing narrows of Shuswap lake, 1173 (1153); Sicamous station	1147.0	1171	1151
Salmon Arm	1166.0	1175	1155
Tappen Siding	1173.5	1168	1148
Notch Hill station (Shuswap summit)	1183.0	1708	1688
Shuswap	1198.5	1173	1153
Duck's	1214.5	1150	....
Kamloops	1231.5	1153	....
Tranquille	1239.5	1134	....
Cherry Creek station	1245.5	1134	....
Savona's	1256.5	1158	....
Penny's	1262.5	1252	....
Ashcroft	1276.5	996	....
Spatsum	1291.5	854	....
Spence's Bridge station	1303.5	768	....
Drynock	1309.5	752	....
Lytton	1325.5	687	....
Cisco	1331.5	558	....
Keefer's	1341.5	555	....
North Bend	1352.5	487	....
Spuzzum	1367.5	394	....
Yale	1379.5	217	....
Hope	1393.5	208	....
Ruby Creek station	1401.5	94	....
Agassiz	1411.5	52	....
Harrison	1420.5	38	....
Nicomen	1429.5	23	....

	Miles from Winnipeg.	Feet above the sea. (Abbott.)	Feet above the sea. (Revised.)
Mission	1439.5	33	....
Wharnock	1449.5	14	....
Hammond	1457.5	19	....
Port Moody	1469.5	5	....
Hastings	1478.0	22	....
Vancouver, 2904.8 miles from Montreal	1482.0	3	....

d. Emerson Branch.

From Collingwood Schreiber, engineer of government railways, Ottawa.

It agrees with the Saint Paul, Minneapolis & Manitoba Railway on the international boundary.

	Miles from Winnipeg.	Feet above the sea.
Winnipeg	0.0	757
Red River, grade on Louise bridge	0.8	752
Winnipeg Junction (of this branch with the main line)	2.0	752
Saint Boniface, 429.6 miles from Port Arthur	3.0	751
River Seine, high water	10.5	760
Saint Norbert	12.0	767
Niverville	23.5	774
Rat River, low water, 752; high water	30.0	763
Otterburne	30.6	779
Dufrost	39.0	791
Arnaud	47.0	794
Roseau River, low water, 761; high water, 1880	54.5	779
Dominion City	55.0	785
Joe River, low water, 756; extreme high water	62.6	785
Emerson, 391.1 miles from Saint Paul	65.0	790
Grade on the international boundary, connection with the St. P., M. & M. Railway	65.1	790

c. Southwestern Branch.

From R. M. Pratt, engineer, Winnipeg; and west of Manitou in part fr[om] profile in the office of P. A. Peterson, engineer, Montreal.

The profile requires an addition of twenty-four feet, which is made here. [It] agrees near Gretna and at Emerson with lines of the Saint Paul, Minneapolis [&] Manitoba Railway on the international boundary, and at Thornhill w[ith] levelling from Park River, North Dakota, in the survey of the beaches of L[ake] Agassiz.

	Miles from Winnipeg.	Feet above the sea.
Winnipeg, 1422.8 miles from Montreal	0.0	757
Junction of this branch with main line	1 1	760
Saint James	3.6	764
Assiniboine River, ordinary low and high water	3.7	736-754

	Miles from Winnipeg.	Feet above the sea.
La Salle (or Stinking) River, ordinary low and high water	18.3	737–750
La Salle station	18.5	770
Scratching River (R. aux Gratias), low and high water	42.0	744–770
The upper part of this stream, above the marshes in which it is lost in T. 7, Rs. 2, 3 and 4, is called Boyne River (R. aux Iles du Bois).		
Morris	42.8	772
Rosenfeld, junction of lines to the south and west	56.2	796
On the line south from Rosenfeld:		
Gretna	70.1	829
Grade on the international boundary, connection with the Necho line of the St. P., M. & M. Railway	70.4	830
On the line (abandoned) from Rosenfeld to Emerson:		
Crossing the first initial meridian, grade	62.1	794
Marais River (R. aux Marais), bed	68.9	781
West Lynne	75.7	790
Red River, low and high water	77.0	750–787
Emerson	77.2	790
On the line west from Rosenfeld:		
Morden	80.6	978
Thornhill	87.9	1314
Summit, grade	94.4	1588
Darlingford	95.9	1560
summit, grade	99.4	1618
Manitou	102.4	1586
In the descent from the top of the bluff of the Pembina River valley at 106 miles (grade, 1552) to its bottom at 112 miles, the profile is very irregular, with frequent cuts 10 to 50 feet deep and hills of 10 to 30 feet.		
La Riviere	112.5	1304
Pembina River, water, 1287; grade	112.7	1304
Ascending from the Pembina valley, the profile is broken by many ravines to 119 miles, where grade at the top of the bluff is 1547. The width of this valley is one to two miles.		
Pilot Mound	125.2	1549
Summit, grade	125.9	1555
Crystal City	130.0	1513
Crystal Creek, water, 1474; grade	130.6	1500
Summit, natural surface and grade	132.2	1519
Clearwater, water of Clearwater (Cypress) Creek, 1426; grade at station	134.1	1498

	Miles from Winnipeg.	Feet above the sea.
Smoothly undulating contour reaches from 137 to 141 miles, with grades from 1515 to 1532; also between 141 and 147 miles, with grades from 1525 to 1535 feet.		
Cartwright	144.9	1533
Badger Creek, water, 1476; grade	147.6	1509
Moderately undulating surface extends thence to 156 miles, the highest grades being 1535 to 1551 feet.		
Holmfield	155.4	1551
Long River (White Mud River), water, 1541; grade	155.7	1551
Thence the line rises gradually westward to 169.4 miles, where the natural surface and grade are 1649 feet.		
Killarney	164.1	1625
Little Pembina station	169.7	1649
Pembina River, water, 1605; grade	170.3	1645
The valley here is only 40 feet deep and about 40 rods wide.		
Lake, water, 1636; grade	171.7	1641
Lake, water, 1645; grade	172.2	1648
Summit, level grade	181.1–181.7	1660
Boissevain	182.7	1683
Whitewater Lake, low and high water	192.7	1632–1637
Deloraine	202.7	1644
The last twenty-five miles of this line lie near the northern base of Turtle Mountain.		

f. Manitoba & Southwestern Railway.

