ENGINEER DEPARTMENT, UNITED STATES ARMY.

AN ESSAY

CONCERNING

IMPORTANT PHYSICAL FEATURES EXHIBITED IN THE VALLEY OF THE MINNESOTA RIVER,

AND

UPON THEIR SIGNIFICATION,

BY

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[PART II OF REPORT ON THE MINNESOTA RIVER, SUBMITTED TO BRIG. GEN. A. A. HUMPHREYS, CHIEF OF ENGINEERS, OCTOBER 31, 1874.]

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1874.

WASHINGTON, D. C., *December* 7, 1874.

GENERAL: I have the honor to request that Part II of my recent report on the Minnesota River be printed with the small maps, (each an octavo page,) for special distribution.

The title of this part is, "An essay concerning important physical features exhibited in the valley of the Minnesota River, and upon their signification."

The conclusion is that these features are a part of extended physical phenomena on this continent, which are of much practical importance to engineers, and possessed of special scientific interest. The object of this distribution is to submit the matter to the consideration of scientific men, so that the truth of the conclusions may be tested.

Very respectfully,

G. K. WARREN,
Major of Engineers, Bvt. Maj. Genl., U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers.

[Indorsements.]

OFFICE OF THE CHIEF OF ENGINEERS,
December 8, 1874.

Respectfully submitted to the honorable the Secretary of War, and recommended that the report and maps be printed for distribution as requested.

A. A. HUMPHREYS,
Brig. Genl. and Chief of Engineers.

Approved:
By order of the Secretary of War.

H. T. CROSBY,
Chief Clerk.

DECEMBER 8, 1874.

AN ESSAY CONCERNING IMPORTANT PHYSICAL FEATURES EXHIBITED IN THE VALLEY OF THE MINNESOTA RIVER, AND UPON THEIR SIGNIFICATION.

BY G. K. WARREN.

Introductory—Minnesota Valley formerly the course of a great river—General view of the Mississippi Basin—Valley of Minnesota formerly drained the basin of Lake Winnipeg—Evidence of former great extension of Lake Winnipeg—Professor Hind's description of Winnipeg Basin—Hypothesis to account for the former drainage of the Winnipeg Basin along the valley of the Mississippi, and for the change to the present outlet by Nelson's River—Hypothesis confirmed, by Lake Michigan and Illinois River; by Lake Winnebago and Fox River; by Saint Joseph's and Saint Mary's Rivers changing from Wabash River to Maumee River; by subsidence along the North Atlantic shore; by effects along the Saint Lawrence and Niagara Falls; by results on the shores of the Great Lakes; by the cañons of the Rio Colorado of the West and Rio Grande; by the basin of Great Salt Lake; by the peninsula of Florida; by the recent extension of the Gulf of Mexico northward in the valley of the Mississippi—Reference to a former continental change of level—Local changes of elevation of earth's surface inadmissible—Great permanence of continental structure since recent Tertiary period—Same structure in Glacial period—Shore-lines of continent indicate northern subsidence and southern elevation—Map restoration of ancient basin of the Mississippi.

Introductory.

The name first given to the Minnesota River by travelers and explorers was Saint Peter's, believed by Mr. Nicollet to have been derived from a Frenchman by that name, who, before Le Seuer visited it in 1795, had located himself at its mouth. This name it retained on all the maps and works of subsequent explorers down to the organization of a territorial government. Mr. Nicollet especially urged the preservation of the name on account of its early adoption and long historical use, and had it been a question simply among scientific men it probably would not have been changed.

It has, however, been a common occurrence for our settlers, when the country came to be occupied by them, to change names given by early French travelers. Sometimes they were merely grotesque changes in pronunciation and spelling by which the origin and significance of the original name was nearly or quite lost, and sometimes it was to adopt a name more easily spoken or one whose meaning was more appropriate and pleasing to them.

Not unfrequently the name of the river was changed to that of the native tribe found there, and at other times, as in the present case, the name which these aborigines gave to the stream was adopted. These new names given by the settlers afterward became incorporated in the laws, and thus acquired a precedence over those assigned by the first explorers.*

* In some noted instances scientific explorers have inexcusably changed the names given by previous explorers and writers of the highest standing. Frémont changed "James's Peak" to "Pike's Peak," "Lake Bonneville" to "Great Salt Lake," "Ogden's River" to "Humboldt River," and thus men who had fairly won the honor of so naming such important places were unfairly deprived of it.

It would be fortunate if the new name was always as appropriate as to this case. The river flowing through the land of the Dakotas, whose language abounds in pleasant sounds, and whose names of natural objects are often expressive of characteristic features, pleasing or otherwise to the senses or to the imagination, was named by them *Minne-sota*. *Sota* in their language means *nearly* clear or *clouded*. The whitish water of the Minnesota makes it appear very distinct from that of the Mississippi where the rivers join, the latter having an amber-tint and appearing quite dark where it is several feet deep.

The line where the two waters join and mingle is marked by little whirls and eddies, and by ascending and descending currents, imitative of gentle ebullition.

Here the whitish water rising through the amber-colored has the pleasing effect of thin, ever-varying clouds or curling smoke. It is altogether probable that this optical effect gave origin to the name Minnesota, Cloudy-water.

This pleasing effect is only seen during the low-water stages of both rivers, the amber-tint of the Mississippi being derived from the drainage of forests and lakes containing decaying vegetation, and the whitish tinge of the Minnesota probably from minute particles of clay obtained from the Cretaceous or Tertiary deposits along its southern branches.

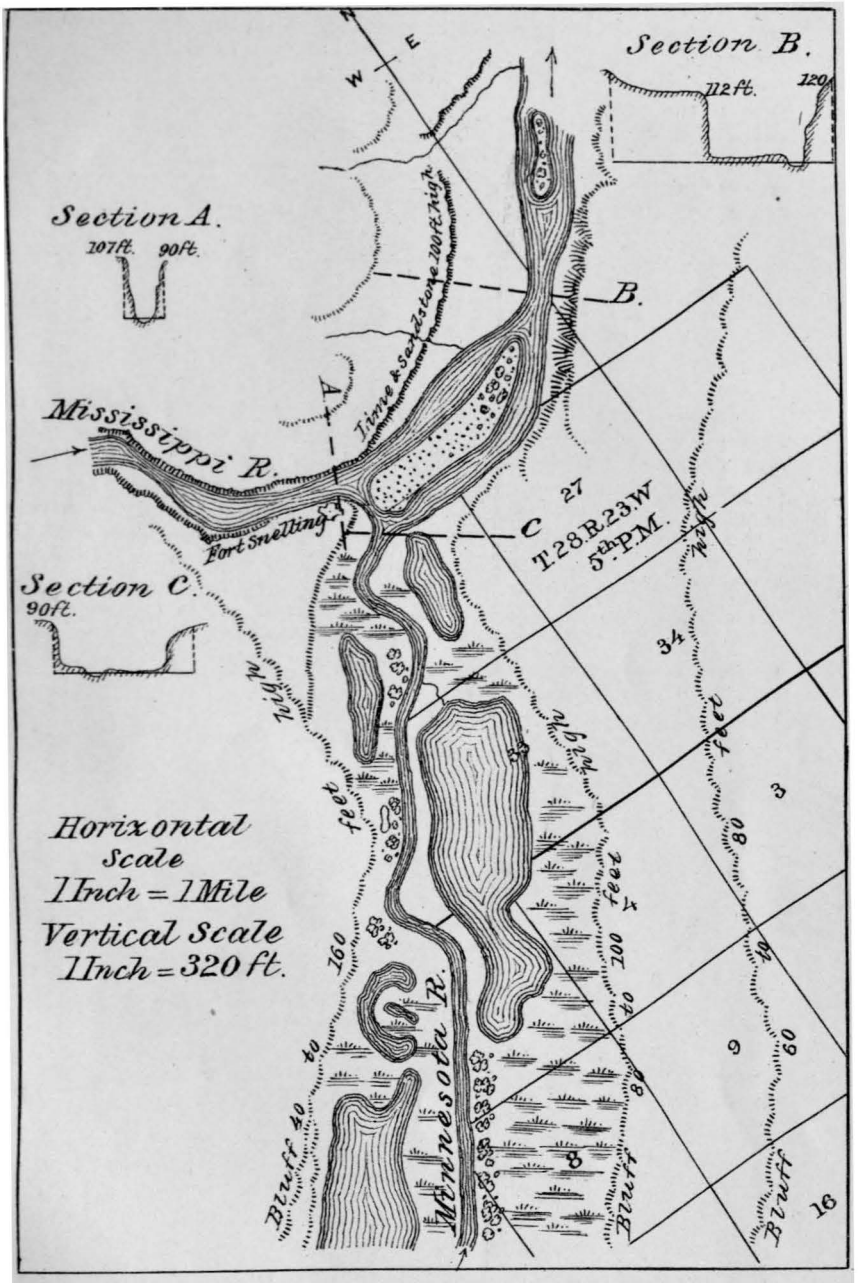
Minnesota valley formerly the course of a great river.

