THE GLACIAL LAKE AGASSIZ.

By Warren Upham.

CHAPTER I.

INTRODUCTION.

BASIN OF THE RED RIVER OF THE NORTH AND OF LAKE WINNIPEG.

The glacial lake which is the theme of this volume extended along the Red River Valley and covered the lake country of Manitoba. Its situation in the center of the continent, and its geographic relation to the drift-covered area and to lakes Bonneville and Lahontan, are displayed in Plate II. Lake Agassiz was the largest of the many Pleistocene lakes of North America, some of which were formed by the barrier of the ice-sheet during its recession, while others were produced by increased rainfall in the great western arid region that has no drainage to the sea.

Only a comparatively small fraction—about one-fifth—of the area of Lake Agassiz lies within the United States, but this includes the greater portion of its exactly explored shore-lines. A very large part of its area in Canada, besides a considerable tract within its limits in northern Minnesota, is covered by forest, which makes it impracticable to trace there the beach ridges and deltas, low escarpments of erosion, and other evidences of this lake so continuously as has been done through the prairie region. This great expanse of prairie, upon which the shore-lines have been accurately and continuously mapped, comprises the Red River Valley and adjoining higher land, and reaches north to the southern ends of lakes Winnipeg and Manitoba and of Riding Mountain. Farther north tracts of prairie, divided by woodlands and thickets, continue interruptedly along the eastern base of Riding and Duck mountains, permitting considerable parts of the ancient shores to be traced in that district.

As this report necessarily treats of the topographic features of the basin of the Red River and Lake Winnipeg, it has seemed desirable to devote a chapter to the rock formations which underlie the glacial drift and the old lake bed, with discussion of the preglacial erosion that gave the general outlines of the Red River Valley plain and of the Manitoba escarpment bounding it on the west. Though this part is presented somewhat briefly, it is hoped that the reader will be able to obtain in it a comprehensive review of the entire geologic history of this area, and of its uplift and sculpturing to the form of a basin, previous to the Ice age and the time of Lake Agassiz.

The economic geology of this basin has received a large share of attention during the progress of the field work and in the present volume. Owing to the structure of the drift deposits and of the underlying rocks, many artesian wells have been obtained in the Red River Valley, descriptive notes of which are given, with analyses of their waters, and an explanation of the sources, in part near and probably in part hundreds of miles distant, from which the waters and their dissolved mineral matter are derived. No commercially valuable deposits of ores, coal, natural gas, or salt can be reported, but the northern part of the Red River Valley, in Manitoba, has magnesian limestone of excellent quality for building purposes and for the manufacture of lime, and the whole valley has plentiful beds of clay, unsurpassed for brickmaking. The chief resources of this extensive prairie region of Lake Agassiz, however, are found in its very fertile soil and favorable climate for agriculture, and especially for wheat raising.

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During the closing part of the latest completed division of geologic time a vast lake stretched from the southern end of the Red River Valley north to the Saskatchewan and Nelson rivers. The late date of its existence is known by the position of its shore-lines and deltas, which lie upon the glacial drift and have nearly as perfect outlines as those of the present shores of the Manitoba and Laurentian lakes or of the ocean. This ancient lake, several times larger than Superior—indeed, exceeding the aggregate area of the five great lakes tributary to the St. Lawrence—washed the east

and west borders of the Red River Valley and the base of the Riding and Duck mountains. Its surface during storms was raised into waves which formed well-defined beach ridges of gravel and sand, and these are found at many successive levels, showing that the area and depth of the lake were gradually diminished. Before these deserted shores and the inclosed lacustrine area were examined in the field work for this report, their character had been observed and was generally attributed to lake action by the immigrant farmers, who in many instances selected the beach ridges as the sites of their dwellings.

Intervals of small vertical amount divide the consecutive beaches, from the highest to the lowest. Through the earlier and probably greater part of the duration of the lake it outflowed southward by the way of Lake Traverse, Browns Valley, Big Stone Lake, and the Minnesota River to the Mississippi. Seventeen shore-lines on the northern portion of the lake area were formed contemporaneously with this southern outlet. Later the lake was further reduced through stages shown by fourteen shore-lines, while it outflowed by successively lower avenues of discharge northeastward. Finally it was reduced to lakes Winnipeg, Manitoba, and Winnipegosis, which are the lineal descendants and representatives of Lake Agassiz.

RELATIONSHIP TO THE ICE-SHEET.

