Upham, Warren.

...The upper beaches and deltas
of the glacial Lake Agassiz...
1887.

DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 39

THE UPPER BEACHES AND DELTAS OF THE GLACIAL LAKE AGASSIZ

WASHINGTON
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1887

ADVERTISEMENT.

[Bulletin No. 39.]

The publications of the United States Geological Survey are issued in accordance with the statute approved March 3, 1879, which declares that—

"The publications of the Geological Survey shall consist of the annual report of operations, geological and economic maps illustrating the resources and classification of the lands, and reports upon general and economic geology and paleontology. The annual report of operations of the Geological Survey shall accompany the annual report of the Secretary of the Interior. All special memoirs and reports of said Survey shall be issued in uniform quarto series if deemed necessary by the Director, but otherwise in ordinary octavos. Three thousand copies of each shall be published for scientific exchanges and for sale at the price of publication; and all literary and cartographic materials received in exchange shall be the property of the United States and form a part of the library of the organization: And the money resulting from the sale of such publications shall be covered into the Treasury of the United States."

On July 7, 1882, the following joint resolution, referring to all Government publications, was passed by Congress:

"That whenever any document or report shall be ordered printed by Congress, there shall be printed, in addition to the number in each case stated, the 'usual number' (1,900) of copies for binding and distribution among those entitled to receive them."

Except in those cases in which an extra number of any publication has been supplied to the Survey by special resolution of Congress or has been ordered by the Secretary of the Interior, this Office has no copies for gratuitous distribution.

ANNUAL REPORTS.

Of the Annual Reports there have been already published:

I. First Annual Report to the Hon. Carl Schurz, by Clarence King. 1880. 8°. 79 pp. 1 map.—A preliminary report describing plan of organization and publications.

II. Report of the Director of the United States Geological Survey for 1880–'81, by J. W. Powell. 1882. 8°. lv, 588 pp. 61 pl. 1 map.

III. Third Annual Report of the United States Geological Survey, 1881–'82, by J. W. Powell. 1883. 8°. xviii, 564 pp. 67 pl. and maps.

IV. Fourth Annual Report of the United States Geological Survey, 1882–'83, by J. W. Powell. 1884. 8°. xxxii, 473 pp. 85 pl. and maps.

V. Fifth Annual Report of the United States Geological Survey, 1883–'84, by J. W. Powell. 1885. 8°. xxxvi, 469 pp. 58 pl. and maps.

The Sixth and Seventh Annual Reports are in press.

MONOGRAPHS.

Of the Monographs, Nos. II, III, IV, V, VI, VII, VIII, IX, X, and XI are now published, viz:

II. Tertiary History of the Grand Cañon District, with atlas, by Clarence E. Dutton, Capt. U. S. A. 1882. 4°. xiv, 264 pp. 42 pl. and atlas of 24 sheets folio. Price $10.12.

III. Geology of the Comstock Lode and the Washoe District, with atlas, by George F. Becker. 1882. 4°. xv, 422 pp. 7 pl. and atlas of 21 sheets folio. Price $11.

IV. Comstock Mining and Miners, by Eliot Lord. 1883. 4°. xiv, 451 pp. 3 pl. Price $1.50.

V. Copper-bearing Rocks of Lake Superior, by Roland D. Irving. 1883. 4°. xvi, 464 pp. 15 l. 29 pl. Price $1.85.

VI. Contributions to the Knowledge of the Older Mesozoic Flora of Virginia, by Wm. M. Fontaine. 1883. 4°. xi, 144 pp. 54 l. 54 pl. Price $1.05.

VII. Silver-Lead Deposits of Eureka, Nevada, by Joseph S. Curtis. 1884. 4°. xiii, 200 pp. 16 pl. Price $1.20.

VIII. Paleontology of the Eureka District, by Charles D. Walcott. 1884. 4°. xiii, 298 pp. 24 l. 24 pl. Price $1.10.

IX. Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 1885. 4°. xx, 338 pp. 35 pl. Price $1.15.

X. Dinocerata. A Monograph of an Extinct Order of Gigantic Mammals, by Othniel Charles Marsh. 1885. 4°. xviii, 243 pp. 56 l. 56 pl. Price $2.70.

XI. Geological History of Lake Lahontan, a Quaternary Lake of Northwestern Nevada, by Israel Cook Russell. 1885. 4°. xiv, 288 pp. 46 pl. Price $1.75.

The following is in press, viz:

XII. Geology and Mining Industry of Leadville, with atlas, by S. F. Emmons. 1886. 4°. xxix, 770 pp. 45 pl. and atlas of 35 sheets folio.

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The following are in preparation, viz:

I. The Precious Metals, by Clarence King.
— Gasteropoda of the New Jersey Cretaceous and Eocene Marls, by R. P. Whitfield.
— Geology of the Eureka Mining District, Nevada, with atlas, by Arnold Hague.
- Lake Bonneville, by G. K. Gilbert.
— Sauropoda, by Prof. O. C. Marsh.
— Stegosauria, by Prof. O. C. Marsh.
— Brontotheridæ, by Prof. O. C. Marsh.
— Geology of the Quicksilver Deposits of the Pacific Slope, with atlas, by George F. Becker.
— The Penokee-Gogebic Iron-Bearing Series of North Wisconsin and Michigan, by Roland D. Irving.
— Younger Mesozoic Flora of Virginia, by William M. Fontaine.
— Description of New Fossil Plants from the Dakota Group, by Leo Lesquereux.
— Report on the Denver Coal Basin, by S. F. Emmons.
— Report on Ten-Mile Mining District, Colorado, by S. F. Emmons.
— Report on Silver Cliff Mining District, by S. F. Emmons.
— Flora of the Dakota Group, by J. S. Newberry.

BULLETINS.

The Bulletins of the Survey will contain such papers relating to the general purpose of its work as do not properly come under the heads of Annual Reports or Monographs.

Each of these Bulletins contains but one paper and is complete in itself. They are, however, numbered in a continuous series, and may be united into volumes of convenient size. To facilitate this, each Bulletin has two paginations, one proper to itself and another which belongs to it as part of the volume.

Of this series of Bulletins Nos. 1 to 39 are already published, viz:

1. On Hypersthene-Andesite and on Triclinic Pyroxene in Augitic Rocks, by Whitman Cross, with a Geological Sketch of Buffalo Peaks, Colorado, by S. F. Emmons. 1883. 8°. 42 pp. 2 pl. Price 10 cents.

2. Gold and Silver Conversion Tables, giving the coining values of troy ounces of fine metal, etc., by Albert Williams, jr. 1883. 8°. 8 pp. Price 5 cents.

3. On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams. 1884. 8°. 36 pp. Price 5 cents.

4. On Mesozoic Fossils, by Charles A. White. 1884. 8°. 36 pp. 9 pl. Price 5 cents.

5. A Dictionary of Altitudes in the United States, compiled by Henry Gannett. 1884. 8°. 325 pp. Price 20 cents.

6. Elevations in the Dominion of Canada, by J. W. Spencer. 1884. 8°. 43 pp. Price 5 cents.

7. Mapoteca Geologica Americana. A catalogue of geological maps of America (North and South), 1752–1881, by Jules Marcou and John Belknap Marcou. 1884. 8°. 184 pp. Price 10 cents.

8. On Secondary Enlargements of Mineral Fragments in Certain Rocks, by R. D. Irving and C. R. Van Hise. 1884. 8°. 56 pp. 6 pl. Price 10 cents.

9. Report of work done in the Washington Laboratory during the fiscal year 1883–'84. F. W. Clarke, chief chemist; T. M. Chatard, assistant. 1884. 8°. 40 pp. Price 5 cents.

10. On the Cambrian Faunas of North America. Preliminary studies, by Charles D. Walcott. 1884. 8°. 74 pp. 10 pl. Price 5 cents.

11. On the Quaternary and Recent Mollusca of the Great Basin; with Descriptions of New Forms, by R. Ellsworth Call; introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert. 1884. 8°. 66 pp. 6 pl. Price 5 cents.

12. A Crystallographic Study of the Thinolite of Lake Lahontan, by Edward S. Dana. 1884. 8°. 34 pp. 3 pl. Price 5 cents.

13. Boundaries of the United States and of the several States and Territories, by Henry Gannett, 1885. 8°. 135 pp. Price 10 cents.

14. The Electrical and Magnetic Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1885. 8°. 238 pp. Price 15 cents.

15. On the Mesozoic and Cenozoic Paleontology of California, by Charles A. White. 1885. 8°. 33 pp. Price 5 cents.

16. On the higher Devonian Faunas of Ontario County, New York, by John M. Clarke. 1885. 8°. 86 pp. 3 pl. Price 5 cents.

17. On the Development of Crystallization in the Igneous Rocks of Washoe, Nevada, by Arnold Hague and Joseph P. Iddings. 1885. 8°. 44 pp. Price 5 cents.

18. On Marine Eocene, Fresh-water Miocene, and other Fossil Mollusca of Western North America, by Charles A. White. 1885. 8°. 26 pp. 3 pl. Price 5 cents.

19. Notes on the Stratigraphy of California, by George F. Becker. 1885. 8°. 28 pp. Price 5 cents.

20. Contributions to the Mineralogy of the Rocky Mountains, by Whitman Cross and W. F. Hillebrand. 1885. 8°. 114 pp. 1 pl. Price 10 cents.

21. The Lignites of the Great Sioux Reservation, by Bailey Willis. 1885. 8°. 16 pp. 5 pl. Price 5 cents.

22. On New Cretaceous Fossils from California, by Charles A. White. 1885. 8°. 25 pp. 5 pl. Price 5 cents.

23. Observations on the Junction between the Eastern Sandstone and the Keweenaw Series on Keweenaw Point, Lake Superior, by R. D. Irving and T. C. Chamberlin. 1885. 8°. 124 pp. 17 pl. Price 15 cents.

24. List of Marine Mollusca, comprising the Quaternary fossils and recent forms from American localities between Cape Hatteras and Cape Roque, including the Bermudas, by William H. Dall. 1885. 8°. 336 pp. Price 25 cents.

25. The Present Technical Condition of the Steel Industry of the United States, by Phineas Barnes. 1885. 8°. 85 pp. Price 10 cents.

26. Copper Smelting, by Henry M. Howe. 1885. 8°. 107 pp. Price 10 cents.

27. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1884–'85. 1886. 8°. 80 pp. Price 10 cents.

28. The Gabbros and Associated Hornblende Rocks occurring in the neighborhood of Baltimore, Md., by George H. Williams. 1886. 8°. 78 pp. 4 pl. Price 10 cents.

29. On the Fresh-water Invertebrates of the North American Jurassic, by Charles A. White. 1886. 8°. 41 pp. 4 pl. Price 5 cents.

30. Second contribution to the studies on the Cambrian Faunas of North America, by Charles D. Walcott. 1886. 8°. 369 pp. 33 pl. Price 25 cents.

31. A systematic review of our present knowledge of Fossil Insects, including Myriapods and Arachnids, by Samuel H. Scudder. 1886. 8°. 128 pp. Price 15 cents.

32. Lists and Analyses of the Mineral Springs of the United States; a preliminary study, by Albert C. Peale. 1886. 8°. 235 pp. Price 20 cents.

33. Notes on the Geology of Northern California, by Joseph S. Diller. 1886. 8°. 23 pp. Price 5 cents.

34. On the relation of the Laramie Molluscan Fauna to that of the succeeding Fresh-water Eocene and other groups, by Charles A. White. 1886. 8°. 54 pp. 5 pl. Price 10 cents.

35. The Physical Properties of the Iron-Carburets, by Carl Barus and Vincent Strouhal. 1886. 8°. 62 pp. Price 10 cents.

36. Subsidence of fine Solid particles in Liquids, by Carl Barus. 1887. 8°. 58 pp. Price 10 cents.

37. Types of the Laramie Flora, by Lester F. Ward. 1887. 8°. 354 pp. 57 pl. Price 25 cents.

38. Peridotite of Elliott County, Kentucky, by Joseph S. Diller. 1887. 8°. 31 pp. 1 pl. Price 5 cents.

39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, by Warren Upham. 1887. 8°. 84 pp. 1 pl. Price 10 cents.

Numbers 1 to 6 of the Bulletins form Volume I; Numbers 7 to 14, Volume II; Numbers 15 to 23, Volume III; Numbers 24 to 30, Volume IV; Numbers 31 to 36, Volume V. Volume VI is not yet complete.

The following are in press, viz:

40. Changes in River Courses in Washington Territory due to Glaciation, by Bailey Willis.

41. Fossil Faunas of the Upper Devonian—the Genesee Section, by Henry S. Williams.

42. Report of work done in the division of Chemistry and Physics, mainly during the fiscal year 1885–'86. F. W. Clarke, chief chemist.

43. On the Tertiary and Cretaceous Strata of the Tuscaloosa, Tombigbee, and Alabama Rivers, by Eugene A. Smith and Lawrence C. Johnson.

In preparation:

— Historic statement respecting geologic work in Texas, by R. T. Hill.

— The Nature and Origin of Deposits of Phosphates of Lime, by R. A. F. Penrose, jr.

— Bibliography of North American Crustacea, by A. W. Vogdes.

— The Gabbros and associated rocks in Delaware, by F. D. Chester.

— Report on Louisiana and Texas, by Lawrence C. Johnson.

— On the subaërial decay of rocks and the origin of the red color of certain formations, by Israel C. Russell.

— Bibliography of North American Geology for 1886, by Nelson H. Darton.

STATISTICAL PAPERS.

A fourth series of publications, having special reference to the mineral resources of the United States, has been undertaken.

Of that series the following have been published, viz:

Mineral Resources of the United States [1882], by Albert Williams, jr. 1883. 8°. xvii, 813 pp. Price 50 cents.

Mineral Resources of the United States, 1883 and 1884, by Albert Williams, jr. 1885. 8°. xiv, 1016 pp. Price 60 cents.

Mineral Resources of the United States, 1885. Division of Mining Statistics and Technology. 1886. 8°. vii, 576 pp. Price 40 cents.

Correspondence relating to the publications of the Survey, and all remittances, which must be by POSTAL NOTE or MONEY ORDER (not stamps), should be addressed

TO THE DIRECTOR OF THE
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

WASHINGTON, D. C., *April* 30, 1887.

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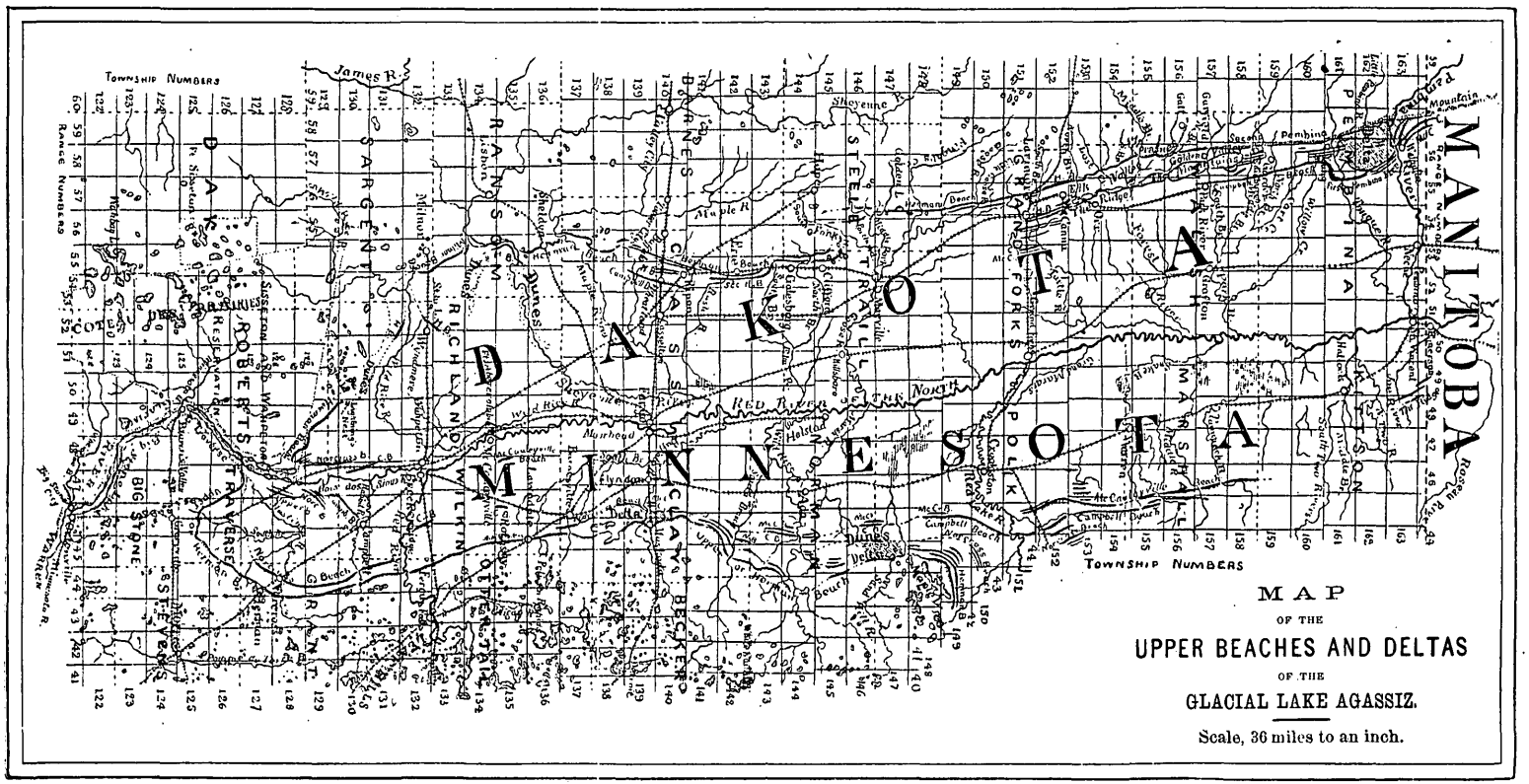

MANITOBA
MINNESOTA
DAKOTA
TOWNSHIP NUMBERS
RANGE NUMBERS
MAP
OF THE
UPPER BEACHES AND DELTAS
OF THE
GLACIAL LAKE AGASSIZ.
Scale, 36 miles to an inch.

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE

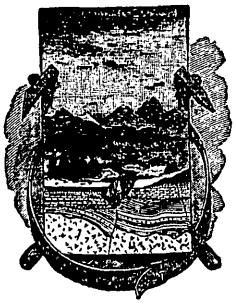
UPPER BEACHES AND DELTAS

OF THE

GLACIAL LAKE AGASSIZ

BY

WARREN UPHAM



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CONTENTS.

ILLUSTRATIONS.

Allgemeine Theorie.

The greater the depth, the smaller the share of friction each layer of water is called upon to bear and the greater the velocity of current which can be communicated by a given wind.

The height of wave is likewise conditioned by depth of water, deep water permitting the formation of those that are relatively large.

Where the water approaches a shelving shore its habits is changed.

The velocity of the undulation is diminished, while the velocity of the advancing particles of water in the crest is increased; the wave height is diminished, and the wave length is increased; the crest becomes acute, with the front steeper than the back; and these changes culminate in the breaking of the crest, when the undulation proper ceases. There is no impact

of breakers at least lower than the troughs of the waves near the breaker line, the oscillation communicated by the wave may even overcome and momentarily reverse the movement of the undertow. Inside the breaker line no oscillation proper is communicated. The breaker wave crest, dashing forward, overcomes the undertow and throws it back.

The waves and undertow accomplish a sorting of the detritus. The finer portion, being lifted up by the agitation of the waves, is held in suspension until carried outward to deep water by the undertow. The coarser portion, sinking to the bottom more rapidly, cannot be carried far. Beyond the zone of agitation remains as a part of the shore only that bulk is the subject of littoral transportation. It is called shore drift.

The source of shore drift is twofold. A large part is derived from the ~~[illegible]~~ denudations of sea-cliffs, & is thus the product of littoral erosion.

Another part is contributed by streams depositing at their mouths the heavy part of their detritus, & is more remotely derived from the erosion of the land. — — — — —

The zone occupied by the shore drift in transit is called the beach.

Where the sublittoral bottom of the lake has an exceedingly gentle inclination the waves break at a considerable distance from the water margin. The most violent agitation of the water is along the line of breakers & the shore drift, depending upon agitation for its transportation, follows the line of the breakers instead of the water margin. It is thus built into a continuous undying ridge at some

distance from the waters edge. this ridge is called a barre.

Bars and barres are absolutely dependent on their drift for their existence.

When the current holds its direction & the shore line diverges the embankment takes the form of a spit, a hook, a bar or a loop. When the shore line holds its course & the current diverges shoals & superficially or by descent, the embankment usually takes the form of a terrace.

The spit not only follows the line between the current & still water, but adds in giving definition to that line and eventually walls in the current by contours adjusted to its natural flows.

Of the current determining the formation of a spit as it touches the shore, the construction of the embankment is continued until it spans the entire natural = bar

At the mouth of a river its maintenance is antagonized

by the outflowing current, and if its integrity is established at all it is only on rare occasions & for a short time. That is to say, its full height is not maintained.

Suess - Flussterrassen.

Der Wasserfaden bewegt sich, sein natürliches Gefälle suchend, in Serpentinen auf der Höhe des Schwemmlandes. Bei Hochwasser und vermehrter Fluth-Kraft in den Krümmungen ~~[illegible]~~ verkleinert er den Radius seiner Bogen & schneidet er an den convexen Theilen Stufen in das Land. Bei fortschreitender Arbeit sinkt er tiefer ein, die Serpentinen werden verlegt; ihre Ausladung wird allmälig geringer; von Zeit zu Zeit geschieht es, daß ein convexer Theil in die Nähe eines alten Steilrandes, doch in tiefere Lage gelangt. Nun entsteht eine zweite Stufe, später vielleicht eine dritte u.s.f. Verlegung der Serpentinen bei Vertiefung des Bettes is also die Ursache.

Antlitz der Erde

Bd. II. p. 694.

Gletscher ordnen material nach Korngrösse; Flüsse dagegen nach Grösse, der beförderten materials.

The characters of a fossil delta, or the delta as it exists after the desiccation of the lake concerned in its formation, are as follows: The upper surface is a terrace with the form of an alluvial fan. The lower slope or face is steep, ranging from 10-25°. It joins the upper slope by an angle and the plain below by a gentle curve. The line separating the upper surface from the outer slope is horizontal, and, in common with all other contours of the structure, is approximately a circular arc.

The fossil delta is invariably divided into two part by a channel running from its apex to some part of its periphery & occupied by a stream.

Ed. Jisum

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., June 8, 1886.

SIR: I have the honor to transmit herewith for publication as a Bulletin of the Survey a paper embodying the results of the investigations of Mr. Warren Upham, assistant geologist, upon the upper beaches and deltas of the extinct Lake Agassiz, which, in glacial times, occupied the basin of the Red River of the North.

This is but an initial contribution, embracing only so much of the data gathered as from their degree of completeness and interest warrant present publication as a record of results. The investigation is still in progress, and the general discussion of data and the eduction of conclusions are reserved until its completion. Meanwhile the great mass of carefully determined facts here recorded will, besides their inherent independent value, be of important and immediate service to the students of other extinct and shrunken glacial lakes.

Very respectfully,

T. C. CHAMBERLIN,
Geologist in Charge of Glacial Division.

Hon. J. W. POWELL,
Director U. S. Geological Survey, Washington, D. C.

UPPER BEACHES AND DELTAS OF LAKE AGASSIZ.

By WARREN UPHAM.

INTRODUCTION.

That part of the extinct Lake Agassiz which lies in Minnesota, so far as it is prairie, was explored by the writer in 1879 and 1881 in connection with the Geological and Natural History Survey of Minnesota, the results of which are partly used in the preparation of this report for the purpose of giving completeness and significance to the observations obtained in the survey to which this bulletin more especially relates.[1]

Further exploration of this lake was begun for the United States Geological Survey by the writer, with Robert H. Young as assistant, in 1885, mapping the upper or Herman beaches in Dakota from Lake Traverse to the international boundary, besides portions of the lower shore lines, with exact determinations of their elevation by leveling. As the Herman beaches and deltas are thus surveyed along the entire extent of Lake Agassiz in the United States, excepting the wooded region of Northern Minnesota, where their exact survey seems impracticable, they are made the subject of the present report, reserving the detailed description of the lower beaches and the inclosed lacustrine area until their exploration within the United States is finished, for which the field work of 1886 will probably suffice.

Discussions of the history of Lake Agassiz and of the causes that have changed the relations of surfaces of level here are mainly deferred to the end of the examination of the whole area of this lake. Observations gathered thus completely may be reasonably expected not only to add much to our knowledge of the conditions attending the glacial

[1] The Geological and Natural History Survey of Minnesota, Eighth Annual Report (1879), pp. 84 to 87, containing a general statement of the extent of this lake, with notes of its beaches and deltas at a few points, and proposing for it the name Lake Agassiz; and Eleventh Annual Report, pp. 137 to 153, describing and mapping the Herman, Norcross, and Campbell beaches, noting the decrease in the northward ascent of the lake level during its successive stages, and attributing these changed levels to the attraction of the lake by gravitation toward the diminishing ice sheet. This work in Minnesota was done under the direction of Prof. N. H. Winchell, State geologist, with the assistance in 1881 of Horace V. Winchell as rodman in leveling.

period and the recession of the ice sheet but also to shed needed light on the nature and relations of the earth's crust and interior.

The glacial Lake Agassiz is confidently believed to have been formed in the basin of the Red River of the North and of Lake Winnipeg during the final melting and gradual recession of the ice sheet. It thus belongs to the closing epoch of the ice age, when the continental glacier, subdued by a more temperate climate, was yielding its ground between Lake Traverse and Hudson Bay. During this retreat free drainage from the melting ice could not take place, because the descent of the land is northward. As soon as the border of the ice had receded beyond the watershed dividing the basins of the Minnesota and the 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 and its branches to the height of the lowest point over which an outlet could be found. Until the ice barrier was melted upon the area now crossed by the Nelson River, thereby draining this glacial lake, its outlet was along the present course of the Minnesota River. At first its overflow was upon the nearly level, gently undulating surface of the drift, about 1,100 feet above the sea; but in process of time this cut a channel 125 to 150 feet deep and from 1 to 2 miles wide, in which lie Traverse and Big Stone Lakes, respectively 970 and 962 feet above the sea. From this outlet the plain of the Red River Valley, 30 to 50 miles wide, stretches 315 miles north to Lake Winnipeg, which is 710 feet above the sea. Along this entire distance there is a very uniform continuous descent of a little less than one foot per mile. The drift deposited by the ice sheet upon this area, together with that which may have been dropped by floating ice borne on the waters of the lake, and the silt brought in by glacial rivers and by those of the surrounding land, were here received in a lake, shallow near its mouth, but becoming gradually deeper northward. Beyond our national boundary this lake covered a large area, varying from 100 to 200 miles in breadth at and west of Lake Winnipeg, and its total length appears to have been at least 600 miles. 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.[1]

THE UPPER OR HERMAN BEACH.