[Operated by the Canadian Pacific Railway Company.]

From R. M. Pratt, engineer, Winnipeg, and west of Elm Creek in part from profile in the office of P. A. Peterson, engineer, Montreal.

With uniform addition of twenty-four feet.

	Miles from Winnipeg.	Feet above the sea.
Winnipeg	0.0	757
Junction with Canadian Pacific Railway	1.2	760
Colony Creek, bed	2.8	758
Sturgeon Creek, low water	7.5	756
Assiniboine River, low and high water	14.0	754–764
Headingly	14.2	776
La Salle River, low and high water	26.8	766–771
Starbuck	27.2	781
Elm Creek station, junction of Carman branch	45.0	819
On the Carman branch:		
Maryland (on the Burnside beach of Lake Agassiz)	47.5	814
Barnsley (end of track)	51.0	854

	Miles from Winnipeg.	Feet above the sea.
End of grade, one mile north of Carman	56.0	861
Boyne River (R. aux Iles du Bois), low and high water	56.5	842-854
On the main line west from Elm Creek junction:		
Burnside beach of Lake Agassiz, crest, 845; grade	46.1	841
The descent from the crest eastward is ten feet in 25 rods, and westward seven feet in an equal distance.		
Slough, water, 965; grade	57.8	967
Slough, water, 1016; grade	63.0	1018
Slough, water, 1043; grade	66.0	1045
Boyne River, low water, 1034; grade	68.9	1047
Norcross beach *b* of Lake Agassiz, crest, 1167; grade	75.2	1162
The descent from the crest eastward is 15 feet, and westward 10 feet.		
Norcross beach *a*, crest, 1195; grade	75.7	1191
Herman beach *dd*, crest, 1211; grade	76.0	1206
The descent from the crest eastward is 15 feet, and westward 7 feet.		
Summit, on the Herman beach *d*, natural surface and grade	76.2	1217
Little Boyne River, low water, 1169; grade	77.3	1209
Treherne	77.6	1212
Boyne River, low water, 1166; grade	78.4	1222
Herman beach *bb*, crest, 1252; grade	80.6	1247
The descent from the crest both to the east and west is about ten feet.		
Summit, natural surface and grade the same, being the highest grade on this profile	84.8	1248
Holland	85.9	1237
Cypress River station	95.0	1232
Cypress River, low water	95.7	1214
Glenboro (end of track, 1886)	105.0	1231
Summit in sec. 4, T. 6, R. 16	.....	1489
Divide between Souris River and Pelican Lake, in Lang's Valley (the channel of a glacial river that flowed southeast to the Pembina River)	.....	1364
Prairie west of Lang's Valley	.....	1524
Souris River at Souris City	.....	1164
" " at Milford	.....	1114

The following branches of the Canadian Pacific Railway, running northward from Winnipeg on the west side of the Red River, receive an addition of twenty-four feet, like the main line from Winnipeg west :—

g. West Selkirk Branch.

From profile in the office of P. A. Peterson, engineer, Montreal.

	Miles from Winnipeg.	Feet above the sea.
Winnipeg	0.0	757
Junction with main line	1.5	759
This branch is very nearly level, ranging from 760 to 750 feet, between Winnipeg and Lower Fort Garry (also called the "Stone Fort").		
Lower Fort Garry	19.5	754
West Selkirk	23.5	736
End of the "river track"	24.1	724
Red River, ordinary stages of low and high water	24.1	712–725

h. Stonewall Branch.

From R. M. Pratt, engineer, Winnipeg.

	Miles from Winnipeg.	Feet above the sea.
Winnipeg	0.0	757
Air Line Junction, with main line	1.9	761
Stony Mountain station	13.3	773
Stonewall	19.8	810

WINNIPEG & HUDSON BAY RAILWAY.

From Collingwood Schreiber, engineer of government railways, Ottawa. With addition of twenty-four feet, as before explained.

	Miles from Winnipeg.	Feet above the sea.
Winnipeg	0.0	757
Junction with the Canadian Pacific Railway	4.7	780
Burnside beach of Lake Agassiz about three miles south of Shoal Lake, crest and grade the same.	31.0	860
Lowest natural surface crossed by the railway beside Shoal Lake, 852; grade	38.2	855
Shoal Lake, five to fifteen feet deep, surface at ordinary low stage, 850; low and high water	....	849–853

MANITOBA & NORTHWESTERN RAILWAY.

From profiles in the office of George H. Webster, engineer, Portage la Prairie.

These profiles are referred to the Canadian Pacific Railway station at Portage la Prairie, which is called 100 feet. The original figures accordingly receive here a uniform addition of 754 feet to refer them to mean sea level.

a. Main line.

	Miles from Portage la Prairie.	Feet above the sea.
Portage la Prairie, Canadian Pacific Railway station, 1478.8 miles west from Montreal, 56 miles west from Winnipeg	0.0	854
Portage la Prairie, Manitoba & Northwestern Railway station	0.0	856
Channel by which the Assiniboine River overflowed into Lake Manitoba, May 3–15, 1882, bed, 850; grade	2.9	859
Macdonald	9.8	837
Westbourne	16.9	831
White Mud River, first crossing, bed, 812; grade	17.4	831
Burnside beach of Lake Agassiz, crest, 860–862; grade at switch of spur track to gravel pit	21.8	860
Woodside	26.8	858
White Mud River, second crossing, bed, 849; grade	27.3	859
Summit, grade (one foot above natural surface)	32.2	878
Depression, filling 3 feet; grade	34.0	876
Gladstone beach, natural surface at crest, 878; grade	34.3	880
Verge of plain of Gladstone, natural surface, 882; grade	34.5	884
Gladstone, section house and tank, grade	34.7	884
" passenger station	34.9	883
White Mud River, third crossing, bed, 871; grade	35.7	889
Gopher Creek, bed, 876; grade	36.5	888
Secondary Emerado beach, forty rods wide, crest, 916; grade	39.1	917
Depression west of this, 914, marking the beginning of a more rapid ascent westward.		
Emerado beach, about thirty rods wide, crest, 927–929, wind-blown in hollows one to two feet below the crest	39.9	927-9
Depression west of this, 925.		
Third Blanchard beach, crest and grade alike	42.4	969
This beach ridge is thirty rods wide, with descent of five feet both to the east and west from its crest.		
Midway	43.3	975
Second Blanchard beach, crest, 979; grade	43.9–44.1	980
This deposit is almost flat, not having the usual ridged form. It is nearly a quarter of a mile wide, and is bordered on the west by a depression of two feet, to 977.		
First or upper Blanchard beach, another tract nearly like the last, natural surface, 994; grade	45.3–45.4	995
Depression, natural surface, 991; grade	45.5	993