The conditions to which Lake Agassiz owed its existence, however, were very unlike those of the present time. It could not have been held in a landlocked basin, for there has been no subsidence of the country between this area and Hudson Bay since the Glacial period. Instead, the area of Lake Agassiz and all the region northeastward to Hudson Bay and Strait have experienced a gradual uplift during the time of the departure of the ice-sheet and subsequently. As shown by the northwardly ascending shore-lines of this lake and by fossiliferous marine beds overlying the glacial drift on the lower country adjoining Hudson Bay and along the Ottawa and St. Lawrence rivers, the vertical extent of this uplift was greatest toward the north and east. It was little at Lake Traverse, but amounted to 400 or 500 feet in Manitoba, and was approximately 500 to 600 feet on the southwest side of Hudson and James bays and upon all

the interior portion of the continent thence to Ottawa and Montreal. It is evident, therefore, that no barrier of land held the lake which covered the Red River Valley and a large part of Manitoba. But a southward outlet is found through which the lake flowed to the Mississippi, and no marine fossils have been detected in or above the drift upon this area, from which reasons it is certain that these ancient shore-lines were not produced by subsidence of the land beneath the sea-level, followed by reelevation. While the beaches and deltas here described are thus known to be lacustrine, fossils have been discovered in them at only two localities, these being shells of five species of fresh-water mollusks, occurring in beaches that belong to the middle and later part of the lake's history.

From all these features of the former lake, when they are considered in their relationship to the Glacial period and its drift deposits, we are led to the conclusion that the northern barrier by which its water was held in was a waning ice-sheet. The glacial striæ, till, terminal moraines, and other drift formations prove that the northern half of our continent has been enveloped by a continuous mantle of ice stretching from the eastern shores of New England and Canada west to the Rocky Mountains and the Pacific, and from the northern part of the United States to the Arctic Sea. When this ice-sheet was melted away, its border gradually withdrew from south to north, and hydrographic basins descending northward were temporarily occupied by glacial lakes, held by the ice barrier until its continued retreat allowed free drainage of these basins in the direction of their slopes. This explanation fully accounts for the presence of Lake Agassiz in the basin of the Red River and of Lake Winnipeg during the recession of the ice-sheet, for the scantiness of its fauna, and for the northward ascent of its originally level shores, since the earth's crust had been depressed by the ice burden, and was uplifted, in the preservation of its equilibrium, when the ice-sheet departed.

The work of Gilbert, Chamberlin, Leverett, and others in the basins of the Laurentian lakes has proved that their formerly much higher levels, marked by shore-lines similar to those of Lake Agassiz, were contemporaneous with the departure of the ice-sheet and the formation of its recessional moraines. Records of many other smaller glacial lakes have been observed

upon all the glaciated area of our continent from New England to British Columbia. The ice-sheet of northwestern Europe also formed such lakes during its final melting. Some of these lakes, pent up in valleys 2,000 to 3,000 feet above the sea, between the eastern side of the Scandinavian Mountains and the remnant of the ice still covering eastern Sweden, attained lengths of about 100 miles and depths of about 1,000 feet.[1] In Scotland, likewise, the famous Parallel Roads of Glen Roy are shown to be the shores of successive stages of a lake held by the barrier of the waning Scottish ice-sheet.[2] The positions of the European glacial lakes, as of those in North America, were determined by the areas of greatest thickness of the ice and the manner of its recession.

When the Glacial period in North America was ending, as soon as the border of the ice had receded beyond the watershed 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 northeastward, 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 Prof. Louis Agassiz, the first prominent advocate of the theory that the drift was produced by land ice.[3] 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 boundary of the ice-sheet from

[1] A. H. Hansen, in Nature, Vol. XXXIII, 1886, pp. 268, 269, 365.

[2] T. F. Jamieson, in Quart. Jour. Geol. Soc., Vol. XLVIII, 1892, pp. 5–28.

[3] Geol. and Nat. Hist. Survey of Minnesota, Eighth Annual Report, for the year 1879, pp. 84, 85. (Jean Louis Rodolphe Agassiz was born in Motier, Switzerland, May 28, 1807, and died in Cambridge, Mass., December 14, 1873. His observations of the Swiss glaciers and his principal writings concerning them and the glacial origin of the drift were during the years 1836 to 1846. In the autumn of 1846 Agassiz came to the United States, and the remainder of his life was mostly spent here in zoological researches and in teaching in Harvard College, where he founded the Museum of Comparative Zoology. The interests of science in this country were inestimably advanced by his great influence as a teacher and by his extensive writings in zoology, in which and the care of the museum his work has been ably continued by his son, Alexander Agassiz. See the biography, Louis Agassiz: His Life and Correspondence, edited by Elizabeth Cary Agassiz. 2 vols. 1885.)

southern New England and Long Island to North Dakota and Assiniboia. The characters of other drift deposits 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.