Along nearly the whole of the upper shore line of Lake Agassiz, as traced in Minnesota and Dakota, there exists a remarkable deposit of beach gravel and sand, forming a continuous, smoothly rounded ridge, such as is found along any part of the shores of the ocean or of our great

[1] The Geological and Natural History Survey of Minnesota, Eighth Annual Report, for the year 1879, pp. 84, 85.

lakes where the land sinks in a gently descending slope beneath the water level. Usually the beach of Lake Agassiz (Fig. 1) is a ridge 3 to 10 feet above the land next to it on the side away from the lake and 10 to 20 feet above the land adjoining it on the side where the lake lay. In breadth this beach ridge varies from 10 to 25 or 30 rods. It is thus a broad wavelike swell, with a smooth, gracefully rounded surface.

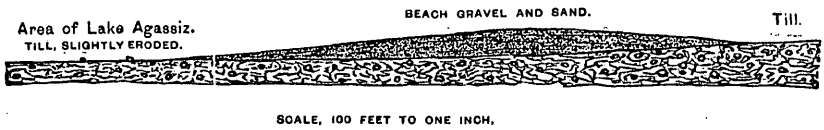

FIG. 1. Typical section across a beach ridge of Lake Agassiz.

Such being a section across the beach, it is to be remembered that this ridge extends along the whole distance that has been explored, with only here and there gaps where it has been cut through by streams and rare intervals—of a quarter or a half of a mile, or, at the longest, 2 or 3 miles—where the outline of the lake shore or the direction of the shore currents prevented such accumulation. It is also deficient on the shores of the strait that occupied the Elk and Golden Valleys in Dakota, but is well developed along the chain of islands east of this strait. There are similar interruptions in the beaches of present lakes and on the sea coast; and, like these modern deposits, the beach of Lake Agassiz varies considerably in its size, having in any distance of 5 miles some portions 5 or 10 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 a beach ridge, and one has been clearly traced as an essentially continuous formation along a distance of 400 miles in Minnesota and Dakota. In calling it continuous, I mean to say that whenever interrupted it is found a little distance farther along, beginning again at very nearly the same height.

The gaps where the beach is not a distinctly traceable ridgelike deposit of gravel and sand cannot exceed one-tenth of its whole course. In a few places the lake undermined its shore, forming 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. In other places—sometimes 2 or 3 miles in length—the area where this ancient lake had its margin is a marsh or shaking bog, full of spring water and rough with hummocks of grass.

Commonly the land upon each side of this beach of Lake Agassiz is till or unstratified clay, containing some intermixture of sand and gravel and occasional stones and bowlders. 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 2 or 3 to 6 inches in diameter. No bowlders referable to transportation by floating ice have been found in any of the beach deposits of this lake.

When Lake Agassiz stood at its greatest height and formed the upper beach, its outlet was about 75 feet above the present surface of Lake Traverse, or 1,045 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 50 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 and Manitoba Railway at a point about 1½ miles northwest from Herman, Minnesota.

THE NORCROSS BEACH.

Three lower beaches, of the same character as to form, size, and material with the highest, have been also noted; their course has been traced through long distances and their height has been determined by leveling. At the next epoch after that of the upper or Herman beach, when the lake level was again nearly stationary long enough to form a ridge of gravel and sand upon its shore, the outlet had been eroded about 20 feet deeper than at the time of the upper beach, but was still 55 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, 5 miles northwest from Herman.

THE CAMPBELL BEACH.

A third series of beach deposits was formed when the outlet of Lake Agassiz had been lowered some 50 feet more, nearly to the level of Lake Traverse. The beach of this third stage of Lake Agassiz takes its name from the township of Campbell (T. 130, R. 46), in the southern part of Wilkin County, Minnesota, which it crosses from southwest to northeast.

THE M'CAULEYVILLE BEACH.

The fourth and lowest beach of Lake Agassiz, while it outflowed to the south, was formed after a further erosion of 15 feet, lowering the outlet to 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 3½ miles northeast from McCauleyville (T. 134, R. 48), in Wilkin County, Minnesota.

Four distinct series of beach ridges of gravel and sand were thus formed by Lake Agassiz at successive stages of height during its process of deepening the channel by which it outflowed southward.

THE RED RIVER VALLEY.

The central part of the basin of Lake Agassiz, within the limits of Minnesota and Dakota, now drained by the Red River, has an exceedingly flat surface, sloping imperceptibly northward, as also from each side to its central line. The Red River has its course along the axial depression, where it has cut a channel 20 to 60 feet deep. It is bordered by only few and narrow areas of bottom land, 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 10 to 30 miles from the river. Its tributaries cross the plain in similar channels, which, as well as the Red River, have occasional gullies connected with them, dry during most of the year, varying from a few hundred feet to a mile or more in length. Between the drainage lines areas often 5 to 15 miles wide remain unmarked by any watercourses. The highest portions of these tracts are commonly from 2 to 5 feet above the lowest.

This vast plain, 40 to 50 miles wide, lying half in Minnesota and half in Dakota and stretching from Lake Traverse and Breckenridge north to Winnipeg, is the widely famed Red River Valley, the most fertile wheat land of the continent. The material of the lower part of this ancient lake bed, shown in the banks of the Red River and reaching several miles from it, is fine clayey silt, horizontally stratified, but its south end and large areas of each side of this plain are mainly unstratified bowlder clay, which differs from the rolling or undulating till of the adjoining region only in having its surface nearly flat. Both these formations are almost impervious to water, which therefore in the rainy season fills their shallow depressions; but these are very rarely so deep as to form permanent lakes. Even sloughs that continue marshy through the summer are infrequent, but where they do occur they cover large tracts, usually several miles in extent.

On all the area drained by the Red River in Minnesota the glacial drift is so thick that no exposures of the underlying rocks have been found, and they have only few outcrops within this basin in Dakota. The depth of the drift varies from 100 to 250 feet. The prominent topographic features of all this region are doubtless due to the form of the underlying rock surface, upon which the drift is spread in a sheet of somewhat uniform thickness.

Erosion, before the ice age, had sculptured the rocks that are buried and concealed under this universal drift sheet and had formed the broad, nearly level depression of the Red River Valley, which in the United States is 1,000 to 800 feet, from south to north, above the sea. Slopes and terraces of these rocks beneath the drift cause the rise eastward from this valley to the lake-sprinkled plateau, 1,300 to 1,500 feet above the sea, which reaches from Glenwood, Alexandria, and Fergus Falls to the sources of the Mississippi. For example, though the traveler finds no ledge of rock in going from the Red River at Fargo and Moorhead 75 miles east-northeast to Itasca Lake, it yet appears that the form of the surface, marked by two remarkable terraces, is due to that of the bed rock. The flat of the Red River Valley extends from Moorhead to about 6 miles east of Glyndon, with a slight ascent of about 50 feet in these 15 miles. The next 2 or 3 miles rise 200 feet to the top of a terrace, which reaches from south to north the whole length of

the Red River Valley in Minnesota, though it is not all the way so distinct nor so high as here. Beyond this ascent the surface is again nearly level, being a sheet of slightly undulating or rolling till, with a rise of perhaps 4 or 5 feet per mile, through 25 miles eastward. Next is a terrace, also reaching a long distance from south to north, which is ascended in 3 or 4 miles, rising about 300 feet, to the White Earth Agency, which thus commands a very extensive western prospect. Thence a more rolling plateau extends, with little change in the average height, 30 miles eastward to Itasca Lake.

In like manner the elevation of the Coteau des Prairies, 1,500 to 2,000 feet above the sea, and the terracelike ascent at the west side of the flat Red River Valley in Dakota, lying at a distance of 20 to 35 miles west of the Red River and stretching from the south bend of the Sheyenne River north to the British line, where it is called Pembina Mountain, are due to the contour of the bed rock, rather than to differences in the thickness of the drift.

The till upon each side of Lake Agassiz 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, but has been only slightly stratified. The action of its waves gathered from this deposit of till, which was the lake bed, the gravel and sand of its beaches; and corresponding 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. The position of the thick beds of stratified fine silt and clay in the central depression of the Red River Valley shows that they were not deposited by the waters of Lake Agassiz, which must have spread them more generally over its entire area; but, instead, proves that they were brought by the rivers which flowed into this hollow and along it northward after the glacial Lake Agassiz had been reduced to its present representative, Lake Winnipeg. The occurrence of shells and remains of vegetation in these stratified beds at McCauleyville 32 and 45 feet below the surface, or about 7 and 20 feet below the level of the Red River, and numerous other observations of remains of vegetation elsewhere along the Red River Valley in these beds, demonstrate that the valley was a land surface, subject to overflow by the river at its stages of flood, when these remains were deposited. Even at the present time much of the area of stratified clay is covered by the highest floods, and probably no portion of these stratified deposits is more than 10 feet above the high water line of the Red River and its tributaries.

THE OUTLET OF LAKE AGASSIZ.

The excavation of the remarkable valley occupied by Lakes Traverse and Big Stone and the Minnesota River was first explained in 1868 by General G. K. Warren, who attributed it to the outflow from this ancient

lake that filled the basin of the Red River and Lake Winnipeg. He made a careful survey of this valley from Lake Traverse to its mouth, and his maps and descriptions, with the accompanying discussion of geologic questions, are most valuable contributions to science.[1] After his death, in recognition of this work, the glacial river that was the outlet of Lake Agassiz was named River Warren.[2]

The heights of Lakes Traverse and Big Stone are, respectively, 970 and 962 feet above the sea, and the lowest point of the divide between them is only 3 feet above Lake Traverse. These lakes are from 1 to 1½ miles wide, mainly occupying the entire width of this troughlike valley, which is inclosed by bluffs of till about 125 feet high. Lake Traverse is 15 miles long; it is mostly less than 10 feet deep and its greatest depth probably does not reach 20 feet. Big Stone Lake extends in a somewhat crooked course from northwest to southeast 26 miles; its greatest depth is reported to be from 15 to 30 feet. The portion of the channel between these lakes is widely known as Brown's Valley. As we stand upon the bluffs here, looking down on these long and narrow lakes and the valley which extends across the 5 miles between them, where the basins of Hudson Bay and the Gulf of Mexico are now divided, we have nearly the picture that was presented when the melting ice sheet of British America was pouring its floods along this hollow. Then the entire extent of the valley was doubtless filled every summer by a river which covered all the present areas of flood plain, in many places occupying as great width as these lakes. General Warren observed that Lake Traverse is due to a partial silting up of the channel since the outflow from the Red River basin ceased, the Minnesota River at the south having brought in sufficient alluvium to form a dam, while Big Stone Lake and Lac qui Parle are similarly due to the deposits of stratified sand and silt which the Whetstone and Lac qui Parle Rivers have spread across the valley below them.

THE NORTHERN BARRIER.

The northern barrier by which the water of Lake Agassiz was restrained from flowing in the direction of the present drainage to Hudson Bay was supposed by General Warren to have been an elevation of the land much above its present height northeast of Lake Winnipeg.

[1] "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 considered—depth of the bed-rock," with maps, Report of Chief of Engineers, 1878, and American Journal of Science, (3) 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 (for 1883), pp. 213 to 231; also in American Journal of Science, (3) XXVII, January and February, 1884; and Geology of Minnesota, Vol. I, p. 622.

He thought that this elevation was shared by other northern portions of North America and that these regions have recently been depressed at least several hundred feet. The depths of the great lakes and many topographic features of the interior of the continent, besides this channel of Lakes Traverse and Big Stone and the Minnesota River, appeared to him to support this opinion. On the contrary, my belief is that the surface of the continent had nearly the same form then as now and that the continental ice sheet, resting on the land in a solid mass of great depth, formed the northern shore of Lake Agassiz and was the barrier that prevented it from flowing into Hudson Bay.[1]

The four series of beach deposits which mark the shores of Lake Agassiz at as many stages of its height are found to have a gradual ascent northward, as compared with the present level line or the surface which a body of water would have now if confined in this valley. As before stated, these beaches were formed at epochs when the lake level was nearly stationary for a considerable time during the excavation of its channel of outlet at Lake Traverse and southward.

Exploration and leveling along the upper beach in Minnesota extended from the north end of Lake Traverse about 25 miles eastward to Herman, and thence about 140 miles north to Maple Lake. Through this distance it lies from 15 to 30 miles east of the Red River. The ascent of this beach northward is at a rate that increases from 6 inches to 1 foot a mile in its southern portion for about 75 miles. Farther north its rate of ascent increases from 1 foot to 16 inches a mile. In all, the surface of Lake Agassiz in Minnesota at this time of its greatest height ascended northward, above a line now level, 125 feet in these 140 miles, from 1,045 feet, very nearly, above sea at Lake Traverse, to 1,170 feet, very nearly, at the north side of Maple Lake, 20 miles east-southeast from Crookston. Through this distance the upper beach clearly marks one continuous shore line.

Before Lake Agassiz had fallen below the line of this beach in the south half of its explored extent, it had formed a slightly lower parallel beach, three-fourths of a mile to 1½ miles distant, through the northern third of Clay County; and this secondary beach, sometimes double or treble, was noted at several places along the next 30 miles northward. At the northwest side of Maple Lake definite beach ridges were formed when Lake Agassiz had fallen in that latitude successively about 8, 15, 30, and 45 feet from its highest level. Yet all these beaches were accumulated while the lake remained with only very slight depression of

[1] That this lake existed because of the barrier of the receding ice sheet was pointed out by Prof. N. H. Winchell in his First Annual Report of the Geological and Natural History Survey of Minnesota, for 1872, p. 63, and in his Sixth Annual Report, for 1877, p. 31. He also explained in like manner the formerly higher levels of the great lakes, Popular Science Monthly, June, 1873; and the same view is stated by Prof. J. S. Newberry in Report of the Geological Survey of Ohio, Vol. II, 1874, pp. 6, 8, and 51.

level, not sufficient for the formation of any secondary beach ridge, along its southern part for some 75 miles northward from Lake Traverse and Herman.

The Norcross beach in Minnesota has been explored and its height measured through the same distance of 140 miles, in which it ascends northward about 62 feet by a slope that increases slightly from south to north, averaging nearly 6 inches a mile. The surface of Lake Agassiz had fallen at this time from its highest level 20 feet at Lake Traverse, 50 feet in Northern Clay County, and 83 feet northwest of Maple Lake. Its fall in this extent had been thus 63 feet more at the north than at the south. Double and multiple ridges occur along the northern half of this distance and show that the lake level at the time of formation of the Norcross beach fell 5 to 10 feet northward, while it remained without change or with less change than was required to form additional beach ridges southward.

The heights of the Campbell and McCauleyville beaches in Minnesota are known for a distance of 150 miles, in which the northward ascent of the lake level during the Campbell stage was about 37 feet and during the McCauleyville stage 25 feet. The fall of Lake Agassiz from the upper or Herman beach to the McCauleyville beach was 85 feet at its mouth and 185 feet near Maple Lake; and, instead of the northward ascent of the upper beach 125 feet in 140 miles, this had been gradually diminished to 117, 110, 95, 80, 62, 50, 37, and finally 25 feet at the time of the formation of the McCauleyville beach.

In Dakota the same series of beaches are found and they have been traced along the whole or parts of their course, with determination of their elevations, to a distance about 75 miles farther north than in Minnesota. In 224 miles from Lake Traverse to the international boundary the lake level in Dakota at its highest stage, during the time of formation of the first Herman beach, ascended northward about 185 feet, from 1,045 to 1,230 feet above the sea; during the time of the first Norcross beach it ascended 120 feet, from 1,025 to 1,145 feet; during the time of the Campbell beach it ascended 65 feet, from 975 to 1,040; and during the time of the first McCauleyville beach it ascended 35 feet, from 960 to 995 feet above our present sea level. A later McCauleyville beach shows only 25 feet ascent in these 224 miles, or an average of 1⅛ inches a mile.

Comparison of the elevations of these beaches in Dakota and Minnesota at the same latitude 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 lake surface above a line now level was approximately 33 feet, at the time of the first Her-

man beach, in about 70 miles from west to east, the rate per mile being very nearly half as much as from south to north; and during the time of formation of the later Herman beaches it diminished to 30, 26, and 21 feet. When the first and second Norcross beaches were formed this ascent toward the east was 14 and 11 feet in about 60 miles, and during the Campbell and McCauleyville stages it was reduced to only 6 and 4 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 increased, 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 the lake level in its highest stage was 10 feet from west to east in 45 miles; at the latitude of Fargo and Moorhead, 75 miles north from the outlet, it was 15 feet in 50 miles; and at the latitude of Grand Forks, 150 miles north from the outlet, it was 33 feet in 70 miles, approximately. The accompanying table shows the relations of these beaches and the changes which took place in surfaces of level here during the existence of this glacial lake.

If the barrier north and northeast of Lake Agassiz had been land, its subsidence to give way for drainage northward in its present course to Hudson Bay would cause the beach deposits of the former lake shores to have the opposite slope, or a descent from south to north and from west to east. These observations are therefore inconsistent with such explanation of the cause of this lake; but they appear to prove that its northern barrier was the receding continental glacier. I have thought that all the differences of the once level lines of Lake Agassiz from our present level line might have been produced by the gravitation of the water of the lake toward the ice sheet. At first this attraction would have been relatively large, because of the nearness of the great mass of ice on the northeast in Minnesota and northward in British America; but as the ice retreated it must have been gradually diminished and reduced to a comparatively small influence by the time the ice sheet had withdrawn so as to permit the northward drainage of the lake.

Among other agencies that have been proposed to account for such changes are (1) effects due to the weighting of the earth's crust by the ice and its removal; (2) the cooling and contraction of the crust by the ice and glacial waters, and the subsequent warming and expansion owing to the amelioration of the climate; and (3) crust changes of unknown origin, having no relationship to the glacial phenomena.[1] These several agencies will receive studious consideration in my final report, when a more extended range of observations will come under review.

[1] Prof. T. C. Chamberlin, Geology of Wisconsin, Vol. I, 1883, p. 290, and Proc. Am. Assoc. Adv. Sci., Minneapolis meeting, Vol. XXXII, 1883, page 212; also, paper before Philosophical Society, Washington, March 13, 1886.

Mr. G. K. Gilbert, American Journal of Science (3), XXXI, pp. 290-299, April, 1886

AREA AND DEPTH OF LAKE AGASSIZ.

The beaches of Lake Agassiz, as here described in Dakota and from Lake Traverse and Herman north to Maple Lake, in Minnesota, extend through a prairie region very favorable for exploration and leveling. The farther course of the upper beach turns to the east and northeast and lies in a trackless forest, much of which consists of almost impassable tamarack swamps. It is therefore quite impracticable to trace its course exactly through this wilderness; but, from the known elevation of Red Lake (about 1,150 feet above the sea), of the Lake of the Woods (1,062 feet), and of Rainy Lake (about 1,120 feet), the outline of Lake Agassiz when it had its greatest height can be mapped approximately.

From the north side of Maple Lake this outline extends eastward, passing south of Red Lake, across the Big Fork of Rainy River, and along the south side of Rainy Lake, its height above Red and Rainy Lakes being probably about 50 and 150 feet, respectively. Thus Lake Agassiz at this time of greatest height reached along the international boundary farther east than the meridians of Minneapolis and Saint Paul. Its expanse included only few islands, these being of small area and near the shore.

When this glacial lake attained its greatest extent, it probably exceeded Lake Superior, both in length and in area. 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; and above Pembina and Saint Vincent, about 450 feet.

In the following tabulations the figures represent the height, in feet, above sea level, where not otherwise stated.

The letters *a*, *b*, *c*, *d*, represent successive beaches along the northern part of Lake Agassiz, which seem to be merged in a single beach toward its south end.

The columns marked *north ascent* show the ascent of the lake from its south end, which was at Lake Traverse, and those marked *east ascent* show the ascent of the lake from its western to its eastern shore.

The successive elevations of the mouth of Lake Agassiz, situated at its south end (Lake Traverse), were, for the Herman beach, 1,045 feet; for the Norcross beach, 1,025 feet; for the Campbell beach, 975 feet; and for the McCauleyville beach, 960 feet.

Elevations of the crests of the beaches of Lake Agassiz.

[The figures in parenthesis are derived for the boundary line from the nearest observations, chiefly near Walhalla, for which the figures without the parenthesis stand; similarly, the figures in parenthesis for the latitude of Grand Forks are derived from observations near Maple Lake, 15 miles south, for which the figures without parenthesis stand.]

Location.	Herman beach.			Norcross beach.			Campbell beach.			McCauleyville beach.		
		East ascent.	*North ascent.*		*East ascent.*	*North ascent.*		*East ascent.*	*North ascent.*		*East ascent.*	*North ascent.*
(1) On the international boundary line in Dakota, 224 miles north of Lake Traverse. (Only the west or Dakota shore could be examined at the boundary.)	(*a*) 1,226 (1,235)	.....	(185)	(*a*) 1,140 near Young (1,155).	.....	(120)	1,050	.....	65	(*a*) 1,004 (1,006)	.....	(35)
	(*b*) 1,212 (1,220)	.....	(166)	(*b*) 1,141 (1,143)	.....	(108)				(*b*) 992 (994)	.....	(25)
	(*c*) 1,197 (1,202)	.....	(149)									
	(*d*) 1,182 (1,187)	.....	(135)									
(2) On the latitude of Grand Forks, 150 miles north of Lake Traverse, west side, in Dakota.	(*a*) 1,162	.....	107	(*a*) 1,092	.....	57	1,014	.....	31	(*a*) 991	.....	21
	(*b*) 1,146	.....	93	(*b*) 1,080	.....	47				(*b*)	.....	.....
	(*c*) 1,134	.....	80									
	(*d*) 1,121	.....	69									
(2) On the latitude of Grand Forks, 150 miles north of Lake Traverse, east side, in Minnesota.	(*a*) 1,180 (1,195)	(33)	125 (140)	(*a*) 1,094 (1,103)	(14)	62 (71)	1,022	6	37	(*a*) 996	4	25
	(*b*) 1,165 (1,178)	(30)	110 (123)	(*b*) 1,082 (1,090)	(11)	50 (58)				(*b*) 989	.....	18
	(*c*) 1,147 (1,158)	(26)	95 (106)									
	(*d*) 1,132 (1,141)	(21)	80 (90)									
(3) On the latitude of Fargo and Moorhead, 75 miles north of Lake Traverse, west side, in Dakota.	1,099	.....	45	.....	.....	.....	997	.....	15	.....	.....	.....
(3) On the latitude of Fargo and Moorhead, 75 miles north of Lake Traverse, east side, in Minnesota.	1,114	15	60	1,065	.....	30	1,002	3	18	983	.....	13
(4) On the latitude of Wahpeton and Breckenridge, 35 miles north of Lake Traverse, west side, in Dakota.	1,065	.....	10	.....	.....	.....	.....	.....	.....	972	.....	4
(4) On the latitude of Wahpeton and Breckenridge, 35 miles north of Lake Traverse, east side, in Minnesota.	1,075	10	20	1,045	.....	10	992	.....	7	.....	.....	.....

THE UPPER OR HERMAN BEACH IN MINNESOTA.[1]

[See the accompanying map, Plate I.]

FROM LAKE TRAVERSE EAST TO HERMAN.

Lake Traverse, elevation 970 feet above the sea.

Bluffs next to Lake Traverse south from the Mustinka River, elevation 1,072 to 1,075 feet above the sea.

Bluffs opposite to these and for 3 or 4 miles northward, on the west side of Lake Traverse, 1,090 to 1,070 feet.

Bluff or ridge forming the highest land between the Mustinka River and the Bois des Sioux River, from Sec. 35 to Sec. 13, T. 128, R. 47 (the west part of Monsen), an island beach ridge of Lake Agassiz during its maximum stage, about 1,050 feet.

Upper or Herman beach in Secs. 2 and 11, T. 126, R. 47 (Walls), 1,060 to 1,062 feet, 4 to 5 miles east from the north end of Lake Traverse, where the steep eroded bluff gives place to the gentle slope of the natural surface, allowing the accumulation of a distinct beach ridge of gravel. This is smoothly rounded, 15 to 20 rods in width, bounded eastward on the side toward the ancient lake by a moderately steep slope which descends 10 or 12 feet, the land 1 to 4 miles distant northeastward within the area that was covered by the lake being 20 to 40 feet below this beach. On the other side this ridge is succeeded by a slight depression 2 to 5 feet deep, beyond which the land soon rises 10 to 15 feet above the beach. The material of the beach is gravel, containing pebbles up to 2 or 3 inches in diameter, but all the surface elsewhere on each side is till.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

FIG. 2. Map of a township, showing its division in sections.

Beach in Secs. 30 and 32, T. 126, R. 46 (Croke), passing southeastward near the southeast corner of Sec. 30, 1,066 to 1,067 feet.

Beach near the middle of Sec. 9, T. 125, R. 46 (Tarrah), 1,057 feet. Its contour and material and those of the adjoining areas are nearly the same as at the locality already described. The width of the gravel beach here is 25 or 30 rods; the smoothed surface of till which descends thence northward is 10 to 20 feet lower in its first mile; on the south the sheet of till is at first for 40 or 50 rods about 5 feet lower than the top of the beach, but beyond this it gradually rises to a height 10 to 25 and 50 feet above the beach. The average height of its moderately undulating surface, 6 miles to the south at Graceville, is nearly represented by the railroad at the depot there, 1,107 feet.

[1] The townships herein referred to are numbered north from the base line, and the ranges are numbered west from the fifth principal meridian. The method of numbering the sections is shown by Fig. 2, above.

Beach at Dennis W. O'Brien's house, in the SW. ¼ of Sec. 11, T. 125, R. 46, 1,061 to 1,062½ feet. Northward from O'Brien's, as far as the view reaches, across T. 126, R. 46 (Croke), and T. 126, R. 45 (Doleysmount), Lake Agassiz was very shallow, the smooth and nearly level surface of till being 1,045 to 1,035 feet above the sea.