	Miles from Portage la Prairie.	Feet above the sea.
Level grade (½ to 2 feet above the natural surface)	45.7–46.1	1004
Lower McCauleyville beach, crest and grade alike..	46.4	1016
Depression west of this, 1014.		
Middle McCauleyville beach, crest, 1029; grade.....	47.0	1025
Descent of three and five feet, respectively, to the west and east from the crest.		
Stream, bed, 1018; grade.....	47.1	1027
Upper McCauleyville beach, crest, 1039; grade.....	47.6	1035
Descent of four and six feet, respectively, to the west and east from the crest.		
Lower Campbell beach, crest, 1061; grade.....	48.2	1056
This beach ridge is twenty rods wide, with descent of eight feet east and five feet west.		
Slight beach mark, natural surface.....	48.6	1070
Beginning of nearly level grade on the east margin of the Arden beach ridge (two feet above the natural surface).....	48.7	1079
Arden.....	51.6	1086
Upper Campbell beach ridge, excavated for ballast, crest, 1089; grade.....	51.8	1084
Snake Creek, bed, 1061; grade.....	52.0	1079
Lower Tintah beach ridge, crest and grade alike....	55.4	1111
This has a width of about thirty-five rods, with a descent of four feet to the east and three feet to the west.		
Beach ridge associated with the preceding, crest, 1115; grade.....	55.7	1116
Dune crossed on steep grade, crest, 1133; grade....	56.9	1134
Depression west of this, 1131.		
Dunes three to five feet high occur at 57.15, 57.2, and 57.3 miles, with crest and grade alike in each, respectively 1150, 1152½, and 1154 feet.		
Level grade (0 to 7 feet above the natural surface).....	57.3–57.7	1151
Upper Tintah beach, crest, 1158; grade.....	57.8	1157
This has a descent of eleven feet in fifty rods east, and three feet in six rods west.		
Nearly level natural surface, 1174–1172; grade...	58.1–58.8	1174–1177
Ridge of dune sand, crest, 1177; grade.....	58.9	1178
This has a descent of five feet to the east and three feet to the west.		
Ridge of dune sand, crest, 1179; grade.....	59.3	1180
This likewise has a descent of five feet to the east and three feet to the west.		
Dunes at the level of the Lower Norcross beach occur at 60.1, 60.2, 60.25 and 60.3 miles, with their crests successively at 1192, 1192⅓, 1192½, and		

	Miles from Portage la Prairie.	Feet above the sea.
1193½ feet. The intervening hollows are two, four, and five feet deep in order from east to west, i.e. at 1190, 1188½, and 1187½ feet. Grade here	60.1–60.5	1193
From the dunes at 58.9 miles and 59.3 miles to 60.5 miles the surface is wind-blown sand with hollows two to four feet deep. The railway bed, formed of this sand, is somewhat insecure, because of its liability to be channelled by the wind.		
Neepawa	61.0	1206
Upper Norcross beach, crests successively 1223½, 1225, and 1225; grade	61.45–61.6	1227–1232
The descent westward from each crest is only one foot.		
Eroded escarpment, base, 1225; crest, 1240; grade	61.6–61.7	1232–1239
Herman beach *bb*, crest, 1304; grade	64.0	1305
This ridge has a width of forty rods, with descent of seven feet both to the east and west from its crest. It is found to consist of sand and gravel suitable for ballast, nearly like that of the Arden ridge, and has been purchased by the railway company for this use.		
Herman beach *b*, crest, 1323; grade	64.7	1320
This ridge descends seven feet from crest to base in fifteen rods, the amount of descent and length of slope being nearly alike on the east and west.		
Stony Creek, bed, 1359; grade	66.3	1373
Bridge Creek station	70.3	1600
Summit grade (two feet above natural surface)	76.0	1798
Little Saskatchewan River, bed, 1654; grade	78.4	1669
Minnedosa, junction of Rapid City branch	78.5	1670
Summit, grade (two feet above natural surface)	83.9	1928
Depression, filling eight feet; grade	83.9	1906
Summit, grade (three feet above natural surface)	87.0	1956
Basswood	88.5	1949
Outlet from Basswood Lake, bed, 1932; grade	88.6	1950
Summit, highest grade on this railway	92.8	1983
Newdale	96.8	1975
Grade and natural surface	100.0	1972
Grade and natural surface	103.0	1950
Strathclair	106.1	1901
Salt Lake, bed, 1855; water, 1860; grade	108.3	1867
Summit, cutting four feet; grade	109.0	1879
Shoal Lake station	114.9	1812
Oak River, bed, 1791; water, 1794; grade	115.0	1811

	Miles from Portage la Prairie.	Feet above the sea.
Shoal Lake, about a third of a mile south; water, approximately	115.0	1793
Summit, cutting two feet; grade	117.0	1830
Kelloe	123.2	1814
Solsgirth	129.8	1789
Grade (eight feet above the natural surface)	132.0	1697
Ravine, bottom, 1596; grade	132.8	1648
Birdtail Creek, bed, 1538; water, 1540; grade	134.5	1558
Summit, grade (one foot above the natural surface)	137.0	1704
Birtle	137.6	1703
Summit, cutting one foot; grade	138.0	1706
Stony Creek, bed, 1683; grade	139.0	1701
Summit, grade (one foot above the natural surface)	144.0	1747
Foxwarren	145.2	1742
Summit, grade	149.0	1772
Silver Creek, bed, 1631; water, 1632; grade	153.9	1704
Binscarth, junction of Shell River branch	154.9	1713
Two miles northwest of Binscarth, natural surface and grade	157.0	1654
Three miles farther northwest, natural surface, 1515; grade	160.0	1521
Johnson's Creek, bed, 1350; grade	161.8	1468
Old bed of the Assiniboine River, bed, 1317; stagnant water, 1319; grade	162.7	1344
Assiniboine River, bed, 1309; water, 1314; grade	162.9	1342
One mile northwest of Assiniboine River, natural surface, 1405; grade	164.0	1468
Two miles farther northwest, natural surface and grade	166.0	1533
Harrowby	167.6	1593
Grade and natural surface	173.0	1638
Langenburg	180.1	1681

b. Rapid City Branch (Saskatchewan & Western Railway).

