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ART. L.—*Valley of the Minnesota River and of the Mississippi River to the junction of the Ohio: its origin considered;* by Gen. G. K. WARREN, Major of Engineers. With Diagrams A, B, C, C′, D, E, F and G (making plates 11 to 18 of the volume).

Definition of the term "valley," prominent natural features and length.—The *valley* to be considered is the part included between the high banks, commonly called bluffs. Whenever it becomes necessary in this article to refer to the whole area drained by the river, the word *basin* will be used to designate it.

Between these high banks the greater portion is subject to overflow at time of floods, forming what is sometimes called the *flood plain;* the smaller part above overflow is generally composed of alluvial terraces of sand and gravel. In some cases the distinction between the terraces and the bluffs is difficult to make.

The Mississippi River in its usually navigated parts touches only here and there at places exempt from flood-waters, and these are natural landings for steamboats and sites for towns. In course of time the convenience of the people living there makes them desirable locations for bridges. It is very rare, however, that both banks of the river are above submergence; where one bank is, the opposite one is generally low, and covered many feet deep at extreme high-water, making it difficult to construct bridges sufficiently elevated for steamboats to pass under them.

The distance along the general course of this valley from St. Louis to St. Paul is about 620 miles, but steamboatmen, by the course they take along the navigable channels, make the distance about 800 miles. This was the only part specified in the law authorizing this investigation, but it was necessary in order to present the subject itself properly to include the whole distance from the mouth of the Minnesota to the Ohio; this is an extent of about 760 miles along the general course of this valley, and we have prepared a map of it in twenty-two sheets on a scale of two inches to a mile. The manner in which this is done is described in Chapter VI of this report.

General map and profile prepared for publication.—Although we have, in constructing the map, exhausted all means of obtaining knowledge in regard to this part of the Mississippi Valley, there are some parts of it too little determined to make its publication as a whole, advisable, and therefore we have only prepared for publication the index map of those twenty-two sheets, on a scale of six miles to an inch. (If photo-lithographed it may vary from this scale.) Here, again, generalizations have led us to make this index map include the Minnesota River Valley. That valley, under another clause of the law, was also made a part of my investigation, and a map in twenty sheets on a scale of two inches to the mile was made for it. The map submitted for publication is also an index map to those Minnesota Valley sheets now on file at Engineer headquarters in Washington. We have also extended this general map southward so as to include overflowed land as far as the northern part of Arkansas, and northward to include a part of the basin of the Red River of the North. It is designated as Diagram 1, in five sheets.

The two systems of the United States land surveys, one on each side of the river, are so checked upon each other in its construction and by special surveys by ourselves, that the valley on this small scale is probably as correct as it can be represented. The whole of the flood-plain is shaded with light ruled lines, except the principal lakes and water-courses, which are shaded with heavy lines. The alluvial terraces above overflow are shaded with dots. The high banks or bluffs are without shading. On sheet five there are some overflowed lands that are above the Mississippi floods, which have special shading.

In order to complete a presentation of the Mississippi flood-plain to the Gulf of Mexico, the page Diagram A is added, reduced from Plate II of the report of Humphreys and Abbot on the physics and hydraulics of the Mississippi.

General considerations as to the formation of the Mississippi Valley have caused me to present also the page Diagram B, showing the Mississippi basin as it is, and extending northward to include the Lake Winnepeg basin with the ancient extension of the lake southward and outflow through the valley of the Minnesota and Mississippi Rivers.

Profiles prepared for publication.—Accompanying this chapter are two sheets of longitudinal profiles of the valley from the junction of the Minnesota River to the junction of the Ohio. The horizontal scale is about eight miles to an inch, and the vertical 200 feet to an inch, reduced in publication. The datum is the sea-level according to the best determinations, and both sides of the valley are given side by side. The parts of the banks above low-water are shaded to indicate the strata of different geological periods, but it must be borne in mind that this low-water line does not represent the low-water slope of the winding river, but is drawn from point to point along the general course of the valley, so as to bring the rocks into their proper relative positions. These longitudinal profiles are designated as Diagram 2, in two sheets.

Another sheet, designated as Diagram 3, gives twenty transverse valley sections, on a larger scale than the profiles: three of them on the Minnesota Valley; one on the Mississippi, above the junction with the Minnesota; fourteen of them in the valley between the Minnesota and the Ohio; one at the mouth of the Missouri River, and one at the mouth of the Illinois River. These sections are designed to show the extent of our positive knowledge of the depth of the bed-rock, and will be described in detail in the latter part of this chapter.

We are mainly indebted for the geological data in these profiles and sections to the report of David Dale Owen, October, 1851, on the Geological Survey of Wisconsin, Iowa and Minnesota; to the report on the Geological Survey of Iowa, by Prof. James Hall, Prof. J. D. Whitney and Mr. A. H. Worthen, published in 1858, and the report of Mr. A. H. Worthen, director of the Geological Survey of Illinois, published in 1866.

Method of treating question of depth of bed-rock.—The question of depth of the bed-rock beneath the sand that usually forms the bed of the river will occupy the remainder of this chapter.

In presenting my ideas in regard to it, I have thought the best order in which I could arrange them would be that in which they arose in the progress of the investigation. It was from the first obvious that means and time would not allow of my covering such an extended field by actual borings, and that the most that could be done was to draw such probable inferences as could be done by a study of the rocks visible in the bluffs and by an effort to comprehend the manner in which the valley was formed.

The consideration of the anomaly presented by Lake Pepin lying in the course of the river, and said to have a depth of sixty feet near its lower end, was the beginning of this effort. If the valley in this portion had once been all of this depth, and since filled in, then the bed-rock could not be less than sixty feet below the water surface. Explanations of the cause of this lake had been attempted by Long and by Featherstonhaugh, which did not seem to me satisfactory.

Explanation of the cause of Lake Pepin and similar lakes.—The results of the levelings on the Minnesota and Mississippi Rivers made by me showed that just below the entrance of any considerable affluent there was an accumulation of deposit in the main stream brought by the tributary; that over this deposit the slope of the water was greater than the average slope, and that it was shoal and impeded navigation; that just above the affluent the slope was less than the average, and the water deeper. So far, this was in accordance with conditions which generally exist in rivers, and might be so even where the main stream was gradually wearing away and deepening its bed.

But a marked peculiarity was exhibited at the junction of the Minnesota and Mississippi Rivers. Regarding the Mississippi as the affluent (which we might do from the comparative sizes of the two valleys), the rule here would be as it is elsewhere, steep slope and shoal water below the affluent and almost no slope and very deep water above. In this instance the effect is felt above for at least thirty miles. On the other hand, taking the Mississippi as the main stream (as the volume of its water has always caused it to be regarded), then we have the anomaly of the main stream filling up the valley and damming back the affluent so that the latter brings no coarse material whatever into the main valley or has any part in forming the shoal below the junction of the two streams.