The Minnesota River valley is most elevated at Lake Traverse, lying in the valley, latitude 45° 40′, longitude 96° 55′, about 1,000 feet above the ocean-level. Its general course is southeast to Mankato, latitude 44° 09′, longitude 94° 05′, where the elevation is above 765 feet above the ocean. From Mankato downward, the general course is northeast to the junction with the Mississippi, where the elevation is 695 feet above the ocean; latitude 44° 42′, longitude 93° 15′. The valley at the upper end is as wide as at its lower end. Intervening parts are sometimes much wider, and rarely narrower. The whole is sunk from 130 feet to 250 feet below the general level of the country.

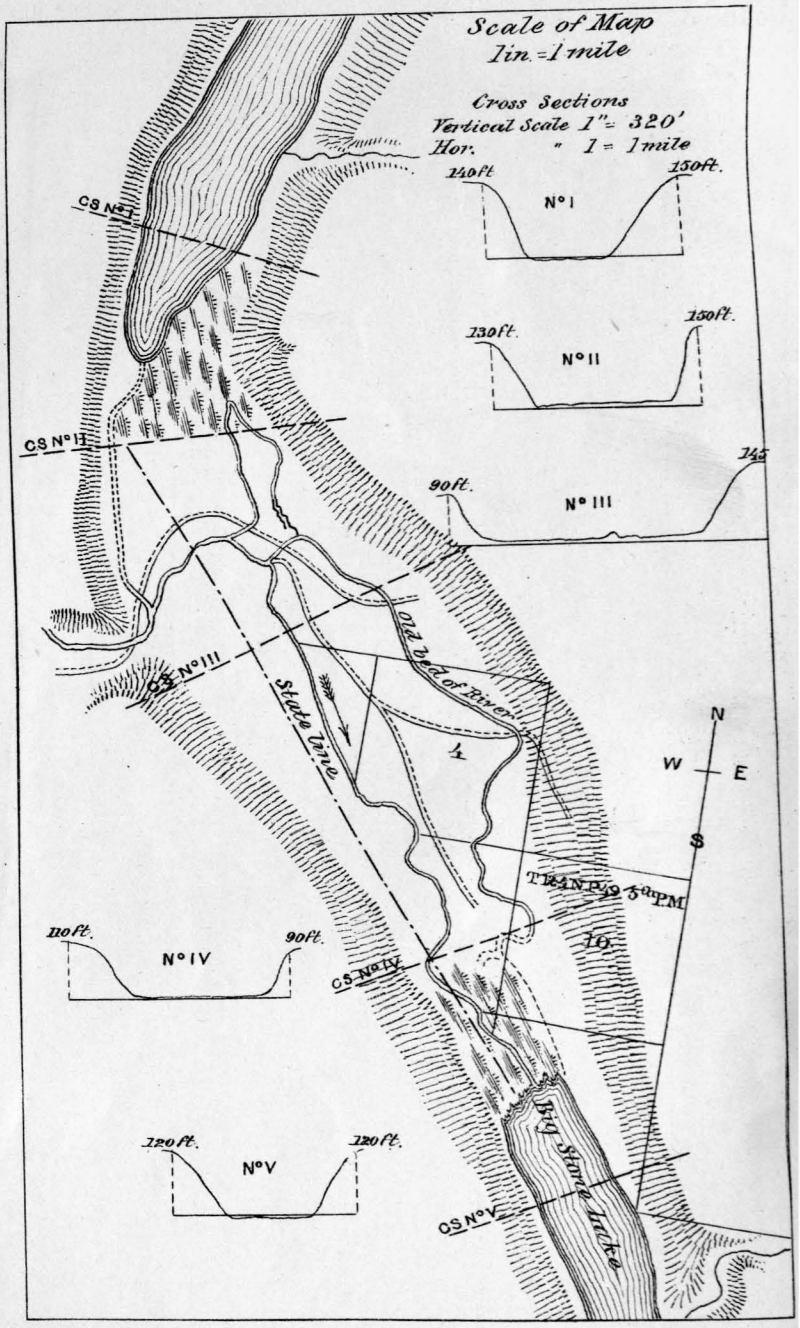
The distance from Lake Traverse to Mankato, by the valley of the river, is one hundred and seventy-seven miles; thence to the mouth, seventy-nine miles; total, two hundred and fifty-six miles.

The valley of the Mississippi below the junction, and of the Minnesota above it, is wide and beautiful, and is continuous in direction and of nearly the same breadth, varying from about one mile to two miles. [See map.] In marked contrast is the valley of the Mississippi above their junction, it being only about one-quarter mile wide and nearly at right angles with the other. It is a mere gorge, whose bottom is almost completely filled by the river, and evidently has its origin in the waterfall now at Saint Anthony. This fall in quite recent times must have been where the river now joins the main valley, and since receded to its present position, seven miles above the junction.

The valley of the Minnesota above, and of the Mississippi below, is much wider than the existing streams require. It could not have been formed by the action of existing forces, as the Mississippi above has been. It must have been excavated by some force that is no longer in operation, and if this was a river it must have been of much larger size than the Mississippi below the junction with the Minnesota. It will be the object of this essay to show that this force *was a river;* that it drained, in times subsequent to the last glacial drift formations, all the Winnipeg Basin. I shall endeavor to explain the cause of its disappearance, and show that this cause has produced the same effects elsewhere; and I shall briefly trace certain other effects, which an



Map showing the river valley where the Minnesota and Mississippi Rivers join, with sections of the valley below the junction, and on each above the junction.



Map showing the Minnesota valley at the summet-Reduced from survey made under direction of Col. J.N Macomb U.S Engs. 1872.

N. PETERS, PHOTO-LITHOGRAPHER, WASHINGTON, D. C.

operation of nature so extended most probably would produce and has produced.

It is a general truth that the valleys of nearly all our rivers show indications of volumes of water in former times greatly exceeding those now flowing. I say *nearly* all, because some of our rivers in southern latitudes and rainy regions are an exception. But generally it may be said that our rivers might have their volumes restored to what they were by a change of meteorological conditions, so as to increase the rain-fall to the required extent without changing the areas of their drainage basin. If this were practicable without invoking other changes on the earth's surface of the greatest magnitude, it is evident that it would affect rivers like the Minnesota and Mississippi above their junction (lying contiguous, and having basins of limited areas) proportionately, and the valleys would always be proportionate to the areas of the drainage basins and volumes of discharge. This in reality is so generally the case, that a marked exception like that presented here, (where the much larger stream occupies the much smaller valley,) requires us to admit that if the great valley is a valley formed by a river, it must have been by a river draining a basin of vastly greater area than now drained by the Minnesota.

The disproportionate size of the Minnesota Valley at the mouth of the river increases as we ascend. For whereas the valley nearly maintains its width on the average all the way to the source, the stream gradually dwindles away to nothing, so that at the upper end of the valley where it is a mile wide, the only water there is, is received from small streams coming through the ravines on each side, which have formed dams by their torrent-like deposits, and the intermediate spaces are occupied by lakes of considerable depth. That these small affluents could not have formed the great valley is obvious enough. Their own small ravines show their power to erode, and this is proportioned to their volumes; but, on their waters reaching the great valley, their power is lost, and instead of eroding there, they are making deposits and filling up. This feature of the affluents of the Minnesota Valley I believe I was the first to note and attribute proper importance to. I have in my report of January, 1867, shown how this effect was taking place in the Mississippi, and by it explained the formation of Lake Pepin and Lake Saint Croix.

The Qu'Appelle branch of the Assinniboine River in British America, closely resembles the Minnesota River. There are similar lakes along its upper course, described by Prof. H. Youle Hind, in his report of explorations of Assinniboine and Saskatchawan rivers, &c., concerning which I make the following extract in relation to the Qu'Appelle River:

> The narrowest breadth of the bottom of the Qu'Appelle Valley is half a mile; its greatest breadth about one mile and a half. Its shallowest part is 120 feet below the level of the prairie, and its greatest depth is between 350 and 400 feet. * * The highest part of the bottom of the Qu'Appelle Valley is only 85 feet above the south branch (of the Saskatchawan,) at its summer-level, and from 75 to 78 feet above it during the spring elevation of its waters. This occurs at a point distant 11¼ miles from the junction, (of the two valleys,) where a lake is found which discharges itself both into the Saskatchawan and Assinniboine. Before connecting with the Assinniboine it falls about 280 feet in 256 miles, or 1 foot 1 inch per mile. The difference of level between the South Branch on one end and the Assinniboine at the other, does not exceed, according to our estimate, 200 feet.
>
> In its long, deep, and narrow course there are eight lakes, having an aggregate length of fifty-three miles. * * * Numerous soundings of the Qu'Appelle Lakes showed them to hold from 40 to 60 feet of water, which depths are maintained with great regularity.
>
> * * * * * * * *
>
> The construction of a dam 85 feet high and 800 yards long would send the waters of the South Branch down the Qu'Appelle.

In another place Professor Hind says:

How were the deep lakes hollowed out? Lakes filling the breadth of the valley, but during the lapse of ages not having increased its breadth, preserving, too, for many miles such remarkable depths; and although in some instances far removed from one another, yet maintaining those depths with striking uniformity. What could be the nature of the eroding force which dug out narrow basins 54 to 66 feet deep at the bottom of a valley already 300 feet below the slightly undulating prairies, and rarely exceeding one mile in breadth! * * * They seem to point to the former existence of a much deeper valley now broken into detached lakes by the partial filling up of intervening distances.