	Miles from Portage la Prairie.	Feet above the sea.
Minnedosa	78.5	1670
Little Saskatchewan River, first crossing, bed, 1643; water, 1645; grade	80.2	1658
Riverdale	87.1	1636
Little Saskatchewan River, second crossing, bed, 1569; water, 1570; grade	92.4	1579
Rapid City	93.9	1579
A survey from Rapid City westward supplies the following:		
Surface, S. E. ¼ of sec. 19, T. 13, R. 20	101.5	1701
" W. ½ of sec. 16, T. 13, R. 21	105.5	1734

	Miles from Portage la Prairie.	Feet above the sea.
Oak River, sec. 23, T. 13, R. 22, water, 1668; proposed grade	109.2	1703
Surface on line between secs. 28 and 33, T. 14, R. 25	132.0	1688
Surface, S. W. ¼ of sec. 6, T. 15, R. 25. 135.5		1623

c. Shell River Branch.

Binscarth	154.9	1713
Four miles north of Binscarth, grade and natural surface	158.9	1791
Four miles farther north, grade (three feet above natural surface)	162.9	1797
Russell	166.2	1830

d. Line surveyed west from Langenburg to the south side of the Beaver Hills.

	Miles from Portage la Prairie.	Feet above the sea.
Red Deer Horn Creek, bed	185.0	1721
Surface	188.0	1729
Surface	195.0	1726
Big Cut Arm Creek, bed	198.5	1651
Surface	203.0	1720
Surface	210.0	1709
Crescent and Leech lakes, a few miles north of this line, approximately	....	1679
Surface	220.0	1763
Surface	230.0	1816
Surface	234.0	1863
Ravine, bottom	236.0	1882
Surface, end of survey	237.5	1919

This line ends in the west part of T. 23, R. 7 W. from the second initial meridian, between the Beaver Hills on the north and the Pheasant Hills on the south, and about fifteen miles east of the File Hills.

e. Line surveyed northwest from Langenburg, passing northeast and north of the Beaver Hills.

	Miles from Portage la Prairie.	Feet above the sea.
Summit	194.0	1774
Surface	212.0	1721
Armstrong's Coulée, first crossing, bed	213.9	1686
" " second crossing, bed	217.4	1652
Yorkton	222.5	1633
Mill Creek (South branch of White Sand River), bed	223.3	1585
Surface	226.0	1620
Summit	231.0	1697

	Miles from Portage la Prairie.	Feet above the sea.
Creek, bed	233.1	1654
Big Bone Creek (or Little White Sand River), bed	233.5	1651
Surface	238.0	1690
Owl Creek, bed	240.2	1683
Surface	243.0	1709
Clair Creek, bed	244.5	1691
Small lake	245.7	1711
Surface	252.0	1747
Chippewa Creek, bed	253.8	1736
Surface	256.5	1770
Fern Creek, bed	258.3	1747
Surface	260.6	1781
Bear Creek, bed	262.7	1762
Spring Creek, bed	265.3	1785
Surface	270.0	1820
Water-course, bed	272.5	1813
Surface	273.0	1825

Along its last forty miles this line lies from two to seven miles southwest of White Sand River. It terminates near the north side of T. 30, R. 10 W. from the second initial meridian, a few miles north of the Beaver Hills and about twenty-five miles east of the Big Touchwood Hills.

REGINA & LONG LAKE RAILWAY.

From R. M. Pratt, engineer, Winnipeg.

	Miles from Regina.	Feet above the sea.
Regina, junction with the Canadian Pacific Railway, 356.6 miles from Winnipeg	0.0	1885
Qu'Appelle River, low water, 1595; grade	21.4	1606
End of track	22.2	1606
Arm of Long Lake here, in sec. 23, T. 20, R. 21, water	22.2	1598

[Longlaketon, at the southeast end of the main lake, is about three miles farther northwest.]

NORTHWEST COAL & NAVIGATION COMPANY'S RAILWAY.

From Dr. George M. Dawson, of the Geological and Natural History Survey of Canada.

	Miles from Dunmore.	Feet above the sea.
Dunmore, junction with the Canadian Pacific Railway, 652.8 miles from Winnipeg	0.	2405
Bull's Head Creek, grade on bridge	2.	2314
Seven Persons River, grade on bridge	16.	2446
Crossing the west line of T. 11, R. 8, a summit of grade	27.	2772

	Miles from Dunmore.	Feet above the sea.
Entering the northeast corner of T. 10, R. 11	40.	2592
Depression, grade	49.	2562
Crossing the west line of T. 10, R. 12	53.	2614
" " T. 10, R. 14	65.	2609
" " T. 9, R. 16	78.	2677
" " T. 9, R. 17	84.	2707
" " T. 9, R. 18	90.	2768
Depression, grade	91.	2751
Crossing the west line of T. 9, R. 19	96.5	2806
" " T. 9, R. 20	103.	2877
Summit of grade	106.	2999
Lethbridge	109.	2954

This elevation proves the approximate correctness of that barometrically determined by Dr. Dawson, before this railway was built, for the Belly River (3,117 feet) at the "Coal Banks," about a mile southwest of Lethbridge. The general surface of the country here is 250 to 300 feet above the river.

DRAINAGE SYSTEM OF THE RED RIVER OF THE NORTH.

From levelling by U. S. engineers, under the direction of Major C. J. Allen, of Saint Paul; from railway surveys; and from the U. S. Geological Survey of Lake Agassiz.

a. Red River.