I called attention to this in my report published in 1867, and again made the anomalous condition a feature in my report on the Minnesota River,* where diagrams were given of the streams and valleys at the junction, and of the Minnesota at its source in Lakes Big-Stone and Travers, which I here repeat as Diagrams C and C′. The Minnesota Valley maintains these widths and depths throughout its course. I have also prepared a small contour map of the sources of the Minnesota and Mississippi Rivers, to show the important position occupied in this system of slopes by the Minnesota Rivers, and give it as Diagram G.

In the report on the Minnesota, above referred to, I showed that the valley of the Minnesota River had, in the period subsequent to the glacial-drift epoch, been occupied by a much larger river, which had formed the outlet of a great lake, embracing the lake Winnipeg and receiving the drainage of its basin, and extending as far south as the present Lake Traverse at the sources of the Minnesota River.† This ancient river, if its volume were as great in proportion to area as that of the

* Annual Report Chief of Engineers, 1875, Part I, page 387.
† Ibid, 1868, pp. 307–314.

Mississippi above the Falls of St. Anthony, probably equaled Niagara in volume, and would have been sufficient to prevent the formation of such excessive accumulation of *débris* in its course, such as the Mississippi is now making below the Minnesota River, although it is probable that the material brought into it from the near proximity of the Falls of St. Anthony would have had the usual effect of somewhat increasing the slope and shoalness just below its junction, and decreasing the slope and increasing the average depth just above.

Accepting, then, the conclusion which I have elsewhere made reasonable, that the drainage of the Winnipeg basin was formerly along the Minnesota and Mississippi below the junction, then when the flow of water from that great northern basin ceased there would no longer be the volume of water necessary to remove the deposits brought by the affluents into a channel of too great capacity for the requirements of the new conditions.

In building the railroad bridge across the mouth of the Minnesota, Mr. Shepard, the engineer, made borings to ascertain the character of the foundations. A rod was forced down about sixty feet, at which distance a stratum was reached so yielding that the rod's weight would be barely supported. He did not endeavor to probe further, for just before reaching this soft layer he passed through a harder one of sufficient thickness and resistance to support his structure. This bridge is a work of minor character. This shows that the deposit in the old valley exceeds sixty feet at this point. The Minnesota being a muddy stream, its fine silt has much filled the lake which the Mississippi *débris* at its mouth caused.

The *débris* and material brought over and from the Falls of St. Anthony has been carried downward by the water, gradually accumulating and filling the valley as it advanced. One should here stop and consider the manner in which river deposits are made. The finest clay is so easily mingled with the water, that the slightest disturbances in the fluid as it moves along even with gentle currents, is sufficient to keep it from settling down until still water is reached. The amount of this on the Upper Mississippi is comparatively very small. Such materials as can be moved only by the swiftest currents are rolled over along the bottom, gradually diminishing in size by friction, and furnishing smaller particles susceptible of being thus moved by feebler currents. The resulting material is pebbles, gravel and sand, the fine material, such as clay and vegetable matter, being all washed out.

When deposits of gravel or sand are made of materials moved along the bottom, it takes place as soon as the current slackens, as it must do on reaching a place having a larger sectional area. The deposit is sudden, and the material is all taken up in diminishing the section, until the velocity of transportation is restored; then deposition continues immediately in front of the last deposit. Such deposition, therefore, does not extend laterally from the course of the current into any contiguous dead water, as depositions from water holding a clayey or vegetable matter would.

Thus in the valley of the Mississippi, the lakes alongside the river's course are deeper than the river, which has continued to raise its bed by deposits of sand after the lakes were cut off from its current.

From the Falls of St. Anthony down to the St. Croix River the Mississippi Valley receives no considerable tributary. The St. Croix comes from a region of trap rock now furnishing little or no large and heavy sedimentary matter. The result has been that the Mississippi deposit of sand and gravel has been thrown across its mouth, holding back its water and forming the St. Croix Lake. At low water, while the depth of the Mississippi at the junction is two and one-half feet, the depth in Lake St. Croix is twenty-five feet. It is not probable that twenty-five feet depth represents the amount of filling of the ancient valley at this point, because the lake itself must have been somewhat shoaled with fine deposits of clay and vegetable matter.

The next considerable tributary to the Mississippi Valley is the Chippewa River. This, entering at right angles with a steep river slope and a probable high-water volume of at least 40,000 cubic feet per second, comes from a region inexhaustibly supplied with siliceous sand and gravel containing a considerable of the heavy magnetic sand, whose oxidation often cements the other sand deposits.* It brings quantities of these materials which, spread out below, give a very steep slope to the Mississippi River, and very bad shoals for navigation.

Lying just above this deposit is Lake Pepin, which it completely accounts for. The reason this lake has not been filled up by the Mississippi above is that the supply of sand from the Chippewa is so great as to raise the level more rapidly than the filling above can keep pace with. The Chippewa from the left bank pushes its sand-bar out, so as to confine the outlet of the lake to the opposite shore. There is an observable relation between the condition of the lake and the deposits of the Chippewa. The deepening of the waters by the deposit of Chippewa sands is felt at low water sometimes as far up as the mouth of the St. Croix, when floods in the Chippewa make these deposits large, and on the other hand, in times of droughts the waters of the lake cut the outlet deeper, and lower its level, so that the shoal water is moved down the river two to three miles below the St. Croix.

* "The analysis of the soil on this part of the Chippewa River (the Yellow Banks) gives ninety-three per cent of insoluble matter, which is chiefly white sand, with only two per cent of organic matter, less than four per cent of soluble saline matter, consisting chiefly of oxide of iron and alumina with only a trace of calcareous earth."—Owen's Report, p. 56.

If we follow the Mississippi down we find similar conditions produced by the Wisconsin River as by the Chippewa; that is, a great increase of the slope and shoaling of the river below the junction, with gentler slopes, deep water, and lake-like aspect above. There would probably have been a large lake here, if the affluents above had not silted it up.

Another instance is afforded by the damming-back effect of the Mississippi deposit at the mouth of the Illinois River, making it at low water almost like a lake up to La Salle.

Lake Pepin must therefore be regarded as due to the deposit by the Chippewa of heavy coarse sediment into the valley of an ancient and larger river. This view may be strengthened further by the following considerations: It lies immediately in the course of the main valley above an important tributary. In this respect it agrees with Lac-qui-parle, on the Minnesota, just above the Lac-qui-parle River; with another lake on the same valley just above Yellow Earth River; with Big Stone Lake in the same valley, just above Whetstone River; with Lake Traverse, which is formed by deposits from a stream at each end, and thus empties sometimes in both directions. It agrees in this relation with the lakes on the Qu'Appelle, which all lie just above a considerable tributary, and with like lakes on the Upper Fox of Lake Winnebago. This constant relation seems unmistakably one of cause and effect.