The valley of the Minnesota was not formed by glacial action. There is nothing in the configuration of the country to have caused glaciers to act along such a line. Had this valley existed at the time the glaciers covered the country, they would have obliterated it, as we know they have many former river-valleys. Moreover, this valley, at its upper part and all along its course, is through the glacial drift itself, and therefore must have originated since the deposit of that material. *A priori* we may assign to water alone the formation of the valley, for we know of no other sufficient cause. But the evidence that it was done by the action of water is direct, and exists, in deposits and terraces, such as are made by streams; in isolated high islands in the valley, such as are left behind by cataracts; in pot-holes and water-marks high above any present level of the stream; and in the fact that there is nothing in the valley to interrupt the continued flow of water.

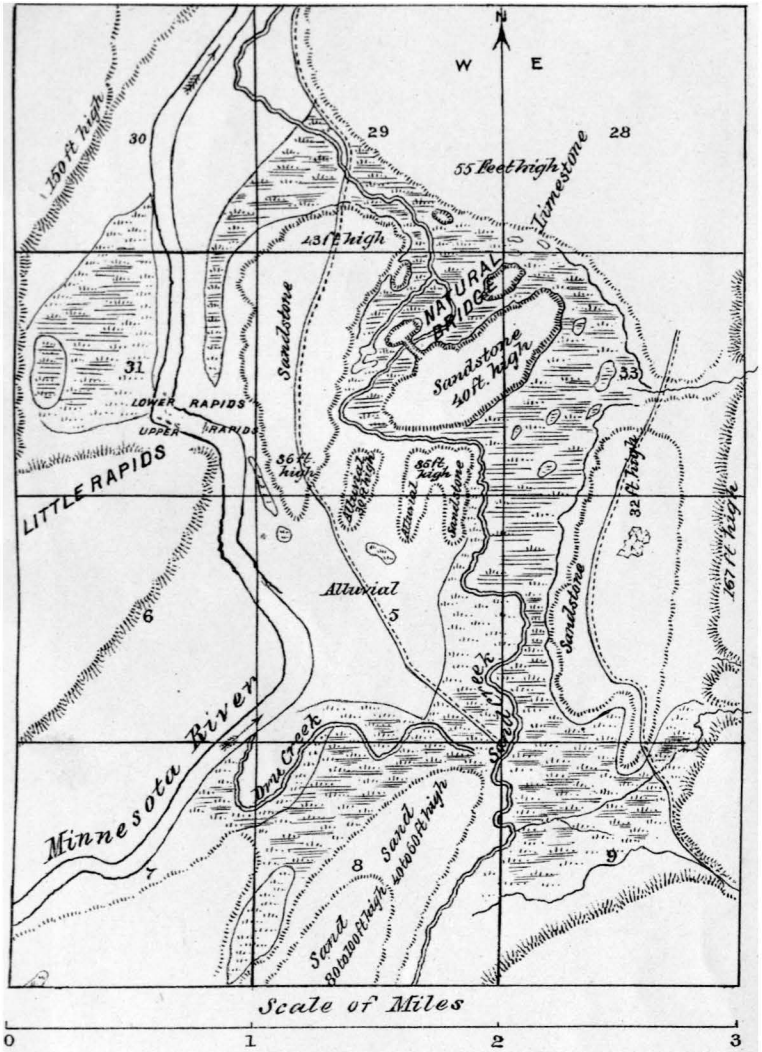
Step by step along the valley the indications of the former great river since the last Glacial period are apparent, and I will here introduce a specimen of this evidence, taken from the report of a scientific explorer who makes his statement without reference to any hypothesis. It is from Owen's Geological Report. In that Dr. Shumard says, p. 492:

Two or three miles below the mouth of this river (Red Wood) is one of the most interesting exposures of granite, on the left bank of the river. It rises in irregular smooth knobs to the height of 125 feet. At an elevation of 40 to 50 feet above the present channel an ancient bed of the river is distinctly recognizable. The bottom of the bed, as well as the sides, are worn into polished grooves 5 to 12 inches deep; there are besides smoothly-worn pot-holes, not only in the former bed, but also at various heights even to the top of the rock, and most of the granite surface is rounded and almost polished, all giving evidence of having been laved for a very long period of time by a swift current, and corroborating the conclusions heretofore drawn from the existence of level terraces of alluvial land far above the present highest-water mark, and from the position of strata containing fresh-water shells in elevated positions, that the Saint Peter's once flowed at a higher level, or rather that the land has been elevated at a very recent period.

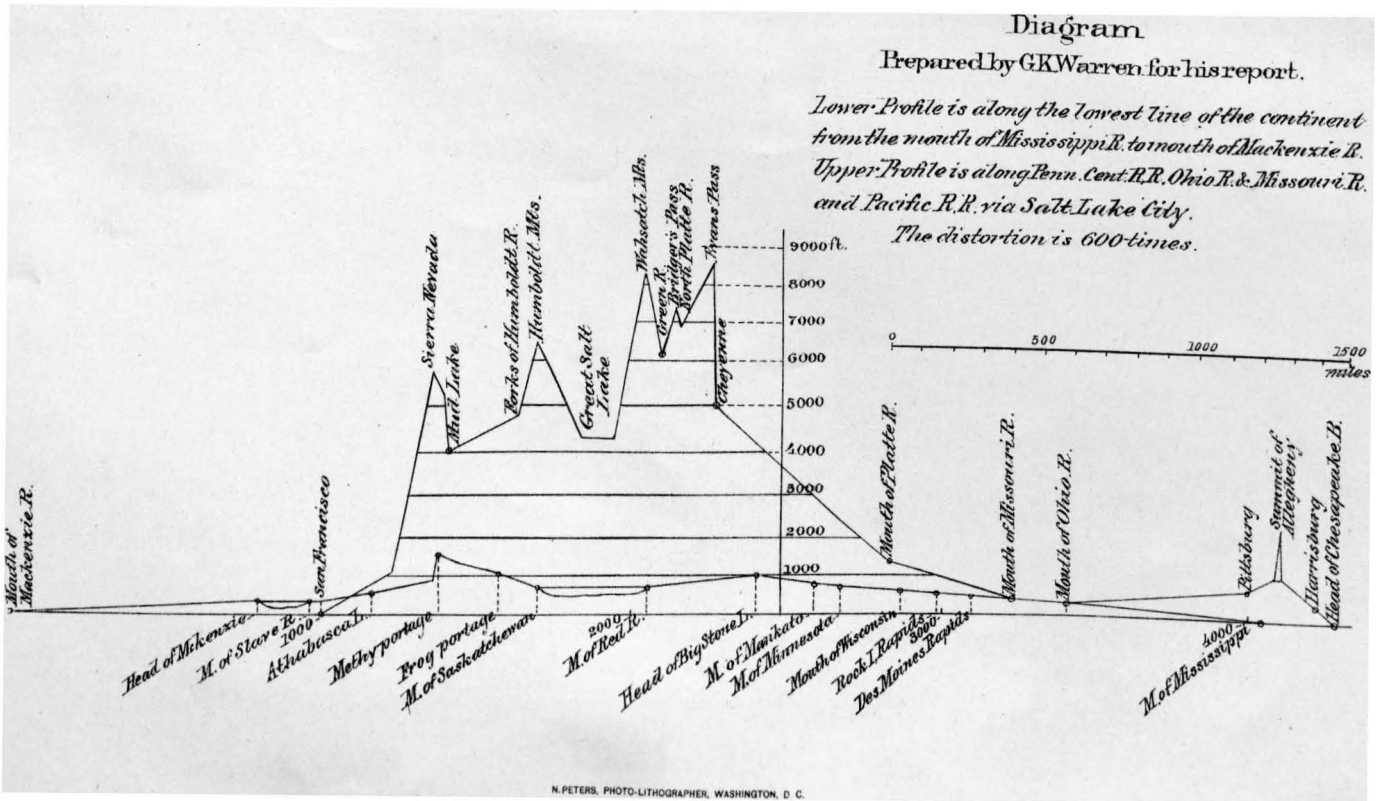
There is sufficient evidence in the manner in which this valley has been eroded to show that it was done by the action of a river which formed water-falls at certain points, which gradually receded up stream. An instance of the high islands of rock left in the valley, such as occur where a receding cataract divides into two channels, is noted by Dr. Shumard in Owen's Geological Report, and a sketch of it shown on page 486. A better representation of it is given on sheet No. 13 of my map of the Minnesota Valley, on scale two inches to a mile.

There is a much finer exhibition of this effect in the vicinity of Little Rapids, thirty miles from the mouth. It is shown on sheet No. 18 of my map of the valley. There the falls on the former river must have divided into at least three channels. A map of this locality is given with the text.