For the next 3 miles eastward the beach is less conspicuous than usual. In the northwest part of Sec. 8, the SE. ¼ of Sec. 5, and through the middle of Sec. 4, T. 125, R. 45 (Leonardsville), this shore line is again distinctly marked by a slight terrace in the till, descending northward in a moderately steep slope 5 to 10 feet, rather than by the usual accumulation of gravel. The top of this terrace is at 1,056 to 1,057 feet. The house of Patrick Leonard is built upon the edge of this terrace at the middle of the east side of section 4.

Beach, low gravel ridge 20 rods wide, 5 feet high above adjacent level, in the southeast part of Sec. 24, T. 126, R. 45 (Doleysmount), 1,060 to 1,061 feet.

These determinations indicate that in Traverse County the surface of Lake Agassiz, during its maximum stage, was very nearly 1,045 to 1,055 feet above our present sea level.

In the northwest corner of Stevens County this upper or Herman beach is well displayed in the NW. ¼ of Sec. 19, T. 126, R. 44 (Eldorado), having an elevation of about 1,063 feet. Through Sec. 18 it is 20 to 25 rods wide, with its crest at 1,063 to 1,066 feet, being a gently rounded ridge of sand and gravel, containing pebbles up to 2 or 3 inches in diameter. Its height is 7 to 10 feet above the land next west and 5 feet above the depression next east. The surface on each side is till, slowly falling westward and rising eastward.

In the southeast part of Sec. 7, same township, the crest of the beach is at 1,067 to 1,070 feet. Here and onward the next two miles, through the NW. ¼ of Sec. 8, the southeast part of Sec. 5, and the western and northern part of Sec. 4, this formation is finely exhibited in a ridge of gravel and sand 20 to 30 rods wide, 15 feet or more above its base westward, where lay the glacial Lake Agassiz, and 8 to 10 feet above the depression eastward, which divides it from the higher, moderately undulating expanse of till beyond. In the east part of Sec. 5 its elevation is 1,065 feet, and through Sec. 4, 1,065 to 1,072 feet.

Sill of Ezra S. Dunning's house, Sec. 3, T. 126, R. 44 (Eldorado), 1,074 feet.

Water in the South Branch of Mustinka River, 5 feet deep, in the NW. ¼ of Sec. 34, T. 127, R. 44 (Logan, Grant County), 1,053 feet.

Upper or Herman beach, in the northwest part of Sec. 27, same township, 1,067 to 1,069 feet; in the SW. ¼ of Sec. 22, 1,067; in the north part of this Sec. 22 and the south part of Sec. 15, forming a broad, smoothly rounded gravel ridge, 1,068 to 1,071 feet.

This beach near the middle of Sec. 15, a third of a mile southwest from Dr. C. O. Paquin's, about 30 rods wide, with a broad, nearly flat

top, 1,070 feet, having a descent of about 15 feet on its northwest side to the area of Lake Agassiz and half as much on the southeast, the surface thence rising very gradually in the 1½ miles eastward to Herman. The beach ridge is gravel; the land at each side, till.

Beach, equally well exhibited, close to Dr. Paquin's house, at the southeast corner of Sec. 10 and in the southwest part of Sec. 11, same township, 1,069 to 1,071 feet; and in this Sec. 11, at the railroad, and for 50 rods southwestward, 1,064 to 1,066 feet.

Depression, 40 rods wide, next southeast at the railroad (lowest 20 rods from the top of the beach), 1,060 to 1,063 feet.

Surface of till at the southeastern snow fences of the railroad, about a third of a mile southeast from the beach, 1,073 feet; at the northwest end of the northwestern snow fences, about 25 rods northwest from the highest part of the beach, 1,054 feet; and at the one hundred and eightieth mile post, about a quarter of a mile northwest from the last, 1,049 feet.

Saint Paul, Minneapolis and Manitoba Railway, Breckenridge division, track at Herman, 1,070 feet; at the one hundred and eightieth mile post, 1,051 feet.

FROM HERMAN NORTH TO THE RED RIVER.

Joseph Moses's house, floor of piazza, in the SW. ¼ of the NW. ¼ of Sec. 18, T. 128, R. 43 (Delaware), 1,067 feet; upper or Herman beach here, on which this house is built, 1,066 to 1,067 feet.

H. D. Kendall's house, at the east side of the SE. ¼ of Sec. 12, T. 128, R. 44 (Gorton), on the western slope of this beach, 1,062 feet; top of the beach ridge, about 25 rods east of Mr. Kendall's house, 1,067 feet.

Beach through the next 1½ miles north from Mr. Moses's house, along the west side of Secs. 18 and 7, T. 128, R. 43 (Delaware), 1,066 to 1,068 feet. The beach for this distance is finely exhibited, having a width of about 25 rods, rising 5 to 8 feet above the depression at its east side and 10 to 15 feet above the land west.

L. I. Baker's house sill, in the SW. ¼ of Sec. 6, same township, of same height with the top of the beach ridge, on which it is built, 1,068 feet.

Beach in Sec. 31, T. 129, R. 43 (Elbow Lake), not so conspicuous as usual, 1,066 feet; in (or near) the SW. ¼ of Sec. 19, same township, 1,070 feet; in the SW. ¼ of Sec. 18, at the house of Henry Olson, a gracefully rounded low ridge, as elsewhere, composed of gravel and sand, including pebbles up to 3 inches in diameter, 1,065 to 1,066 feet; at Mrs. John S. Ireland's, in the NW. ¼ of same Sec. 18, 1,070 feet; at Dr. J. M. Tucker's, in the NE. ¼ of the NE. ¼ of Sec. 2, T. 129, R. 44 (North Ottawa), 1,071 feet; about 1 mile north of the last, near the north side of Sec. 35, T. 130, R. 44 (Lawrence), 1,075 feet; and about 1 mile farther north, also 1,075 feet. Through nearly the whole of this distance it is a typical beach ridge of sand and gravel.

Beach about 30 rods west of M. L. Adams's house, in the NE. ¼ of Sec. 26, T. 130, R. 44 (Lawrence), 1,075 feet, being 4 feet above the

land adjoining this ridge on the east and about 10 feet above the flat land near on the west; in Sec. 23, same township, 1,076 feet; and near the south side of Sec. 10, same township, 1,069 to 1,074 feet.

Extensive sloughs or marshes occur in Sec. 36 and in Secs. 25 and 24, same township, each being about a mile long, lying on the east side of the beach ridge at Dr. Tucker's and reaching 2½ miles northward; the elevation of these above sea level is about 1,060 feet.

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

Beach in Sec. 34, T. 131, R. 44 (Western), the southwest township of Otter Tail County, near John F. Wentworth's, 1,070 to 1,075 feet; surface at Mr. Wentworth's barn, 1,072 feet.

Beach 25 rods east of Albert Copeland's house, in the SW. ¼ of Sec. 28, same township, 1,070 to 1,066 feet; where it is crossed by the old road from Fergus Falls to Campbell, near the northwest corner of this Sec. 28, 1,072 feet; through the next 2 miles north, finely developed, with nearly constant height, 1,072 feet, being 7 to 10 feet above the depression at its east side and 20 feet above the area westward, which was covered by Lake Agassiz; at Michael J. Shortell's, Sec. 9, same township, 1,073 feet; one mile farther north, 1,078 feet; and at A. J. Swift's, in the SE. ¼ of the NW. ¼ of Sec. 4, 1,076 feet. The beach at Mr. Swift's, and for half a mile farther north, is well exhibited and, as in many other places, is bordered on its east side by a narrow strip of marsh.

Beach in the SW. ¼ of the NE. ¼ of Sec. 33, T. 132, R. 44, 1,076 feet; top of large aboriginal mound, situated on the beach here, 1,082 feet; land 30 rods west, 1,060 feet; lakelet 250 feet in diameter, about an eighth of a mile northeast from the large mound, 1,051 feet.

Red River of the North, near the northeast corner of Sec. 33, T. 132, R. 44, 1,014 feet; on the line between this township and T. 132, R. 43 (Buse), 1,041 feet; at Dayton bridge, in the NE. ¼ of the SW. ¼ of Sec. 20, T. 132, R. 43, 1,064 feet, being 8 feet below the bridge. S. A. Austin's house, foundation, in the NW. ¼ of the SW. ¼ of Sec. 29, same township, 1,147 feet. Old grade for railroad at Dayton bridge, about 1,102 feet.

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

FROM THE RED RIVER NORTH TO MUSKODA.

Beach near the south side of Sec. 21, T. 132, R. 44, 1,077 feet; in this Sec. 21, an eighth of a mile north of the road from Fergus Falls to Breck-

enridge, 1,079 feet; and for the next mile north, 1,077 to 1,080 feet. This is a typical beach ridge, gently rounded, composed of sand and gravel, containing pebbles up to 3 inches in diameter; its width is 30 to 40 rods, and its height above the very flat area on its west side, which was covered by Lake Agassiz (usually somewhat marshy next to the beach), is about 15 feet. On the east there is first a depression of 4 to 6 feet, succeeded within a fourth of a mile eastward by a gentle ascent, which rises 5 to 10 or 15 feet above the beach. The material on each side of the beach is till, slightly modified by the lake on the west. It is all fertile prairie, beautifully green, or in many places yellow or purple with flowers during July and August, the months in which this survey was made. In August, 1881, no houses had been built on this beach, nor within one mile from it, along its first 11 miles north from the Red River, the first house found near the beach being in Sec. 26, T. 134, R. 45 (Akron), in Wilkin County.

Beach at a low portion, probably in the SE. ¼ of Sec. 5, T. 132, R. 44, 1,075 feet. A lake, nearly a mile long, lies on the flat lowland about one and a half miles west from this low part of the beach. The elevation of this lake was estimated at 1,055 or 1,050 feet; it is only a few feet lower than the general surface around it.

Beach, probably near the north side of this Sec. 5, 1,078 feet. On its east side here and for a half mile both to the south and north is a slough, partly filled with good grass and partly with rushes; its width is about a quarter of a mile and its elevation about 1,070 feet. The land west of the beach descends, within 1 or 2 miles, from 1,060 to 1,050 feet.

Beach a fourth of a mile north from the point last noted, 1,071 to 1,072 feet. This is a typical gravel beach, only 4 feet above the slough on the east and bordered on the west by marshy grassland, which slopes gently down 5 to 15 feet below this beach ridge.

Beach at its lowest portion for this vicinity, within a third of a mile north of the preceding and near the center of Sec. 32, T. 133, R. 44 (Carlisle), 1,070 to 1,068 feet, being only 2 feet above the marsh or slough on its east side. A railroad grade, abandoned, lies a third of a mile east of this. Beach a fourth of a mile farther north, 1,077 feet, and, about one mile north from its lowest portion, 1,075 feet, cut by a ravine, the bottom of which is nearly at 1,063 feet. This ravine is some 30 rods west of the abandoned railroad embankment. Beach a fourth of a mile north-northwest from the last, 1,077 feet.

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

Beach near the west side of Sec. 7, same township, at the west line of Otter Tail County, 1,083 feet. Here it is a smoothly rounded gravel ridge about 15 feet above the edge of the flat area that was covered by Lake Agassiz on the west and 10 feet above a marsh or slough that lies a few rods distant on its east side.

Sill of Rudolph Niggeler's house, in the SE. ¼ of Sec. 26, T. 134, R. 45 (Akron), 1,076 feet. This is on a portion of the beach extending about a third of a mile from south to north; a quarter of a mile to the north its elevation is 1,082 feet. In the northeast part of Sec. 35 and in the north half of Sec. 26 this beach is interrupted by sloughs, which take its place for a quarter of a mile.

Beach in the south half of Sec. 23, same township, 1,079 to 1,080 feet; in the NW. ¼ of this Sec. 23, 1,075 to 1,080 feet.

Through Secs. 14, 10, and 3, same township, the beach does not have its ordinary ridged form, but is mostly marked by a deposit of gravel and sand lying upon a slope that rises gradually eastward. Its elevation here is 1,075 to 1,085 feet. In the southern part of this distance, probably in the SW. ¼ of Sec. 14, the margin of the flat, somewhat marshy area that appears to have been covered by Lake Agassiz is very definite at 1,075 feet, which thus was probably the height of the lake here.

Beach in the SW. ¼ of Sec. 34, T. 135, R. 45 (Tanberg), composed of gravel, nearly flat, 25 to 30 rods wide, 1,084 to 1,087 feet, bordered by a depression of 2 to 5 feet on the east and by an expanse 10 to 15 feet lower on the west.

Beach in the NW. ¼ of this Sec. 34, 1,084 to 1,087 feet. Here the land next east does not present the usual slight hollow dividing the beach ridge from the higher land eastward; instead is a springy belt, mostly 1,089 feet, quite marshy, yet slowly rising 2 to 4 feet above the belt of beach gravel. Occasional hummocks, about 2 feet above the general surface and covered with rank grass about 6 feet high, form part of this belt of marsh and shaking bog. Next to the east is a slough about 1,086 feet, or 3 feet below the springy tract; and this is succeeded by a surface of moderately undulating till, which rises gradually eastward.

Martin E. Renkliv's house sill, in the SW. ¼ of Sec. 22, same township, 1,094 feet. Shore line of Lake Agassiz, an eighth of a mile west of Mr. Renkliv's, on the border of a marshy flat area, not marked by any distinct gravel ridge, about 1,075 feet.

Sloughs, mostly filled with rushes and having areas of water all the year, occupy a width of 1 to 2 miles next west of the shore line and beach of Lake Agassiz and extend nearly continuously 10 miles from south to north from the middle of T. 134, R. 45 (Akron), to the south edge of T. 136, R. 45 (Prairie View). The elevation of this belt of sloughs is 1,080 to 1,050 feet, being considerably lower on its west than on its east border. The highest land westward in the west edge of T. 135, R. 45 (Tanberg), between these marshes and Manston, is about 1,060 feet. Along most of this distance the ordinary beach ridge is wanting.

Saint Paul, Minneapolis and Manitoba Railway, Fergus Falls division, track at Lawndale water tank, in or near the southeast corner of Sec. 33, T. 136, R. 45 (Prairie View), 6 miles northwest from Rothsay and 8 miles southeast from Barnesville, 1,088 feet. Here a sidetrack has been laid, extending about a third of a mile northward, with its northern end some 50 rods east of the main line, to take ballast from the beach, which is well exhibited here and onward, having its typical ridged form. The elevation of its crest is 1,091 to 1,094 feet. It is composed of gravel and sand in about equal amounts, interstratified mainly in level layers, but with these often obliquely laminated. Most of the gravel is quite fine, and the coarsest gravel found here has pebbles only 2 to 3 inches in diameter. About half of it is limestone.

Beach ridge, 1 mile farther north, 1,094 feet; three-fourths of a mile north of the last and close south of a ravine, 1,099 feet.

Beach about 3 miles north from Lawndale water tank, probably in the south part of Sec. 16, T. 136, R. 45 (Prairie View), not ridged, but a belt 25 rods wide, of gravel and sand, on a slope of till that rises eastward, 1,080 to 1,102 feet. Beach, a ridge of gravel and sand, a third of a mile north from the last, 1,105 feet. The beach in Sec. 9 of this township is spread more broadly than usual, its higher parts being 1,095 to 1,107 feet. Here the beach deposits are crossed obliquely by several broad depressions 10 to 15 feet deep, running south-southwest. The depression east of all these banks of gravel and sand is about 1,090 feet above the sea.

Beach, a well marked ridge of gravel of the usual character, in the SW. ¼ of Sec. 4, same township, 1,096 to 1,098 feet, and at John Hart's house, in the NW. ¼ of this Sec. 4, 1,103 feet.

Entering Clay County, the elevation of this upper or Herman beach at the east side of Sec. 33, T. 137, R. 45 (Humboldt), is 1,100 feet above the sea. The land thence for two-thirds of a mile east is low and smooth, not higher than the beach. Beyond this the next third of a mile northeastward, in the north part of Sec. 34, is very rocky, with many bowlders up to 6 and rarely 10 feet in diameter, the contour being moderately rolling 10 to 30 or 40 feet above the beach. Farther eastward here and through the next 15 miles north to the Northern Pacific Railroad, the moderately rolling or smoothly hilly till rises 100 to 250 feet above this beach within the distance of about 10 miles between it and the east line of the county.

Elevation of the beach ridge in the east half of Sec. 28, T. 137, R. 45 (Humboldt), one-fourth to three-fourths of a mile south of Willow River, 1,098 to 1,100 feet. In the 3 miles westward to Barnesville the area that was covered by Lake Agassiz shows here and there bowlders projecting 1 to 2 feet above the surface, which is till, slightly smoothed by the lake.

Saint Paul, Minneapolis, and Manitoba Railway, track at Barnesville, 1,007 feet.

The beach for three-fourths of a mile north from Willow River consists of a belt of gravel and sand, lying on an eastwardly ascending slope of till. Through the next 1½ miles northward, in the NW. ¼ of Sec. 22 and in Sec. 15, T. 137, R. 45 (Humboldt), the shore of Lake Agassiz is not marked by the usual beach of gravel and sand, but instead becomes a belt of marshy and springy land 20 to 50 rods wide, rising by a gentle slope eastward, rough with many hummocks and hollows, in some portions forming a quaking bog, in which horses and oxen attempting to cross are mired.

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

Highest part of southern island in the east edge of Lake Agassiz, in the NE. ¼ of Sec. 5, T. 137, R. 45 (Humboldt), extending northward into T. 138, R. 45 (Skree), 1,117 to 1,122 feet. This island was about a mile long from south to north. Beach on its west side, a well developed ridge of gravel, near the middle of the north line of Sec. 5, 1,095 feet; and for a third of a mile north-northwest from this, 1,094 to 1,096 feet. On the east side of the beach, as it continues northward, is a slough two-thirds of a mile long from south to north and about 30 rods wide, 1,085 feet. This was evidently filled by a lagoon, sheltered on the southeast by the island and separated from the main lake by the beach. Toward the northeast it widened into a shallow expanse of water, 8 to 15 feet deep, about 1½ miles wide, divided from the broad lake on the west by two islands and this beach, or bar, which connected them. Lake Agassiz here appears to have stood at the height of 1,090 to 1,095 feet.

Beach or bar in the north part of Sec. 32, T. 138, R. 45 (Skree), a broad rounded ridge of gravel, with pebbles up to 3 or 4 inches in diameter, 1,103 feet, and through the next half mile, in the south half of Sec. 29, 1,102 to 1,104 feet. Along part of this distance the beach ridge is bounded eastward by a steeper descent than usual, the land next east being 1,085 to 1,090 feet above the sea. This beach or bar continues northward in a typical ridge through Secs. 29 and 20, same township.

Beach or bar at L. Williams's house, in the SW. ¼ of the SE. ¼ of Sec. 20, same township, 1,101 feet; a quarter of a mile farther north, 1,106 feet; three-quarters of a mile north of Mr. Williams's, near the middle of the north line of Sec. 20, 1,110 feet, continuing a very definite ridge through the south half of Sec. 17, 1,109 to 1,110 feet.

Near the middle of this Sec. 17 the beach deposit of gravel and sand ceases at the west side of the northern island, which was situated in

the east half of this section and extended also eastward in a long, low projection nearly across the south side of Sec. 16, and northward half way across Sec. 8. Highest part of this island, in or near the NE. ¼ of the NW. ¼ of Sec. 17, about 1,125 feet. The old shore of the north half of this island has no beach ridge nor other deposits of gravel and sand, but is plentifully strewn with large bowlders up to 5 and 10 feet in diameter, and many of these project 2 to 5 feet above the general surface. The lake waves eroded here and deposited the sand and gravel gathered from this till as a beach a little farther south.

North and northeast from this northern island a lower expanse, nearly level and in some portions marshy, resembling the broad flat valley of the Red River, extends 1½ miles to the east shore of Lake Agassiz, its height being 1,075 to 1,090 feet, or 10 to 25 feet below the surface of the ancient lake. The distance between these islands was 2 miles, and the distance from the summit of the first to that of the second, nearly due north, 4 miles. Each of them rose about 25 feet above Lake Agassiz. The strait between them and the mainland eastward was 10 to 20 feet deep and from 1 to 1½ miles wide, excepting a narrow place near the southeast corner of Sec. 16. East of the northern island the main shore of the lake was indented by a bay a third to a half of a mile wide and about 10 feet deep, stretching 2½ miles southeastward from the lake at the northwest corner of Sec. 10 to the west part of Sec. 23, same township. The shore of the lake east of its islands along this bay and northwesterly to the north line of this township lacks the beach deposits which elsewhere distinguish it.

In its continuation northwestward the shore line of the old lake runs diagonally across Sec. 32, T. 139, R. 45 (Hawley), where it again presents the anomalous character of a very springy and marshy belt, 20 to 40 rods wide, rough with hummocks and in many places so deeply miry that it is dangerous for teams. This boggy tract has a gentle descent westward, its lower portion being about 1,085 feet, and its upper border, very nearly level across this entire section, being 1,098 to 1,100 feet, which was almost exactly the height of Lake Agassiz, as shown by its distinct beach of gravel and sand at the south and north. Next eastward rises a moderately undulating slope of till, strewn with abundant bowlders; and rarely a bowlder, 2 to 5 feet in diameter, is seen on the springy land that marks the border of the ancient lake.

DELTA OF THE BUFFALO RIVER.

The delta brought into the east side of Lake Agassiz by the Buffalo River extends about 5 miles southwestward from Muskoda, forming a continuously descending plain of stratified sand and fine gravel, declining from 1,100 feet near Muskoda to 1,073 feet at its southwestern limit in the north part of Sec. 34, T. 139, R. 46 (Riverton). Here and northward along a distance of 3 miles to the Buffalo River, this delta

plain is terminated by a steep slope like the face of a terrace; the outer portion of the original delta, beyond this line, has been carried away by the waves and shore currents of the lake when it stood at the lower level marked by the Norcross beach.

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

FROM MUSKODA NORTH TO THE WILD RICE RIVER.

Beach in the next 2 miles north of Muskoda, mainly 1,113 to 1,125 feet; at its lowest depression, about 1 mile north of Muskoda, 1,105 feet; at William Perkins's house, in the SE. ¼ of the SE. ¼ of Sec. 30, T. 140, R. 45 (Cromwell), 1,122 feet; an eighth to a third of a mile south-southeast from Mr. Perkins's, 1,130 feet. A nearly or quite continuous depression, from a fifth to a third of a mile wide, lies at the east side of this beach, declining in elevation from 1,118 feet, near Mr. Perkins's house, to 1,100 feet at Muskoda. This distance is about 3 miles.

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

Beach through the north half of Sec. 30, T. 140, R. 45, 1,128 to 1,131 feet, and through the west part of Secs. 19 and 18, same township, 1,125 to 1,130 feet, composed of sand and fine gravel, not generally in a typical ridge, but often with a depression 2 to 5 feet lower eastward and bounded on the west by a descent of about 30 feet within an eighth of a mile. A surface of slightly undulating till rises very gradually from this beach eastward.

In T. 139, R. 46 (Riverton), and in Secs. 35 and 26, T. 140, R. 46, the eroded western border of the delta of Buffalo River marks the shore of Lake Agassiz at the time of the Norcross beach.

In the west part of Sec. 24, T. 140, R. 46, and for 4 miles northward, the Norcross beach lies only 1 mile to a half mile west of the upper beach and is about 50 feet lower. The terracelike area between these beaches is strewn with occasional bowlders up to 6, 8, or 10 feet in diameter and rarely of larger size, much more abundant than upon the average surface of the till in this region, indicating that the surface

there has been considerably eroded by the waves of the lake. The largest bowlder seen in Clay County lies about 50 rods west of the upper beach, in or near Sec. 12, T. 140, R. 46. Its dimensions are 15 by 12 by 5 feet and its top is 1,095 feet above the sea. It is gneiss, minutely porphyritic, with white feldspar crystals up to an eighth or a quarter of an inch long.

The elevation of the foot of the western slope of the upper or Herman beach along the north part of the east line of T. 140, R. 46, is 1,095 to 1,100 feet. Crest of the Norcross beach in Sec. 12, T. 140, R. 46, 6 miles north of Muskoda, 1,080 feet, and along the distance of 3 miles through Secs. 13, 12, and 1, it varies from 1,075 to 1,085 feet. In Sec. 31, T. 141, R. 45 (Keon), its height is 1,085 feet. Like the Herman beach, it is a low, smoothly rounded ridge of gravel and sand, usually having a depression of 3 to 5 feet or more at its east side.

Upper or Herman beach at a high portion in or near the SE. ¼ of Sec. 1, T. 140, R. 46, 1,136 feet. For a mile next south from this point, it is a finely rounded ridge of gravel rising northward from 1,130 to 1,136 feet. The depression at its east side is 4 to 6 feet lower; then the surface gently rises at a quarter to a third of a mile from the beach to 1,135 or 1,140 feet, beyond which eastward this nearly level but slightly undulating expanse of till rises only 5 or 10 feet a mile.

Beach a fourth of a mile north-northeast from the high point mentioned, probably in the NW. ¼ of Sec. 6, T. 140, R. 45 (Cromwell), 1,128 to 1,127 feet. This is an ordinary beach ridge of gravel and sand, with a depression of 2 or 3 feet next east.

Near the south line of Sec. 29, T. 141, R. 45 (Keon), both the Herman and Norcross beaches, here about two-thirds of a mile apart, are intersected by a watercourse. At its north side the upper or Herman beach, near the east line of Sec. 29 and in the NW. ¼ of Sec 28, consists of two well marked ridges of gravel and sand, some 30 rods apart and about 10 feet above the land eastward and between them. These ridges unite in or near the SW. ¼ of the SW. ¼ of Sec. 21, at the height of 1,130 to 1,132 feet.

Beach three-fourths of a mile farther north, probably near the north line of Sec. 21, a typical gravel ridge, 1,134 feet, 10 feet above the land next east; but a sixth of a mile farther northeast this beach ridge is depressed to 1,123 feet.

A lower beach, contemporaneous with the Herman beach farther south, but formed when the surface of the lake in this latitude had fallen slightly from its highest level, is finely exhibited, at a distance of one-third to two-thirds of a mile west from the upper beach, through the 4 miles from the south side of Sec. 20 to the northeast corner of Sec. 4, same township. The elevation of this secondary beach in the south part of Sec. 20 is 1,115 feet; thence to a stream near the east line of the SE. ¼ of Sec. 17, 1,118 to 1,123 feet; at each side of this stream, 1,118 feet;

northward, in the northwest part of Sec. 16 and in the SW. ¼ of Sec. 9, 1,118 to 1,121 feet; and in the north part of Sec. 9, 1,121 to 1,127 feet.