Valley now filling up.—From what has been stated above, it is clear that the river valley in the part we have considered is not now being deepened by erosions, but, on the contrary, is filling up, and it appears to be doing so all along its lower course except at the rapids.

Recent drainage of Lake Winnipeg southward.—As I have stated in previous reports, I regard the ancient river draining the Winnipeg southward by the Minnesota and Mississippi Valley as existing subsequent to the glacial deposits. This is based upon the fact that the river's course is cut through those deposits, as shown by the banks in many places from Lake Traverse, in Minnesota, to Warsaw, in Illinois, and that the ancient bed of Lake Winnipeg is free from glacial deposits, and exhibits only the silt-deposit since made by the ancient lake itself.

Valley formed since the glaciers began to retire.—It also seems most probable that the ancient valley itself, as a whole, was formed in the region of glacial deposits, partly during the period this great field of ice was receding, and partly since it left the ancient Mississippi basin, for the following reasons: When this ice-period was on the increase, its southern margin must have been gradually advancing in this region, crushing down and planing off the ridges and filling the ravines and water-courses with the *débris* not only of the neighboring rocks, but with the great mass of hard rocks and other material brought from regions far to the north. There seems a probability that much of the present Upper Mississippi basin had previously been for long ages exposed only to erosions of streams and of the atmosphere, so that it was probably much cut up and fissured, as we see in regions farther west, where no glacial action has occurred. It must have been an easy matter then for the glacier to have thoroughly filled up all the valleys and ravines, leaving the surface everywhere of the well-known rounded hill and basin forms of the drift regions. Wherever the glacial scratchings are preserved, their uniform directions indicate a massive movement to the southwest quite independent of all influence of underlying inequalities. The water which flowed from them would seek the first lowest line and excavate its course without regard to the nature of the older stratified rocks buried beneath the glacial deposits, and such seems to have been the case, for the valley takes a great variety of courses, running about northeast at St. Paul, due west at Rock Island, and its directions fill every azimuth in different parts from northeast around by south to west. To the old stratified rocks its course seems to have no relation, now cutting across an anticlinal, then following the strike in one direction and again in the opposite one.

How the valley was formed.—At St. Paul, on the Mississippi, and in the Minnesota above, are the banks of an ancient watercourse when at such higher level than now that the river-bed was the magnesian limestone rock, the same as that of the Mississippi, just above the Falls of St. Anthony. The existing channel of the ancient valley has probably been formed by a cataract in the great river, similar to that at St. Anthony. This view is sustained by the high islands of rock in the valley of the Minnesota, being remains of strata once continuous across it. These high islands also exist below in the Mississippi, such as Barn Bluff, at the head of Lake Pepin, and the Trempeleau hills. Some of these detached bluffs may have been formed by bends approaching each other by erosions gradually forming a neck and cutting it off. One such, nearly completed, is seen in the Dalles of the Chippewa River. The period which must have elapsed in doing this work was long, but it is probable that the volume of water, during the melting of the glaciers north of it, was greatly in excess over that of the present drainage of the Winnipeg basin. The period may have been somewhat shortened by the new water-course regaining in places some ancient one, filled only with glacial *débris.*

If we look at the valley shown on the map from Lake Traverse to Rock Island, we see that it gradually widens and contracts along its course, but, as a whole, widens as we descend. It widens where the rocks on the banks are soft, and narrows where they are harder and capable of resisting atmospheric erosion, as they are near Dubuque. This is in accordance with usually received ideas, that where the stream is confined by hard banks its increased velocity, due to such contractions, may have caused the streams to abrade deeper. It is improbable that the ancient river, where it cut its way either as a cataract or in any other manner of river erosion, made the valley as wide as we now see it. It most probably underwent subsequent widening from the impinging of the currents against the foot of the high banks, thus removing the *débris* falling from the cliffs above, as well as scouring away the unbroken strata against which it washed. Even now, although the great river has disappeared, we see that the valley is still widening in some places where the river flows at the foot of the high bluffs, although, in the great majority of cases, the atmospheric erosions have covered the steep, rocky scarps with detritus, which, clothed with vegetation, preserves them from the influence of the air. Where the river now impinges against the banks composed of soft strata, we sometimes see its effect in the fresh-cut appearance of the cliff, and are led to give greater weight to similar operations in the past, when like forces were probably more intense.

I have selected one (Diagram D) such cliff in the wide part of the valley below La Crosse, which part indicates much widening since the first cutting out of the river's course. It is apparent that no stream of water could have cut down from C to AB while the opening D was available. But if we allow that cataract on the right of the diagram represents the conditions when the stream began to flow which cut the valley, then its present course is natural, the subsequent widening bringing it to the state we see on the left of the diagram.

Geologists of high character have estimated the age of the gorge at Niagara Falls on the present rates of recession, and, though the result is uncertain, it indicates the origin to be in recent geological times, although antedating the historical era. In a similar way the time required by the Mississippi to cut the gorge from Fort Snelling to the Falls of St. Anthony has been calculated by Professor N. H. Winchell,* on data that makes it vary from 6,000 to 12,000 years, by assuming that the forces in producing this result have remained uniform during this period.

That any date in geological time, capable of being expressed in definite numbers of years, can be deduced from existing observations, seems highly improbable; but whenever a condition is observed which may be referred properly to the causes now at work, whether of greater intensity or less, it is reasonable to regard the work done as of recent geological origin. We cannot neglect this uncertain method of drawing inferences, since it is the best we have, and we should endeavor, by continued inves-

* Report Geological Survey Minnesota, 1876.

tigation, to make more definite this method of finding the unknown factor, time.

Since the Falls of St. Anthony were at the junction of Minnehaha Creek, they have receded six and a quarter miles. The Minnehaha Falls, since that time, have receded three-fifths of a mile. Both streams have cut into the same formation, starting with the same height of fall. These relative rates have been as about 1 to 10. The proportion of the volumes of the two streams, judging by their present drainage areas, is about as 72 square miles is to 21,600 square miles, or about as 1 to 300. That is to say, the recession of the Minnehaha Falls has been thirty times faster than it would have been if proportioned to the volume. This may be accounted for by the greater atmospheric influence of the smaller falls, which, examination shows, keeps ahead of the effect of the water, forming a cave under the fall by the dropping down of material which the water then washes away. At the greater falls the volume of water almost constantly protects the rocks from the action of the atmosphere. Hence we must give, as said before, a very considerable influence to the operations of the atmosphere in aiding the erosions of small streams, and in demolishing cliffs where the water can remove the *débris*.