We have evidence that since the disappearance of the ancient Minnesota River, the Mississippi has filled up the valley at the mouth not less than sixty feet. There is only very little slope to the present river from



Map showing islands left in the valley by a cataract in the ancient water course. Made to accompany report of Gen. G.K. Warren Maj. of Engrs.



the mouth up thirty miles to the Little Rapids. This space in the valley is like a lake that has been nearly filled with alluvium. At these rapids the hard limestone rock is from forty to fifty feet above the river-surface, and underneath it is soft sand-rock, easily worn away. The high detached islands in the valley show there must have been a cataract at this point, in the course of the ancient river. The upper level was that of the lime-rock and the lower level was that of the ancient bed, which, through the action of the Mississippi, has since filled up as stated fully sixty feet. A sudden descent, then, must have occurred here, as great as one hundred feet. Such was the power at work to form this valley.

The valleys of the tributaries of the Minnesota are sensibly proportioned to the present volumes, with the exception of the Chippeway, and there is reason to believe it formerly received the drainage of the region of Otter-Tail Lake, which now goes to Lake Winnipeg.

The topographical and hydrographical features of the Minnesota Valley are shown in detail as far as known on the map, on scale of two inches to the mile, accompanying the report of which this is a part.

I introduce here in the text a reduction of the portion exhibiting the summit-level between Lakes Big Stone and Traverse.

I consider it well established, that a river of large volume greatly exceeding the present stream formerly flowed throughout the Minnesota River Valley; that this river existed since the deposit of the glacial drift, as shown by the valley, at its upper end being excavated in that material; and that it did not disappear merely from a diminished supply of rain in the basin, now drained, since other adjacent basins are not thus affected.

General view of the Mississippi Basin.

I will now endeavor to show what was the source of this former great river, and in order to make this more readily perceived I will present some general observations concerning the present Mississippi Basin.*

The area drained by the Mississippi, exclusive of the mountain-regions, is formed mainly by two great plains inclining toward each other, and whose intersection forms the lowest longitudinal line of the basin. The Minnesota River occupies this lowest line from Lake Traverse to the Mississippi; thence southward it is the Mississippi that is so situated. The river-valley along this line is generally, and as a whole, much wider and indicative of greater eroding action than that of any of the valleys of the tributary streams. The slope of this main valley is however generally less than that of the tributaries, and the volume of water flowing in it is, in several places, less above a tributary than in the tributary itself. With but few exceptions, the valleys of the tributaries are relatively proportional to their present volumes of water, so that we must look beyond the present Mississippi Basin to explain the anomaly presented by its axial valley, when compared with the like things in all the rest of this region.

If now we extend our consideration to the basin north of the Mississippi Basin, we find its lowest line to be the prolongation of the Minnesota Valley, declining with the gentlest of slopes in the opposite direction to the north, the axial valley soon widening out into a great expanse of smooth, flat land. This must have been the bed of a former great lake, whose waters flowed down the Minnesota Valley; and if we follow this ancient bed northward, we find it passing, by an almost imperceptible slope, beneath the

Valley of the Minnesota formerly drained the basin of Lake Winnipeg.

*I shall use the word "basin" to denote the whole area drained by a river, and employ the word "valley" to designate the space between the main bluffs, whether occupied by water or by bottom lands or by alluvial terraces.

waters of Lake Winnipeg. The present level of this lake is determined by the outlet to Hudson's Bay, known as Sea River or Nelson's River. Its elevation above the sea, as estimated by Major Long, and adopted by Professor Hind, is about 630 feet, but there is considerable limit of error in this determination. The summit-elevation along the lowest line between this lake and the Mississippi is in the Minnesota Valley at Lake Traverse, which is elevated about nine hundred and ninety-five feet above the sea, so that if the lake-surface were to rise three hundred and sixty-five feet, it would again flow to the Mississippi.

This most probably was the real condition at a time when the outlet by Sea River to Hudson's Bay did not exist.

Evidence of former great extension of Lake Winnipeg.

Abundant evidence exists as to the former great extension of Lake Winnipeg; the work of Prof. Hind is full of it. The great lake-bed, which has been left dry, has excited the wonder of all who have seen it, and I present the following quotations to show how it impressed itself upon different explorers as viewed in regions many miles apart.

The first is that from Long's Expedition,* vol. 2, p. 3, describing the appearance, just after leaving the drift-formation along Lake Traverse:

> The plain upon which we were traveling was apparently boundless. It was covered with a short grass of a pale yellowish-green hue. The eye of the mineralogist could not detect a single stone within a mile's travel, and the few that were detected during the day were rolled and uninteresting. In some places pebbles were as abundant as if we had been traveling upon the bed of some former river or lake. The mind endeavors in vain to establish limits to the vast expanse of water, which certainly, at some former day, overflowed the whole of that country.

Near the junction of the Red Lake River these travelers note, vol. 2, p. 32:

> This completed a journey of two hundred and fifty-six miles, [that is, since leaving the head of Big Stone Lake.] * * * The dull monotony of a journey upon prairie-land never appeared to us so fatiguing. * * * *The country is very flat* and remarkably deficient in water. *There are no valleys*, and but few brooks and even springs.

I italicise this quotation where it specially indicates lake-bed. The season of the year was the last of July. On reaching Lake Winnipeg it is stated, vol. 2, p. 76:

> Among the remarkable features of Red River may be enumerated its total want of islands, excepting near its mouth, and the circumstance that it has no bottom or valley, properly speaking. It runs in a mere trench in the prairie. Toward the mouth of the river the country becomes an impenetrable swamp.

So far, then, as Long's expedition shows the character of this region, it is just what the bed of a receding lake would be with a stream, "a mere trench" along the lowest line, cut in the surface of a plain which passed insensibly beneath the existing water.

Major Long in his topographical report, p. 224, vol. 2, says:

> The immediate valley of Red River is not bounded by parallel ranges of bluffs or banks like that of the Saint Peter and other tributaries of the Mississippi, but expands to a great width. * * * * * * * *
>
> The flatness of the surface that almost uniformly prevails throughout the valley of Red River may be regarded as a defect in its natural character that cannot easily be remedied.

Mr. Nicollet saw this ancient lake-bed for the first time at a point

* 8vo. Printed by G. B. Whittaker, Ave-Maria Lane, London, 1828.

about 90 miles from where Major Long's expedition entered upon it. He says, [Sen. Doc. 237, 26th Cong., 2d sess., p. 52:]

We reached a spot which my barometer sufficiently informed me was on the dividing ridge, and not far from its eastern verge; so that we had actually traveled over the great swell of the plateau that separates the Upper Shayen from Devil's Lake and the Red River; but we were not yet in sight of the great valley of the latter, though every moment expecting to come within it. While proceeding onward we saw Dixon, who always preceded us at a distance to indicate our best route, and with his eagle eye to reconnoiter the country before us, suddenly come to a stop, light his pipe, and quietly sit himself down upon a small knoll with his back turned toward us. This was contrary to his usage, for he had always before, when he suggested a halt for any purpose, been in the habit of turning round to wait our coming. On this occasion he was immovable, and I could not guess the cause. When we reached him, we found him in the most ecstatic contemplation before the vast and magnificent valley of the Red River, which there displayed itself before us, spreading itself in an almost insensible slope to the east, to the north, and to the south, and bounded only by the horizon.

Mr. Nicollet then begs leave "to introduce a few reflections upon the magical influences of the prairies," and he concludes by saying, "I pity the man whose soul could remain unmoved."

The following is from the "Report of a Geological Survey, &c., by David Dale Owen, U. S. Geologist," (p. 175.*) He was then just west of Otter-tail Lake:

Nothing but personal observation can convey to the mind the singular effect produced by this dead level plain. The line of the horizon is so perfectly straight that it might almost serve the purpose of astronomical observations for determining the altitude of the heavenly bodies. While standing on this great savanna, straining the eyes in quest of some object more prominent than a blade of grass, it occurred to me that there is probably no spot on the globe more suitable than this on which to measure a degree of latitude.

* * * * * * * * *

A few remarks will suffice to record our observations from this point to the settlements of Red River, since these plains extend the whole distance * * * and give a monotonous sameness to the whole face of the country. The descent of streams watering these plains is effected more by an excavation into the alluvial deposits than by any depressions of the country.

When near the 49th parallel, at Pembina, Mr. Owen reports thus:

After a hot and fatiguing ride over the plains we arrived an hour after sunset at the foot of Pembina Mountain. In the twilight, as we stood, at our encampment on the plains, it looked as if it might be 300 feet or more in height; but in the morning by broad daylight it seemed less. When I came to measure it I was somewhat surprised that it did not exceed 210 feet. I observed on this, as on many other occasions, that a hill rising out of a level plain appears higher than it really is, especially when, as in this case, the trees on its flanks and summit are of small growth. Pembina Mountain is, in fact, no mountain at all—nor yet a hill. It is a terrace of table-land, the ancient shore of a great body of water that once filled the whole of the Red River Valley.

On its summit it is quite level and extends so for about five miles westward to another terrace, the summit of which, I was told, is level with the great buffalo plains that stretch away toward the Missouri. * * * * *

Instead of being composed of ledges of rock, as I was led to suppose, it is a mass of incoherent sand, gravel, and shingle, so entirely destitute of cement, that with the hand alone a hole several feet deep may be excavated in a few minutes. The Pembina River has cut through this material a deep, narrow valley, but little elevated above the adjacent plain.