The elevation of the upper beach in T. 141, R. 45 (Keon), 1,123 to 1,137 feet, shows that the height of Lake Agassiz here, during its maximum stage, was about 1,120 feet. The secondary beach was made by the lake after it had fallen 6 to 10 feet.

Surface of ground at Christian Sether's house, in the SW. ¼ of Sec. 10, 1,129 feet. Upper beach through the west part of this Sec. 10, 1,130 to 1,137 feet, increasing in height from south to north. This is a typical beach ridge of gravel, with a rather abrupt descent on its east side to land 6 or 8 feet lower, which thence ascends with a slightly undulating surface eastward.

Upper beach in Sec. 3, same township, 1,134 to 1,137 feet, 10 feet above the land next east. Secondary beach, parallel with this and about three-fourths of a mile distant to the northwest, in Secs. 4 and 34, 1,123 to 1,127 feet, being thus 10 feet lower than the highest parts of the eastern beach. Extensive sloughs, inclosing lakelets, lie between these beaches in Secs. 34 and 35, T. 142, R. 45 (Hagen), at an elevation of 1,115 to 1,120 feet, but sinking northward to 1,105 feet. The secondary beach continues to the northeast corner of Sec. 26, declining in height northeastward as it approaches the South Branch of the Wild Rice River, being at 1,125 to 1,115 feet.

Upper beach in Sec. 35 and in the south part of Sec. 25, T. 142, R. 45, 1,140 to 1,142 feet. This is a typical beach ridge of sand and gravel, about 30 rods wide, with the land next southeast 5 to 8 feet lower, and divided from the secondary beach northwesterly by a slough about 1 mile wide, this slough being at 1,115 to 1,105 feet.

Beach at B. O. Helde's house, in the south half of the SW. ¼ of Sec. 30, T. 142, R. 44 (Ulen), 1,138 feet. The flat expanse of the Red River Valley reaches east on the South Branch of the Wild Rice River to Sec. 16, T. 142, R. 45 (Hagen), probably being there about 975 feet above the sea, or 160 feet below this upper beach of Lake Agassiz, 4 or 5 miles southeast.

Beach through Secs. 30 and 29, T. 142, R. 44 (Ulen), extending 1½ miles east-northeast from Mr. Helde's to the South Branch of the Wild Rice River, in a low, gently rounded ridge of gravel, 30 rods wide, 5 to 8 feet above the area of till next southeast and about 15 feet above the surface close at its northwest side, 1,138 to 1,142, mostly 1,140, feet.

Beach at Nels Wiger's house, probably in the NW. ¼ of Sec. 28, 1,133 feet; about 40 rods west from this, 1,140 feet.

South Branch of Wild Rice River, in the SW. ¼ of Sec. 21, same township, 1,095 feet.

Beach, a typical gravel ridge, in or near the west half of Sec. 16, a half mile to 1½ miles north of the South Branch, 1,140 to 1,143 feet; surface of till an eighth to a quarter of a mile next east, 1,135 feet. Farther east the slightly or moderately undulating expanse of till has

an average ascent of about 10 feet a mile for 15 miles to the base of the high land at the White Earth Agency, which is dimly visible, blue, close to the horizon. Westward the surface gradually descends to the Norcross beach, nearly 60 feet lower, which is the farthest land in sight in that direction, about 3 miles distant, beyond which lies the flat Red River Valley.

Beach, a well defined ridge, in Secs. 9 and 4, T. 142, R. 44 (Ulen), 1,139 to 1,144 feet.

Entering Norman County, an unusually high portion of the beach is found in or near the SE. ¼ of the SE. ¼ of Sec. 33, T. 143, R. 44 (Home Lake), having its crest at 1,149 feet. It holds this elevation for an extent of some 20 rods, on each side of which its height is mostly from 1,139 to 1,145 feet. Its material is coarse gravel, principally limestone, with pebbles up to 4 and 6 inches in diameter. Surface close east of this beach, 1,137 feet. A slight swell above the general descending slope westward, about 2 miles distant, has a height very nearly 1,125 feet. This may be the continuation of the secondary beach that was seen in T. 141, R. 45 (Keon). It hides the view farther west, except from the highest point of the beach (1,149 feet), where the distant belts of timber along the Red and the Wild Rice Rivers are visible.

Beach at J. T. Huseby's house, in the SW. ¼ of the NW. ¼ of Sec. 26, T. 143, R. 44 (Home Lake), 1,147 feet; through 1¼ miles next north, in the NW. ¼ of Sec. 26 and the west part of Sec. 23, forming a broad, low ridge of gravel and sand, 1,145 to 1,149 feet.

In or near Secs. 17 and 16, T. 143, R. 43 (Flom), a prominent massive hill, called "Frenchman's Bluff," of somewhat irregular form, composed of morainic till, rises 150 feet or more above this beach.

Through the W. ½ of the NW. ¼ of Sec. 14, T. 143, R. 44 (Home Lake), the beach is mostly a typical gravel ridge, with its crest at 1,147 to 1,152 feet. In the NW. ¼ of Sec. 11, same township, it curves northeastward and attains an unusually massive development, its crest being at 1,150 to 1,158 feet, rising 15 feet above the land next southeast and 30 feet above the border of the area of Lake Agassiz at its northwest side.

Beach, a well marked gravel ridge near the southwest corner of Sec. 1, same township, 1,156 feet, and an eighth of a mile east-northeast from this, 1,150 feet.

J. G. Aurdal's house, foundation, in the NW. ¼ of the NE. ¼ of Sec. 6, T. 143, R. 43 (Flom), 1,148 feet. This is situated on the beach, which here is a deposit of gravel and sand 8 feet or more in depth, lying upon a slope of till that ascends southeastward.

Anton Johnson's store, foundation, on this beach, in the SE. ¼ of the SE. ¼ of Sec. 31, T. 144, R. 43 (Fosum), 1,142 feet.

Creek flowing northwesterly between the last two, about 1,105 feet.

Wild Rice River, 2 miles north of Johnson's store, approximately 1,075 feet.

Secondary Herman beach, a well marked, broad, smoothly rounded gravel ridge, extending from southwest to northeast, crossed by the township line road at the north side of the NE. ¼ of the NW. ¼ of Sec. 2, T. 143, R. 44 (Home Lake), 1,137 feet. It is about 30 rods wide and rises 5 to 10 feet above the depression at its southeast side.

FROM THE WILD RICE RIVER NORTH TO MAPLE LAKE.

A broad belt of timber borders the Wild Rice River, lying mostly on its north side, in T. 144, R. 43 (Fosum), and T. 144, R. 44 (Wild Rice), and at the time of this survey, in 1881, no road nor bridge afforded a crossing here. Therefore this series of levels was resumed north of the Wild Rice River by starting from Rolette Station of the Saint Paul, Minneapolis and Manitoba Railway, 890 feet above the sea, near the middle of Sec. 17, T. 146, R. 46 (Lockhart), about 1½ miles north of the Lockhart farm. Proceeding eastward from this point, the first observations of the upper beach were in T. 145, R. 43 (Waukon); T. 146, R. 44 (Sundal); and T. 147, R. 44 (Garfield).

This beach is intersected by the Wild Rice River near the middle of T. 144, R. 43 (Fosum), and thence it passes north-northwesterly through the west part of T. 145, R. 43 (Waukon). In Secs. 7 and 6, same township, it is a low smooth ridge of gravel and sand about 25 rods wide, rising 5 to 10 feet. In the west half of this Sec. 6 and in Sec. 36, T. 146, R. 44 (Sundal), the old Pembina trail lies on it.

About 2 miles west of the upper beach, a secondary Herman beach, of similar material and contour, probably 20 feet lower, was observed a few rods east of the stake at the middle of the north side of Sec. 14, T. 145, R. 44 (Strand), having a height of 6 to 8 feet above its base, with a smaller ridge of sand and gravel, 3 feet high above its base, close west of this stake. Again, a half mile farther west, in the northeast corner of Sec. 15, same township, another Herman beach, probably 10 feet below the last, was noted, having a height of 4 or 5 feet above its base.

Traveling northwestward along the Pembina trail, the upper beach ridge was not distinctly observed after leaving Sec. 36, T. 146, R. 44 (Sundal), until it is again occupied by the trail in Sec. 9 of this township. The intervening 3 miles are flat and nearly level. Probably the beach, less noticeable than usual, lies within a half or 1 mile east of the trail here. In the eastern part of Sec. 9 this beach is about 25 rods wide, rising 5 feet from its east side and descending 10 feet to its western base, which was the margin of Lake Agassiz.

Thence the upper beach extends nearly due north through the east edge of Sec. 4, same township, and Sec. 33, T. 147, R. 44 (Garfield). In the east edge of the SE. ¼ of Sec. 28 and the west edge of the NW. ¼ of Sec. 27, T. 147, R. 44, it is a typical ridge of gravel and sand, with its crest 1,166 to 1,173 feet above the sea. There is a gradual descent toward the west. The depression on the east is a sixth to a fourth of a mile wide,

sinking 6 to 10 feet below the beach. Farther eastward the land is moderately undulating till, rising 20 to 30 feet above the beach and bearing frequent groves of small poplars, bur oak, and canoe birch.

Water in Sand Hill River, at the ford of the old Pembina trail, in the west part of Sec. 28, T. 147, R. 44, ordinary low stage, July 26, 1881, 1,071 feet.

Even Grödvig's house threshold, at the top of the bluff north of this ford, in the north half of the NW. ¼ of this Sec. 28, 1,136 feet.

When Lake Agassiz stood at its greatest height, the Sand Hill River brought into its margin a delta 6 miles long from south to north and 3 miles wide, reaching from the upper beach to the west side of T. 147, R. 44 (Garfield), and T. 146, R. 44 (Sundal). This westwardly sloping deposit of stratified gravel and sand has about an equal area and thickness with the delta of the Buffalo River at Muskoda. Upon this delta plain dunes have been heaped up by the winds, probably before vegetation had spread over this area after the withdrawal of the glacial lake.

In the south half of Sec. 32, T. 147, R. 44 (Garfield), and in a belt which thence extends approximately north and south, the sand of this delta, as originally deposited, rises eastward with a slope of 25 or 30 feet in 1 mile, from 1,100 to 1,125 or 1,130 feet above the sea. Beneath this plane, however, channels have been eroded by the winds and sand-hills 25 to 75 feet above it have been blown up in irregular groups and series, scattered over a tract about a mile wide and extending 3 or 4 miles southward from the Sand Hill River, in Sec. 29, the northeast part of Sec. 30, and in Secs. 31 and 32, T. 147, R. 44 (Garfield), and reaching southward in Secs. 5 and 8, T. 146, R. 44 (Sundal). The most southern of these hills is an isolated group in the east part of the NE. ¼ of Sec. 18, T. 146, R. 44 (Sundal). Another isolated group lies north of the Sand Hill River, in the NW. ¼ of Sec. 16, T. 147, R. 44 (Garfield). These sand dunes are in part bare, being so frequently drifted by the winds as to allow no foothold for vegetation; other portions are clothed with grass or with bushes and scanty dwarfed trees, including bur oak, the common aspen or poplar, cottonwood, green ash, black cherry, and the frost grape.

Elevations of the highest points of these dunes, in order from south to north, are approximately 1,190, 1,180, and 1,200 feet. The highest dune appears to be in or near the east half of the NE. ¼ of Sec. 30, T. 147, R. 44 (Garfield).

Secondary Herman beach, a smoothly rounded ridge of gravel and sand 10 to 15 feet high above the adjacent level, 1,148 to 1,153 feet above the sea, about three-fourths of a mile east of the old Pembina trail, in the west half of Secs. 21 and 16, T. 147, R. 44 (Garfield), extending 1½ miles north from the Sand Hill River to the cluster of dunes in the NW. ¼ of Sec. 16.

Upper Herman beach, the first of the series which was here formed contemporaneously with the single Herman beach farther south, run-

ning approximately from south to north through or near the northeast corner of Sec. 4, T. 147, R. 44 (Garfield), a smooth gravel ridge, in some parts hidden by scattered groves, 1,165 to 1,175 feet. Farther east is a large area of woodland. Second Herman beach, in the east part of Sec. 5, same township, and Sec. 32, T. 148, R. 44 (Godfrey), about a mile west from the upper beach, 1,149 to 1,153 feet; this is a ridge of gravel and sand, about 40 rods wide, with very gentle, prolonged slopes toward both the east and the west. Natural surface at the northeast corner of Sec. 32, T. 148, R. 44 (Godfrey), 1,146 feet. Third Herman beach, running north, in the NW. $\frac{1}{4}$ of Sec. 5, T. 147, R. 44 (Garfield), and the west part of Sec. 32, T. 148, R. 44 (Godfrey), a half or two-thirds of a mile west from the last, 1,130 to 1,135 feet, consisting of a distinct ridge in its southern part, but farther north being a flat area of gravel and sand slightly elevated above the land next east.

Second Herman beach, a broad low ridge of gravel and sand, extending north-northeast through Sec. 28, T. 148, R. 44 (Godfrey), from its southwest corner to its north line, 1,148 to 1,150 feet. The northward continuation of this beach is a low, flattened ridge, the western one of two parallel ridges of gravel below that of the upper beach, extending northeasterly and northerly through or near the west edge of Sec. 10, same township, 1,150 to 1,154 feet. Through the next 3 miles in Sec. 3, same township, and in the east part of Secs. 35 and 26 and the NW. $\frac{1}{4}$ of Sec. 25, T. 149, R. 44 (Tilden), it is a prominent beach ridge, with its crest at 1,153 to 1,161 feet, somewhat steep on its east side, which descends about 10 feet to a belt of lowland and marsh that divides it from the parallel beach a quarter to a third of a mile east.

The eastern of these parallel beach ridges is only 8 or 10 feet below the average elevation of the upper beach. It probably marks a slight fall in the water surface at this latitude; but, as no corresponding beach formation has been observed in Dakota, it is neglected in the foregoing table of elevations of the beaches of Lake Agassiz. It is clearly continuous 8 miles, the first 4 miles extending northerly and the next 4 miles easterly. These parts are connected in Sec. 25, T. 149, R. 44 (Tilden), by a graceful curve, that portion of this beach and its extent thence eastward being known as the "Attix ridge," from Henry and William Attix, brothers, who have built their houses upon it. In its northward course, nearly through the middle of Secs. 10 and 4, T. 148, R. 44 (Godfrey), its crest is at 1,158 to 1,163 feet; in the west edge of Sec. 36, T. 149, R. 44 (Tilden), and along its curved course to the northeast and east at the west and north sides of Sec. 25 and in the southeast part of Sec. 24, same township, 1,163 to 1,168 feet, and in Secs. 21 and 22, T. 149, R. 43 (Grove Park), 1,171 to 1,173 feet. Slough, a third to a half of a mile wide, extending along the east side of this beach, in Sec. 3, T. 148, R. 44 (Godfrey), and in the southeast part of T. 149, R. 44 (Tilden), 1,155 to 1,160 feet.

Upper beach in the SW. ¼ of Sec. 11, T. 148, R. 44 (Godfrey), forming a plain of stratified gravel and sand a quarter or a third of a mile wide from east to west, 1,168 to 1,173 feet. This beach near the south side of Sec. 11 becomes a distinct gravel ridge of the usual character, about 25 rods wide, with its crest at 1,173 feet, bordered by a slough 20 to 40 rods wide at its east side. About a third of a mile farther southeast and some 50 rods west of the southwest extremity of Maple Lake, in Sec. 14, same township, the elevation of this beach ridge is 1,175 to 1,178 feet.

Maple Lake, water surface July 28, 1881, 1,169 feet.

Upper beach, top of its well marked gravel ridge in the east edge of the NE. ¼ of the NE. ¼ of Sec. 3, T. 148, R. 44 (Godfrey), about 20 rods north of Mr. Horton's, 1,180 feet.

Beyond this point, through its next 2½ miles, curving from a northward to a northeastward and eastward course, this upper beach of Lake Agassiz is magnificently exhibited, forming a massive, gently rounded ridge of gravel and sand about 30 rods across, with its crest 1,178 to 1,186 feet above the sea. It is bordered on its southeast side by a tract of slightly undulating till 10 to 15 feet lower, mostly covered with small timber and brush and holding frequent sloughs and lakelets in its depressions. The top of the beach is not wooded, but small trees and bushes encroach upon its slopes. A road extends along the crest of its curving portion for a distance of about 1 mile through Sec. 36, T. 149, R. 44 (Tilden).

The marsh which borders the northwest side of the northeast part of Maple Lake shows a descent of 5 to 7 feet northwestward, or away from the lake, in its width of 1 to 1½ miles Maple Lake is prevented from flowing in this direction by a beaver dam near the lake. Creek draining this marsh where it intersects the upper beach near the east line of the NE. ¼ of Sec. 27, T. 149, R. 43 (Grove Park), 1,163 feet. Here the beach skirting the north side of the marsh is a flat deposit of gravel and sand, a fourth to a half of a mile or more in width, highest next to the marsh, above which it rises 5 to 8 feet in a moderate slope. Its elevation in the north half of Secs. 26 and 27 is 1,169 to 1,172 feet, being even 1 or 2 feet lower than the Attix ridge, which lies some two-thirds of a mile farther north, in the south half of Secs. 21 and 22. This belt of beach gravel and sand continues 6 miles in a nearly due east course, and beyond that it extends still eastward along the north side of a great tamarack swamp, which begins in Sec. 34, T. 149, R. 42, and is said to be 8 miles long. Maple Lake and this tamarack swamp hold the same relation to the upper beach ridge, which was a barrier between them and Lake Agassiz and which now wholly or partially obstructs the drainage of these areas.

Third Herman beach, a small ridge of gravel and sand, extending from southwest to northeast, 8 to 10 rods wide and rising 4 or 5 feet, crossed by the Crookston road in the SW. ¼ of Sec. 23, T. 149, R. 44

(Tilden), and seen to reach at least a mile each way from this road, 1,146 to 1,149 feet.

Natural surface at the southeast corner of Sec. 15, same township, 1,134 feet.

Fourth Herman beach, crossed by road to Crookston and Red Lake Falls near the center of the SE. ¼ of this Sec. 15, 1,132 to 1,134 feet. This is a well marked gravel ridge, mainly single, but twofold where it is crossed by this road. The distance of 1 mile here between these third and fourth Herman beaches consists of till, with a nearly smooth surface, which has bowlders up to 3 and rarely 5 feet in diameter quite numerously scattered over it. Southeastward from the third to the first or upper beach the surface mostly is modified drift, with no bowlders.

Four to five miles north from the fourth Herman beach the road to Red Lake Falls crosses the Norcross beach in Sec. 27, T. 150, R. 44 (Lake Pleasant), where it is a belt of gravel and sand about a half mile wide, extending from west-southwest to east-northeast, at an elevation of 1,083 to 1,095 feet.

THE UPPER OR HERMAN BEACH IN DAKOTA.

[See the accompanying map, Plate I.]

FROM LAKE TRAVERSE NORTHWEST TO MILNOR.

From the south extremity of Lake Agassiz, in Sec. 18, T. 125, R. 45 (Leonardsville), Traverse County, Minn., the upper or Herman beach extends northwestward 75 miles to the most southern bend of the Sheyenne River in Ransom County, Dakota, and thence its course is nearly due north, but with slight deflection westward, to the international boundary. The mouth of Lake Agassiz was where now a slough 2 to 3 miles wide, with frequent areas of open water, stretches northward from the northeast end of Lake Traverse. On the west side of this slough and of Lake Traverse bluffs of till rise 100 to 125 feet; their tops and the rolling surface of till which extends thence westward are 1,070 to 1,100 feet above the sea.

The beginning of the upper or Herman beach in Dakota is in Secs. 10, 3, and 4, T. 128, R. 48, nearly 2 miles south from the north line of the Sisseton and Wahpeton reservation. It rises with terracelike steepness 20 or 30 feet above the surface of undulating till which borders it on the northeast. Its material is sand and gravel, with pebbles up to 1½ or 2 inches in diameter, about half of which are limestone. Beyond its steep margin this deposit of beach gravel forms a belt about a mile wide, approximately level, but with frequent short swells and low flattened ridges 5 to 10 or 15 feet above the intervening depressions. Its elevation is 1,060 to 1,070 feet above the sea, or from 90 to 100 feet above Lake Traverse.

For its first 3 or 4 miles the terracelike margin of the beach sweeps with a gentle curve westerly and northerly to a point in the SW. ¼ of Sec. 34, T. 129, R. 48, where it turns quite abruptly, taking a nearly due west course for the next 3 miles to the west side of Sec. 31 of this township.

In the NW. ¼ of Sec. 3, T. 128, R. 48, a third of a mile east of W. J. Allen's house, the ascent at the beach margin is about 10 feet to an elevation of 1,060 feet, approximately. The belt of sand and fine gravel is here about a half mile wide. Occasional hummocks, rising 5 to 10 feet and 50 to 100 feet long, which were observed on this part of the beach, appear to have been heaped up by the wind before the protecting mantle of grass and other vegetation was spread over it. In the SE. ¼ of Sec. 32, T. 129, R. 48, similar dunes, 1,075 to 1,080 feet above the sea, have been excavated for use as plastering sand. Nearly all portions of this beach and even its dunes are now covered with a black soil and plentiful vegetation; but certain species preferring dry and sandy soil, as the dwarf rose, grow in greater abundance on the beach, and especially among its hummocks and hollows, than on the flat or slightly undulating surface of till at each side.

The margin of this Herman beach, marking the shore of Lake Agassiz at its maximum stage, passes in its western course about 60 rods north of the southeast corner of Sec. 32 and turns again to the northwest near the middle of the west side of Sec. 31, T. 129, R. 48. At the latter locality it is a low wavelike ridge of sand and fine gravel, about 1,060 feet above the sea. On the south it is bordered by land 3 to 5 feet lower for a width of one and a half miles. J. R. Grimesey's well, 13 feet deep, at the southwest corner of Sec. 31, on this low tract outside the beach ridge, encountered only very fine stratified sand, irregularly laminated and containing numerous tubular limonitic concretions. Farther to the southwest and west, a gently undulating surface of till, scarcely higher than the beach of Lake Agassiz, stretches away several miles, beyond which the highland of the Coteau des Prairies is seen in the far distance.

The Herman beach crosses T. 129, R. 49, in a diagonal course, entering it a half mile north of its southeast corner and running northwest to the north side of Secs. 5 and 6. In Sec. 23 and the northeast part of Sec. 22, its elevation is about 1,055 feet; but its dunes rise 3 or 4 feet higher. At the middle of the north side of Sec. 16, on the line between Roberts and Richland Counties, it is a ridge of sand and fine gravel about 8 rods wide, rising 4 to 6 feet above the land on each side. Its crest here, and for a mile to the southeast and northwest, is 1,060 to 1,065 feet above the sea. Northeastward the surface falls about 20 feet in the first mile. On the southwest side of this distinct beach ridge, a smooth, slightly undulating tract 1½ to 2 miles wide, extending through this township, consists of sand and fine clayey silt. Its elevation varies from 1,055 to 1,080 feet, attaining the latter height in

the northwest part of the township. This belt, with its continuation southeastward, previously described, was doubtless covered by Lake Agassiz before the erosion of its outlet to the level of the Herman beach; but much of its stratified sand and silt may be modified drift deposited by streams from the melting ice sheet. The glacial recession here was from southwest to northeast, and this was probably an avenue of drainage during a short time, till the continued retreat of the ice left a considerable expanse of water, the beginning of Lake Agassiz, between itself and the shore.

In the north part of Secs. 5 and 6, T. 129, R. 49, and in Secs. 31 and 32, T. 130, R. 49, this beach consists of two or three parallel wavelike ridges of gravel and sand, divided by depressions an eighth to a quarter of a mile wide and 5 to 10 feet lower.

This belt reaches north to the Lightning's (or Thunder's) Nest, a massive dune of fine sand, partly bare and now wind blown, but mostly covered with bushes and herbage, situated near the center of Sec. 30, T. 130, R. 49. Its base on the south is 1,060 feet and its top 1,120 feet, approximately, above the sea. It covers a space about a quarter of a mile in extent from southeast to northwest, with nearly as great width, and rises in two summits of nearly equal height. The Lightning's Nest is the most prominent in a series of dunes, elsewhere rising only 10 to 30 feet, mostly grassed, which extends a mile or more to the southeast and is traceable several miles northwest to the east end of a very conspicuous tract of dunes 50 to 100 feet above adjacent level, with summits at 1,100 to 1,150 feet above the sea, which stretches about 4 miles in a west-northwest course in the south part of T. 131, R. 50, 1 to 2 miles south of the Wild Rice River. By winds, eroding and drifting, these sand hills were heaped up from the Herman beach and its associated belt of modified drift, probably soon after the retreat of the ice, though their forms have been constantly changing since that time.

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

Swan Lake, 3 miles long, reaching from Sec. 3 to Sec. 7, T. 130, R. 51, estimated 1,070 feet above the sea, with undulating till 5 to 10 feet higher on the northeast and 10 to 20 feet higher on the south and west.

Herman beach, a ridge of fine sand, 20 to 25 rods wide and about 3 feet high, near the south line of Sec. 36, T. 132, R. 52, extending west-northwest, approximately 1,065 feet. On the north, the exceedingly flat plain of Lake Agassiz, sinking very slowly northeastward, reaches as far as the eye can see. On the south, flat land, covered by Lake Agassiz before the time of this beach, continues 1½ miles, ascending in that distance from 1,060 feet to about 1,080 feet, and moderately undulating till rises beyond to 1,100 and 1,125 feet.

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

Northern Pacific, Fergus Falls and Black Hills Railroad: track at Wyndmere, 1,060 feet; at the Herman beach 1½ miles west of Wyndmere, track 1,064 and crest of the beach 1,065 feet, rising 8 feet above the adjacent land 20 rods away both east and west; surface along the railroad thence westward 8 miles, 1,060 to 1,063 feet, with Star Lake, a third of a mile in diameter on this level area, only 2 or 3 feet below the surrounding land, close north of the railroad, in Sec. 5, T. 132, R. 52; a higher beach of Lake Agassiz, crossed 3 miles east of Milnor, and therefore called the Milnor beach, crest and track, 1,083 feet, 4 or 5 feet above the adjoining land 10 rods away both east and west; another beach ridge formed during the same stage of Lake Agassiz, a third of a mile farther west, crest and grade, 1,084 feet; land close east, 1,079, and west, 1,076 feet; track at Milnor, 1,095 feet.