I attribute a more recent origin of the gorge of the Mississippi from Fort Snelling to the Falls of St. Anthony than to that of the Minnesota above the junction. The general map indicates that the same force which formed the valley below the junction formed that of the Minnesota above.

The hypothesis which I have heretofore advanced and endeavored to sustain, that the loss of the Winnepeg outlet along the Minnesota was due to a change of the continental slopes by a northeasterly depression, will explain this more recent origin of the St. Anthony Falls gorge. This supposed change of slope might have caused a change of outlet of the lakes about the present source of the Mississippi, so that the waters flowed out on the northeast and, falling into a depression leading southward, made this upper part of the Mississippi. When we note the great extent of the eroded valley of the Minnesota, and also the fact that all the smaller streams, like the St. Croix, Chippewa, Black and Wisconsin, have cut through the sedimentary rock down to the granitic or trap rocks, it seems improbable that the Mississippi above Fort Snelling, with its greater power, should not have accomplished as much if it had been as long at work.

Regarding the Mississippi Valley as originating as a whole by the action of a stream since the glacial ice occupied its basin, I would note that as far down as the island of Rock Island there is no decided indication of other than successive changes attending such action, and the gradual filling up of the valley by tributary sediment after the great volume of water from the Winnipeg basin had disappeared.

Anomalies of Rock Island Rapids and Des Moines Rapids.—At Rock Island the river has left the ancient valley, which just below Rock River seems to be lost. We might have supposed that it ended here but for finding it again below Muscatine and continuous down to the Des Moines Rapids, where it is lost again. Just below, however, we find it again, and it then is continuous until it widens out into the broad expanse below the junction of the Ohio, although the river again leaves the main valley, without sufficient apparent cause, at Fountain Bluff and at the Grand Chain.

We had not time to study out where the course of the ancient valley was between Rock Island and Muscatine, but at the Des Moines Rapids we were more fortunate.

The following description of this vicinity and Diagram E will present the points that appear deserving of consideration.

The river, as it passes the town of Madison on its right bank, which is there 150 feet high, washes against a bluff composed of clay and sand arranged in a manner resembling "the ebb and flow structure." Mr. Worthen gives a good description of this formation in the Iowa Geological Report, volume i, part 1, page 187. This kind of bluff is seen only on the right bank, and extends continuously a distance of about twenty-five miles from the mouth of Skunk River down to the point D (see Diagram E), where it joins the Keokuk limestone rock just back of Montrose.

In descending the river from Madison, the river gradually recedes from this bluff, and a few miles above D the bluff is three miles from the river. A large portion of the intervening space is occupied by a sand terrace, varying from twenty to fifty feet in height above the high water; the other portion is bottom land, subject to overflow.

The river, before reaching Montrose, has a width within its banks at ordinary stages of about half a mile, and the depth of water in the pools at low stage is from fifteen to twenty feet, the bed being of sand, with no rock in place; nor is there any rock in the right-bank bluffs till just below Montrose, where it begins also in the river-bed. On the left bank or Illinois side the bluffs are of rock, the same as at the rapids, where they have been cut through by the river. This cut begins at Montrose, where the river makes a turn at a right angle to the eastward, but the depth at low water is only two to three feet, and the width at ordinary stages has widened to one mile. On both sides of the rapids the rock bluffs rise almost immediately from the water. The river on the rapids continues easterly about two miles, then turns southward and maintains this direction until all the rapids are passed and for a mile beyond; then turns southwest until the mouth of the Des Moines River is passed, and then turns southward again.

The rock disappears in the bed on passing Keokuk; the water then deepens, flowing on a sandy bed, and resumes its width of about half a mile between its ordinary banks. On the rapids there are no considerable or permanent islands, but as you go above or below, you find them as soon as the rock-bed is left.

At Warsaw, three miles below the foot of the rapids, the Carboniferous rocks show in the bluffs, and so does the unmodified glacial drift, covered with the loess. (See Diagram F.)

The Mississippi Valley at Warsaw is about eight miles wide; part of it a sand terrace, but most of it subject to overflow.

Proceeding up the Des Moines from the mouth, we leave the limestone strata at the point H (Diagram E), and do not meet with it again, either in the river bed or bluffs, till we reach the point C, where we find it in both places, and thence all along up this valley.

In this distance between H and C the bluffs are only on the left bank or north side, and the material appears similar to that at Madison or to the loess at Warsaw, shown in Diagram F. If we examine the valley of Sugar Creek, we find the bluffs cut down as low as on the Des Moines between H and C, and all of similar material, clay and sand, but no rock in place. Nor could we find on any of the branches between ABC and DEH any rock in place or learn of any. Within these limiting lines those who have dug wells for water find it without reaching rock.

At the place marked K on the sand terrace a well fifty feet deep encountered no rock, although this was as far down as the level of low water in the river.

The width of the main valley above Fort Madison is nearly the same as below Keokuk, and if we prolong the line of bluff between these two places, it will include a space between them where there is no known rock *in situ*, and which it appears reasonable represents the ancient channel, since filled up.

The loess formation.—This name has been given in this country to a fine material deposited over all the other formations, including the glacial deposits near the river, but not upon the river sand-and-gravel terraces, which are therefore the more recent. It has a thickness of many feet in places. It is generally regarded as having been deposited in quiet water. In many places it is nearly uniform in thickness, conforming with the previous irregularities of the surface, as snow lies where it has not drifted. This would be brought about by a silt laden fresh-water current spreading out over one more dense and quiet, through which the fine silt dropped. Such conditions would exist in salt water, and the silt would prevent the existence of many kinds of marine life, and would contain the animal remains brought from the fresh-water streams.

The margins of the loess deposits are not well defined, and do not appear to have been investigated as they should be. The deposit is well shown near Rock Island, but does not appear as high up as Dubuque (so far as I know). It extends up the Missouri as far as Sioux City, and the Missouri River made immense deposits into the body of water in which the loess was laid down. From the absence of marine fossils, this body of water has been regarded as fresh and without connection with the Gulf of Mexico except through an outlet. Judging by what I know of the deposits, I should think it did not connect with our present Great Lakes, and that a tongue of land or promontory separated the arms extending up the Mississippi and Missouri Rivers.