The height of this lake-terrace above the ancient bed west of Pembina, as given by Mr. Owen, is 210 feet. The lake-bed here is about 50 feet above Red River, which at this point is about 100 feet above Lake Winnipeg, making this lake-terrace 360 feet above the level of Lake Winnipeg, a height sufficient, as I have shown already, to extend the present Lake Winnipeg to Lake Traverse. The uncertainty that exists

*4to. Printed by Lippincott, Grambo & Co., Philadelphia, 1852.

as to the correctness of the elevations, requires me to state that too much reliance must not be placed on them. The hypothesis of changing continental slopes, which appears further on, does not require that we should find an ancient lake shore in the middle or northern part, high enough above the sea at present to be on a level with Lake Traverse. On the contrary, it rather requires that the shore-line that formerly existed should be at a lower level now.

I will introduce here an extract from Professor Hind's report upon the Winnipeg Basin, but any one interested in the questions of physical geography should consult his report.

Extracts from the *Narrative of the Canadian Red River Exploring Expedition of* 1857, *and of the Assinniboine and Saskatchewan Exploring Expedition of* 1858, *by Henry Youle Hind, M. A., F. R. G. S., Professor of Chemistry, &c., &c.* * * *In two volumes.* Published by Longman, Green, Longman and Roberts, 1860. Vol. 2, p. 230 *et seq.*

CHAP. XXXVI. SURFACE GEOLOGY.

GEOGRAPHICAL BOUNDARIES.

Prof. Hind's description of Winnipeg Basin.

The basin of Lake Winnipeg, including under this term the country drained by the rivers flowing into it, extends from the 90th to the 118th meridian, its most easterly point being the lake and swamps from which the Savanne River takes its rise, in longitude 90° 14′, latitude 48° 53′, and the most westerly limit from which it draws contributions is probably the Glacier, near Howse Pass, in longitude 117° 35′, latitude 51° 52′.

The southern extension of its boundary is at Lake Traverse, in Dakota Territory. * It stretches north as far as Frog Portage, longitude 103° 30′, latitude 55° 26′.

This basin consequently extends over 28 degrees of longitude and 10 degrees of latitude. The elevation of its eastern boundary is 1,485 feet above the ocean, and the height of land near the sources of the tributary which rises farthest to the west is 6,347 feet above the same level.

Its northern boundary is separated from the valley of the Missinnippi by a low portage, over which waters flow during floods, while toward the south, Lake Traverse, which also sends water into the Mississippi during spring freshets, is only 820 feet above the sea.*

The outlet of Lake Winnipeg is through the contracted and rocky channel of Nelson River, which flows into Hudson's Bay.

The mean breadth of this great inland basin is about three hundred and eighty English miles, and its mean length nine hundred and twenty miles, hence its area is approximately three hundred and sixty thousand square miles. Its shape assimilates to that of a truncated section of a circle, lying in a position the reverse of that produced by the meridians and parallels distinguishing its boundary.

The eastern rim of the basin of Lake Winnipeg is formed by part of the Laurentide range of mountains, which consist of gneiss interstratified in some localities with bands of crystalline limestone, and much embossed by domes of intrusive granite, syenite, and occasionally with elevations of trap.

The highest summit of the Laurentide Mountains, as far as known, does not exceed 1,950 feet above the sea, or 1,350 feet above Lake Superior.

Striking off in a southwesterly direction from the Savanne Lake the height of land extends to Lake Traverse, and is composed of drift-hills covering Laurentian, Silurian, and Devonian rocks, with low granite ranges and exposures of trap. From the dividing ridge, at the source of the Pigeon River, southwesterly to Vermilion Lake, the Height of Land ridge is called by the Indians *Mis-sabe-Wa-chu ;* in its continuation to the low water-shed, between Rainy River and the Mississippi, it has the name *Ish-kona-bi Wa-chu.* Continued southwesterly from the Falls of Pokegama, this ridge would pass south of Leech Lake, and strike the Red River of the North near the Great Bend, at which point Doctor Owen found silurian rocks in 1848.

From this point on Red River the rim of the basin assumes a northwesterly direction as far as the elbow of the South Branch of the Saskatchewan, along the denuded

*NOTE.—This last elevation is too little. Mr. Nicollet's barometrical determinations made it about 975 feet elevation, and this is confirmed by the levels of various surveys made since, although having a probable error of 25 feet. —G. K. W.

flanks of the Grand Coteau du Missouri. From the elbow it turns southwest as far as Chief Mountain Lake, under the 114th meridian, latitude 49°, where it meets with the flanks of the Rocky Mountains, trending first north, and then northwesterly. The North Branch and the main Saskatchewan indicate approximately its low northern boundary.

SURFACE FEATURES.

Lake Winnipeg, at an altitude of 628 feet above the sea, occupies the lowest depression of this great central basin, covering, with its associated lakes, Manitoba, Winnipegosis, Dauphin, and Saint Martin, an area slightly exceeding thirteen thousand square miles. * * * * * * *

The country, possessing a mean elevation of one hundred feet above Lake Winnipeg, is very closely represented by the outline of Pembina Mountain, forming part of the eastern limit of the Cretaceous series. * * * * *

The area occupied by this low country, which includes a large part of the valley of Red River, the Assiniboine, and the main Saskatchewan, may be estimated at 70,000 square miles, of which nine-tenths are lake, marsh, or surface rock of Silurian or Devonian age, and generally so thinly covered with soil as to be unfit for cultivation except in small isolated areas.

Succeeding this low region, there are the narrow terraces of the Pembina Mountain, which rise in abrupt steps, except in the valleys of the Assiniboine, Valley River, Swan River, and Red Deer's River, to the level of a higher plateau, whose eastern limit is formed by the precipitous escarpments of the Riding, Duck, and Porcupine Mountains, with the detached outliers, Turtle, Thunder, and Pasquia Mountains. This is the great Prairie Plateau. * * * * area in the basin of Lake Winnipeg is about 120,000 square miles; it possesses a mean elevation of 1,100 feet above the sea. * * * * * * * *

BEACHES AND TERRACES.

* * * * * * *

In the valley of Lake Winnipeg the first prominent ancient beach is the Big Ridge. Commencing east of Red River, a few miles from Lake Winnipeg, this ridge pursues a southwesterly course until it approaches Red River, within four miles of the Middle Settlement; here it was ascertained by leveling to be 67½ feet above the prairie. On the opposite side of the river, a beach on Stony Mountain corresponds with the Big Ridge, and three or four miles farther west it is observed marking the limit of a former extension of the valley of Lake Winnipeg. On the east side of Red River the Big Ridge is traced nearly due south from the Middle Settlement, to where it crosses the Roseau, forty-six miles from the mouth of that stream, and on or next the 49th parallel. It is next met with at Pine or Tamarac Creek, in the State of Minnesota, and from this point it may be said to form a continuous and horizontal gravel-road beautifully arched, and about 100 feet broad the whole distance to the shores of Lake Winnipeg, or more than 120 miles.

On the west side of Red River, and north of the Assiniboine, I traced the Big Ridge from a point about three miles west of Stony Mountain to near Prairie Portage. Here it appears to have been removed by the agency of the Prairie Portage River and the waters of the Assiniboine, which are said to pass from the valley of that river into Lake Manitoba during very high floods.

Another and higher ridge was observed on White Mud River, about twenty miles west of Lake Manitoba. It resembled in every particular the ridge on the east side of Red River, being about 100 to 120 feet broad, and about 25 feet above the level prairie. It was again noticed in the rear of Manitoba House, where the same characteristics were preserved. It probably crosses the Assiniboine three or four miles west of Prairie Portage, and is perhaps identical with the lowest ridge or step of the Pembina Mountain.

In the rear of Dauphin Lake, the next ridge in the ascending series occurs; it forms an excellent pitching track for Indians on the east bank of Riding Mountain. Probably these ridges are found close together at the foot of Pembina Mountain, where no less than four distinct steps occur close together, near the sources of Scratching River. The summit of these steps may be the plateau, whose altitude was ascertained by Dr. Owen to be 210 feet above the prairie-level, and the first steps may be continuous with the Big Ridge, limiting the level prairies of Red River and the Assiniboine.

The prairies inclosed by the Big Ridge are everywhere intersected by small subordinate ridges, which often die out, and are evidently the remains of shoals formed in the shallow bed of Lake Winnipeg when its waters were limited by the Big Ridge. Many opportunities for observing the present formation of similar shoals occurred in Lake Manitoba, St. Martin's Lake, Lake Winnipeg, and Dauphin Lake. These, when the lakes become drained, will have the form of ridges in the level country then exposed. Indeed, it may be said that the region between Dauphin Mountain and Lake Manitoba, in the direction of Ebb-and-flow Lake, and south of that body of water, is

but recently drained, or still in process of draining, being removed from the surface of Ebb-and-flow Lake by a very few feet, and covered with water to a large extent in the spring. At present it consists of marsh, bog, and ridge, in continued succession. When completely drained the country will resemble the present prairies of the Assiniboine, with the gentle rich depressions, and the low dry, gravelly ridges.

The Pembina Mountain is *par excellence* the ancient beach in the valley of Lake Winnipeg. Dr. Owen thus describes it as it presents itself a few miles south of the 49th parallel.