EARLY OBSERVATIONS OF LAKE AGASSIZ.

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,[1] in 1848 by Owen,[2] in 1857 by Palliser,[3] in 1858 by Hind,[4] and in 1873 by Dr. G. M. Dawson.[5] Each of these geologists explored considerable tracts of the lacustrine area, recognizing its limits in a few places; and Hind especially described and mapped portions of the lower beach ridges. Dr. Dawson's work was in connection with the British North American Boundary Commission, and includes detailed notes of the part of this area lying between the Lake of the Woods and the Pembina Mountain. Several references to these authors and quotations from their reports are presented in later pages of this volume.

The 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.[6] After his death, in commemoration of this work,

[1] Narrative of an Expedition to the Source of St. Peters River, Lake Winnepeek, Lake of the Woods, etc., performed in the year 1823, * * * under the command of Stephen H. Long, U. S. Topographical Engineer. London, 1825. Vol. II, p. 3.

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

[3] Journals, detailed reports, etc., presented to Parliament, 19th May, 1863, p. 41.

[4] Report of the Assiniboine and Saskatchewan Exploring Expedition. Toronto, 1859. Pp. 39, 40, 167, 168.

[5] 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.

[6] "On certain physical features of the Upper Mississippi River," American Naturalist, Vol. II, pp. 497–502, November, 1868. Annual Report of the Chief of Engineers, United States Army, for 1868, pp. 307–314. "An essay concerning important physical features exhibited in the valley of the Minnesota River, and upon their signification," with maps; Report of Chief of Engineers, 1875. "Valley of the Minnesota River and of the Mississippi River to the junction of the Ohio; its origin consid-

the glacial river that was the outlet of Lake Agassiz was named River Warren.[1]

That this lake existed because of the barrier of the receding ice-sheet was first pointed out in 1872 by Prof. N. H. Winchell.[2]

WORK REPORTED IN THIS MONOGRAPH.

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; and in the latter year the highest or Herman beaches in that State, and small parts of lower shore-lines, were carefully surveyed and mapped, their heights being determined by leveling, with the assistance of Horace V. Winchell as rodman. This work has been reported in publications of the Minnesota Geological Survey.[3] It is also used in this monograph, which comprises in addition, for the part of the lake area in Minnesota, a large amount of later observations made during my field work for the United States Geological Survey, pertaining chiefly to the lower beaches, artesian wells in the Red River Valley, and terminal moraines upon the region eastward to Red Lake, Itasca and Leech lakes, and Brainerd.

Exploration of the Lake Agassiz shore-lines, deltas, and associated glacial and lacustrine formations was again entered upon by the writer, for the United States Geological Survey, in 1885, as a part of the work of the Glacial Division, under the direction of Prof. T. C. Chamberlin. During the years 1885 to 1887, inclusive, the upper or Herman beaches in North Dakota, and extensive portions of the lower shores both in North Dakota and Minnesota, were mapped and their altitudes ascertained continuously by leveling, in which I was assisted by Robert H. Young. We traveled mostly afoot for this surveying, our daily advance varying from 3 to 10

ered; depth of the bed rock," with maps; Report of Chief of Engineers, 1878, and Am. Jour. Sci. (3), Vol. XVI, pp. 417–431, December, 1878. (General Warren died August 8, 1882.)

[1] Proc. A. A. A. S., Vol. XXXII, for 1883, pp. 213–231; also in Am. Jour. Sci. (3), Vol. XXVII, Jan. and Feb., 1884; and Geology of Minnesota, Vol. I, p. 622.

[2] Geol. and Nat. Hist. Survey of Minnesota, First Annual Report, for 1872, p. 63; and Sixth Annual Report, for 1877, p. 31. Professor Winchell also explained in like manner the formerly higher levels of the Laurentian lakes, Popular Science Monthly, June and July, 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.