The streams which brought this fine loess material which has been so spread out must have brought down heavier material along the bottom that fell as soon as it reached the enlarged section, just as rivers make their deposits of heavy material now on reaching their natural receptacles. A most interesting case in point is in the deposits made in the Great Salt Lake in quaternary times, where its terraces show a level nearly a thousand feet above its present surface. The streams, like the Weber, built out the terrace at their point of discharge in the fan shape of a river-bar up to this terrace level near the ancient shore, and extending back in the river valley, which must then have appeared as a fiord. Although the ancient Weber River deposit diminished in amount as it extended into the ancient lake, yet it terminated quite abruptly. I think, then, there is good reason to regard the bluff-deposits at Fort Madison and vicinity, on the west side of the valley, as belonging to the loess period, and not to glacial times. These deposits are where streams would bring them from the northwest, while the glacial deposits seem to have come from the northeast. This filling up of the ancient valley of Keokuk and Madison, and also in the neighborhood of Rock Island, is where the mouths of considerable rivers probably were during the existence of the large body of water in which the deposition of the loess was made.

Formation of rapids since the loess.—When the body of water of the loess period disappeared and the emergence of the land again took place, the Mississippi did not regain its ancient channel, but cut the new one now occupied. These rapids cannot be accounted for by any special hardness of the rocks, but their resistance is increased because of the dip of the strata being nearly that of the river-slope. When the river was at a higher level and made the sweeping bend above Montrose so as to wash the loess bluffs, but little more erosion would have been required there to have carried the river back again to its ancient channel during some extraordinary flood, and yet it might have been that the new channel would even after this remain the permanent one for ordinary stages.

Such an explanation as this may be applicable to the cases at Fountain Bluff and at the Grand Chain on the Mississippi just above the mouth of the Ohio, and to the almost incomprehensible changes of course in the Lower Ohio itself, shown on the general map.

Another interesting supposition may be made that the Mississippi in the last terrace period might have succeeded in washing down the bluffs, separating it near Burlington from the Crooked Creek flowing into the Illinois. (See Diagram 1, sheet 4.) The new channel would have double the descent to the mouth of the Illinois of the existing one, and we might have gained a new course for the river, leaving a larger ancient channel occupied by a smaller stream, and there would have been set at work a new cause to modify all the valley of the Illinois River and all the Mississippi above.

Summary of principal points presented.—I will summarize the principal facts that seem to be made out along the course of the Minnesota and Mississippi:

1. That the Minnesota Valley and the Mississippi Valley above the Ohio have been, as a rule, formed since the deposition of the glacial drift, for this exists in unmodified and modified forms in the banks of the river; and that the Winnipeg basin drained out southward along it.

2. That the loess deposits, extending up to the neighborhood of Savannah, are later than the last glacial drift.

3. That channels like those at the Des Moines Rapids and river terraces in that vicinity are more recent than the loess.

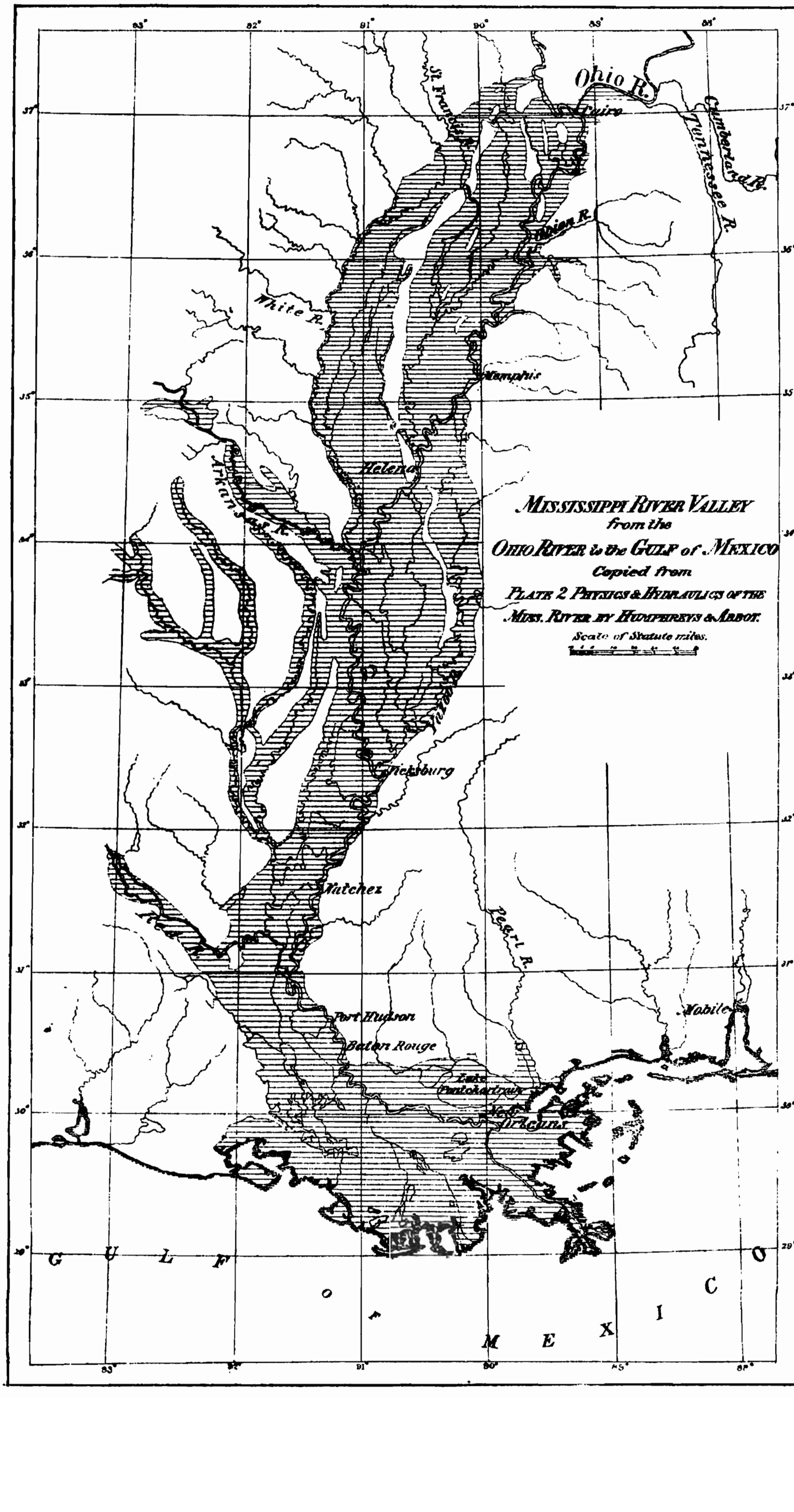
Explanatory hypotheses.—I have advanced this hypothesis of southern elevation and northern depression several times before and illustrated its effect on the Minnesota and on the Wisconsin Rivers, and in the first instance considered what the results would be in contiguous regions, and how far facts seemed to correspond, and it is unnecessary to repeat them here.