The Herman beach west and north of Wyndmere has an irregular surface, with frequent hummocks of sand heaped 5 to 10 feet above adjacent hollows. Most of these dunes are now grassed. From near Wyndmere this beach, with frequent small dunes, extends north through the west edge of T. 133, R. 51, and thence westerly to another tract of prominent dunes 50 to 100 feet above adjacent surface, with their tops at 1,100 to 1,150 feet, which extends about 10 miles in a west-northwest course from the southwest part of T. 134, R. 52, to the east part of T. 134, R. 54, terminating about 2 miles east of the Sheyenne River. Like the similar high dunes south of the Wild Rice River, these are mainly covered by herbage, bushes, and small trees; but many portions are

now being drifted by the winds, so that they are wholly destitute of vegetation. These dunes mark the course of the Herman beach, here greatly increased in volume by delta deposits from the Sheyenne River.

Morainic knolls and hills, rising 20 to 50 feet, with plentiful bowlders, lie close west of Milnor, extending in a belt from southeast to northwest. They are probably a continuation of the Altamont and Gary moraines of the Coteau des Prairies. Near Lisbon, about 15 miles northwest from Milnor, some of these morainic hills are quite conspicuous, rising 100 feet or more above the surrounding country.

Evidence of a stage of Lake Agassiz 20 or 30 feet higher than that of the Herman beach is found, as already noticed, in many places along the southern part of its boundary in Dakota. The portion of this glacial lake formed earliest by the recession of the ice seems to have reached from Lake Traverse to the Sheyenne River, and its level appears to have been then nearly that of the general surface and the top of the bluffs bordering Lake Traverse. Distinct traces of this stage of the ancient lake have not been recognized in Minnesota, nor along the greater part of its boundary in Dakota, from the Sheyenne River northward.

FROM MILNOR NORTH TO SHELDON.

The highest level of Lake Agassiz, near Milnor, is marked by the Milnor beach, already mentioned, where it is crossed by the railroad. This beach is fine clayey sand, in somewhat irregular and interrupted low ridges and terraces, abutting at the west on undulating till, which gradually rises 10 or 20 feet higher, while on the east a descent of 10 or 15 feet, within about 20 rods, is succeeded by a flat area, which thence sinks very slowly northeastward. The elevation of the Milnor beach at the railroad is 1,084 feet, and at Mr. G. V. Dawson's house, at the middle of the east side of Sec. 22, T. 133, R. 54, 1,092 feet. Its course between these points is north-northwest, and this is continued to the mouth of a former channel of the Sheyenne River, near the center of Sec. 4 in this township, 3 miles east from the most southern bend of the river.

During all the stages of Lake Agassiz the Sheyenne River brought into it much sediment, carrying the clay farther than the sand and gravel, which were laid down near the river's mouth. Extensive areas of these originally flat beds have been changed by wind action to irregular groups and belts of sand hills or dunes, which vary from a few feet to more than a hundred feet in height above the surrounding level. Besides the large tract of these dunes before described east of the Sheyenne River, others of even greater extent and equally conspicuous border the river and reach 2 or 3 miles from it in the northeast part of T. 135, R. 54, and along its next 15 miles.

Watercourses formerly occupied by this stream are found west of the Milnor beach. One of them is marked by a sandy flat, which reaches

from the present course of the Sheyenne River, in Sec. 1, T. 133, R. 55, southeastward through T. 133, R. 54, to the vicinity of Milnor. Another runs from near the middle of the SW. ¼ of Sec. 32, T. 134, R. 54, about 1¼ miles east-southeast to the middle of Sec. 4, T. 133, R. 54. This is a channel, 30 to 50 rods wide, about 40 feet below a ridge of coarse gravel, which extends along its northeast side, dividing it from the lower area that was covered by Lake Agassiz and from the present valley of the river. The crest of the ridge is nearly flat, upon a width of 10 to 30 rods, and is 75 to 100 feet above the river, being highest westward. It contains pebbles and cobbles of all sizes up to 6 inches in diameter, about half being limestone and nearly all the others granitic. This ridge or plateau of gravel is a remnant of an old delta plain of the Sheyenne River, apparently deposited before the formation of the Milnor beach, above which it rises some 40 or 50 feet, which suggests that the deserted channel of that depth on its south side was probably eroded during the Milnor stage of Lake Agassiz. Similar gravel occurs on the side and verge of the bluff, 100 feet high, northwest of the Sheyenne River, in the SW. ¼ of Sec. 29, T. 134, R. 54, but a rolling surface of till extends thence northwest.

Sheyenne River in Sec. 32, T. 134, R. 54, 1,037 feet above the sea, and on the west line of the NW. ¼ of Sec. 29, T. 135, R. 54, 1,019 feet. Its bed through these townships is mostly 4 to 6 rods wide, with water 1 to 2 or 3 feet deep, and is strewn in many places with cobbles and bowlders up to 2 or 3 feet and rarely 6 or 8 feet in diameter. Its bottom-land near the south bend, about a third of a mile wide, is 15 or 20 feet above the ordinary low stage of water, and during a term of fourteen years preceding this survey in 1885 it had not been overflowed; but driftwood, found by the first immigrants, proves that the river sometimes reaches this height. Bluffs of till here, in the southwest corner of T. 134, R. 54, rise 100 to 125 feet above the stream.

Bluffs of till close west of the Sheyenne River, in Sec. 20, T. 134, R. 54, 1,100 to 1,110 feet; moderately rolling till a quarter of a mile farther west, 1,115 to 1,125 feet; same in Secs. 17 and 18, 1,090 to 1,130 feet; and on the east side of the river, in Secs. 21, 16, and 17, 1,085 to 1,075 feet, descending northeastward. Prominent swell of till west of the Sheyenne River in the SE. ¼ of Sec. 30, T. 135, R. 54, having four aboriginal mounds on its crest, 1,113 feet; top of these mounds, 1,117 feet, very nearly. Highest portions of the area of undulating till seen westward from this Sec. 30, 3 or 4 miles distant, 1,125 to 1,150 feet.

Surface at Charles G. Froemke's house, in the NW. ¼ of Sec. 29, T. 135, R. 54, 1,073 feet; bottom land of the Sheyenne River close west, 1,037 to 1,027 feet; ordinary low water of the river, 1,019 feet.

Portion of area of Lake Agassiz, a strip a fourth to a third of a mile wide, west of the Sheyenne River, in Secs. 32 and 5, a half mile to 2 miles south of Mr. Froemke's, 1,065 to 1,075 feet. Herman beach one-fourth to two-thirds of a mile east of the Sheyenne River here and ex-

tending southeasterly toward the western limit of dunes in the east part of T. 134, R. 54, 1,073 to 1,079 feet. Crest of this beach, a low ridge of sand and fine gravel, at J. Altmann's house, near the middle of Sec. 20, T. 135, R. 54, 1,073 feet. Within 10 or 15 rods east there is a descent of about 10 feet. This beach ridge runs north and northeasterly to near the northeast corner of this Sec. 20, and thence it passes eastward about 3 miles, having an elevation of 1,075 to 1,065 feet to where it is intersected by the Sheyenne River, near the northeast corner of Sec. 14. North of the river it continues about a half mile in Sec. 12, its elevation being 1,065 to 1,070 feet, to the west end of a tract of dunes 25 to 100 feet above their vicinity, with summits at 1,100 to 1,150 feet, which extends thence about 15 miles eastward. This Herman beach was sufficient to turn the course of the Sheyenne River along its west and north side for a distance of 8 miles, from Sec. 9, T. 134, R. 54, north and east to Sec. 14, T. 135, R. 54, though it is only a ridge of sand and gravel 5 to 10 feet higher than the smoothed area of till, occasionally covered by 1 to 3 feet of sand, which lies west of it and in which the river has now cut its channel 50 to 60 feet deep.

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

Herman beach in the NW. ¼ of the NW. ¼ of Sec. 10, T. 135, R. 54, 1,075 to 1,080 feet. This is a deposit of gravel and sand extending along the verge of the plateau of till just described in Sec. 9. Fifteen or 20 rods to the east the elevation is 1,065 feet, and it sinks slowly thence eastward to about 1,050 feet at the west base of the dunes in Secs. 12 and 1 of this township.

Lakelet back of this beach, situated in the east edge of the SE. ¼ of Sec. 4, T. 135, R. 54, about 50 rods long from south to north, 1,060 feet, being 25 feet below the average of the adjacent undulating till. Shallow lakelet, 40 rods across, close east of the beach, a quarter of a mile east from the northwest corner of Sec. 3, also 1,060 feet; adjoining land, 1,065 to 1,070 feet, excepting on the west, where the Herman beach has an elevation of 1,080 feet, with undulating till beyond it a few feet higher.

Herman beach at the middle of the west side of Sec. 34, T. 136, R. 54 (Sheldon), 1,082 feet; surface 25 rods east, 1,070 feet, thence descending slowly eastward. Here and for 1½ miles south, through Sec. 3, this beach is a flattened ridge of sand and fine gravel, 25 or 30 rods wide, with a depression 3 to 6 feet deep along its west side. In the NW. ¼ of Sec. 28, its elevation is 1,080 feet.

Fargo and Southwestern Railroad track at Sheldon, 1,078 feet. Wells in Sheldon village are 10 to 15 feet deep, in sandy clay free from

gravel or bowlders 6 to 10 feet, with sand below. These deposits belong to the Herman beach, which is here spread upon a width of about a half mile.

FROM SHELDON NORTH TO THE NORTHERN PACIFIC RAILROAD.

This beach, terracelike, at Hugh McIntosh's house, in the south edge of the NW. ¼ of Sec. 8, T. 136, R. 54 (Sheldon), has its crest 1,083 to 1,084 feet above the sea. His well, near the top of the beach, 22 feet deep, is soil and sandy clay to a depth of 7 feet, then sand 15 feet to water. Till rises to the surface 20 rods farther west. About 30 rods east, on land 10 feet lower, a well 10 feet deep is all caving sand below the black soil, which is 1 or 2 feet deep next to the surface.

From the east base of the beach near Mr. McIntosh's there is a very slight descent eastward to 1,065 feet, approximately, about Island Lake, which lies some 10 feet lower. This lake, nearly round, about a third of a mile in diameter, is crossed by the line between Secs. 9 and 10. Its island, which is said to have an area of 12 acres, lying in Sec. 9, is wooded; but the shores around the lake are destitute of timber, being in part marshy, with grass and rushes, and in part hard sand. The maximum depth of water is only 6 feet, but it has not been dried up during the six years from the first immigration here to the time of this survey.

Maple River in Sec. 32, T. 137, R. 54, about 2 miles northeast from its most southern bend, 1,017 feet. It is 20 to 40 feet wide and 1 to 3 feet deep, with cobbles and bowlders in many portions of its channel.

Herman beach, a sand and gravel deposit extending a quarter of a mile from south to north on the verge of the bluff of till west of Maple River in the northwest part of this Sec. 32, 1,072 to 1,077 feet. In the north edge of the NW. ¼ of this section, the northeast corner of Sec. 31, and the east edge of Sec. 30, it is a plateaulike tract a fourth of a mile wide, with a subsoil of sand and fine gravel, 1,086 feet, from which both east and west a gentle slope falls 5 feet within 20 or 30 rods. In the NW. ¼ of Sec. 20 and the west half of Sec. 17, it is a gracefully rounded ridge, 1,085 to 1,087 feet, with descent of about 5 feet on its west side and 10 to 15 feet within as many rods on the east. The surface east of the Maple River in this T. 137, R. 54, has an elevation of 1,075 to 1,065 feet, declining toward the north and east.

In the east half of T. 137, R. 55, a surface of till, moderately undulating near the beach of Lake Agassiz, but prominently rolling at a distance of 3 miles to the west, rises to 1,150 and 1,175 feet in the vicinity of the Maple River above its south bend.

The Herman beach, a broad flattened ridge of sand and gravel, passes in a north-northeast course through the center of Sec. 8, T. 137, R. 54, its elevation being 1,083 feet. A smoothed surface of till, 1,082 to 1,087 feet, with occasional sloughs in depressions 15 to 20 feet deep, occupies

the west half of this Sec. 8; and close east of the beach a flat of till on the east line of the section, at 1,065 to 1,070 feet, was the bed of the lake.

Continuing northeastward, the beach is offset a mile to the east in Secs. 4 and 3, T. 137, R. 54, so that the greater part of Sec. 4 was a bay of Lake Agassiz during its Herman stage, with bottom at 1,080 to 1,065 feet, inclosed on the west, north, and east by beach deposits. The highest portion of the hook or spit east of this bay is in the SW. ¼ of Sec. 3, 1,093 to 1,096 feet. It is composed of sand and fine gravel, with pebbles, mostly less than an inch but occasionally 2 inches in diameter, forming a smoothly rounded swell 30 to 40 rods wide. This cape, projecting south and west a mile into the lake, was accumulated by the southward drift of the beach material along the shore, caused by northern winds, as is also observable at various other places on both the east and west shores of this extinct lake and on both sides of Lake Michigan at the present time.

Herman beach in the west edge of Sec. 26, T. 138, R. 54, 1,094 feet. On the east side of the beach here, near the center of this section, is a slough filled with rushes and containing water all the year; its elevation is about 1,065 feet, that of the land on its east side in the east part of this section being about 1,075 feet. In the NE. ¼ of the NE. ¼ of Sec. 34, the beach is intersected by a sluggish creek, apparently formed by springs within a half mile northwest, its ravine being fully 40 feet below the general level of the beach and the land westward. Again, in the NW. ¼ of the SW. ¼ of Sec. 26, the beach is cut by a dry channel, the outlet in rainy weather from a small slough.

Through the west half of Sec. 23, T. 138, R. 54, the beach is a low, smoothly rounded ridge of sand and fine gravel, about half of which is limestone and the rest granite or other Archean rocks. As in the 3 miles next southward, it is largely composed of fine gravel, and pebbles abound, often covering half the surface of the knolls made by gophers. Most of the pebbles are less than an inch in diameter, but some measure 2 and a few 3 inches. The elevation of this beach ridge is 1,092 to 1,100 feet; on the north line of this section its height is 1,099 feet. A broad depression 3 to 5 feet below the beach borders its west side. Toward the east there is a descent of about 10 feet in 25 or 30 rods, and thence a gradual slope sinks to 1,060 or 1,050 feet within 1 to 1½ miles.

Undulating till in Secs. 22 and 15, T. 138, R. 54, 1,095 to 1,110 feet; crests of prominently rolling till in the west edge of Sec. 11 and the south part of Sec. 10, 1,115 to 1,125 feet; thence northwestward lower undulating till has an elevation of only 1,090 to 1,100 feet for nearly two miles and rises quite slowly beyond.

This somewhat irregular contour has caused considerable diversity in the development of the beach, so that its deposits are massed in unusual amount in some places, while elsewhere they are deficient or wholly wanting. In the SW. ¼ of the SW. ¼ of Sec. 14, T. 138, R. 54,

a swell of gravel, with pebbles of all sizes up to 2 inches or rarely 3 inches in diameter, rises to 1,105 feet, extending about 40 rods from south to north; and similar gravel, at 1,095 to 1,105 feet, occurs in the west part of the NW. ¼ of Sec. 23, west of the distinct beach ridge. The northwest part of Sec. 14 is a nearly flat tract, having a subsoil of sand and fine gravel, with an elevation of 1,090 to 1,095 feet. Beach ridge extending south from the east side of a prominent swell of till in the SW. ¼ of Sec. 11, 1,086 to 1,089 feet, having a continuous depression of about 5 feet on its west side and bordered eastward by land 6 to 10 feet below its crest. In the northwest part of this Sec. 11 and the southeast part of Sec. 3 the shore of Lake Agassiz is marked by slight erosion in the rolling and undulating surface of till rather than by the usual beach deposits of gravel and sand.

Beyond this, a conspicuous beach ridge 25 to 40 rods wide, elevated 10 feet above the undulating till on its west side and bordered by a still lower surface on the east, extends from the middle of the SW. ¼ of the SE. ¼ of Sec. 3, T. 138, R. 54, northwestward to near the middle of the north line of the NW. ¼ of this section, where it is interrupted by a drainage gap about 20 feet below its crest. Thence this massive beach ridge continues in a north-northeast course through Sec. 34, T. 139, R. 54, to near the middle of its north line. Its material is sand and gravel, with pebbles up to 1½ inches in diameter. In Sec. 3 its elevation is 1,095 to 1,090 feet, and in Sec. 34, 1,089 to 1,094 feet. It passes onward as a very distinct and typical beach ridge, with the same north-northeast course, through Secs. 27 and 22, T. 139, R. 54, having an elevation of 1,087 to 1,095 feet in Sec. 27 and 1,089 to 1,096 feet in Sec. 22. Its eastern slope in these sections descends 15 to 20 feet.

About a half mile west from this great beach ridge the east edge of Sec. 4 has irregular deposits of beach gravel and sand in swells and bars 5 feet above the general level, and in the east edge of Sec. 33, T. 139, R. 54, a well defined parallel beach begins, having a width of 20 to 25 rods and elevation of 1,092 to 1,094 feet, with a depression 2 to 4 feet lower on the west and descent of about 5 feet on the east. This western Herman beach extends as a continuous ridge 2 miles to the north-northeast, excepting a gap where it is intersected by a small stream in the NW. ¼ of Sec. 27. Its material is sand and gravel, with pebbles up to 2 inches in diameter, about half of which are limestone. Both this and the east beach have a black soil a foot or more in depth, and are scarcely inferior to the adjoining areas of till in productiveness. Farther west a slightly undulating or nearly flat surface of till extends from a half mile to 1½ miles before it rises above 1,095 feet; and the highest of its swells, seen 3 to 6 miles away to the west and northwest, do not exceed 1,150 or 1,175 feet. Western Herman beach on the north line of the NW. ¼ of Sec. 27, 1,095 feet; about 6 rods to the south, 1,097 feet, and northeastward, in Sec. 22, 1,092 to 1,095 feet, to its junction with the eastern or main beach in the east part of this section.

A lower Herman beach, formed after the lake level here had fallen slightly, appears in the northwest edge of Sec. 26, T. 139, R. 54, having its crest at 1,072 to 1,075 feet; passing north-northeast.
west half of Sec. 23, its elevation is 1,075 to 1,080 feet; through Sec 14, 1,080 to 1,087 feet, being highest near the center of this section; and in the east part of Secs. 11 and 2 and northward to the SW. ¼ of Sec. 36, T. 140, R. 54, 1,083 to 1,080 and 1,075 feet. Its maximum development is in Sec. 14, where it is a massive, smoothly rounded ridge of sand and fine gravel, 30 rods wide, with a descent of 15 feet on each side. In Secs. 26 and 23 it is bordered on the west by a continuous depression 4 to 8 feet below it; and, through Secs. 14, 11, and 2 and in the SW. ¼ of Sec. 36, a slough 3½ miles long, mown for its luxuriant marsh hay, having an elevation of 1,067 to 1,072 feet, lies between this and the main beach, a half mile farther west.

Floor of S. P. Gardner's house, in the northwest corner of Sec. 27, T. 139, R. 54, 1,096 feet.

Main Herman beach through the west edge of Sec. 14, T. 139, R. 54, 1,096 to 1,093 feet, declining northward; in the west part of Sec. 11, 1,093 to 1,095 feet; in Sec. 2, 1,092 to 1,095 feet, changing from a north to a north-northeast course; in the southeast edge of Sec. 35 and the northwest edge of Sec. 36, T. 140, R. 54, 1,092 to 1,096 feet; and in the west part of Sec. 25, where it is cut by the Northern Pacific Railroad, 1,093 to 1,099 feet. At the railroad cut its crest is 1,097 to 1,099 feet and the track is 1,091 feet. Along this distance of 5 miles it is a typical beach ridge of sand and gravel, with pebbles up to 2 inches and occasionally 3 to 6 inches in diameter, about 30 rods wide, rising nearly 25 feet above the slough on the east, and bordered on the west by a continuous depression, mostly about an eighth of a mile wide, 3 to 7 feet below its crest. Slightly undulating till rises beyond to 1,125 and 1,140 feet within 1 or 1½ miles west, which is as far as the surface lies within view.

Northern Pacific Railroad, track at Wheatland, 991 feet; on bridge over creek in the east edge of Sec. 25, T. 140, R. 54, 4 miles west of Wheatland and three-fifths of a mile east of the Herman beach, 1,074 feet; bed of the creek, 1,055 feet; track at summit, 4½ miles west from the Herman beach, same as the natural surface, 1,206 feet; and at Buffalo, a half mile farther west, 1,200 feet.

FROM THE NORTHERN PACIFIC RAILROAD NORTH TO GALESBURG.

Herman beach, a broad, smoothly rounded, continuous ridge of the same material and contour as southward, for the next 4 miles north from the Northern Pacific Railroad, bearing north-northeast, 1,097 to 1,100 feet, very constant in elevation. The descent of its east slope is 15 or 20 feet in about 20 rods, and of its west slope, about 5 feet. Thence westward the surface is undulating till, in swells 10 to 15 feet above the

depressions, rising gradually to 1,150 and 1,200 feet above the sea at a distance of 3 to 5 miles, the farthest seen in that direction. In a broad view this area seems an almost flat plain.

Where this beach is cut by the Saint Paul, Minneapolis and Manitoba Railway from Ripon to Hope, near the middle of the line between Secs. 32 and 33, T. 141, R. 53, its crest was 1,096 to 1,099 feet above the sea. It has been excavated here for ballast to a distance of about 30 rods south from the railway. It is mostly gravel; the pebbles seldom exceed 2 inches in diameter; about half is limestone and the remainder granitic. The thickness of this beach deposit is only 8 to 10 feet; its east slope falls 12 or 15 feet, and its west slope, 5 to 7 feet.

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

Southward from this locality the Herman beach is double for a distance of about 4 miles. The secondary beach ridge east of that already described is similar in size and material. Its south end is in the west part of Sec. 19, T. 140, R. 53, a half mile east from the main beach, and it passes thence north-northeastward through Secs. 18, 7, and the east edge of Sec. 6, having an elevation of 1,081 to 1,084 feet. It becomes merged with the main beach in the SE. ¼ of Sec. 32, T. 141, R. 53. Between these beach ridges is a depression, approximately 1,075 feet, partly occupied by a grassy slough, which is all used as mowing lane, having no area of water or bog.

Herman beach, in the SW. ¼ of Sec. 28, T. 141, R. 53, 1,094 to 1,096 feet, not so distinct as usual, being intersected by Swan Creek and having no well marked depression along its west side. Farther north in this section it is a ridge of the ordinary type, with its crest at 1,096 to 1,098 feet. In Sec. 21 it is narrowed to 8 or 10 rods in width, but continues as a very distinct ridge with a slight ascent northward, from 1,097 to 1,101 feet. Its east slope falls 15 to 20 feet in about 20 rods and there is a depression of 3 to 6 feet on the west. Thence a surface of undulating till, seeming nearly flat in a general view, rises gradually westward to about 1,150 feet at a distance of 2 or 3 miles.

This beach ridge passes onward through Sec. 16 and the south part of Sec. 9, T. 141, R. 53, with an elevation of 1,095 to 1,100 feet; but, having been followed thus continuously in a north-northeast course for more than 15 miles, it ceases in the east part of this Sec. 9. Its north end abuts at 1,100 to 1,105 feet upon a terrace slope of till, which rises about 10 feet higher. This forms the east boundary of a slightly undulating expanse of till, which thence gradually rises to 1,150 and 1,200 feet in 2 to 5 miles west and northwest. From Sec. 9 northward through

the east part of Sec. 4 and in the west edge of Sec. 34 and the west part of Secs. 27, 22, and 15, T. 142, R. 53, passing close east of Erie, the Herman shore of Lake Agassiz is marked by such a terrace or escarpment formed by wave erosion, and the usual deposit of beach gravel and sand is absent. The base of the escarpment is at 1,095 feet, approximately, and it rises with a moderate slope 25 to 40 feet.

About a half mile east of this escarpment, however, lies a broad low ridge of beach sand and fine gravel, having an elevation of 1,085 to 1,090 feet. Its course is from the west part of Sec. 10 north-northeast through Secs. 3 and 34 and nearly due north through the east edge of Secs. 27, 22, and 15. The descent eastward is more gentle than usual, falling only 6 to 10 feet in a quarter of a mile, beyond which is a flat area of till. On the west a depression 3 to 5 feet deep, partly occupied by a grassy slough, intervenes between this beach ridge and the wave-cut escarpment. On the north line of Sec. 15 the crest of the ridge is at 1,092 feet; the depression west, 1,088; the base of the escarpment, 1,092, and its top, about 1,115 feet.

Saint Paul, Minneapolis and Manitoba Railway from Ripon to Portland, track at tank and section-house close south of Rush River, 1,096 feet; at Erie, 2 miles farther north, 1,128 feet; summit, about 1 mile north of Erie, 1,133 feet; South Branch of the North Fork of Elm River, bridge, 1,083 feet; bed of creek, 1,064 feet; track at summit 1 mile north, 1,091 feet; at Galesburg, 1,081 feet; North Branch of the North Fork of Elm River, bridge, 1,078 feet; bed of creek, 1,065 feet; track at Clifford, 1,057 feet. At Erie and westward the surface is prominently rolling till, which rises within 3 miles to a height 100 feet above the shore of Lake Agassiz.

In Secs. 10 and 3, T. 142, R. 53, the Herman beach is again well exhibited in its usual character. On the north line of Sec. 10 it is a gently rounded ridge of sand and gravel, with pebbles up to 2 inches and rarely 3 or 4 inches in diameter, half being limestone; its width is about 20 rods; the elevation of its crest is 1,106 feet and the slopes fall 10 feet on the east and 3 feet on the west. For the next mile northward, through the west part of Sec. 3, this beach ridge has a width of 10 to 15 rods; its elevation is mostly 1,105 to 1,108 feet, with a depression 5 to 7 feet deep along its west side; but in a few places the ridge itself is depressed to 1,099 feet. Passing northward this beach in the west half of Sec. 34, T. 143, R. 53, is a very smooth, gracefully rounded, wavelike swell, 30 to 40 rods wide, 1,108 to 1,112 feet in elevation, rising 15 feet above its east base and having a depression of 3 to 5 feet on the west. A well in the NE. $\frac{1}{4}$ of the SW. $\frac{1}{4}$ of Sec. 34, on the top of this beach, went through 12 feet of sand and gravel, going into till below. In the SW. $\frac{1}{4}$ of Sec. 27, the beach continues with the same massive development and nearly north course, its elevation being 1,111 to 1,115 feet. In the NW. $\frac{1}{4}$ of this section it becomes a still broader deposit of gravel and sand, a fourth to a third of a mile wide, with no depression on its

west side. Here its course is turned northwestward, entering the SE. ¼ of Sec. 21 with an elevation of 1,109 feet; but it seems not to be distinctly traceable farther. About a half mile west of this beach a plateau of till, 1,125 to 1,128 feet above the sea, extends a third of a mile from southeast to northwest in the SE. ¼ of Sec. 28; but for a mile south and west of this plateau and for 3 miles northwest the surface of slightly undulating till averages only 1,105 to 1,120 feet.