[3] Geol. and Nat. Hist. Survey of Minnesota, Eighth Annual Report, for 1879, pp. 84–87; Eleventh Annual Report, for 1882, pp. 137–153, with map; and Final Report, Vols. I and II.

miles. A preliminary report of part of these observations was published in 1887.[1]

By cooperation 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. Traveling with horse and wagon, and assisted by Mr. Young, 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 Shoal Lake, between Lakes Winnipeg and Manitoba, and Orange Ridge post-office, near the southeast end of Riding Mountain. The mainly wooded character of the country farther north makes continuous leveling 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, Langs 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 150 miles. A report of this work has been published by the Canadian Geological Survey.[2]

For all these surveys in the United States and Manitoba 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 leveling, which was

[1] U. S. Geol. Survey Bulletin, No. 39. The Upper Beaches and Deltas of the Glacial Lake Agassiz. Pp. 84, with map

[2] Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, Vol. IV, for 1888–89, Part E, Report of Exploration of the Glacial Lake Agassiz in Manitoba, pp. 156, with two maps and a plate of sections.

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 20 to 40 or 50 miles. A very large number of railway profiles, extending beyond the limits of Lake Agassiz to Lakes Superior and Michigan and to the Pacific Ocean, were examined during this work, and the altitudes of their stations, summits of grade, bridges, and low and high water of the streams crossed, were tabulated for convenient reference and comparison, being uniformly referred to the sea-level at mean tide. This auxiliary part of the investigations relating to Lake Agassiz has been separately published.[1] In the present volume the altitudes of the railway stations are noted on Pls. XXIII to XXXIII, which give the detailed surveys of the lake beaches and deltas. For the whole area of this glacial lake, so far as it has been explored with leveling and is traversed by these railway surveys, their altitudes are noted on Pl. X.

Exact or close agreements of several independent surveys from the sea to this district, and of the profiles of the many intersecting lines of railway in Minnesota, South and North Dakota, and Manitoba, give complete assurance that these heights, and those determined therefrom by leveling along a thousand miles or more of the shore-lines of Lake Agassiz, are not only consistent together but also absolutely true within limits of error probably nowhere exceeding 5 feet. Such exact determinations of the elevations of the beaches 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, within the portion of the lake area surveyed by me, 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. Some interesting problems are thus presented as to the relationship of these progressive changes of level, when they were produced, and their causes.

During the year of my exploration in Manitoba, and since that time, important observations of the beaches of Lake Agassiz farther northward along the Manitoba escarpment and near the mouth of the Saskatchewan

[1] U. S. Geol. Survey, Bulletin No. 72. Altitudes between Lake Superior and the Rocky Mountains. 1891. Pp. 229.

have been made during work for the Geological Survey of Canada by Mr. J. B. Tyrrell.[1] Notes of these additions to our knowledge of the glacial lake are included in this monograph, and contribute much to the history of the differential uplift of the lake area. Mr. Tyrrell finds that in northwestern Manitoba the lower beaches formed during the time of southward outflow of Lake Agassiz have been changed in height, so that they now ascend 2 to 3 feet per mile northward. Their changes of level are thus twice as great as those of the higher and earlier beaches within the area of my leveling, and they took place after the uplifting of the more southern part of the lake area had nearly ceased.

The close relationship of Lake Agassiz and the uplift of its area with the recession of the ice-sheet showed that this work would not be complete without a special examination of the terminal moraines which form conspicuous belts of hilly drift upon the country both east and west of the lacustrine area, and whose courses in the Red River Valley are commonly marked only by a somewhat uneven or almost flat surface of till, with frequent or often plentiful bowlders. Accordingly, in 1889 several months were given to field work in tracing these moraines. The region explored in North Dakota extended from the head of the Coteau des Prairies, west of Lake Traverse, northward and northwestward to Devils Lake, Turtle Mountain, the Souris River, and the Coteau du Missouri, in the northwestern part of this State. On the other side of Lake Agassiz my field work in 1889 extended east to Lake Itasca and the upper part of the Mississippi. With the account of these observations given in Chapter IV, brief notes are also supplied from my earlier reports relating to the terminal moraines in Minnesota.[2]

While my explorations and studies of Lake Agassiz have been in progress for the Minnesota, United States, and Canadian Geological Surveys, I have presented portions of their results in various reports and papers, as

[1] Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, Vol. III, for 1887–88, Part E, Notes to accompany a preliminary map of the Riding and Duck mountains in northwestern Manitoba, 16 pages, with map. Other papers by Mr. Tyrrell, including descriptions of portions of the Lake Agassiz beaches, are "Post-Tertiary Deposits of Manitoba and the adjoining territories of northwestern Canada," Bulletin, G. S. A., Vol. I, 1890, pp. 395–410, and "Pleistocene of the Winnipeg Basin," Am. Geologist, Vol. VIII, pp. 19–28, July, 1891.