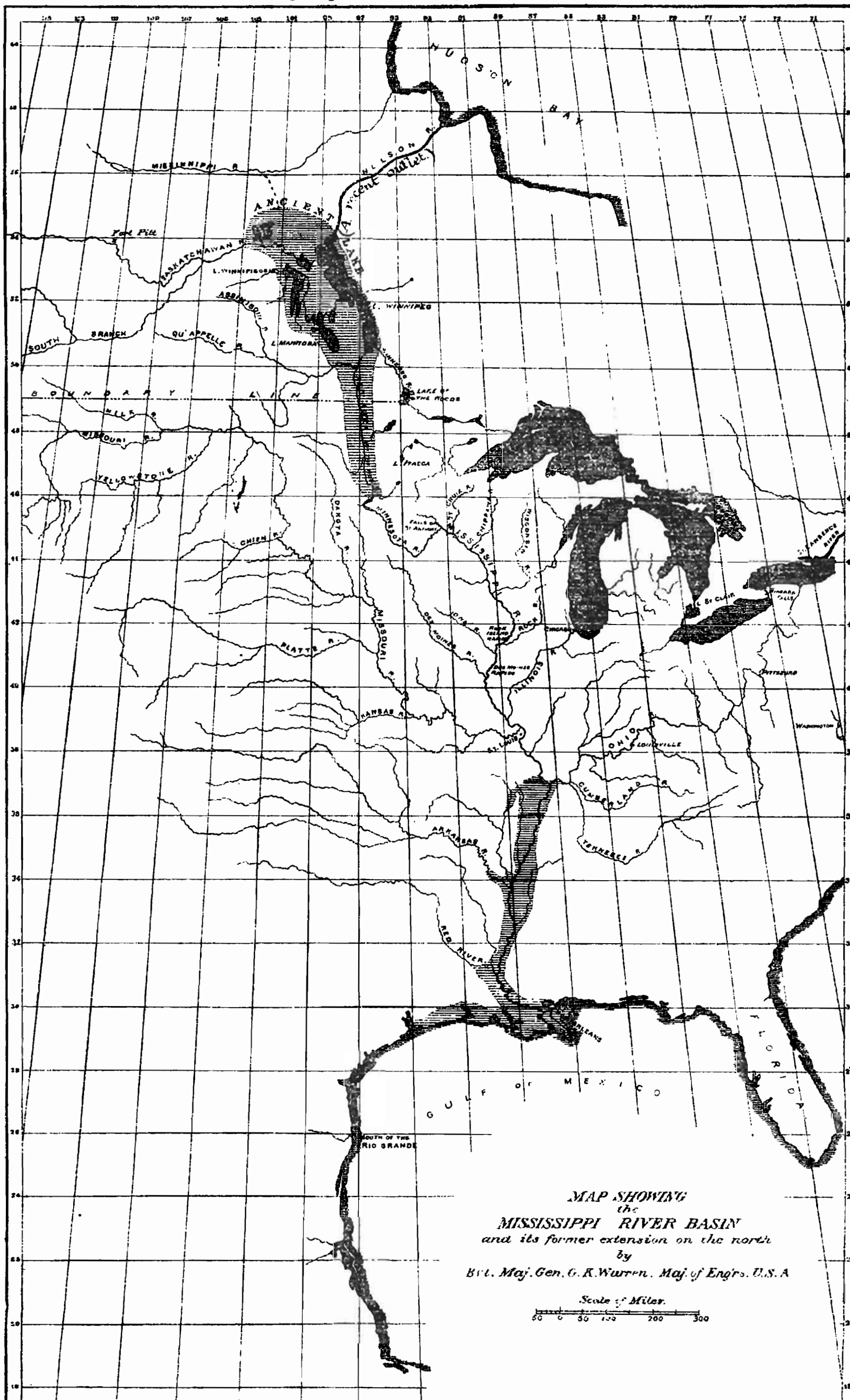
The hypothesis appears to be in accordance with a number of very important facts, and is consistent with observations as to southern elevation and northern depression now going on. It explains, by one widely exerted influence, many effects which, on the grounds of glacial action alone, requires many special glaciers, and it will answer as an explanation of the coming on and disappearance of the loess body of water, and for the change in the drainage of Lake Winnipeg.

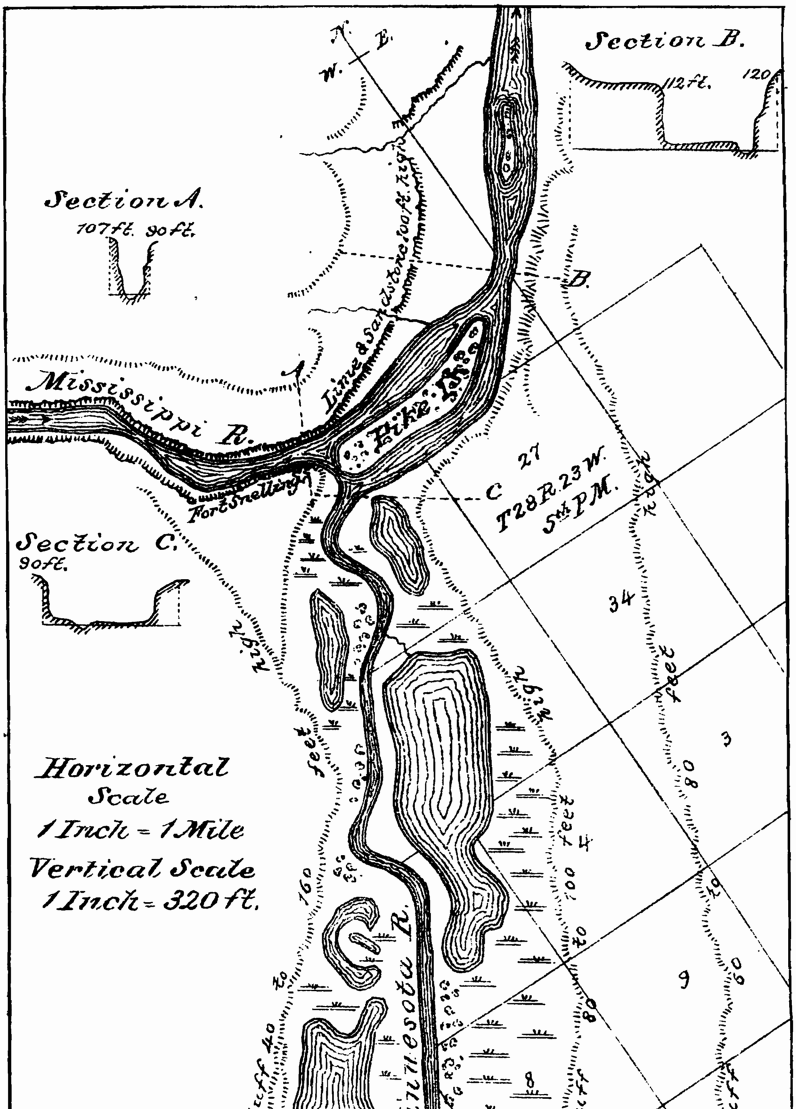
I think this change of relative elevation south and depression north has been probably reversed at some periods, and repeated. This is important, for, if we can show that any movement of the earth's crust is a recurrent phenomenon, it may help us to trace out its cause.