	Feet above the sea.
Lakes on the Otter Tail River in Becker county, Minnesota	1500–1400
Otter Tail Lake	1315
Red River in Fergus Falls, descending 80 feet, approximately	1210–1130
Mouth of Pelican River, about	1115
Mouth of the Bois des Sioux River, Breckenridge and Wahpeton	943
Mouth of the Bois des Sioux River, highest flood, about	958
Lake Traverse, head of the Bois des Sioux River, low and high water	971–976
Red River at McCauleyville and Fort Abercrombie	910
Red River at McCauleyville and Fort Abercrombie, highest flood, about	934
Surface of ground at Fort Abercrombie	937
Red River at Moorhead and Fargo, bed, 862; ordinary low and high water, 870-885 or 890; extreme low and high water (range, 32 feet)	866–898
At Belmont (formerly Frog Point), extreme low and high water (range, 50 feet)	797–847
Mouth of Red Lake River, Grand Forks, bed, 779; extreme low and high water (range, 44 feet)	784–828
Mouth of Pembina River, Pembina and Saint Vincent, bed, 739; ordinary low and high water, 753–782; extreme low and high water (range, 40 feet)	748–788

	Feet above the sea.
At Emerson, on the international boundary, ordinary low water and extreme high water	750–787

The following elevations of the Red River at Winnipeg and northward are derived from surveys for the Canadian Pacific Railway, being in considerable part from the published report of Sandford Fleming, engineer in chief, 1880, p. 269, from which a uniform subtraction of six feet is here made to accord with the revised profile of this railway.

Mouth of Assiniboine River, Winnipeg, extreme low water, 724; ordinary summer stage, 730; ordinary spring floods, 740-745; high water, 1882, 750; do., 1860, 759; do., 1852, 761; do., 1826, 763; general level of the land surface, 758; extreme low and high water (range, 39 feet)	724-763
At the Louise bridge, Winnipeg, extreme low water, 723; ordinary spring floods, about 740; high water, 1882, 749; do., 1826, 763; general level of the land surface, 756; extreme low and high water (range, 40 feet)	723-763
At Saint Andrew's church, extreme low water, 715; ordinary spring floods, about 735; high water, 1852, 745; do., 1826, 753, nearly the same as the general level of the land surface; extreme low and high water (range, 38 feet)	715-753
At Lower Fort Garry (the "Stone Fort"), extreme low water, 711; ordinary spring floods, about 730; high water, 1852, 736; do., 1826, 746; general level of the land surface, 752; extreme low and high water (range, 35 feet)	711-746
At West Selkirk, extreme low water, 710; ordinary spring floods, about 720; high water, 1852, 726; do., 1826, 732; general level of the land surface, 739; extreme low and high water (range, 22 feet)	710-732
At Saint Peter's church, general level of the land surface, 730; extreme low and high water (range, 15 feet)	709-724
Lake Winnipeg, mean, 710; extreme low and high water, approximately	708-713

b. Pembina River.

Whitewater Lake, low and high water	1632-1657
At bridge of the Manitoba & Southwestern Railway, near Little Pembina station	1665
Divide between the Souris and Pembina Rivers, in Lang's Valley	1364
Bone Lake in Lang's Valley	1357
Grass Lake and Pelican Lake	1355
(Range of Pelican Lake from low to high water, 3 feet.)	
Lakes Lorne and Louise, about	1345
Rock Lake, about	1335
At the Marringhurst bridge, about	1330
Swan Lake, about	1310
At bridge of the Manitoba & Southwestern Railway, La Rivière	1287

	Feet above the sea.
At the Mowbray bridge, on the line between secs. 21 and 22, T. 1, R. 8, about	1235
On the international boundary, about	1125
At the "tish trap," seven miles west of Walhalla, North Dakota (fall, 7 feet in an eighth of a mile), estimated about	1050–1043
At the Walhalla bridge, low and high water	934–943
At the Saint Joseph bridge, seven miles east from the last	865
At Neche, bed, 810; low and high water	813–832
Mouth of Tongue River, about	770
At bridge of the Duluth & Manitoba Railroad	757
Junction with the Red River, Pembina, extreme low and high water	748–788

c. Assiniboine River.

At bridge of the Manitoba & Northwestern Railway, bed, 1209; water	1314
Mouth of the Qu'Appelle River, about 17 miles south of the foregoing	1264
At bridge of the Canadian Pacific Railway, 1¾ miles east of Brandon	1161
Mouth of the Souris River, approximately	1100
At outcrop of Niobrara limestone in sec. 36, T. 8, R. 11, about 3¾ miles east of the mouth of Cypress River, approximately	1000
At Portage la Prairie, ordinary low and high water, two miles southwest from the town, near the former site of the Hudson Bay Company's fort	842–850
At Portage la Prairie, extreme high water, May 3–15, 1882, when the river overflowed here, sending part of its waters north to Lake Manitoba. This rise was caused by an ice jam a few miles farther east. It is said that the river had previously overflowed here to Lake Manitoba about twenty years before (probably in 1860).	854
Big Slough, occupying a deserted channel of the Assiniboine close south of Portage la Prairie, ordinary stage of water, 849; in ordinary spring floods, 850; in the great flood of May, 1882, 854; range, 5 feet	840–854
At Pratt's Landing, 2½ miles southeast from Portage la Prairie, ordinary low and high water, 840–849; lowest and highest stages	837–852
At centre of lot 142, Baie St. Paul, near the southeast end of Long Lake	796
In lot 230, Baie St. Paul	779
At St. Francois Xavier church	765
At crossing of the Winnipeg meridian, in Headingly	757

	Feet above the sea.
At Headingly, 1½ miles further east, ordinary low and high water	754–764
Mouth of Sturgeon Creek	745
At Saint James, ordinary low and high water	736–754
Junction with the Red River, ordinary low and high water, 728–742; extreme low and high water	724–763

d. Lakes on the Qu'Appelle River.

From H. Y. Hind; referred to sea level approximately by comparison with elevations determined by levelling.

	Feet above the sea.
Sand Hill Lake	1685
Divide in glacial water-course between the Elbow of the South Saskatchewan and this lake	1704
Buffalo Lake	1635
Qu'Appelle River at bridge of the Regina & Long Lake Railway	1595
Long Lake, tributary to the Qu'Appelle River	1598
Fishing Lakes	1504–1500
Crooked Lake	1389
Round Lake	1364
Junction of the Qu'Appelle with the Assiniboine	1264

e. Souris or Mouse River.