The secondary Herman beach, already described in its course east of the Erie escarpment of till, continues northward with an elevation of 1,095 feet, approximately, through the east half of Secs. 10 and 3, T. 142, R. 53, and Secs. 34 and 27, T. 143, R. 53. In Secs. 22 and 16 this beach turns in a gradual curve to the northwest and west and its crest varies in height from 1,095 to 1,104 feet, being highest in or near the southeast corner of Sec. 16. There it is a ridge of gravel and sand about 30 rods wide, rising 10 to 15 feet above its northeastern base and descending 6 to 10 feet on the southwest to a nearly flat tract of moist mowing land fully a mile wide, with a height of 1,090 to 1,095 feet. Through Secs. 17, 8, and 5 it again curves to the northwest, north, and north-northeast, having an elevation of about 1,100 feet. In the north half of Secs. 5 and 4, T. 143, R. 53, a smooth plain with sand subsoil extends a mile eastward from the east base of this beach ridge, descending in this distance from 1,090 to 1,075 feet.

Continuation of this beach northward nearly through the middle of Sec. 32, T. 144, R. 53, 1,096 to 1,099 feet. It is a typical beach ridge of fine gravel and sand 8 to 10 feet above the land on its east side and having a descent of about 5 feet westward, beyond which the surface of undulating till rises in 1 or 1½ miles to 1,125 and in the next 2 miles to 1,175 or 1,200 feet. A half mile east from this beach and only 20 to 30 rods west of the railroad, there is a parallel beach ridge of similar size and material, 1,090 to 1,092 feet. The former of these beaches, where it crosses the south line of Sec. 20, a fourth to a half mile west of Galesburg, is spread in a broad, nearly flat deposit which rises westward from 1,096 to 1,101 feet. On the west it is bordered by a depression about 8 feet lower.

FROM GALESBURG NORTH TO LARIMORE.

In Sec. 20, T. 144, R. 53, the beach is about a third of a mile wide, its higher western margin being at 1,097 to 1,102 feet. From its crest a slope descends first somewhat steeply and then slowly to the amount of 20 or 25 feet in two-thirds of a mile eastward, having a subsoil of sand and very fine gravel to a depth of 5 to 10 feet, underlaid by till, as is shown by wells at Galesburg. Crest of this beach through the west half of Sec. 17, 1,102 to 1,107 feet; in Sec. 6, T. 144, R. 53, where it is intersected by the North Branch of the North Fork of Elm River, and in Secs. 32 and 29, T. 145, R. 53, 1,115 to 1,125 feet, being 10 to 15

feet higher than on the south and north; in Secs. 20 and 17, about 1,110 feet; in the southwest part of Sec. 8, 1,117 feet; westward through Sec. 7 of this township and through the northeast part of Sec. 12, T. 145, R. 54, 1,112 to 1,117 feet. In the west part of Sec. 7 a slough about an eighth of a mile wide, having an elevation of 1,100 feet, approximately, borders the southwest side of this beach ridge. On the line between Traill and Steele Counties, where the top of the ridge is at 1,114 feet, it is a typical beach deposit about 25 rods wide, composed of sand and gravel, with pebbles up to 2 or 3 inches in diameter. Its course is due west, and the descent from crest to base on the south is 6 or 8 feet and northward 12 or 15 feet, beyond which a very gentle slope sinks toward the northeast. A well on this beach, in the east edge of the NW. ¼ of Sec. 12, T. 145, R. 54, went through sand and fine gravel 13 feet, finding till below. Within a few hundred feet farther west the beach is interrupted for a distance of about 1 mile by an area of till some 15 feet lower, with no beach deposits. It reappears, however, as a typical beach ridge of gravel and sand for a distance of three-fourths of a mile in the NW. ¼ of Sec. 11 and the NE. ¼ of Sec. 10, having an elevation of 1,114 to 1,112 feet, with a slough on its south side 6 to 8 feet lower.

Returning to the vicinity of Galesburg, a slightly higher beach, approximately parallel with the foregoing, remains to be traced. It becomes recognizable in the west edge of Sec. 20, T. 144, R. 53, where the border of the area of rolling till that extends thence westward bears occasional deposits of gravel at 1,115 to 1,120 feet. In the east part of Sec. 18 it is a well developed beach ridge of sand and fine gravel 30 to 50 rods wide, with a depression on the west 4 to 6 feet below its top, which has an elevation of 1,120 to 1,123 feet. The next half mile or more westward in Sec. 18 is very smooth till, 1,120 to 1,125 feet; but within one mile farther west prominent swells of till rise to 1,160 and 1,175 feet. Northward in Sec. 7 this beach, continuing at 1,120 to 1,123 feet, is quite broad, without a distinctly ridged form, and is indented from the east by a large slough, whose elevation is approximately 1,100 feet, including several acres of water free from grass and rushes. Crest of beach in the SW. ¼ of Sec. 6, 1,122 to 1,126 feet. North Branch of the North Fork of Elm River 1,105 feet, dry in summer, in a valley 15 to 40 rods wide. Beach through Secs. 31 and 30, T. 145, R. 53, 1,125 to 1,129 feet; and in the west half of Sec. 19, 1,127 to 1,124 feet, sinking slightly from south to north. The farther course of this shore is not marked by continuous beach deposits; but, following the contour line of 1,125 feet, it must turn west in the SW. ¼ of Sec. 18, T. 145, R. 53, and extend through Secs. 13 to 16, T. 145, R. 54, to the South Branch of Goose River.

Highest ground crossed by road on the line between Traill and Steele Counties at the west side of Sec. 18, T. 145, R. 53, 1,125 feet.

Natural surface at the southwest corner of Sec. 3, T. 145, R. 54, a dozen rods west of the South Branch of Goose River, 1,104 feet. This

stream, about 1,070 feet, is 8 to 20 feet wide and mostly 1 to 2 feet deep. Its bottom land, 5 to 10 feet above this stage of low water, varies from 20 to 100 rods in width and is inclosed by bluffs rising 30 to 50 feet, increasing in height southwestward. The valley has no timber, the largest wood growth being willows 5 to 8 feet high and 2½ inches or less in diameter. With the aid of these, however, beavers construct dams and were living on this stream when this survey was made in 1885, one of their dams then occupied being found by my assistant in the west edge of Sec. 10, T. 145, R. 54.

Floor of Henry Bentley's barn in the southwest corner of the SE. ¼ of Sec. 6, T. 145, R. 54, on the Herman shore of Lake Agassiz, 1,123 feet. This is a moderate slope, ascending 10 or 15 feet, eroded in till, which from its top stretches westward about 2 miles in a nearly level expanse. From the south side of Sec. 6, such a low escarpment, with its top at 1,120 to 1,123 feet, extends due north, or a few degrees west of north, about 5 miles.

E. W. Palmer's house, in the northwest corner of the SW. ¼ of Sec. 2, T. 145, R. 55, 1,145 feet. Well here, 27 feet deep: soil and hard cemented gravel and sand, 2 feet; sand with occasional layers of fine gravel, 22 feet; and darker clayey quicksand, 3 feet, with water.

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

Near the middle of the north half of Sec. 23, T. 146, R. 55, the elevation of this beach is 1,142 to 1,144 feet. It is a ridge of gravel and sand, extending a quarter of a mile from southeast to northwest, with crest 15 feet above the surface on each side. Toward the east it descends in a long slope, but more steeply westward. In Sec. 14 this shore line curves westerly, the crests of its somewhat irregular beach deposits being about 1,135 feet, with a descent of 10 to 15 feet in 25 rods east. Through Sec. 11 they range from 1,135 to 1,147 feet, being highest in the SE. ¼, where the descent eastward is 20 feet or more. These beach deposits are sand and gravel, with pebbles up to 1½ or 2 inches in diameter, massed in flattened hillocks or swells, mostly ridged lengthwise with the shore and occasionally inclosing hollows without outlet. The forma-

tion has a width of a quarter of a mile or more in its northward course through the west part of the east half of Sec. 11. An undulating surface of till rises slowly to the west, while on the east a very smooth expanse of till sinks slowly toward the Red River.

Herman beach ridge, 30 rods wide, in or near the east edge of the SE. ¼ of Sec. 2, T. 146, R. 55, 1,125 feet. Irregular accumulations of the higher beach a quarter of a mile farther west, approximately, 1,140 feet. These upper deposits and those described in the last two paragraphs seem to have been formed while the level of this margin of Lake Agassiz was held above its Herman stage by the barrier of the retreating ice sheet, still remaining unmelted within a few miles east, and by that of the high area on the south in Ts. 144 and 145, R. 54.

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

North Fork of the Middle Branch of Goose River, where it intersects the Herman beach in the southeast part of Sec. 26, T. 147, R. 55, approximately, 1,085 feet. Its bottomland is 30 to 80 rods wide, bordered by bluffs rising 30 to 40 feet.

Through Secs. 26 and 23, T. 147, R. 55, the Herman shore is marked by swells and flattened ridges of sand and fine gravel at 1,130 to 1,143 feet, occupying a width of an eighth to a third of a mile, with a depression of several feet along their west side. Four sloughs, elevation about 1,120 feet, lie within the east part of these beach deposits, or on their east border, in the SE. ¼ of Sec. 23. In the south part of Sec. 14, this massive but irregular beach has an elevation of 1,132 feet on the east side of a large slough.

In the middle of Sec. 14, T. 147, R. 55, the beach assumes a definitely ridged form and extends thus northward along the east side of Golden Lake, which owes its existence to this barrier. Crest of beach, through the center and north part of Sec. 14, 1,132 to 1,137 feet; in Sec. 11, east of Golden Lake, 1,132 to 1,141 feet; and at Golden Lake post office, in the east edge of the SW. ¼ of Sec. 2, 1,138 feet. An eighth of a mile north from the south end of this lake the action of its waves has eroded the greater part of the beach ridge. The material of the beach exposed by an excavation near the post office is coarse gravel, with very abundant pebbles up to 3 and occasionally 4 to 6 inches in diameter.

Golden Lake, water July 28, 1885, 1,122 feet above the sea; highest level reached by this lake in recent years, 1,128 feet. It is a beautiful sheet of water, 1¼ miles long and a quarter to a third of a mile wide. Its west shore is moderately undulating till, with the highest swells 20 to 30

feet above the lake. In a few places its grassed bluffs rise steeply from the water's edge 10 to 20 feet. Farther west the rolling surface of till, seen for a distance of 3 or 4 miles, rises to 1,225 or 1,250 feet. This lake has no trees on its margin, excepting two small cottonwoods, each about 25 feet high, on its northwest shore; bushes grow in several places, mostly on the east; but the greater part of the lake border, like all the surrounding country, is prairie.

Beach ridge through the north part of Sec. 2, T. 147, R. 55, 1,138 to 1,132 feet. In the south half of Sec. 35, T. 148, R. 55, it has been mostly eroded by a lake which borders this beach on the east from the north part of Sec. 2 to the north part of Sec. 35, having a length of 1 mile and a width of an eighth to a fourth of a mile. The elevation of this lake is 1,104 feet. It has no trees nor bushes, excepting a few willows 4 to 6 feet high near the middle of its west side, and is wholly surrounded by hard grassy shores. Crest of beach west of the north part of this lake, 1,140 to 1,142 feet, and through the south half of section 26, 1,137 to 1,142 feet, similarly bordered on the east by two lakelets, which have approximately the same height as the preceding, 1,104 feet. The land east of these three lakes is flat, 1,113 to 1,117 feet near them, with a very gentle slope descending thence eastward.

More diffuse and irregular beach deposits in north to south swells and short massive ridges of gravel and sand, inclosing occasional hollows with no outlets, some of which hold small ponds and sloughs, extend from the north edge of Sec. 26 northward through the west half of Sec. 23, T. 148, R. 55, with an elevation of about 1,135 feet. The depression on the west is some 5 feet lower and on the east there is a descent of 10 feet from the crest to the base of the beach. Fingal's Creek in the northwest corner of section 23, where it intersects the beach, about 1,110 feet. Undulating and rolling till within 3 or 4 miles westward rises to 1,250 feet.

Herman beach through the west part of Sec. 14, T. 148, R. 55, 1,142 to 1,147 feet, being mainly a somewhat typical ridge, with short swells of beach gravel and sand on its east side 10 to 15 feet lower, inclosing hollows, but few or no sloughs. Two lakes at 1,110 feet, approximately, lie close east of this beach near the center and in the NW. $\frac{1}{4}$ of this section. They are bordered on the east by land 10 feet higher, from which a very gentle descent sinks toward the Red River.

Continuation of this beach ridge northward through the east edge of Sec. 10, T. 148, R. 55, 1,142 to 1,146 feet, 3 to 5 feet above the depression on its west side. On the east, three lakelets at 1,120 feet, approximately, lie in the west edge of the NW. $\frac{1}{4}$ of Sec. 11, each being about 20 rods long from south to north and 15 rods wide. Crest of beach ridge, 30 to 40 rods wide, extending nearly due north through the east edge of Sec. 3, 1,144 to 1,150 feet; east base about 1,125 feet; depression on the west, 5 to 10 feet, nearly level upon a width of 40 rods; beyond is an ascent of undulating and rolling till to 1,250 feet within 2

or 3 miles. In the SW. ¼ of the SW. ¼ of Sec. 36, T. 149, R. 55, this Herman shore is marked by irregular swells and massive short ridges of gravel and sand, with occasional inclosed sloughs. This is succeeded by a half mile of the ordinary continuous single ridge, 1,147 to 1,150 feet.

Watercourse intersecting the beach near the northwest corner of Sec. 36, T. 149, R. 55, about 1,115 feet; bottomland 10 to 15 feet higher, a third of a mile wide, bordered by bluffs rising about 25 feet above it. Some portions of this creek are very shallow or dry, with scarcely any channel, but other portions are pools 6 to 9 feet deep and 20 feet wide, extending 10 to 20 rods or more.

Magnificent beach ridge, passing north-northwest through the east part of Secs. 26 and 23, T. 149, R. 55 (Lind), 1,147 to 1,150 feet. A road, which was formerly an Indian trail, runs on its top here and for several miles northward. This beach is composed of the usual sand and gravel, thickly filled with pebbles up to 2 and rarely 4 inches in diameter. It forms a broad wavelike ridge, 30 to 40 rods wide, including the slopes. On its west side is a depression of 5 to 10 feet, 20 to 60 rods wide, which is moist grass land, excepting a small reedy slough in the south edge of Sec. 11. Farther west undulating and rolling till rises to 1,175 feet within a quarter or a third of a mile and attains a height of 1,250 to 1,300 feet within 3 to 5 miles. On the east side of this upper Herman beach there is a very smooth slope descending 25 or 30 feet in as many rods. Next is a nearly level belt 20 to 60 rods wide, increasing in width from south to north, succeeded by a lower Herman beach ridge rising 8 to 10 feet, with its crest at 1,127 to 1,130 feet, or 20 feet below the upper beach. These parallel Herman beaches are very finely developed thus for nearly 6 miles, passing north through Secs. 23, 14, 11, and 2, T. 149, R. 55, and the southwest part of Sec. 35, T. 150, R. 55. High portion of the upper beach in the south edge of Sec. 14, 1,153 feet, and depression west, 1,142 feet; crest onward through this section, 1,153 to 1,149 feet. In the north part of Sec. 11 and the south edge of Sec. 2, it is a few feet lower, is irregular in height and outlines because of intersecting watercourses, and has a less continuous and shallower depression on its west side. In Sec. 2, however, both beach ridges are finely displayed, having the same contour as southward. Crest of upper beach in Secs. 2 and 35, 1,152 to 1,155 feet; depression on the west, 8 to 15 feet, partly occupied by a long slough. The northwest part of Sec. 35, in the course of these beaches, is lower smooth till, with no deposits of sand and gravel.

Goose River, near the north line of the NW. ¼ of Sec. 35, and the Little Goose River, in the north part of Sec. 15, T. 150, R. 55, where they cross the ancient lake shore, are in valleys about 30 feet deep, eroded in till. Each consists of pools 5 to 7 feet deep and 10 to 20 feet wide, alternating with other portions so narrow that one may step across them.

In the east part of the west half of Sec. 26 and the southwest corner

of Sec. 23, T. 150, R. 55, the upper Herman shore is offset a third of a mile east from the remainder of its course and consists of massive irregular swells of till, partly overspread with gravel and sand, 1,152 to 1,160 feet. Among them are hollows 4 to 6 feet deep without outlet, and their entire belt, a quarter of a mile wide, is crossed by depressions as low as 1,145 feet. Through Sec. 22 this shore bears a typical beach ridge of sand and gravel, 40 or 50 rods wide, 1,157 feet, with depression of 10 to 15 feet on the west; descent of eastern slope, 20 to 25 feet in 30 or 40 rods. In Sec. 15 this upper beach, 1,152 to 1,157 feet, has a quite irregular form, chiefly due to erosion by the Little Goose River and its small tributaries. It is again exhibited in its ordinary type through Sec. 10, being a ridge 25 or 30 rods wide, with crest at 1,155 to 1,157 feet, 15 to 20 feet above its east base, and with a narrow depression of 4 to 8 feet on the west; through the west part of Sec. 3, T. 150, R. 55, and the west edge of the SW. ¼ of Sec. 34, T. 151, R. 55, 1,157 to 1,159 feet, excepting gaps cut by small watercourses; and in the east edge of the NE. ¼ of Sec. 33, 1,154 to 1,157 feet. Thirty rods west from the northeast corner of this Sec. 33, its elevation is 1,155 feet, with slopes descending 12 feet eastward and 8 feet westward.

Lower Herman beach, a half mile to three-fourths of a mile east of the foregoing, in the west edge of Secs. 14 and 11 and the east edge of Sec. 3, T. 150, R. 55, 1,130 to 1,135 feet, from which there is a descent of 5 feet to its west base and 10 feet to the east. From the SE. ¼ of Sec. 34, T. 151, R. 55, this beach passes northeasterly to Larimore.

Upper Herman beach, a well defined ridge, running north through the east part of Sec. 28, T. 151, R. 55, 1,155 to 1,159 feet; thence north-northwesterly through Secs. 21 and 16, 1,157 to 1,160 feet, and through the southwest part of Sec. 9, the northeast of Sec. 8, and the SE. ¼ of Sec. 5, 1,157 to 1,162 feet. Where it is crossed by the Saint Paul, Minneapolis and Manitoba Railway from Larimore to Devil's Lake, in the south part of the NE. ¼ of Sec. 5, its crest was 1,162 feet, 4 feet above the track, and it holds the same height for about 50 rods northeastward. Two-fifths of a mile east from this beach the railroad crosses a second beach deposit whose crest and the track are the same, 1,146 feet.

SHORE WEST OF THE ELK AND GOLDEN VALLEYS.

Through Sec. 32, T. 152, R. 55 (Elm Grove), the upper beach runs northwesterly, its elevation being 1,160 to 1,163 feet. Its material is coarse gravel, with pebbles up to 6 inches in diameter, in part accumulated as a ridge 10 or 15 feet above the land at its base northeast and 5 to 8 feet above its southwest base, and in part lying on the flank of swells of very stony till, the crests of which are only 5 to 10 feet higher than the beach. This till or morainic drift contains a multitude of granitic and limestone bowlders up to 1½ feet in diameter, but few or none of larger size. In the rolling till which rises thence westward to

1,250 or 1,300 feet within 2 or 3 miles, are many granitic bowlders up to 5 feet or more in diameter, exceeding the usual proportion in the till of this region.

In the north edge of Sec. 32 and the south part of Sec. 29, T. 152, R. 55, this beach is the terracelike border of a nearly level tract of sand and gravel an eighth of a mile or more in width, at an elevation of 1,171 to 1,173 feet. The bordering slope is beach gravel, with its base at 1,155 to 1,158 feet; but the slow descent thence eastward is till, somewhat eroded by wave action and having many small and large granitic bowlders up to 4 or 6 feet in diameter strewn on the surface or partially covered by the soil. In the NE. ¼ of Sec. 30 this upper Herman beach is typically developed, being a gracefully rounded ridge of sand and gravel, 25 or 30 rods wide; crest, 1,165 to 1,166 feet; foot of eastern slope, 1,150 feet; depression west, usually 2 to 5 feet, beyond which is a slowly ascending area of smooth undulating till.

Upper beach through Sec. 19, T. 152, R. 55, a low rounded ridge of sand and gravel about 25 rods wide; crest, 1,166 to 1,168 feet; base of its east slope on the north line of this section, 1,158. In the SW. ¼ of Sec. 18, this beach is cut by the South Branch of the Turtle River; its elevation in this section south of the stream is 1,167 to 1,168 feet. There is no considerable valley here and the creek runs only in spring or after unusual rains, being reduced to stagnant pools during the rest of the year. Within 2 miles southeast, however, it becomes a living stream, fed by almost ice-cold springs; and thence to the secondary Herman beach, near Larimore, it has cut a valley 50 to 90 feet deep.

Elm Grove, comprising about 5 acres, is on this creek, a third of a mile east of the upper Herman shore line, which continues north-northwestward through the southwest part of Sec. 18, T. 152, R. 55, and the northeast edge of Sec. 13, T. 152, R. 56 (Niagara), to the west side of Little Elm Grove, 10 acres or more in extent, in the east part of Sec. 12. Along this distance of 1½ miles the surface presents a very favorable slope, from 1,150 to 1,200 feet elevation, on which a beach ridge or definite beach deposits would usually be found well developed; but the waves and currents of Lake Agassiz could not act very efficiently here, because this area lay in the lee of islands and a wave-formed bar or beach several miles to the east, which are the eastern boundary of the Elk Valley. Consequently deposits of beach sand and gravel are scanty on the upper western shore of Lake Agassiz here and for 40 miles northward along the extent of the Elk and Golden Valleys, east of which a narrow chain of islands and bars rose above the surface of Lake Agassiz during its highest Herman stage. Between the South Branch of Turtle River and Little Elm Grove the beach formation consists only of a thin covering of sand and gravel spread on the sloping area of till, elevation from 1,160 to 1,175 feet. Several of the small grassy channels eroded here, dry excepting in spring and times of excessive rain,

are almost completely paved with stones up to 1 or 2 feet in diameter, but few stones occur upon the adjoining surface of till.

From the Little Elm Grove the highest western shore of Lake Agassiz (consisting of a similar slope of till ascending gently westward, with inconspicuous deposits of beach gravel and sand, not accumulated in any distinct ridge, but probably recognizable almost continuously) extends northward through Secs. 12 and 1, T. 152, R. 56, and Secs. 31 and 30, T. 153, R. 55 (Agnes), to the central part of Bachelors' Grove, which it passes through in the west half of Sec. 30. This grove borders the head stream of Turtle River for 1½ miles, with an average width of about a quarter of a mile, thus comprising approximately 250 acres. It is dense woods, chiefly elm and basswood in its east half, but nearly all bur oak for the west half. Much bur oak is also found along several miles of this stream next westward, but it is not seen from the margin of Lake Agassiz, being hidden in the valley, 40 to 50 feet deep, which the stream has eroded in that area of undulating and rolling till.

Surface at M. S. Wallace's house, in the middle of the west edge of Sec. 32, T. 153, R. 55, 1,146 feet. Bridge over the North Branch of Turtle River on the east line of the SE. ¼ of Sec. 30, 1,150 feet; channel (dry August 5, 1885), 1,142 feet. There is no valley here, only a trenchlike channel in the flat expanse of Lake Agassiz, 8 feet deep.

Herman beach, for the first mile or more north from Bachelors' Grove, passing through the NW. ¼ of Sec. 30 and the west edge of Sec. 19, 1,165 to 1,170 feet. This is mostly a well defined beach ridge, 20 to 30 rods wide, composed of sand and gravel, with pebbles up to 2 inches in diameter. It rises slowly to a height of 10 or 12 feet above the flat land on the east and is bordered on the west by a depression of 1 to 3 feet, beyond which a smoothly undulating and rolling surface of till rises to an elevation of 1,200 and 1,250 feet at a distance of 3 miles. In the NW. ¼ of this Sec. 19 the beach deposit becomes complex, consisting of several irregular ridges rising 5 to 8 feet above their bases, 1,167 to 1,170 feet above sea level, with inclosed hollows, and the depression close west occasionally sinks to 1,155 feet.

Surface at Michael McMahon's house, 40 rods west from the center of Sec. 13, T. 153, R. 56 (Oakwood), 1,176 feet. Rounded hill of till a half mile northeast, about 1,205 feet; swells of till in the southwest part of Secs. 12 and 2, 1,195 to 1,210 feet.

Through these Secs. 13 and 12, the southwest part of Sec. 1, and in Sec. 2, T. 153, R. 56, to the grove on the north line of this section at the junction of the north and south branches of Lost Creek, and thence northeast and north through Sec. 35, T. 154, R. 56 (Elksmount), the Herman shore, between 1,160 and 1,170 feet, is not marked by any considerable deposits of gravel and sand. Farther north this shore is distinguished not only by a noticeable change in the topographic features along a nearly level line at 1,170 feet, dividing the very flat area of the glacial lake from the undulating and rolling till on the west, but also

by occasional beach deposits. Through the south half of Sec. 26 a somewhat typical beach ridge of sand and gravel, 15 to 25 rods wide, with a depression of 3 to 6 feet on its west side, runs north and northwest, its crest being at 1,175 to 1,170 feet, declining from south to north. On the east its slope falls 5 to 10 feet in 10 to 20 rods; and thence a more gentle descent, with surface of sand and fine gravel, sinks to 1,155 feet within an eighth of a mile. In the NW. ¼ of this Sec. 26 the beach ridge ceases and is succeeded northward by an expanse of nearly flat till, which along the north line of this section sinks eastward from 1,175 to 1,155 feet.