Approximate practical conclusions.—The only practical conclusion which can be drawn from the preceding discussion seems to be that the origin of the excavation of the valley is comparatively modern, and that it was from the operation of forces producing probably uniform results, and in a way that we have some approximate comprehension of it in general, from our knowledge of special localities.

Note.—Descriptions of the best known sections of the valley follow in the report.

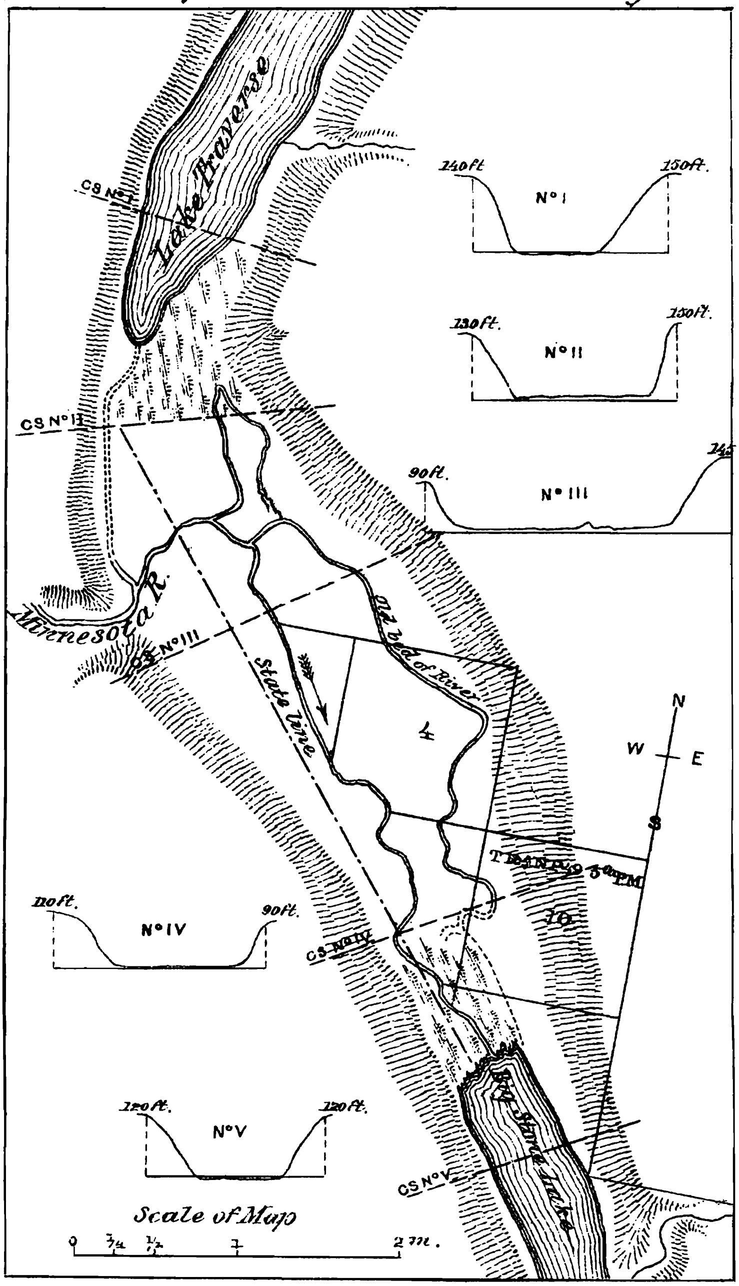

MISSISSIPPI RIVER VALLEY
from the
OHIO RIVER to the GULF of MEXICO
Copied from
PLATE 2 PHYSICS & HYDRAULICS OF THE
MISS. RIVER BY HUMPHREYS & ABBOT.
Scale of Statute miles.
Ohio R.
Cairo
St. Francis R.
Cumberland R.
Tennessee R.
Obion R.
White R.
Memphis
Helena
Arkansas R.
Vicksburg
Natchez
Red R.
Pearl R.
Mobile
Port Hudson
Baton Rouge
Lake Pontchartrain
New Orleans
G U L F O F M E X I C O


MAP SHOWING
the
MISSISSIPPI RIVER BASIN
and its former extension on the north
by
Bvt. Maj. Gen. G. K. Warren. Maj. of Eng'rs. U.S.A.
Scale of Miles.
HUDSON BAY
NELSON R.
ANCIENT LAKE
Fort Pitt
SASKATCHAWAN R.
L. WINNIPEG
L. MANITOBA
ASSINIBOIN R.
QU'APPELLE R.
SOUTH BRANCH
BOUNDARY LINE
LAKE OF THE WOODS
MISSOURI R.
YELLOWSTONE R.
CHIEN R.
DAKOTA R.
MINNESOTA R.
MISSISSIPPI R.
IOWA R.
DES MOINES R.
ROCK R.
ILLINOIS R.
CHICAGO
PLATTE R.
MISSOURI
KANSAS R.
ST. LOUIS
OHIO R.
LOUISVILLE
CUMBERLAND R.
TENNESSEE R.
ARKANSAS R.
RED RIVER
N. ORLEANS
GULF OF MEXICO
FLORIDA
MOUTH OF THE RIO GRANDE
PITTSBURG
WASHINGTON
NIAGARA FALLS
L. ST. CLAIR
ST. LAWRENCE RIVER