On the international boundary, crossing from Assiniboia into North Dakota, 215 miles west of the Red River, about	1650
At Minot, North Dakota	1535
At Towner, North Dakota	1445
Crossing the international boundary 170 miles west of the Red River, about	1400
At Plum Creek, Manitoba, about	1335
At the Elbow west of Lang's Valley, 21 miles east-southeast from the last, about	1295
At Gregory's mill, in sec. 34, T. 6, R. 18, five miles north from the last, head 8 feet, about	1210–1202
At Souris City	1164
At Milford	1114
Junction with the Assiniboine, about	1100

ALTITUDES ON THE CANOE ROUTE FROM LAKE SUPERIOR TO LAKE WINNIPEG, BY WAY OF THE KAMINISTIQUIA RIVER.

Determined by levelling by S. J. Dawson in 1857 and 1858, and published in Hind's *Narrative of the Canadian Exploring Expeditions*, London, 1860, vol. pp. 399–402; corrected approximately by comparison with the survey of the Canadian Pacific Railway.

a. From Lake Superior to the Lake of the Woods.

	Miles from Lake Superior.	Feet above the sea.
Mouth of the Kaministiquia River, Lake Superior	0.0	602
Mountain portage (Kakabeka Falls), Kaministiquia River, 248 rods, ascending 119 feet (including 14 feet of rapids below the falls).	29.2–30.0	681–800
Rocky portage (or Ecarté portage), 148 rods, ascending 63 feet	30.2–30.7	800–863
Nine portages, ascending successively 6½, 12½, 7, 19, 10, 3, 3, 3, and 15 feet, intervene between the last and Little Dog Lake.		
Little Dog Lake, 1.2 miles across on this route.	52.3–53.5	1002
Great Dog portage, 1⅝ miles, ascending 348 feet, to Great Dog Lake	53.5–55.2	1002–1350
Summit of this portage (a broad and massive sand ridge)	54.0	1470
Highest part of this sand ridge, east of the portage path, about	54.0	1500
"The great falls of Little Dog River are surprisingly beautiful. The difference in level between Little and Great Dog Lakes ..... is descended by the foaming torrent in six successive leaps."		
Great Dog Lake, 90 feet deep, crossed 10¾ miles on this route to the mouth of Dog River...	55.2–66.0	1350
Mouth of Prairie River, tributary to Dog River.	98.8	1378
Cold Water Lake, crossed 0.2 mile on this route.	101.9–102.1	1381
Prairie portage, 2½ miles, ascending 157 feet, to Height of Land Lake	102.1–104.6	1381–1538
Summit of this portage, about	....	1570
The highest land there within view is about..	....	1600
Height of Land Lake, crossed 0.2 mile on this route	104.6–104.8	1538
The portage from this to Savanne Lake "passes over a low sandy ridge supporting small pine."		
Savanne Lake, crossed 1½ miles on the route..	105.4–106.9	1522
Great Savanne portage, 1½ miles, descending 32 feet to the Savanne River	106.9–108.4	1522–1490
Thousand Lakes (Lac des Mille Lacs), 21¾ miles on the route	121.6–143.4	1485
Thousand Lakes (Lac des Mille Lacs), low and high water, approximately	....	1483–1488
The Seine River, outflowing from this lake to Rainy Lake, has a total descent of 368 feet, approximately. Hind states that it "falls 350 feet by twenty-nine steps vary-		

	Miles from Lake Superior.	Feet above the sea.
ing in altitude from three to thirty-six feet."		
Baril Lake, on the head stream of Sturgeon River, crossed 8 miles on the route	143.6–151.6	1487
Brulé portage, 84 rods, descending 47 feet	151.6–151.9	1487–1440
Upper Brulé Lake (or Cannibals' Lake), 8 miles on the route	151.9–159.9	1440
Lower Brulé Lake, 4¼ miles on the route	159.9–164.1	1437
Great French portage, 1¼ miles, descending 100 feet to French Portage Lake	164.1–165.8	1437–1337
French Portage Lake, 1½ miles on the route	165.8–167.4	1337
Pickerel Lake, 13 miles on the route	169.9–182.9	1326
Pickerel portage, 104 rods, descending 7 feet to Doré Lake	182.9–183.2	1336–1329
Doré Lake, 1¾ miles on the route	183.2–185.0	1329
Deux Rivières portage, 128 rods, descending 117 feet to Sturgeon Lake	185.0–185.4	1329–1212
Sturgeon Lake, 23¼ miles on the route	185.4–208.6	1212
First Sturgeon rapids, descending 4 feet in 44 rods	208.6–208.7	1212–1208
Second Sturgeon rapids, portage 12 rods, descending 6 feet	209.0	1208–1202
Island portage, 12 rods, descending 10 feet	221.2	1197–1187
Nequaquon Lake (or Lac la Croix), 8 miles on the route	225–233	1186
Rattlesnake portage, Namekan River, 20 rods, descending 12 feet	235.2–235.3	1181–1172
Crow portage, 32 rods, descending 10 feet	238.6–238.7	1171–1161
Grand Falls portage, 24 rods, descending 16 feet.	245.2–245.3	1158–1142
Foot of Grand rapids, Namekan River	248.8	1127
Lake Namekan, 6¾ miles on this route	251.3–257.8	1126
Rainy Lake, 38 miles on this route	263.3–301.3	1117
" low and high water, approximately		1115–1120
Rapids, Rainy River, ½ mile, descending 3 feet.	301.3–301.8	1117–1114
Chaudière Falls, close east of Fort Francis, portage 32 rods, descending 23 feet	303.3–303.4	1114–1091
Manitou rapids, descending 2½ feet in 60 rods	336.2–336.4	1081–1078
Long Sault, descending 3 feet in ¼ mile	342.9–343.1	1075–1072
Lake of the Woods, crossed 72 miles on this route	381.1–453.1	1060

b. Winnipeg River.

The difference in elevation between the Lake of the Woods and Lake Winnipeg determined by this survey agrees exactly with that found by the railway survey.