[2] Geol. and Nat. Hist. Survey of Minn., Eighth and Ninth Annual Reports, for the years 1879 and 1880; and Final Report, Geology of Minnesota, Vol. I, 1884, and Vol. II, 1888.

MAP SHOWING THE RELATIONSHIP OF LAKE AGASSIZ TO THE DRIFT-BEARING AREA OF NORTH AMERICA AND TO LAKES BONNEVILLE AND LAHONTAN.

Scale, about 550 miles to an inch.

Areas covered by Land Ice during the Quaternary Era. Quaternary Lakes Bonneville and Lahontan and the Glacial Lake Agassiz.

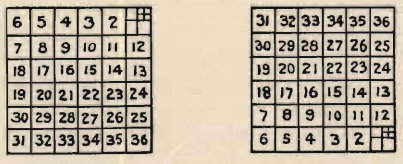
MAP SHOWING THE AREAS OF LAKE AGASSIZ AND OF THE UPPER LAURENTIAN LAKES.

Scale, about 165 miles to an inch.

Lake Agassiz and associated Glacial Lakes — Glacial Striæ — Terminal Moraines

enumerated below in their chronologic order.[1] These preliminary reports and discussions bearing more or less directly on this subject have been drawn from in many places during the preparation of the present work.

The map given in Pl. III shows the whole extent of Lake Agassiz, and, for comparison with it, the upper great lakes that outflow by the St. Lawrence. The courses of glacial striæ and terminal moraines are also shown, so far as they have been mapped; but doubtless numerous moraines in Canada remain to be filled in by future exploration. It should be remarked, however, 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.



United States. Manitoba.

FIG. 1.—Order of sections in townships.

Detailed descriptions of the beaches and deltas occupy three chapters and are illustrated by a series of ten map plates (XXIII to XXXII), hav-

[1] "Preliminary report on the geology of central and western Minnesota," Geol. and Nat. Hist. Survey of Minn., Eighth An. Rep., for 1879, pp. 70–125.

"Lake Agassiz: a chapter in glacial geology," Bulletin of the Minnesota Academy of Natural Sciences, Vol. II, pp. 290–314, Jan., 1882; also in Geol. and Nat. Hist. Survey of Minn., Eleventh An. Rep., for 1882, pp. 137–153, with map.

"The Minnesota Valley in the Ice age," Proc. A. A. A. S., 1883, Vol. XXXII, pp. 213–231; also in Am. Jour. Sci. (3), Vol. XXVII, pp. 34–42 and 104–111, Jan. and Feb., 1884.

Geology of Minnesota, Final Report, Vol. I, 1884, pp. 408, 442, 461, 484, 581, 622.

"The upper beaches and deltas of the glacial Lake Agassiz," Bulletin No. 39, U. S. Geol. Survey, 1887, pp. 84, with map.

"The recession of the ice-sheet in Minnesota in its relation to the gravel deposits overlying the quartz implements found by Miss Babbitt at Little Falls, Minn.," Proc. Boston Soc. of Nat. Hist., Vol. XXIII, pp. 436–447, Dec., 1887.

Geology of Minnesota, Final Report, Vol. II, 1888, pp. 134, 500, 504, 517–527, 551, 656, 662, 664–7.

"Glaciation of mountains in New England and New York," Appalachia, Vol. V, 1889, pp. 291–312; also in Am. Geologist, Vol. IV, Sept. and Oct., 1889.

"Probable causes of glaciation," appendix in Prof. G. F. Wright's Ice Age in North America, 1889, pp. 573–595.

"Report of exploration of the Glacial Lake Agassiz in Manitoba," Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, Vol. IV, for 1888–89, Part E, 1890, pp. 156, with two maps and

ing the scale of 6 miles to an inch. Section lines are drawn on these maps, which will enable the reader to refer readily to the localities designated in the text by the numbers of the section, township, and range. For the convenience of those who may not be acquainted with the unlike systems employed in the United States and in Manitoba for numbering the sections of each township, fig. 1 is here inserted. Occasional reference to this figure, with attention given to the township and range numbers noted on the maps, will soon fix in one's memory the significance of these terms of the land surveys.