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

Surface at Frank Hamilton's house, in the center of the NE. ¼ of Sec. 15, T. 154, R. 56, 1,178 feet.

Upper Herman beach, a definite and massive ridge of sand and fine gravel, 25 to 40 rods wide, for a half mile south from the South Branch of Forest River, in the west part of the NW. ¼ of Sec. 14, T. 154, R. 56, 1,173 to 1,178 feet, passing north and northwest, with a descent of 12 to 15 feet on the east and a depression of 4 to 8 feet on the west.

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

Natural surface at the northwest corner of Sec. 3, T. 154, R. 56, on the line between Grand Forks and Walsh Counties, 1,181 feet.

The upper Herman shore passes north-northwesterly through this corner of Sec. 3 and the east part of Sec. 33, T. 155, R. 56 (Medford), to the Middle Branch of Forest River (farther east formerly called Salt River), which it reaches near the center of the east half of Sec. 28. It has only scanty deposits of beach gravel and sand, nowhere forming a ridge; instead, the surface is mainly till, very flat east of this shore, but undulating or rolling westward.

The South and Middle Branches of Forest River occupy valleys 25 to 40 feet deep and 20 to 30 rods wide. They are bordered with groves,

or at least a continuous line of trees, along the greater part of their course.

In the NW. ¼ of Sec. 28 and the west part of Sec. 21, T. 155, R. 56, the highest shore line of Lake Agassiz is very distinctly marked, at 1,183 to 1,185 feet, by being the upper edge of a flat slope of till, probably with scanty deposits of gravel and sand, which sinks 20 to 30 feet in the next half mile eastward. Farther east, for the width of 3 or 4 miles across the Elk Valley, the surface elevation is 1,160 to 1,125 feet.

Just west of this shore line a knolly belt of morainic drift, bearing a marvelous profusion of bowlders, occupies a width of 25 to 50 rods, generally forming a single series of hillocks rising 15 to 30 or 35 feet. These are strewn with bowlders of all sizes up to 5 feet and rarely 8 feet in diameter, so plentiful that they cover a third or even half of the surface. A few masses of limestone were observed; but fully 99 per cent. of the bowlders are archean granite and gneiss. This is the most eastern portion of a semicircular moraine, which appears to have been accumulated on the eastern boundary of a lobe of the ice sheet during a pause in its retreat. From Secs. 21 and 28 this moraine continues, with nearly the same features, south and southwest to the SE. ¼ of Sec. 32, and thence west-southwest by Pilot Knob in the NW. ¼ of Sec. 5, T. 154, R. 56, to the west side of Sec. 1, T. 154, R. 57, and perhaps beyond. Its hills and knobs rise 25 to 75 feet above the general level of the adjoining smoothly undulating till, their tops being 1,250 to 1,300 feet above the sea. To the north, northwest, and west it reaches, with similar development, in a great curve convex to the northeast, along an extent of 5 or 6 miles, to a cluster of prominent morainic hills rising 50 to 75 feet, situated in Secs. 2 and 3, T. 155, R. 57. This moraine matter was doubtless englacial; among its multitude of both large and small rock fragments a half hour's search failed to discover any marked with striæ or having surfaces planed by glaciation. On the west the area inclosed by this curving moraine is very smooth, only slightly undulating till, at 1,185 to 1,250 feet, ascending slowly westward.

Another distinct morainic series, similar in its very knolly contour, in its material (excepting a larger proportion of gravel, half of which is the cretaceous shale before described), and in the great abundance of bowlders, nearly all granitic, branches from the preceding in the north part of Sec. 8, T. 155, R. 56, and sweeps northeast and north through the west half of Sec. 4, and thence northwest and west through Secs. 32, 29, and 19, T. 156, R. 56 (Vernon), and Secs. 13 to 16, T. 156, R. 57 (Norton), to a group of morainic hills about 75 feet high, a mile northwest of Galt post office. Between this curved moraine and the nearly parallel northern part of the preceding, 4 miles distant to the south, the surface is very smooth undulating till, rising slowly toward the west.

These moraines, with their east base at 1,185 to 1,170 feet above the sea, formed the west shore of Lake Agassiz at its highest stage for nearly 7 miles between the Middle and North Branches of the Forest

River. The North Branch intersects this shore line near the center of Sec. 20, T. 156, R. 56, close to the southwest end of Ramsey's groves, which extend thence about a mile along this watercourse in the north part of Sec. 20 and the SE. ¼ of Sec. 17. The stream in these sections has no valley, only a channel 20 to 30 feet wide and 10 feet deep.

Elevation of road at the southeast corner of this Sec. 20, 1,177 feet.

Golden Valley, on the north line of Secs. 4 and 5, T. 156, R. 56, 1,185 to 1,195 feet, showing an ascent of 10 feet from east to west in its width of 2 miles. About the same transverse slope, raising the west side of this valley 10 or 15 feet above its east side, is found along its whole extent of 20 miles or more, from the Middle and North Branches of Forest River to the Middle and North Branches of Park River. In the north half of T. 156, R. 56, and thence northward, the width of this valley varies from 1¾ miles to only 1 mile. It is flat and consists mainly of clay, free from gravel; but wells find gravel intermixed with the clay, probably till, at a depth of a few feet, and about 20 feet from the surface they sometimes encounter a water-bearing stratum of gravel, chiefly made up of cretaceous shale.

Natural surface at the southwest corner of Sec. 27, T. 157, R. 56 (Garfield), 1,191 feet. Highest part of Golden Valley south of the South Branch of Park River, along the north line of Secs. 27, 28, and 29, in this township, 1,199 feet on the east to 1,211 feet on the west. Surface at school-house on the west side of the NW. ¼ of Sec. 21, 1,207 feet.

South Branch of Park River at the Garfield bridge, near the middle of the north line of Sec. 21, T. 157, R. 56, 1,170 feet, approximately; bottomland about a quarter of a mile wide, 10 to 15 feet above the stream; crest of the south bluff rising to the flat belt of the Golden Valley, 1,191 to 1,209 feet, ascending westward; of the north bluff, 1,189 to 1,205 feet.

Golden Valley, on the north line of Sec. 5, T. 157, R. 56, 1,195 to 1,205 feet; 2 miles farther north, on the north line of Sec. 29, T. 158, R. 56 (Lampton), 1,198 to 1,208 feet. In this northern part of the valley limited tracts of its flat area are strewn with abundant bowlders up to 2 feet and less frequently 3 or 4 feet in diameter. They are probably where swells of till rose nearly to the surface of the water in this strait of Lake Agassiz, so that its fine portions were swept away by waves and currents, to be deposited elsewhere in the valley as clayey silt, leaving the masses of rock which could not be thus removed. Approaching the Middle Branch of Park River, the surface of Golden Valley continues very smooth and flat, but it ceases to have a continuous ascent from east to west, some portions along the center being depressed a few feet. Such a shallow hollow holds a slough about a mile long from south to north and a half mile wide in its broadest part, at 1,193 feet, extending from the north edge of Sec. 20 through the west part of Sec. 17, T. 158, R. 56, in which a small area of water remains throughout

the year. On each side of this slough and for miles south and north, this valley is a great hay meadow.

The west border of the Golden Valley was the most western shore of Lake Agassiz in its highest stage, but it is only very scantily marked by deposits of beach gravel and sand, because of its sheltered position on the western and leeward side of this narrow strait. From the middle of Sec. 20, T. 156, R. 56, this shore line extends in a quite direct course a few degrees west of north 11 miles through the west part of Secs. 17, 8, and 5, in this township, Secs. 32, 29, 20, 17, 8, and 5, T. 157, R. 56, and the east edge of Secs. 31 and 30, T. 158, R. 56. For the next 3 miles, in the east edge of Secs. 19, 18, and 7, T. 158, R. 56, it runs nearly due north. Thence it turns to a northwesterly course through Sec. 6 of this township, passing a mile west of Edinburgh post office and through Sec. 31, T. 159, R. 56. In this vicinity the Golden Valley terminates.

Bushes and trees clothe the slope on the west side of the Golden Valley along its northern part, extending to the south line of T. 158, R. 56; but this ascent farther south, also the entire extent of the Golden Valley, the drift hills forming its east border, and the vast plain of the Red River Valley, are prairie, excepting that narrow belts of timber border the water courses.

Smoothly undulating till rises slowly from the west side of the southern part of the Golden Valley; but in Sec. 30, T. 158, R. 56, rounded hills of till attain a height about 100 feet above the valley, or 1,300 feet above the sea. Thence northward a smooth slope ascends 50 to 60 feet, or in some portions only 30 or 40 feet, within the first quarter or half of a mile to the west, succeeded beyond by a moderately rolling surface with less ascent.

A terrace of beach sand and gravel, containing pebbles and cobbles up to 6 inches in diameter, extends a third of a mile from southeast to northwest, with a width of 5 to 30 rods, in the NW. $\frac{1}{4}$ of Sec. 33, T. 158, R. 56, abutting on the west flank of the rolling and hilly deposits of till which make the east border of the Golden Valley. It was formed by currents entering this strait of Lake Agassiz from the north, eroding the bordering hills in the east edge of Secs. 20 and 29, and thence sweeping this sand and gravel southward. It marks the highest stage of Lake Agassiz, having an elevation of 1,213 to 1,195 feet, declining from north to south, and also sinking 1 or 2 feet from west to east in its width of 100 to 500 feet, being thus slightly higher along its verge than where it rests upon the adjoining hilly till.

Natural surface at the quarter-section stake on the east side of Sec. 8, T. 158, R. 56, 1,203 feet; at Edinburgh post office, near the center of Sec. 5, 1,202 feet.

Middle Branch of Park River a half mile south of Edinburgh, approximately, 1,185 feet; crest of the south bank of the very small valley of this stream, rising to the flat Golden Valley, 1,192 feet on the east to

1,215 feet on the west. The Golden Valley here shows thus a transverse ascent of more than 20 feet in its width of about 1 mile. On the north line of Secs. 5 and 6, T. 158, R. 56, the east edge of this valley has an elevation of 1,210 feet, and its west edge, 1,220 feet. About a half mile farther north, the height of this belt, where it is crossed by a tributary of the Middle Branch, is 1,220 to 1,235 feet, from east to west, being thus above the highest level of Lake Agassiz. Elevation of this tributary at a bridge of a road that runs very crookedly through bushes and small woods in Sec. 32, T. 159, R. 56, 1,204 feet; and at a bridge a few rods north of the middle of the east side of Sec. 29, 1,175 feet.

BEACHES AND ISLANDS EAST OF THE ELK AND GOLDEN VALLEYS.

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

Saint Paul, Minneapolis and Manitoba Railway track at Larimore, 1,134 feet above the sea.

The upper or first and the second Herman beaches before described, respectively $4\frac{3}{5}$ and $4\frac{1}{5}$ miles west of Larimore, are 1,162 and 1,146 feet above the sea. Third Herman beach, a third of a mile east of Larimore depot, crest, 1,133 feet; another beach belonging to the same stage of Lake Agassiz, a third of a mile farther east, crest, 1,134 feet, with descent in thirty or forty rods east 11 feet, and in the same distance west 9 feet. Fourth Herman beach, consisting of four small beach ridges crossed by the railway $1\frac{1}{2}$ to 2 miles east of Larimore, crests, 1,123 to 1,118 feet, with intervening hollows 3 to 5 feet deep. A nearly level tract reaches 4 miles westward from Larimore along the railway to Devil's Lake, averaging 1,130 feet and varying only 2 or 3 feet above and below this level. Beneath the rich black soil here and elsewhere, all about Larimore, are stratified sand and fine silt free from gravel. The beach ridges near this town are consequently composed wholly of sand, quite in contrast with their usually coarser material.

Well at the Sherman House, Larimore, L. C. Neal, proprietor, dug 20 feet and bored 40 feet lower: soil, 2 feet; fine sandy and clayey silt, without coarse sand, gravel, or stones, 5 feet; fine yellowish sand, with less clay, being mainly siliceous, 13 feet; and dark sand, very soft to bore through, two-thirds cretaceous shale in particles up to a twentieth of an inch in diameter, 40 feet, with much water. Hard blue till was found at the bottom. This is the deepest well in the town. All the other wells are said to obtain their supply of water at a depth of about 20 feet, in the upper part of this sand chiefly derived from shale. The origin and manner of deposition of these beds of sand and silt deserve further observations and study.

The beach seen two-thirds of a mile east of Larimore passes north and north-northwesterly through the east half of Secs. 7 and 6, T. 151, R. 54, and the west half of Secs. 31 and 30, T. 152, R. 54, into the southeast corner of Sec. 24, T. 152, R. 55. North of the South Branch of Turtle River it is not a typical ridge, but a series of massive rounded swells of sand 10 to 15 feet high, with their crests at 1,135 to 1,140 feet.

A parallel beach ridge a third to a half mile west of the foregoing, mostly massive, with typical wavelike form, has an elevation of 1,133 feet close east of Larimore; 1,144 feet at a cemetery close north of the South Branch of Turtle River in or near the southwest corner of Sec. 31, T. 152, R. 54; chiefly 1,137 to 1,140 feet in its course thence north-northwesterly through Secs. 36 and 25, the west edge of Sec. 24, and the east half of Sec. 14, T. 152, R. 55; 1,142 to 1,145 feet in the west half of Sec. 11 and 1,143 to 1,147 feet in the east edge of Sec. 3 of this township. Along the west edge of Sec. 11, a duplication of this beach ridge, of the same massive size, lying a half mile farther west, extends a mile south from the North Branch of Turtle River, its crest being at 1,142 to 1,145 feet; but thence southward the general elevation is about 1,130 feet to the tract of this height crossed by the railway west of Larimore, excepting that the South Branch of Turtle River has eroded a valley 40 to 75 feet deep. The distance of one and a half miles from Larimore north to this stream is a gradually descending smooth slope, but its northern bluff rises steeply to a height a few feet above that of Larimore.

North Branch of Turtle River in the north half of Sec. 11, T. 152, R. 55, 1,085 to 1,075 feet; bottomland, an eighth of a mile wide, 10 to 15 feet above the stream; crest of bluffs a quarter to a third of a mile apart, about 1,135 feet.

Saint Paul, Minneapolis and Manitoba Railway at McCanna, 1,140 feet; on bridge over the North Branch of Turtle River, 1,132 feet, 17 feet above the stream; summit, in the northeast corner of Sec. 22, T. 153, R. 55, grade and natural surface, 1,164 feet; Orr, 1,098 feet.

Lower Herman beach, running northwesterly in the northeast part of Sec. 24, T. 152, R. 55, 1,127 to 1,128 feet, with depression of 2 to 3 feet on its west side; in Sec. 13, 1,127 to 1,132 feet; in the west part of Sec. 12 and the northeast part of Sec. 11, 1,130 to 1,135 feet, being in these sections the easternmost in a succession of three beach ridges, the two others of which are 10 feet higher; at E. C. D. Shortridge's house, in the center of Sec. 2, 1,137 feet, forming a broad flat swell of sand and fine gravel, with a depression of 3 to 5 feet on its west side; in the west part of Sec. 36, through Secs. 26 and 23, and the southwest edge of Sec. 14, T. 153, R. 55, a continuous, well defined beach ridge, 1,140 to 1,149 feet, with a descent of 10 to 15 feet on the east and a depression of about 5 feet on the west; in the east edge of the NE. ¼ of Sec. 15 and through the SE. ¼ of Sec. 10, a deposit of sand and fine gravel, with nearly level top 20 to 30 rods wide, 1,145 to 1,149 feet, from which a slope falls 10 or 15 feet in 20 to 30 rods eastward, while on the west it is bordered

by a slough 5 to 20 rods wide, which is partly permanent water and partly mowing land. It is to be noted that the northern two-thirds of the beach here described for a distance of 8 miles corresponds in elevation with the two beaches close east of Larimore and their continuation northward to the North Branch of Turtle River, marking the third Herman stage of Lake Agassiz; but that the southern part records a slightly lower level of the lake, when it had fallen about 10 feet, or to its fourth Herman stage.

On the west side of this beach a smoothly undulating broad swell of till, which was an island in Lake Agassiz, lies in the west part of Sec. 26 and the east edge of Sec. 27, T. 153, R. 55, with nearly level top of several acres, at 1,182 to 1,190 feet. An aboriginal burial mound, raised 4 feet and 50 feet across, is situated on the highest part of this area, 15 rods east-northeast from the quarter-section stake between these sections. Such localities, overlooking an extensive and beautiful panorama, were frequently chosen for this use, as is shown by many mounds on hill-tops and on the margin of bluffs bordering deeply eroded valleys throughout the Northwest. A lower tract of somewhat roughly rolling till, with plentiful bowlders, reaches a third of a mile southeasterly from this swell to the south edge of Sec. 26. Thence a broad ridge of beach gravel and sand, belonging to the second and third Herman stages of Lake Agassiz, with an elevation of 1,153 to 1,151 feet, sinking southward to 1,145 feet, extends south-southeasterly through the east half of Sec. 35 and continues with the same course to Larimore, as before described.

North of this island the upper Herman beach is represented in the east part of the SE. ¼ of Sec. 22 and in the west half of the SW. ¼ of Sec. 23, T. 153, R. 55, by a wide tract of gravel and sand deposits, in irregular ridges and swells rising 4 to 8 feet, mostly trending from north to south, with their crests at 1,164 to 1,170 feet. Next to the north it is a well defined beach ridge, with crest rising from 1,163 to 1,168 feet in its course of a half mile from south to north through the east edge of the NE. ¼ of Sec. 22.

In the SE. ¼ of Sec. 15, T. 153, R. 55, the plain that descends slowly toward the Red River on the east is divided from the Elk Valley on the west by a low swell of till, having an elevation of 1,157 to 1,160 feet, destitute of beach deposits. This is succeeded in the north part of this section and the south part of Sec. 10 by a second island which rose above the highest level of the glacial lake, having a length of 1 mile from south to north and averaging a quarter of a mile wide, its elevation in the SW. ¼ of the NE. ¼ of Sec. 15 being about 1,187 feet, on the line between these sections about 1,175 feet, and near the center of Sec. 10, at the north end of this irregular ridge, about 1,180 feet. Its material is till, partially overspread in its south half by gravel, which seems to have been brought by the currents and waves of Lake Agassiz from the erosion of its northern portion.

The beach of Lake Agassiz during its highest stage extends north from the north end of this island into the SW. ¼ of Sec. 3, T. 153, R. 55, where it is a ridge about 20 rods wide, with an elevation of 1,165 to 1,172 feet, composed of coarse gravel and sand, inclosing plentiful rock fragments, chiefly granitic, of all sizes up to 6 inches in diameter, most of which are only slightly water-worn. Its eastern slope descends 15 to 20 feet in as many rods, and on the west an equal descent takes place within 8 or 10 rods. The steep western slope of this beach or bar, forming the east rim of the strait that filled the Elk Valley, was due to storms on the broad lake, rolling its waves upon the bar and carrying the sand and coarse gravel upward and over its crest. Turning northwestward, this beach passes into the NE. ¼ of Sec. 4, where it consists of irregular accumulations of gravel and sand, occupying a width of an eighth to a fourth of a mile, with their crests at 1,155 to 1,162 feet. In the north edge of Sec. 4 it again becomes a definite beach ridge of the same material and contour as in Sec. 3, and thus passes northeast and north through Sec. 33, T. 154, R. 55, with its crest mostly at 1,165 to 1,172 feet, its lowest part, about 1,162 feet, being near the center of this section. The two islands before described, this beach or bar, and the long island next northward are together commonly called "The Ridge," being the eastern limit of the Elk Valley, which averages 4 miles wide, 1,150 to 1,140 feet above the sea in its eastern and central portions, but rising with a transverse slope to 1,160 feet on its western border.

A third island above the highest stage of Lake Agassiz, 3 miles long from south to north and a quarter to a half mile wide, reaches through the central part of Secs. 28 and 21, the west half of Sec. 16, and into the southwest corner of Sec. 9, T. 154, R. 55. It is till, with somewhat uneven surface, bearing frequent bowlders. Highest points of this in Secs. 28 and 21, 1,185 to 1,195 feet; intervening gaps, about 1,170 feet; summit, near the center of the SW. ¼ of Sec. 18, 1,223 feet, and lower summit, about a half mile to the north, 1,218 feet, each bearing a flat round earthwork about 1 foot higher; lowest depressions intervening, about 1,195 feet; depressions in the northwest part of Sec. 16, 1,185 feet, and highest points in the southwest corner of Sec. 9, 1,194 and 1,195 feet. Beach deposits occur on the east flank of this island in Sec. 21 at 1,155 to 1,165 feet, and from 1,155 feet a smooth slope of sand and fine gravel falls slowly eastward along the east side of this highland through the greater part of its extent.

In the southeast part of Sec. 8, T. 154, R. 55, irregular accumulations of beach gravel, with crests at 1,170 to 1,175 feet, 10 to 15 feet above the adjoining depressions of till, extend northward from the island just described; and in the north part of this Sec. 8 the beach sinks within an eighth of a mile from 1,172 to 1,161 feet and changes to a broad, smooth ridge, which thence passes northward through Sec. 5 of this township, in which it is intersected by the Forest River, with valley a half mile wide and 60 to 75 feet deep, and through the west

half of Sec. 32, T. 155, R. 55, near the center of which it has three aboriginal mounds on its top. The material of this beach ridge is fine gravel and sand. Elevation of its crest on the line between Secs. 8 and 5, 30 to 40 rods east of the quarter-section stake, 1,161 feet; an eighth of a mile north, at the verge of the south bluff of Forest River, 1,155 feet; for the first half mile from the bluff north of this river, 1,152 to 1,157 feet; and at the mounds in Sec. 32, 1,156 to 1,159 feet. These mounds lie in a line bearing north-northeast; top of most southerly mound, 1,162 feet, about 6 feet above the adjacent ground; elevation of the middle one, some 20 rods away, 1,166 feet, and of the most northern, again about 20 rods from the last, 1,167 feet, each being 8 feet higher than its base.

Another beach ridge, 20 rods wide, with descent of 10 feet on each side in as many rods, formed during the same stage of Lake Agassiz, lies a half to three-fourths of a mile west from the foregoing, in the NE. ¼ of Sec. 6, T. 154, R. 55. This is the highest land between the main Forest River and its South Branch. It consists of sand and fine gravel, of which a considerable proportion (about a sixth) is cretaceous shale. The maximum elevation of this ridge, 1,157 to 1,164 feet, is maintained for 50 or 60 rods, from which it sinks to 1,150 feet at each end.

From the north side of Sec. 32, T. 155, R. 55, an island of rolling and hilly till above the highest level of Lake Agassiz, far larger than any of those already described, extends, with the exception of two short gaps, 20 miles northward, varying in width from a half mile to a little more than 1 mile in its southern quarter and from 1½ to 2½ miles through the remainder of its extent. This hilly tract, commonly denominated "the mountains," forms the east border of the Golden Valley. In the north part of Sec. 36, T. 156, R. 56, it has a depression to about 1,180 feet, which probably was a strait of the glacial lake in its highest stage, an eighth of a mile wide and a few feet deep. Again, in the center of T. 157, R. 56 (Garfield), it is intersected by the South Branch of Park River, which has a valley a quarter to a half of a mile wide and about 75 feet deep. The stream, in its course of 1½ miles through this belt, descends about 50 feet, from 1,165 to 1,115 feet, approximately. It seems almost certain that a depression slightly lower than the Golden Valley on the west originally extended across this rolling and hilly area where it is cut by this South Branch of Park River; but the erosion of its valley has undermined and removed portions of adjoining hills and ridges, so that its inclosing bluffs now rise 50 to 100 feet, their highest points being about 1,225 feet above the sea, or 25 to 30 feet above the east edge of the Golden Valley. All these bluffs and two plateaus left in the midst of the valley are till, yellowish near the top and dark bluish below.

Elevation of "the mountains" in their southern and narrower portion, through the west part of T. 155, R. 55, and the northeast corner of T.

155, R. 56, 1,190 to 1,225 feet; through the east half of T. 156, R. 56, 1,200 to 1,250 feet; in the south part of T. 157, R. 56, 1,200 to 1,260 feet; and through the north half of this township and the south half of T. 158, R. 56, 1,200 to 1,275 feet, being highest in Sec. 28 of the township last named, near the northern end of this hilly tract.

The east border of "the mountains" in Sec. 20, T. 155, R. 55, falls somewhat steeply to about 1,135 feet, and thence a flat slope, with no beach ridges, sinks slowly eastward. In the NW. ¼ of the NE. ¼ of Sec. 7 in this township a well defined beach ridge 10 to 15 rods wide, composed of sand and gravel, with pebbles up to 2 or 3 inches in diameter, extends 25 rods south from an eastern spur of the hilly till; crest of this spur, about 1,195 feet; of the beach, 1,172 feet, with depression of 3 to 6 feet on the west. Irregular beach accumulations, 10 to 20 feet lower, continue southward nearly a half mile. The east half of Sec. 6, T. 155, R. 56, has a descent of nearly 100 feet to about 1,100 feet. It is till, with no noteworthy beach deposits. No stream has flowed through the depression in Sec. 36, T. 156, R. 56, and no considerable watercourse crosses the gentle slope of till, overspread with much beach gravel at 1,175 to 1,155 feet, which lies within the next mile east.

In Sec. 30, T. 156, R. 56, the eastern border of this rolling and hilly area falls 75 feet or more within a third of a mile, to about 1,100 feet. Its material is till, with scanty deposits of beach gravel and sand, not distinctly accumulated in ridged form. About half way down this slope, it shows in some places a more abrupt escarpment, with steep descent of 15 or 20 feet. The same features continue through Sec. 19, except that a series of distinct beach deposits is observable about 25 rods east from the crest of the slope, at 1,170 to 1,175 feet, probably formed during the second Herman stage of Lake Agassiz. A little farther north, the upper Herman beach is probably represented, 15 to 30 rods north-northeast from the southwest corner of Sec. 18, in a bank of coarse gravel at 1,182 feet, with a small coulée on its west side. A descent of 125 feet takes place within a half mile on the east side of "the mountains," near where it is cut by a large but short ravine, in the SE. ¼ of Sec. 12, T. 156, R. 56, falling from 1,180 to 1,050 feet, approximately, with no well marked shore lines observable. A grove lies at the east base of this slope a third of a mile south of the ravine. In the NW. ¼ of this Sec. 12 and the west edge of the SW. ¼ of Sec. 1, a well developed beach, in part consisting of two parallel low ridges, has an elevation of 1,170 to 1,177 feet; and in the east edge of Sec. 2, continuing northward, its elevation is 1,177 to 1,184 feet. Its eastern slope falls to 1,170 feet within 10 or 20 rods. Through Sec. 36, T. 157, R. 56, it is not very distinct; but 10 to 25 rods north from the quarter-section stake between Secs. 36 and 25 it is represented by a broad bank of gravel and sand, with crest at 1,187 to 1,190 feet, from which a slight depression falls 1 or 2 feet on the west.