	Miles from the Lake of the Woods.	Feet above the sea.
Lake of the Woods, low and high water, 1057–1063; mean	0.0	1060
Rat Portage, 52 rods, descending 16 feet	0.0–0.2	1060–1044
Les Dalles rapids, descending 3 feet in ¼ mile	8.25–8.5	1043–1040
Grand Décharge, descending 6 feet in ¼ mile	33.55–33.8	1038–1032
Terre Jaune portage, 20 rods, descending 22 feet.	35.7–35.8	1029–1007
Charette Décharge, descending 3½ feet in 8 rods.	36.5	1006½–1003
Terre Blanche portage, 40 rods, descending 8 feet	37.5–37.6	1002–994
Cave rapids, descending 2½ feet in 8 rods	38.0	993½–991
Mouth of English River, approximately	54.0	987
De l'Isle portage, 8 rods, descending 3½ feet	57.0	986½–983
Chute à Jacques portage [Jack's Falls], 12 rods, descending 13 feet	80.1	979–966
Point des Bois portage, 52 rods, descending 10½ feet	89.7–89.9	964½–954
Point aux Chênes portage [the Upper Falls], 20 rods, descending 20 feet	90.0–99.1	954–934
Roche Brulé portage, 12 rods, descending 8 feet.	91.1	933–925
Slave Falls, portage 120 rods, descending 20 feet	95.5–95.9	924–904
Barrier Falls, portage 8 rods, descending 5 feet.	102.0	902–897
Otter Falls, descending 3 feet in 4 rods	107.0	895–892
Seven portages, successively 10, 8, 5½, 8, 3, 8, and 4¾ feet, follow.		
Foot of the seventh portage	116.2	826
Bonnet Lake, 4½ miles across on this route	127.6–132.1	823
Bonnet portage, 4 rods, descending 7 feet	132.2	823–816
Cap de Bonnet portage, 16 rods, descending 5 feet	132.85–132.9	814–869
Big Bonnet portage, 200 rods, descending 34 feet	136.2–136.8	805–771
Petit Roche portage, 52 rods, descending 8 feet.	137.1–137.3	770–762
White Mud portage, 60 rods, descending 13 feet.	140.7–140.9	758–745
Silver Falls [or Lower Falls], two portages, 92 rods, descending 22 feet	144.4–144.7	744–722
Pine portage, 48 rods, descending 8 feet	150.25–150.4	720–712
At Fort Alexander	161.4	710
Mouth of River, Lake Winnipeg, mean, 710; low and high water, approximately	163.2	708–713

There are thus twenty-seven portages (the two décharges being included) tween the Lake of the Woods and Lake Winnipeg.

SASKATCHEWAN RIVER.

From surveys of the Canadian Pacific Railway; of the Geological and Natural History Survey of Canada, by Dr. G. M. Dawson, R. G. McConnell, and J. B. Tyrrell; and of the Assiniboine and Saskatchewan Exploring Expedition, by H. Y. Hind.

	Feet above the sea.
Bow River at the Gap, where it issues from the Rocky Mountains, about	4215
Bow River at Calgary, mouth of the Elbow River	3390
" at the Blackfoot Crossing, near the centre of T. 21, R. 21	2595
Belly River at the "Coal Banks," Lethbridge	2717
Confluence of the Bow and Belly Rivers, forming the South Saskatchewan	2212
South Saskatchewan River at Medicine Hat, low and high water	2137–2154
South Saskatchewan River at mouth of Red Deer River	1958
" in T. 22, R. 18, long. 108° 27′	1782
" at the Elbow	1619
North Saskatchewan River at Rocky Mountain House and mouth of Clearwater River, about	3150
North Saskatchewan River at mouth of Brazeau River	2637
" at big coal seam (27 feet thick, but including two feet of shale), Goose Encampment, long. 114°30′	2307
North Saskatchewan River at proposed crossing of the original line of the Canadian Pacific Railway, long. 114°	2130
North Saskatchewan River at Edmonton, about	2000
Edmonton, 200 feet above high water level of the river, about	2210
North Saskatchewan River at Victoria, near mouths of Egg and Smoky Creeks	1871
North Saskatchewan at Fort Pitt	1722
Junction of the South and North Saskatchewan Rivers, estimated	1200
Cedar Lake	824
Cross Lake	818
Head and foot of Grand rapids of the Saskatchewan, extending from about four and a half to two miles above its mouth (fall stated by Hind to be 43½ feet in these two and a half miles, the upper 28½ feet being passed by a portage a little more than a mile long), approximately	765–720
Lake Winnipeg, mean, 710; low and high water, approximately	708–713

NELSON RIVER.

The following estimated elevations of points on the Nelson River are by Dr. Robert Bell (*Reports of Progress, Geol. Survey of Canada*, 1877-79).

	Feet above the sea.
Lake Winnipeg	710
Great and Little Playgreen Lakes, also	710
Sea River Falls, seventeen miles below Norway House, about	705–700
Pipestone and Cross Lakes, on the Nelson River at the north end of Ross Island, about	665
Sipi-wesk Lake on Nelson River from lat. 55° to 55°20′, about	565
Grand rapid, "a descent of about fifteen feet in the form of a steep chute," four miles south of Split Lake, about	460–445
Split Lake, in lat. 56°15′ to 56°35′, about	440
Gull Lake, eighteen miles below (east-northeast of) Split Lake, about	420
Twelve-feet chute, forty-three miles below (east of) Gull Lake, about	200–188
Foot of Broad rapid, "two miles wide, and full of knobs and little ridges of gneiss," extending five miles next below the Twelve-feet chute, or 116 to 111 miles from the mouth of Nelson River, about	125
Foot of First or Lowest Limestone rapid, about ninety miles by the course of the river above its mouth, probably about	50

ALTITUDES ON THE INTERNATIONAL BOUNDARY FROM LAKE SUPERIOR TO THE ROCKY MOUNTAINS.

From reports of N. H. Winchell, H. Y. Hind, G. M. Dawson, R. G. McConnell, and the U. S. Northern Boundary Commission; referred to sea level by comparison with railway surveys.