I have already quoted this from Dr. Owen in a preceding part of the essay, to show that his determination of the elevation of this ancient beach makes it sufficiently high to restore the outlet southward by the Minnesota Valley, so I do not repeat it here. But this testimony of Professor Hind to the genuineness of this ancient beach, after his thorough explorations in the Winnipeg Basin, leaves no room to question that the level of Lake Winnipeg was formerly so much above what it now is as to overflow all the intervening country, and create the river that eroded the Minnesota Valley.

I have ventured to provisionally restore this ancient lake, on the supposition that its surface be raised about 350 feet above its present level. It is not here claimed that this would, if accurately done, give the shores of the former lake, for there has probably been much change of the slopes of the surface since the lake had its southern outlet, as there seems no way to account for its disappearance but by a change of the inclination of the longitudinal valley of the continent.

The consideration of the probable cause of the former extension and subsequent shrinking of this great lake next demands attention.

Hypothesis to account for the former drainage of the Winnipeg Valley, and for the change to the present outlet by Nelson's River.

Having in the preceding discussion shown that Lake Winnipeg formerly was continuous to the Minnesota Valley, with an outlet along the valley to the Mississippi, we must at once infer that the existing outlet by Nelson's River to the Hudson's Bay did not then exist. We have no example in nature of any great lake having two outlets at the same time in operation. It is not readily conceivable how two such could ever have formed. Our general idea is that a lake is a depression of the earth's surface, which becomes partly or entirely filled with water, and in the latter case it flows out at the lowest point in the margin or rim of the basin. Thereafter this outlet prevents further rise of the water, by draining it off from the lake as fast as it enters, and thus it cannot overflow at some other point. Now, inasmuch as the closing of the Nelson's River outlet at the present time would cause Lake Winnipeg to rise till it would run out at the Minnesota Valley, it at first seemed plausible to suppose that if the Glacial period tempered off gradually into the present geological epoch, there might have been a long time when the glaciers had still sufficient extension southward to close this outlet to Hudson's Bay. Then, on the further recession of the glaciers northward, the present outlet would be presented and the lake drained off. Although something like this may have occurred, it is, so far as I now know, an unsupported hypothesis, and barren of any fruit. It will not aid us in explaining any phenomena presented by other lake-basins and water-courses of North America, nor enable us to predict what probable results we shall find in other regions, and thus intelligently direct further investigations.

The hypothesis which I have found to account satisfactorily for this change of outlet from what it formerly was down the Minnesota and Mississippi to the Gulf of Mexico, to what it now is by way of Nelson's or Sea River to Hudson's Bay, is to regard it as a result of a gradual

change of inclination of the surface of the low interior portion of the continent, caused by a slow elevation of the southern part and subsidence of the northern part, extending through a vast period of time, and probably still going on. The elevating force appears to come from the part of the earth-surface occupied by the Pacific Ocean, and the line of greatest depression is somewhere near Greenland, or between it and the continent. At some intermediate region there would be no change in the elevation, but the change of slope would be going on in the same direction throughout. With these assumed conditions we can mentally go back in time to a period when all of the Winnipeg Lake Basin—the lake being shallow—was at a higher level than the lowest axial line of the continental basin south of it of which it would form a part. In that case no lake would exist in the basin, it being completely drained southward. At such a time the surface of Hudson's Bay and of the Arctic Ocean would be much less than now, and there would be a much greater extension northward of the waters of the Gulf of Mexico. With such conditions the cold at the north would be intensified and extend farther south than now, while the northern extension of the Gulf would carry the warm, moist winds of the south farther north than now. This effect may have gone to considerable extent, and would greatly favor the formation of glaciers. The former existence of glaciers is therefore favorable to this hypothesis.

Let us now consider what would happen along the course of the then great southerly-flowing river when the northern subsidence set in. First, there must have been a decreasing river-slope in the northern portions, and a diminishing power to erode. Wherever some formation of hard rock was met, if the erosion failed to keep pace with the decreasing slope, a lake would begin to form above it. This lake would thereafter catch and hold all the hard abrading material formerly washed along by the stream, and thus farther decrease its eroding power. The lake must gradually expand above the barrier, and its limit would be reached when a new outlet formed. In the present case the outlet was on its northern rim. Such I take to be the history of Lake Winnipeg. Its southern outlet, the Minnesota, met, in the ledges of granitic formation which extend from Big Stone Lake southward along its valley for 110 miles, a material which its eroding power was too small to remove fast enough to prevent the formation and expansion of a lake above it. This growing lake finally found a new outlet by overflowing near Nelson's River. The first material of the bed of the new outlet was probably loose drift, so that it was easily removed, and the outlet widened and deepened rapidly. When the hard rocks in the bed of Nelson's River were reached abrasion proceeded slowly, causing, along with the gradually changing slope, a slow farther recession of the southern shores, to be hastened occasionally by more rapid lowering of the level, as some long-resisting barrier was finally removed. The records of this action in producing ancient shores and beaches are shown in the quotations I have made from the writings of others.

The Nelson's River has every indication of being of recent origin. Professor Hind says of it: "It is characterized by having falls and rapids which effectually oppose communication even by canoes."

The direction of the tributaries of the Winnipeg Basin all indicate that they belonged to the same system of rivers as those of the Mississippi Basin. The course of the Red River as it comes from Otter-Tail Lake, of the Wild Rice River, Shayen Oju River, and other smaller tributaries, all point to a southerly outlet, until in their course they reach the ancient lake-bed, and then they turn in regular curves through an arc

of more than 90° and take an opposite direction. This change of course is just what we should expect from a change in the outlet of Lake Winnipeg, and its gradually draining off. Professor Hind's examinations show that the South Branch of the Saskatchewan formerly continued its southerly course through the valley of the Assiniboine River. I think the changed direction resulted from the formation of a lake on its upper course, which opened a new outlet, and drained off under the action of the same cause which changed the course of the drainage of the Winnipeg Basin. The Little Souris is said to have formerly had a southern course through the valley of the Pembina River, and there is evidence of the former great lake through whose agency the change was effected. It seems to me probable that the Upper Little Souris formerly connected with the James or Dakota River of Dakota.

I will note here that, so far as I know, I was the first to point out the effect of lakes originating along a water-course undergoing a diminution of its slope, which, by expanding, overflow and form new outlets, thus reversing the courses of rivers and changing their channels.

A reference to the map (at the end of this essay) of the ancient valley when Lake Winnipeg had its greatest expansion, and still had its outlet by way of the Mississippi, will show the harmony there is in the directions of all the rivers as members of the Mississippi Basin.

There is no doubt an immense alluvial deposit in the ancient bed of Lake Winnipeg. Where this is cut through by the Red River it is 40 to 80 feet deep. All the tributaries from the west flowed through the soft cretaceous and tertiary strata, and carried to the lake silt, which, spread out over the bottom, gives it such a wonderfully level appearance. These tributaries still carry a great deal of clayey material to the lake, so that it is now, and always has been, as its name signifies in the Ojibbeway tongue, *Wi-nipi*—muddy water.

The following facts and reasons confirm the truth of the hypothesis of northern subsidence:

Lake Michigan and Illinois River.

An exactly similar case to that of the Minnesota Valley and ancient Lake Winnipeg is presented by the valley of the Illinois River and Lake Michigan. The Illinois Valley is throughout broad and deep, far beyond that of rivers generally of the same volume. At its upper end its width is great, even where there is no stream, and it widens out suddenly into what was, undoubtedly, the ancient shore of Lake Michigan, whose waters must then have flowed down the valley of the Illinois. So little have the waters receded from this ancient outlet that the city of Chicago has cut down the barrier sufficiently to serve as a canal for navigation, and a drain for its sewerage, by a direct flow of the water.

The hopothesis given to explain the shrinking of Lake Winnipeg answers equally well for this case. The much less change in the surface-elevation of Lake Michigan, since the southern outlet closed, may be readily accounted for in the greater length of Lake Michigan's new northern outlet than that of Lake Winnipeg. The hard, resisting granite, which, in the Minnesota Valley, prevented erosion, had its counterpart at the head of the Illinois Valley in the continuous, nearly horizontly, stratified, compact, magnesian limestone.

Lake Winnebago and Upper Fox River.

Another similar case is presented by Lake Winnebago and the Upper Fox River, in Wisconsin. All the drainage of the present Winnebago Basin was formerly southward through the valley of the Wisconsin River to the Mississippi. The Wolf River, whose course is southwesterly, formerly flowed direct to

the Wisconsin, but near its junction it traversed granitic ridges, (the same as those met by the ancient Minnesota;) its erosions could not keep pace with the changing continental slope, and a large lake was formed, much larger than the existing Lake Winnebago. This overflowed, finally, into the depression forming Green Bay, and the lake was thereafter greatly reduced. The Little Upper Fox and the Wolf rivers, and others, turned back in their course on reaching this former lake-bed, presenting the anomalous appearance which it has on the maps, so like those of the Red River of the North.

The features of this line between Green Bay and the Mississippi Valley early facilitated communication, and excited wonder, as those at the source of the Minnesota did. There are the same kind of lakes on the Upper Fox as on the Minnesota, and the outlet of Lake Winnebago, like that of Lake Winnipeg, is full of rapids.