Saint Paul, Minneapolis and Manitoba Railway track at Park River depot, 998 feet; natural surface at the southeast corner of Sec. 23, T. 157, R. 56, on the road from Park River to Garfield, 1,178 feet.

Crest of the upper Herman beach crossed by this road 10 rods west from the point named, 1,187 feet; same 20 rods southeast and northwest from the road, 1,192 feet; depression on the west 3 to 8 feet and descent on the east 10 to 15 feet in as many rods. This is a typical beach ridge of sand and gravel, with pebbles up to 2 or 3 inches in diameter, mostly limestone and granite. The cretaceous shale before mentioned is very rare in the till of "the mountains" and in the beaches formed along their east side, indicating that the east limit of this shale is the Pembina Mountain and the western ascent of the Golden Valley, and that the glacial currents by which the drift here was deposited came only from the north and northeast, with no intermixture of currents from west of north.

Highest beach on verge of south bluff of the South Branch of Park River, in the SE. ¼ of Sec. 23, T. 157, R. 56, 1,188 to 1,192 feet, with a basin shaped hollow on its west side 20 feet lower, which changes southward to a depression of about 5 feet. The river bluff is here freshly undermined, showing the depth of the beach sand and gravel to be 5 to 10 feet, lying on till. Lower beach, a quarter of a mile farther east, extending from northwest to southeast, in the SW. ¼ of Sec. 24, 1,167 to 1,170 feet.

Lower Herman beach, a massive ridge of gravel and sand, extending in a curved course convex toward the east from the NE. ¼ of Sec. 2, T. 157, R. 56, through the southeast part of Sec. 35, T. 158, R. 56, crest, 1,160 to 1,165 feet; through the northeast edge of Sec. 36 and the southwest corner of Sec. 25, 40 to 50 rods wide, with slightly undulating surface, 1,160 to 1,167 feet; near the middle of the east side of the SE. ¼ of Sec. 26, 1,165 to 1,166 feet; and at the quarter-section stake on the north side of this Sec. 26, 1,163 feet.

Near the west line of Sec. 23, T. 158, R. 56, two Herman beaches abut upon the east flank of the north end of "the mountains," and extend thence north-northwesterly 2 miles to the Middle Branch of Park River. The eastern one, a well defined ridge of sand and fine gravel, passes close west of the quarter-section stake between Secs. 15 and 10. The elevation of its crest is 1,161 to 1,166 feet, with increase in height from south to north; the descent on the east is 15 or 20 feet in as many rods, and the depression on the west is 3 to 8 feet deep and 10 rods wide. The other beach ridge is 40 or 50 rods farther west, parallel with the preceding and similar in form and material; its crest, rising slightly northward, is at 1,173 to 1,176 feet. Another distinct beach ridge, but of smaller size, runs in a parallel course through the east part of the SW. ¼ of Sec. 9, with its crest at 1,185 to 1,187 feet. These appear to represent in succession the fourth, third, and second Herman beaches

of the series observed northwest of Maple Lake in Minnesota and east and west of Larimore.

Upper Herman beach, northward from the north end of "the mountains," forming in the NW. ¼ of Sec. 21 and the west part of Sec. 16, T. 158, R. 56, a massive, broad ridge, composed of sand and gravel, with pebbles up to 4 or even 6 inches in diameter, crest, 1,197 to 1,207 feet, rising highest northward, where the beach deposit overlies the eastern slope of a wavelike swell of till that rises to 1,212 feet. Small beach ridge, belonging to this stage, in the east edge of the SE. ¼ of Sec. 8, 1,202 to 1,207 feet. Surface at Evan Edwards's house, in the west part of the SW. ¼ of Sec. 9, 1,197 feet, consisting of sand and gravel of this beach to a depth of 10 feet, underlaid by till, yellowish in its first 6 feet and dark bluish below. Summit of a smoothly rounded hillock, probably till, but having few or no bowlders, in the east edge of the NE. ¼ of Sec. 8, about 1,230 feet; train of beach gravel and sand extending thence 30 rods southward, 1,217 feet, with descent of 15 or 20 feet on each side.

Continuing beyond the Middle Branch of Park River, this highest beach is well developed in a broad ridge running due north through the west part of Sec. 4, T. 158, R. 56, with its crest at 1,202 to 1,208 feet. On the east the surface falls 30 or 40 feet, and more slowly beyond, while toward the west a descent of 10 feet is succeeded by a flat surface of till, which rises slowly from the foot of the beach ridge to a swell, 1,215 to 1,225 feet, a half mile away, forming the east boundary of the Golden Valley. This beach is sand and gravel, with pebbles up to 6 inches in diameter. About half of them are limestone; nearly all of the remainder are archean granite, gneiss, and schists; scarcely 1 in 200 is cretaceous shale. Through the west edge of Sec. 33, T. 159, R. 56, the elevation of this excellent beach ridge is 1,202 to 1,205 feet, and in the southwest edge of Sec. 28 and the middle of the east edge of Sec. 29, 1,202 to 1,197 feet, decreasing in height and size northward. For a half mile through the SW. ¼ of Sec. 33, a slight secondary beach ridge, 4 to 9 feet lower, lies about 30 rods east from the foregoing; its crest is at 1,198 to 1,195 feet, sinking a few feet from south to north; it is divided from the higher beach by a continuous depression about 3 feet deep.

Very massive beach ridge, composed of sand and gravel, with pebbles and rock fragments, the largest only slightly water-worn, up to 6 inches in diameter, passing a few degrees west of north through the center of Sec. 20, T. 159, R. 56, crest in the south half of the section, 1,208 to 1,215 feet; in the north half, 1,215 to 1,223 feet. On the east is a descent of 20 to 30 feet within 25 to 40 rods, and on the west 10 or 12 feet from the highest part of the beach within 10 rods to a nearly level area of till, 1,211 feet, which sinks 40 rods farther west to a long slough, about 1,205 feet, parallel with the beach and one-sixth of a mile wide. Beyond this an undulating surface of till, partly covered with bushes and small trees, rises to 1,250 or 1,275 feet within 2 miles, and then in smooth massive swells to 1,450 or 1,500 feet within the next 2 to 4 miles. These are

part of a plateau, thence rising more slowly westward, whose boundary for the next 50 miles or more to the north and northwest is the conspicuous escarpment called Pembina Mountain.

The north end of this massive beach bears on its crest an artificial embankment 100 feet long from east to west and 20 feet wide, raised 2 feet above the natural surface, its top being 1,225 feet above the sea. This is 10 rods south from where the beach is cut to 1,210 feet by a wide gap, as of some ancient watercourse. In the south edge of the SW. ¼ of Sec. 17, T. 159, R. 56, on the south bank of the North Branch of Park River, about 10 rods east from the ford of the "Half-breed road," this beach has an elevation of 1,220 feet.

North Branch of Park River at this ford, 10 to 15 feet wide and a few inches deep, 1,203 feet. Surface at Garder, a mile east, 1,175 to 1,170 feet. Lower Herman beach, passing from south to north along the east side of Secs. 20 and 17, T. 159, R. 56, a third of a mile west of Garder, about 1,185 feet.

FROM GARDER NORTH TO THE TONGUE RIVER.

Secs. 17, 8, and 5, T. 159, R. 56, rise from 1,190 and 1,200 feet on their east side to 1,220 and 1,225 feet on the west, including, therefore, the upper Herman shore of Lake Agassiz; but they present no considerable deposits of beach gravel and sand. A swell of till, sprinkled with very abundant bowlders, nearly all archean granite and gneiss, up to 5 feet in diameter, extends from south to north across the line between Secs. 8 and 5, having its crest at 1,215 feet, from which there is a steep descent of 10 or 12 feet to the west. Sloughs and pools of water, permanent through the year, lie in the west part of Sec. 5, about 1,190 feet above the sea.

The South Branch of Cart Creek in Secs. 31 and 32, T. 160, R. 56, is bordered by a belt of timber a half mile wide; but it has only a small channel a few feet below the general surface and is dry through the greater part of the year. Its alluvial gravel, like that of the Middle and North Branches of Park River, is mostly cretaceous shale, derived from the gorges eroded in this rock at the sources of these streams in the Pembina Mountain.

Along the western border of Lake Agassiz here and northward into Manitoba extends a prominent wooded bluff, the escarpment of a treeless plateau which from its crest stretches with slow ascent westward. This escarpment, commonly called the second Pembina mountain, is a very marked feature in the topography for at least 50 miles. It is caused by the outcrop, mostly overspread by glacial drift, of a continuous belt of nearly horizontal cretaceous shale, several hundred feet thick, usually so hard and enduring that it is popularly termed "slate." Its course coincides nearly with the west line of Ts. 159 and 160, R. 56. Thence it continues in an almost straight course, a few degrees west of north, through Secs. 31 and 30, T. 161, R. 56; Secs. 24, 13, 12, and 2, T.

161, R. 57; Secs. 35, 26, 22, 15, 10, 9, and 4, T. 162, R. 57; Secs. 33, 28, 21, 16, 9, and 4, T. 163, R. 57; and Secs. 33, 32, and 29, T. 164, R. 57, to the international boundary, beyond which it soon turns more to the northwest. The base of the ascent is about 1,225 feet above the sea and its crest approximately 1,500 feet, northward to the Pembina River, beyond which the base sinks to 1,150 and 1,100 feet and the crest to 1,400 and 1,300 feet. The width occupied by the slope varies from a quarter to a half of a mile.

Natural surface at the quarter-section stake on the north side of Sec. 32, T. 160, R. 56, 1,178 feet above the sea. Secs. 32, 29, and 20 of this township are mostly till, smoothed by this glacial lake, the depressions having been filled by leveling down the higher portions, where many bowlders partially embedded testify to considerable erosion. A broad ridge of beach sand and fine gravel, 3 to 5 feet high, extends from south to north through the center of Sec. 29, its crest being at 1,180 to 1,182 feet. This is the third in the series of four Herman beaches observed near Maple Lake, near Larimore, and in T. 158, R. 56. The higher beaches are probably also recognizable 1 to 1½ miles farther west, near the base of the "second mountain," which is 1,220 to 1,230 feet above the sea; but it is impracticable to trace their course and determine their exact elevation, because woods reach from the base of this escarpment a half mile east, where these beaches belong.

Fourth Herman beach, a broad low swell of sand and gravel, extending north-northwesterly through the east half of Sec. 20, T. 160, R. 56, 1,166 to 1,172 feet; through Secs. 17 and 8, an eighth to a quarter of a mile wide, 1,161 to 1,173 feet, having in some places a depth of at least 10 feet, as shown by wells. On the north line of Sec. 20 and again in the north part of Sec. 17, it is intersected by branches of Cart Creek, which occupy valleys about 40 feet deep and an eighth to a quarter of a mile wide. Brush and scattered trees grow in these valleys and on the area between them. Toward the east a descent of 30 or 40 feet is made within the first half mile; westward there is only a slight ascent, to about 1,200 feet, in 1 mile; then a more considerable slope, covered with woods, rises 20 to 40 feet to the base of the "second mountain," on or near the township line.

In the west part of Sec. 8 and again near the northeast corner of Sec. 6, T. 160, R. 56, this beach is intersected by the headstreams of Willow Creek, in valleys about 35 feet deep. On the north line of Secs. 5 and 6 of this township, the fourth and third Herman beaches are merged in an undulating tract of gravel and sand a half mile wide, which rises from 1,160 feet on the east to 1,184 feet on the west. A well on the west part of this belt found the beach deposit 6 feet thick, underlaid by till, which forms the slightly ascending surface next west.

Base of second Pembina Mountain in the east half of Sec. 31, T. 161, R. 56, 1,235 at the south to 1,220 feet northward, coinciding nearly with the upper Herman shore of Lake Agassiz. William Crombie's well, 24

feet deep, near the center of Sec. 30, situated about 50 feet above the Tongue River, a few rods back from the verge of its north bluff, was soil, 2 feet; gravel, nearly all cretaceous shale, 8 feet; underlaid by gravel, nearly all granite and gneiss, with scarcely any intermixture of shale, containing pebbles and cobbles up to 4 inches in diameter, 14 feet, yielding a permanent supply of water. This well is close to the base of the "mountain," at an elevation of about 1,230 feet. Its bed of granite gravel appears to be the upper beach, the overlying shale gravel being a delta deposit brought by Tongue River.

Surface at Young post office, in the northeast corner of the SW. ¼ of Sec. 32, T. 161, R. 56, 1,192 feet. The well here, 14 feet deep, is wholly stratified gravel and sand, being a beach deposit of the second and third stages in the Herman series. Third beach, about an eighth of a mile east of Young post office, a broad ridge of sand and fine gravel, a few feet above the land on its west side, crest, 1,187 feet. Fourth and lowest Herman beach, of similar form with the last, but larger, running a few degrees west of north through the west edge of Sec. 33, 1,173 to 1,175 feet, with depression of 1 to 5 feet on its west side and descent of 25 feet within 30 or 40 rods east. About a third of a mile east from the crest of the last is another parallel beach ridge, belonging to the Norcross stage of this glacial lake.

Tongue River at bridge near the center of the south half of Sec. 28, T. 161, R. 56, about 1,110 feet; bottomland, 10 feet higher; top of bluffs, about 1,150 feet. Gavin's Creek in the south half of Sec. 20, about 1,140 feet; valley 40 feet deep, a sixth of a mile wide.

Lowest Herman beach, a massive ridge of sand and fine gravel, in the NE. ¼ of Sec. 29 and the east part of Secs. 20 and 17, T. 161, R. 56, 1,175 to 1,180 feet.

DELTA OF THE PEMBINA RIVER.

The largest tributary to the Red River in Dakota is the Pembina River, which has cut a valley about 400 feet deep and a mile wide in the plateau of the second Pembina Mountain. During the recession of the ice sheet this stream appears to have been much larger than now, being the outlet of glacial lakes in the basins of the Souris and Assiniboine Rivers.[1] From the bend of the Souris, or Mouse River, eighteen miles southwest of its mouth, the river discharging the waters of these lakes ran southeasterly 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 water-course of similar width, called Lang's Valley, eroded 150 to 200 feet below the general level, extends eleven miles between this lake and the Souris River. The highest portion of Lang's Valley is 1,364 feet above

[1] Ninth Annual Report of the Geological and Natural History Survey of Minnesota, p. 342; and Hind's Report of the Assiniboine and Saskatchewan Exploring Expedition, 1859, pp. 118 and 168.

the sea, and is bordered by bluffs that rise 160 feet. It is a channel similar to that of Lakes Traverse and Big Stone and Brown's Valley, eroded by the River Warren. The delta deposited in the margin of the glacial Lake Agassiz by the Pembina River, thus swollen by a great affluent from the melting ice fields beyond the present limits of its basin, extends twelve miles from south to north and has a maximum width of seven miles, with a maximum thickness exceeding two hundred feet. About five-sixths of this delta of fifty square miles or more lie south of the Pembina River; reaching nearly to the Tongue River.

Its elevation in the northwest part of Sec. 17, T. 161, R. 56, is 1,200 feet; thence northward it rises slowly in two miles to 1,225 feet in the east part of Sec. 6; and in Secs. 31 and 30, T. 162, R. 56, it varies from 1,220 to 1,227 feet. From this crest of the southern part of the delta it slopes slowly east and northeast to 1,080 and 1,090 feet at its eastern border, in Secs. 25, 24, and 13, which coincides nearly with the east line of this T. 162, R. 56. Deep valleys, with frequent tributary ravines, have been eroded in it by several small streams. Westward the delta reaches to the base of the "second mountain," the belt a half mile to one mile wide next beyond the crest, only about 5 feet lower, being a very flat, beautiful prairie, which rises slowly, like the crest, from south to north. The elevation of this belt in Sec. 18, T. 161, R. 56, is 1,190 to 1,195 feet, and at Mr. Henry Goff's house, in the middle of the east edge of Sec. 36, T. 162, R. 57, 1,221 feet. Farther west there is an ascent to about 1,240 feet at the base of the "second mountain." Wells on this area penetrate only beds of sand and gravel, easy to dig and needing to be curbed to prevent caving. A large proportion, probably half, of the gravel is cretaceous shale. Water is obtained at depths varying from twenty-five to sixty feet.

Natural surface at the northwest corner of Sec. 30, T. 162, R. 56, 1,227 feet.

The part of the Pembina delta thus far described is divided from its central and higher part by a depression about a mile wide, through which a portion or the whole of the river flowed during much of the time in which this delta was formed. In the southwest corner of Sec. 18, T. 162, R. 56, this depression is 1,205 feet above the sea, being 20 feet lower than the area on the south. It extends eastward with a slow descent and rises westward to 1,215 feet close east of the Little Pembina River in Sec. 15, T. 162, R. 57. This stream flows through the escarpment of the "second mountain" in the SE. $\frac{1}{4}$ of Sec. 22, about a mile south from this lowest part of the divide on its east side. It there turns abruptly from its eastern course and thence flows north-northwest along the base of the "second mountain" to its junction with the Pembina River; thus leaving the depression just described, which would seem to be its more natural course, and taking in its stead a channel that is eroded through a portion of the delta 50 feet higher.

The most elevated point of this delta, as it now remains, is about 1,270 feet above the sea, near the northwest corner of Sec. 11, T. 162, R. 57, east of the Little Pembina and south of the Pembina River, nearly 300 feet above the junction of these streams, 1½ miles distant toward the northwest. Sec. 12 of this township and the west part of Sec. 7, T. 162, R. 56, slope from 1,225 on the south to 1,215 feet on the north; their southern part is the highest land crossed between the depression before mentioned and the Pembina River by the line dividing these townships. The level of Lake Agassiz in its highest stage here was 1,220 or 1,225 feet above the sea, being 50 feet below the top of the Pembina delta, as is shown by the beach line of this level, 1,226 feet, in the central part of this Sec. 7, 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 vast delta deposit, the material here is sand and gravel, covered by a fertile soil. A small proportion of the pebbles of this gravel is limestone; a large part is cretaceous shale; but more was derived from archean formations of granite and gneiss.

Second Herman beach, a ridge of the usual form, crossed by the road near the east side of the NE. ¼ of Sec. 7, T. 162, R. 56, descending from 1,212 feet to about 1,200 feet in a distance of a third or half of a mile from south to north.

William Roadhouse's well, 110 feet deep, in the NW. ¼ of Sec. 9, T. 162, R. 56, at elevation of 1,184 feet, is all stratified sand and gravel, with pebbles up to 6 inches in diameter, fully half cretaceous shale. Water comes in coarse sand at the bottom, filling the lowest 2 feet. Another well of the same description, but 137 feet deep, is a mile farther east, at Wellington Stewart's house, in the SW. ¼ of Sec. 4, 1,192 feet above the sea.

Crest of the first Pembina mountain in the north part of Sec. 33, T. 163, R. 56, nearly two miles southeast from Walhalla, a few rods west from the summit on the Olga road and 5 feet higher, 1,196 feet. This is a beach accumulation, belonging to the third Herman stage. On the west and southwest the undulating delta plateau, mostly covered with bushes and occasional trees, is 10 to 30 feet lower for a width of 1 to 1½ miles, averaging about 1,175 feet.

Northeast from the crest of the Olga road a short descent is made to a prairie terrace 30 to 60 rods wide, varying in elevation from 1,182 to 1,169 feet, but mainly within 2 feet above or below 1,175. 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 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 ancient lake during its Norcross, Campbell, and McCauleyville stages. From the north part of

this Sec. 33 the "first mountain" extends southeast to Secs. 13 and 24, T. 162, R. 56, before mentioned, and northwest across the Pembina River, 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 1 mile apart.[1]

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

Highest part of the Pembina delta north of Pembina River, in Secs. 25 and 26, T. 163, R. 57, 1,210 to 1,230 feet, rising slowly from east to west; in the west half of Sec. 26 and the east edge of Sec. 27, it is depressed to 1,225 and 1,220 feet; but beyond this it rises to 1,235 and 1,240 feet, next to the foot of the "second mountain." From this upper portion the delta slopes down gradually toward the northeast and north, extending only 2 to 4 miles beyond the Pembina River.

Natural surface at the quarter-section stake on the north side of Sec. 26, T. 163, R. 57, 1,191 feet.

Third Herman beach, crest 5 rods south of this stake, 1,197 feet, from which there is a descent in 5 rods south to 1,192 feet and in 15 rods north to 1,180 feet. This beach curves thence to the northwest and north, and in the opposite direction runs east-southeast 2 miles to near the center of Sec. 30, T. 163, R. 56, where its elevation is approximately 1,192 feet. Other shore lines of the Herman group were not noticed north of the Pembina River.

In the gravel of this delta, as seen in the bluffs of Pembina River near Walhalla and at noteworthy springs 2 miles to the south, on the south side of the river in the southwest corner of Sec. 32, the pebbles of some beds are mainly cretaceous shale, of others mostly limestone, and of others granite, gneiss, and dark trappean rocks. In the aggregate, these three classes have a nearly equal representation. White quartz and moss agate are frequent and bits of silicified wood occur rarely; but no banded agates were found. Numerous pieces of

[1] 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 towards the Missouri, the hunting grounds of the Sioux and the half-breed population of Red River."—Report of a Geological Survey of Wisconsin, Iowa, and Minnesota, 1852, p. 178.

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

lignite, rounded by water wearing, from 2 to 4 inches in diameter, noticed in this delta gravel at the springs, have caused some to look for workable beds of this kind of coal in the vicinity; but the proportion of these fragments is no greater than in the glacial drift generally throughout this region and for hundreds of miles to the south.

Surface at the iron post set on the international boundary on the north side of the fractional Sec. 27, T. 164, R. 57, about a quarter of a mile east from the line between Secs. 27 and 28, 1,018 feet above the sea; top of this post, 1,022 feet.[1]

Smooth surface of till on the top of the "second mountain" in the SE. ¼ of Sec. 32, T. 164, R. 57, 1,268 to 1,311 feet above the sea; shallow lakelet in the SW. ¼ of this Sec. 32, 30 rods long from northwest to southeast, 1,309 feet; natural surface of the northeast corner of Sec. 6, T. 163, R. 57, 1,321 feet.

Base of "Heart Mound,"[2] a peculiar hillock of cretaceous shale, with very steep sides and smoothly rounded top, situated near the center of this Sec. 6, T. 163, R. 57, about 1,360 feet; and its top, about 1,390 feet. Some have erroneously supposed it an artificial mound. Glacial drift, containing granitic bowlders up to 4 or 5 feet in diameter, thinly covers its northeast side; but the other sides and crest of this knob show very clearly that it is an outlier of the cretaceous beds that form higher land about a mile westward, and, indeed, make the whole length of the second Pembina Mountain, being left thus isolated from the surrounding area by erosion.

The lowest exposure of this shale observed is 3½ miles south from Heart Mound, at the "fish trap," a rude weir of brush and poles, on the Pembina River, in the northeast corner of the NW. ¼ of Sec. 30, T. 163, R. 57. Here the river falls 7½ feet in 40 rods, its elevation being estimated about 1,050 feet. The southwestern bluff rises steeply from the

[1] The section on the boundary within the next 2 miles west is described by Dr. G. M. Dawson as follows: "The eastern front of Pembina escarpment is very distinctly terraced, and the summit of the plateau, even at its eastern edge, thickly covered with drift. The first or lowest terrace, which is about one-third from the prairie level toward the top of the escarpment, * * * does not seem to preserve exactly the same altitude. On the boundary line its height above the general prairie level was found to be about 90 feet; a second terrace, 260 feet; and that of the third level, or summit of the plateau, about 360 feet. The surface of the first terrace, which is here wide, is strewn with bowlders, as is also that of the second terrace and plateau above. These are chiefly of Laurentian gneiss and granite, but a few smaller ones of limestone occur. The banks of ravines cutting the top of the plateau and draining westward into the Pembina River show, in some places, a great thickness of light-colored, yellowish, marly drift, with few bowlders embedded in it."—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, 1875, p. 219.

[2] Commonly called by English-speaking people in its vicinity "The Indian Mound," but more properly named as above, in accordance with the usage of the French voyageurs and immigrants, who, probably translating the aboriginal name, call this mound and the area of prairie around it La Baie du Cœur.

fish trap to a height of 150 feet, and at the time of my visit, in August, 1885, was newly exposed by slides, being shown to be a hard, fissile, dark gray shale, nearly horizontal in stratification to a height of 100 feet, capped by glacial drift. In the shale, crystals of selenite, 2 or 3 inches long, are frequent, and the same mineral occurs in its crevices and seams. No fossils were found; but the formation may be with confidence referred to the cretaceous series, and with much probability to its Fort Pierre subdivision.[1] The thickness of this shale, seen at the Heart Mound and the fish trap of Pembina River, is at least 300 or 400 feet; but it probably exceeds this, for there is no indication that these exposures mark its upper and lower limits. Its eroded eastern edge forms the long, high escarpment of the second Pembina Mountain, as the eroded border of the Pembina delta forms the almost equally notable "first mountain." Till, or bowlder clay, containing frequent granitic bowlders, up to 5 or even 8 feet in diameter, covers the shale, so that it is rarely seen excepting in the sections cut by streams.

[1] This reference has been confirmed during the field work of 1886 by the discovery, in the shale at this locality and in its continuation southward on the headstreams of Park River, of *Scaphites Nicolletii* (Morton), *Scaphites nodosus* (Owen), *Baculites ovatus* (Say), and *Baculites compressus* (Say); two species of *Inoceramus*, one of which is *I. altus* (Meek), or near that species, besides other lamellibranchs not yet identified; and the teeth of fishes, apparently *Pachyrhizodus latimentum* (Cope) and *Lamna mudgei* (Cope), or a smaller species, with a vertebral bone, perhaps belonging to one of these.

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NOTICE.

The bulletins of the United States Geological Survey are numbered in a continuous series and will be bound in volumes of convenient size.

This bulletin will be included in Volume VI.