	Feet above the sea.
Lake Superior, mean, 602; extreme low and high water, approximately	599–604
Mountain Lake, at head of Pigeon River	1652
South Lake, at head of Arrow River	1535
Water divide on the boundary, between South and North Lakes	1573
North Lake, at head of waters draining to Rainy Lake	1535
Gunflint Lake	1530
Saganaga Lake	1368
Otter Track Lake	1326
Knife Lake	1322
Basswood Lake	1244
Lac la Croix (or Nequaunon Lake)	1186
Namekan Lake	1126
Rainy Lake, mean, 1117; low and high water, approximately	1115–1120

	Feet above the sea.
Lake of the Woods, mean, 1060; low and high water, approximately	1057–1063
Ridge twelve miles farther west, forming the divide on the boundary between the Lake of the Woods and Rosean Lake	1088
Pine River	1047
Rosean Lake, about	1040
Ridge three miles west of Pine River	1070
Rosean River at Pointe d'Orme	976
Ridge twenty miles east of the Red River	1046
Ridge twelve miles east of the Red River	848
Emerson	790
Red River, ordinary stage, 752; low and high water	747–787
Gretna	820
Pembina Mountain, base and top	1030–1500
Pembina River, approximately	1125
General level of the adjoining country, about	1540
Lac des Roches in North Dakota, and divide between this lake and Badger Creek in Manitoba, about	1520
Turtle Mountain, according to Dr. G. M. Dawson's map	2150
" according to profile in report of the U. S. Boundary Commission	2000–2534
Souris River, first crossing, about	1400
" second crossing, about	1650
Coteau du Missouri, base and crest	1900–2140
Wood Mountain, highest portion on the boundary	2350–3075
" north of the boundary	3350
White Mud River	2550
Boundary Plateau	3000–3250
East fork of Milk River	2700
Wild Horse Lake	2850
Milk River, probably about	2600
West Butte, the highest of the Sweet Grass Hills or Three Buttes	6485
East Butte	6200
Trail from Fort Benton to Fort MacLeod	3548
North Branch of Milk River one mile north of the boundary, long. 113°	4175
Eastern base of the Rocky Mountains, long. 113°25′, about	4500
Waterton Lake (or Chief Mountain Lake), crossed by the boundary in long. 113°52′, in the east edge of the Rocky Mountains	4245
Rocky Mountains, summits in the vicinity of this lake, on the continental water-shed	7,500–10,500

ADDITIONAL ALTITUDES IN MANITOBA AND ADJOINING PORTIONS OF CANADA.

Mostly from reports of the Geological and Natural History Survey of Canada; in part corrected approximately by comparison with the Survey of the Canadian Pacific Railway.

	Feet above the sea.
Lake Nipigon (540 feet deep near Echo Rock)	915
Depressions in the line of water-shed northwest of Lake Superior	1500–1750
Lonely Lake (Lac Seul)	1232
This altitude, determined independently, probably requires some subtraction, for the description of the canoe route from Lonely Lake to Lake Saint Joseph shows that the latter is the higher, the difference being apparently twenty feet or more.	
Lake Saint Joseph (mean of ten barometric observations on as many days)	1172
Lake Lansdowne, near the head of the Attawapishkat River, about	960
Lake Saint Martin	794
Lake Manitoba (determined by levelling by H. S. Treherne, of Saint Paul, Minn.), mean, 809; low and high water, approximately	805–813
Lake Winnipegosis, mean, 828; low and high water, approximately	825–831
Lake Dauphin	839?
Swan Lake, about	860?
Divide between Lake Winnipegosis and Cedar Lake	875?
Cedar Lake, on the Saskatchewan	824
Pembina Mountain, crest of the escarpment	1400–1500
Tiger Hills	1500–1600
Big Tiger Hill, north of Lang's Valley, about	1640
Brandon Hills	1550–1600
Riding Mountain, about	2000
Duck Mountain	2300–2700
Thunder Hill	1900
Churchill River, 105 miles from its mouth, in the direction S. 33° W. (astr.), at the mouth of the Little Churchill River	705
Wa-kai-ow-a-ka Lake, at the head of the Little Churchill River	936
Churchill River, 23 miles above the mouth of the Little Churchill	878
Frog portage, from the Churchill River to the Lake of the Woods, at the head of a chain of lakes and streams flowing southward to the Saskatchewan, estimated	1200

The following altitudes, from Isle à la Crosse Lake to Lake Athabasca, which were noted as determined by Sir John Richardson (*Arctic Expedition in search of Sir John Franklin*), probably require an average addition of about 200 feet.

	Feet above the sea.
Isle à la Crosse Lake, on the Churchill River	1360

Thence southward to Carlton House on the North Saskatchewan, abo seventy miles above the junction of the South and North Saskatchewan Riv [estimated 1200 feet above the sea], Richardson reports a descent of about t hundred feet, across "an undulating country, but without any mark acclivity."

Professor Macoun states that Isle à la Crosse, Clear, and Buffalo Lakes "a on the same level," being stagnant water filled with green scum in summer.

Methy Lake or Lac la Loche	1496
" " (according to Captain Lefroy, cited by Richardson)	1500
Summit of Methy portage (also called Portage la Loche and the Long Portage), on the water-shed between the Churchill and Athabasca Rivers	1556
The "Cockscomb," on this portage at the crest of the bluff descending to the Clearwater River, tributary to the Athabasca	1534
Clearwater River at the north end of this portage	900
Lake Athabasca	600

Altitudes determined by Dr. G. M. Dawson show the present height of glacial lake bed now drained by the Peace River, and of its probable avenues of outflow southeast to Lake Agassiz, as follows:

Peace River at Dunvegan	1300
Top of river-bluff one mile from Dunvegan	2100
General level of the country in this vicinity	2200
Area of lacustrine silt in the basin of the Peace River	2000–2500

The valley of this part of the river, eight or nine hundred feet deep, is cu in a vast plain, from which, according to Richardson, "the Rocky Mount are not visible, and no range of hills greets the eye."

Water-shed between Peace River and Lesser Slave Lake	2430
Water-shed between Tow-ti-now River, a tributary of the Athabasca, and the North Saskatchewan, on the trail from Athabasca Landing to Edmonton	2485

	Feet above the sea.
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