St. Joseph's and St. Mary's, Maumee and Wabash Rivers.

These four streams are all nearly united at Fort Wayne, Ind. By the course of the rivers Saint Joseph and Saint Mary's, (on the map,) we should expect them to flow southward to the Wabash. An examination which I have made shows that they once did so. The Wabash Valley is continued up, so as to unite with the valleys of these streams, and there are deposits in the Wabash Valley which could only have come from these streams. A little way down the Wabash Valley, below where these streams join it, is found horizontally stratified hard magnesian limestone, resisting erosion, the same as that at the ancient Illinois outlet to Lake Michigan. The anomalous present course of the Saint Joseph and Saint Mary's rivers also indicates that they formerly flowed down the Wabash Valley, and the great width of this valley throughout its length, compared with its present volume of water, contrasts strongly with the relation between neighboring streams and valleys. We cannot believe that Lake Erie ever had an outlet down this valley. Its present level is 190 feet below the summit of the valley, and even if Niagara did not exist, an elevation of 50 feet would have flowed it back into Lake Michigan, and thence down the Illinois River. What seems most reasonable, is to consider this change in the direction of the flow of the Saint Joseph's and Saint Mary's rivers to be due to the formation of a lake at a higher level than Lake Erie, (in the same way as we have already noted having taken place on the Fox River of Wisconsin,) which lake formed a new outlet along the present course of the Maumee, the same as Lake Winnebago has along the lower Fox River, but, unlike that lake, this one has been entirely drained off. I have never had time to examine the course of the Maumee to verify this hypothesis. There should exist an ancient lake shore, and a gorge somewhere along the Maumee, if rock is encountered in its course. It, therefore, furnishes a test by which further examination may verify or reject this partial hypothesis.

Hypothesis sustained by effects in contiguous regions.

So far the confirmation to my hypothesis has been mainly tested by its explanation of similar phenomena in not very distant regions, and largely dependent upon my own observations, but the hypothesis itself is in no way startling. Professor Dana, in his Manual of Geology, says:

> Although the earth, in its last stage, has reached a state of comparative stability, changes of level in the land still take place. The movements are of two kinds:
> 1. Secular, or movements progressing slowly by the century. 2. Paroxysmal, taking place suddenly, in connection usually with earthquakes.

It is to the first of these, of course, that my hypothesis belongs. Professor Dana says:

The secular movements which have been observed are confined to the middle and higher temperate latitudes, and are evidently a continuation of the series which characterized the post-Tertiary period. In this and other dynamical changes the post-Tertiary and the age of man have intimate relations.

As I have stated that the change we are considering is one of the present time, I have some difficulty in making quotations from authorities to sustain that view, for such similar effects belong to an antecedent time. I therefore take that evidence which appears unquestionably to belong to the existing period. Professor Dana's manual says:

Subsidence along North Atlantic shore.

In Greenland a slow subsidence is taking place. For 600 miles from Drisco Bay, near 69° N., to the Firth of Igalika, 60° 43′, the coast has been sinking for four centuries past. Old buildings and islands have been submerged, and the Moravian settlers have had to put down new poles for their boats, and the old ones stand, as Lyell observes, "as silent witnesses of the change."

On the North American coast south of Greenland, along the coasts of Labrador to New Jersey, it is supposed thatsimilar changes are going on; though more investigation is required to establish the fact. G. H. Cook concludes, from his observations, that a slow subsidence is in progress along the coast of New Jersey, Long Island, and Martha's Vineyard.

I have, myself, examined a considerable portion of the coast between New Jersey and Maine, and I think that no hypothesis other than a gradual submergence going on at the present time will account for the effects observed.

Effects along the Saint Lawrence River.

If there is a subsidence along the Northern Atlantic shores, and along the interior axial valley, it is not unreasonable to infer that all the intermediate northern region partakes in it, and thus it may be that the Saint Lawrence River is a northern outlet, and of recent existence as such.

This river is a vast arm of the sea, from the Gulf of Saint Lawrence, for a long way, such as might result from a partially sunken river-basin. The great depth in the Saguenay River, over that in the Saint Lawrence at their junction, indicates that a corresponding depth which must once have existed in the latter, has been filled up by detritus brought down by the upper Saint Lawrence and deposited in the lower part, after the course of the stream became reversed.

Niagara Falls.

The cataract of Niagara, a northern outlet, is of recent formation, and it should be noticed as a significant fact that all the northern outlets abound in cataracts and rapids, while the streams flowing south are comparatively free from them, indicating the more recent origin of the former. A few rapids in the course of the main Mississippi Valley can be shown to have a much more recent origin than the rest of the valley.

Shores of the great lakes.

Again, if we consider the lakes by themselves, we see that if the continental slopes are gradually inclining more and more toward the northeast, these bodies of water must have a tendency to move in that direction, which they would obey until stopped by some rocky barrier; these southwestern shores would have smooth rounded outlines like land rising from the water, and the opposite ones would be sharp and ragged in outline from abrasion of the waves and from the submergencies of land long furrowed by atmospheric influences. Lakes Winnipeg, Winnebago, Superior, Huron, Ontario, and Champlain, all are bounded on the east and north by rocky shores where the water is deep, and the reverse condition exists

on the opposite shores, which are more or less shoal. It cannot be that this difference is due to the character of the rock in place, for this could not determine the direction of the action to be the same in places so distant and differing so much from each other. Were the tendency of the changing continental slope to be in the opposite direction from what it is now, there can be little doubt the lakes would be found at the base of the Rocky Mountains as they formerly were in the Tertiary period of geology.

Hypothesis of southern continental elevation.

The evidence of recent elevation of southern areas *pari passu* with the northern depression comes from parts of the continent far removed from the valleyof the Minnesota where this investigation was begun, and as this is not the place to treat of the subject fully, I intend to present only certain general considerations concerning this feature of the subject.

Rio Colorado of the West.

The region of vast cañons embraced in the drainage-basin of this river exhibits effects which would result from its gradual elevation above the sea by a force which acted with maximum intensity at the part of the basin nearest the sea. The sources of this river originating in the high mountains of the most elevated central region could not have the slopes at these places materially diminished by the changing level of the continent, while there would be an appreciable increase of the slopes in the parts near the ocean, where steep shores became more elevated. The surface-strata in the basin of the Colorado were mainly made up of soft cretaceous and more recent geological formations, into which the streams readily cut their way. Abundance of hard rocks, such as bowlders, concretions, &c., fell into these streams, and, by their abrading action in moving along, cut the channel deep, as a saw supplied with sand and water works its way through a block of marble. The clashing sound of these rocks in the bed of these streams has been heard by persons standing on the banks. Thus the abrading action in the Colorado Basin has kept pace with the elevating action, and the great depth of these cañons in a manner measures the extent of the elevation. Had such soft rocks existed along the Minnesota, under like conditions, so that the drainage could have always remained southward, we should have had escarpments there 500 or 600 feet deep.

No serious water-fall exists along the cañons of the Colorado, which is a proof of the powerful and long-continued eroding action, which in some places has sawed into granite rocks. A result similar to this is displayed along the Rio Grande del Norte.

Great Salt Lake.

The peculiarities of the Great Salt Lake Basin admit of an explanation on the hypothesis of a recent elevation of the southwestern part of the continent. The ancient beaches or shore-marks of a former extension of this lake by an elevation of the waters above the present level as much as 1,000 feet are seen on the west slope of the Wasatch and east slope of the Humboldt Mountains. This depth of waters spread the lake over an immense area and far into the present basin of the Columbia River. Before this elevation began we can suppose the ocean to have extended far inland to the south of the Salt Lake Basin, and that the drainage of the latter was toward the Gulf of California. As the elevation proceeded this lake would expand northward until the new outlet was formed through the Cascade Range, by way of the valley of the Columbia. A rapid lowering of the surface and contraction of the area would soon follow, to be continued indefinitely as the new outlet deepened and extended. At some period, as

this elevation went on, the Sierra Nevada and Coast ranges would reach a height sufficient to arrest the moisture coming from the Pacific Ocean so that the evaporation in the interior basin would exceed the precipitation when the lake would begin to dry up, and finally become as it now is.

A similar result in the basin of the Humboldt River and Mud Lakes can be similarly accounted for.

I could bring many observations in support of this view, and may do so on some other occasion.

Peninsula of Florida.

There seems to be every evidence of this being very recently elevated, but, as it is not in the drift region, I do not know whether the evidences there can be distinguished from those which an elevation preceding that time would show.

Recent extension of the Gulf of Mexico.

In my report on the Mississippi River I think I shall establish the fact that since the Drift period the Gulf of Mexico has extended as high up the valley at least as the neighborhood of Dubuque, Iowa. This will mainly depend upon the observations and measurements, which show an interruption in the general width of the main valley at the rapids near Rock Island, near Keokuk, and at the Grand Tower, and at the Grand Chain. At all these places the river now flows through exceptionally narrow and obstructed channels, while a more extensive and unobstructed ancient valley is found alongside of them. The reasoning is this, that this uniformly wide, ancient river-valley existed before this extension of the Gulf northward. That when it afterward became submerged these old channels became so filled with silt, that on the region undergoing a more recent elevation the river at these exceptional localities did not regain its ancient valley, but has since excavated a new one, recent in origin, as its incompleteness shows. It will require much space to fully elaborate this point, and I reserve it for my report on the Mississippi River. The questions involved concern also similar effects on the Ohio and Missouri Rivers, for all of which the same explanation applies.