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a plate of sections. (The division of this report forming its pages 42–56, entitled "History of Lake Agassiz," was reprinted in the Am. Geologist, Vol. VII, March and April, 1891.)

"Artesian wells in North and South Dakota," Am. Geologist, Vol. VI, pp. 211–221, Oct., 1890.

"On the cause of the Glacial period," Am. Geologist, Vol. VI, pp. 327–339 and 396, Dec., 1890.

"A review of the Quaternary era, with special reference to the deposits of flooded rivers," Am. Jour. Sci. (3), Vol. XLI, pp. 33–52, Jan., 1891.

"Glacial lakes in Canada," Bulletin, G. S. A., Vol. II, 1891, pp. 243–276.

"Altitudes between Lake Superior and the Rocky Mountains," Bulletin No. 72, U. S. Geol. Survey, 1891, pp. 229.

"The ice-sheet of Greenland," Am. Geologist, Vol. VIII, pp. 145–152, Sept., 1891.

"Criteria of englacial and subglacial drift," Am. Geologist, Vol. VIII, pp. 376–385, Dec., 1891.

"Inequality of distribution of the englacial drift," Bulletin, G. S. A., Vol. III, 1892, pp. 134–148.

"Relationship of the glacial lakes Warren, Algonquin, Iroquois, and Hudson-Champlain," Bulletin, G. S. A., Vol. III, 1892, pp. 484–487.

"The Champlain submergence," Bulletin, G. S. A., Vol. III, pp. 508–511.

"Conditions of accumulation of drumlins," Am. Geologist, Vol. X, pp. 339–362, Dec., 1892.

"Estimates of geologic time," Am. Jour. Sci. (3), Vol. XLV, pp. 209–220, March, 1893.

"Comparison of Pleistocene and Present ice-sheets," Bulletin, G. S. A., Vol. IV, 1893, pp. 191–204.

"Beltrami Island of Lake Agassiz," Am. Geologist, Vol. XI, pp. 423–425, June, 1893.

"Englacial drift," Am. Geologist, Vol. XII, pp. 36–43, July, 1893.

"Epeirogenic movements associated with glaciation," Am. Jour. Sci. (3), Vol. XLVI, pp. 114–121, Aug., 1893.

"Evidences of the derivation of the kames, eskers, and moraines of the North American ice-sheet chiefly from its englacial drift," Bulletin, G. S. A., Vol. V, 1894, pp. 71–86.

"The succession of Pleistocene formations in the Mississippi and Nelson River basins," Bulletin, G. S. A., Vol. V, 1894, pp. 87–100.

"Wave-like progress of an epeirogenic uplift," Journal of Geology, Vol. II, pp. 383–395, May–June, 1894.

"Causes and conditions of glaciation," Am. Geologist, Vol. XIV, pp. 12–20, July, 1894.

"Tertiary and early Quaternary baseleveling in Minnesota, Manitoba, and northwestward," Am. Geologist, Vol. XIV, pp. 235–246, Oct., 1894. (Abstract in Bulletin, G. S. A., Vol. VI, pp. 17–20, Nov., 1894.)

"Departure of the ice-sheet from the Laurentian lakes," Bulletin, G. S. A., Vol. VI, pp. 21–27, Nov., 1894.

"Quaternary time divisible in three periods, the Lafayette, Glacial, and Recent," Am. Naturalist, Vol. XXVII, pp. 979–988, Dec., 1894.

"Preliminary report of field work during 1893 in northeastern Minnesota, chiefly relating to the glacial drift," in the Twenty-second Annual Report of the Geol. Survey of Minnesota for 1893 (pub. 1894), pp. 18–66, with map and sections.

"Late Glacial or Champlain subsidence and reelevation of the St. Lawrence River basin," Am. Jour. Sci. (3), Vol. XLIX, pp. 1–18, with map, Jan., 1895.

Many changes will be brought by coming years upon the areas thus mapped, in the springing up of new villages, the organization and naming of townships, and the construction of new lines and branches of railways. It is to be hoped, also, that local observers, as teachers in the common schools and in the colleges and universities of Fargo, Grand Forks, Winnipeg, and other cities, will supplement the work herein described and mapped by adding such portions of the lower shore-lines of Lake Agassiz as have not yet been definitely traced. The sections of new artesian wells should likewise be recorded and studied in comparison with the notes of wells here reported.