Reference to a former continental change of level.

It will be observed that, in speaking of the effects at the rapids of the Mississippi, &c., I have introduced a change of level preceding the continental movement going on now, by which a part that is now undergoing elevation experienced a reverse action, and from being above the sea was depressed beneath it. This last action, too, was post-Glacial, or, at least, was since the most southern glacial drift was formed. I acknowledge two such oscillations as being made out, and have been as careful as possible not to confound their effects, in which they much resemble each other.

Local changes of elevation of earth's surface inadmissible.

In my discussion I have held that the movement of theearth's surface we have been considering is secular, and affects large areas at the same time, and that local changes could not be admitted to explain the effects to which attention was called. Such local changes only occur in volcanic regions. The thickness of the earth's strata at present precludes such limited movements elsewhere.

Great permanence of structure since recent Tertiary.

The tertiary strata, where I examined them in Nebraska, were found to have a gentle inclination from the Rocky Mountains, extending over hundreds of miles, yet everywhere appearing level and undisturbed, except by erosion. Viewing them at places where they are margined by the rocks, which

formed the shore of the ancient lake into which these tertiary deposits were made, it seemed like viewing that ancient shore itself.

To show that this permanence of structure in the earth's crust exists, I will present a few points in regard to it as deduced from phenomena of the Glacial period which have come under my observation. The line of distinct unmodified glacial drift, as I have observed it, extends somewhat south of Warsaw, on the Mississippi; thence in an undefined line westward to the Missouri; thence along that river, mostly on the east side of it, as far north as about latitude 46°; thence westwardly till it joins the moraines made by the ancient Rocky Mountain glaciers, which extend eastwardly from the mountains 50 or 100 miles.

This same continental structure exists in the Glacial period.

A large intervening portion of the plains shows no signs of glacial action, and the tertiary and cretaceous fossils almost everywhere lie exposed at the surface. The great glacier, then, must have had its southwestern terminus on these plains, very nearly along the line of the Missouri, south of the parallel of 46° north. This line is very nearly parallel with the summer isothermal of the present time. That this was the line of terminus of the glacier seems confirmed by the glacial scratchings in Wisconsin and Minnesota which are to the southwest, and this being the direction of the shortest line to the terminus, would be the line of least resistance to the glacial movement. This condition evidently implies a disposition of the continental masses of mountain and plain, much as now—an arid region on the plains which limited the formation of glaciers for want of moisture, which presupposes a mountain-mass to the southwest to intercept it then as now.*

Since the relative structure of the continent in its arrangement of mountain and plain appears to have been permanent for a long period, I will introduce the indications afforded by the ocean shores as to the changing level of the continent.

The shore-line of the continent indicates northern subsidence and southern elevation.

The existence of fiords and deep, narrow indentations has been noted as belonging to northern latitudes and glacial regions. Glaciers must do their work mainly above the sea-level, and it must require subsequent submergence to convert valleys thus eroded into fiords. Fiords may, however, be independent of glacial action, for there can be no doubt that a submergence of the cañon regions of Arizona and New Mexico would form fiords out of valleys eroded simply by the atmosphere and by streams. Moreover, the formation of eroded valleys must have been an exceptional form of glacial action. Its most common effect is to grind down all but the large masses composed of the hardest rock, filling, and obliterating, all former inequalities of the surface.

The termination of the great glacier on the Atlantic seems to have been marked all along our shore by an immense terminal moraine, much of which is still visible at Long Island, Block Island, and Martha's Vineyard and Nantucket Islands. The wearing away which these shores are undergoing I can account for only on the supposition of their gradual submergence. Wherever valleys were filled by glacial deposits the subsequent action of rains, if above water, would wash them out, and then, on submergence, fiords would appear.

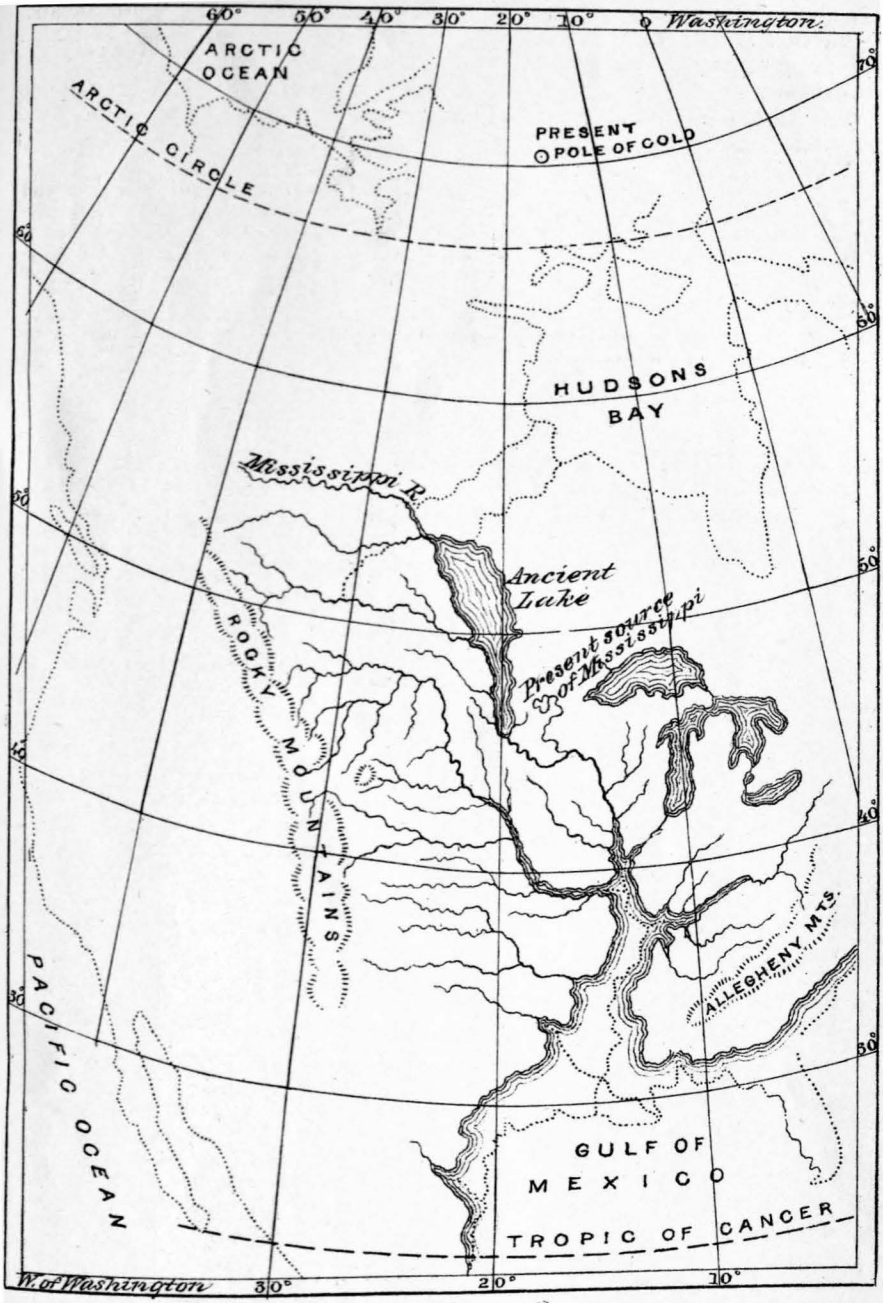
The material which the waves remove from the shores is not swept out into deep water. The lighter clays float inland, to aid in forming flats. The smaller stones and gravel are slowly moved along the shore,

* The wonderful labyrinth of erosions forming the Bad Lands of White River appear to have entirely escaped glacial action and submergence by water, and as they exist now are a monument of atmospheric action, including even the Glacial period.

rolling up and down with the waves until reduced to sand and deposited in littoral cordons or in shoals like Nantucket and Great South Shoals. The large rocks remain distributed over the bed of the ocean.

Looking at the map of the North American continent we see on its northern shores the sharp and ragged lines similar to the contours of the contiguous dry land, while along the southern shores we see the smooth, rounded lines such as form the contours of land beneath the water.

NOTE.—What is said here in this essay might, perhaps, more properly have been said in 1868, at which time the substance of it was given in the annual report. But a somewhat larger scope was there given to my remarks, and time did not suffice to reduce them to definite order. Even now my time is too much occupied to enable me to properly compare my own observations with others. The map of the ancient valley, and the diagram giving a profile of the continent along the lowest line, from the Gulf of Mexico to the Arctic Ocean, and along the lowest line from the head of Chesapeake Bay to San Francisco, were prepared and submitted in 1868, but now again repeated here, having never been published.



Restoration of
the Ancient Basin of the Mississippi.

The dotted shore and river lines represent the present outlines and courses.

N. PETERS. PHOTO-LITHOGRAPHER, WASHINGTON, D. C.