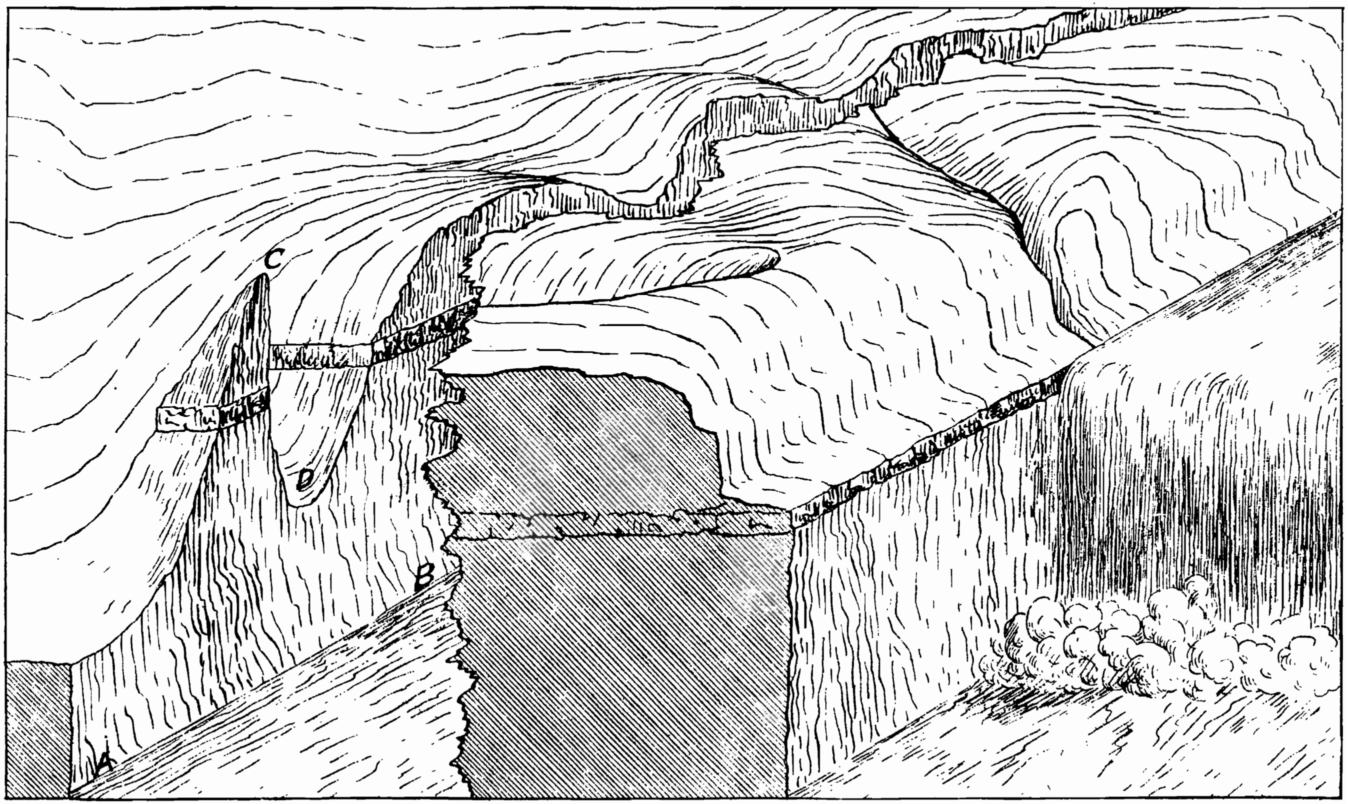


Map showing the river valley where the Minnesota and Mississippi Rivers join, with sections of the valley below the junction, and on each above the junction.

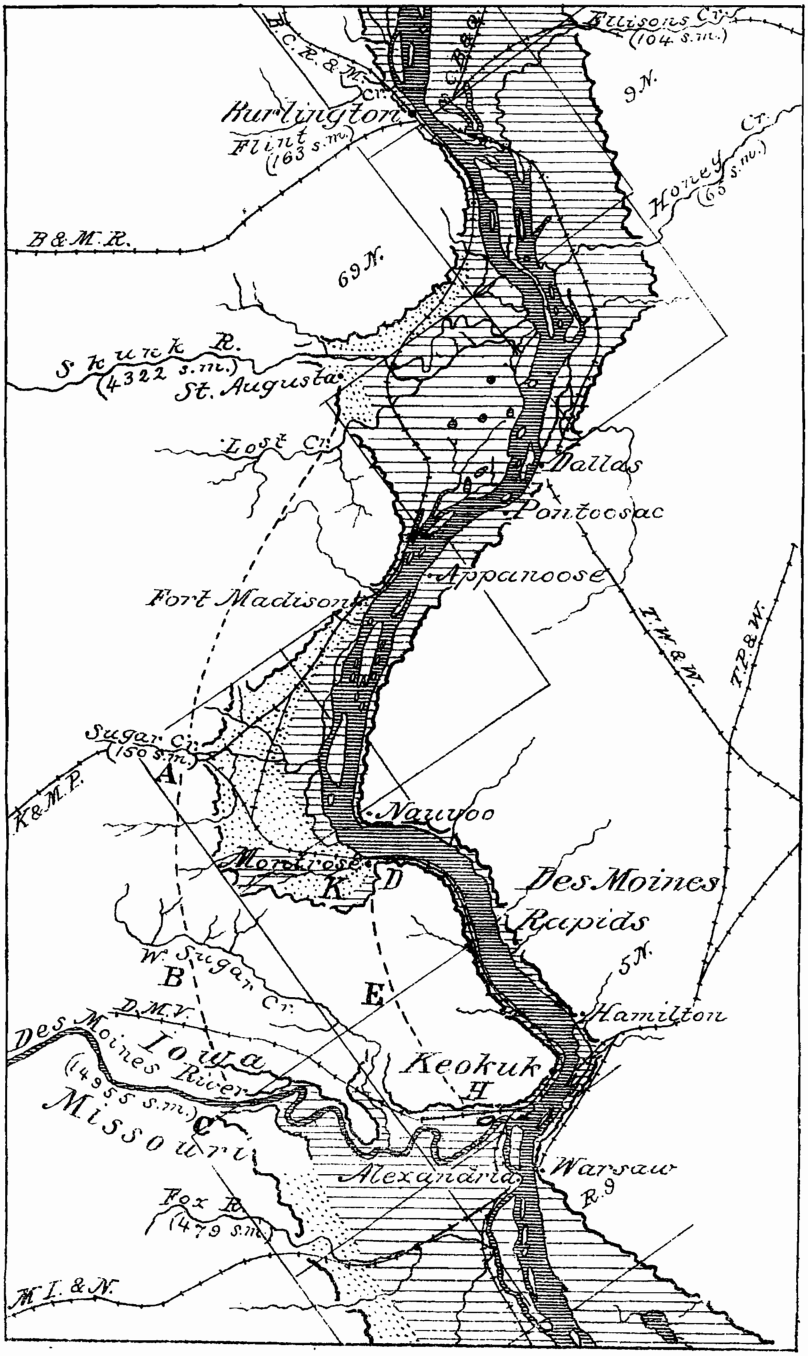
Warren's Report on Minnesota River: Diagram C.

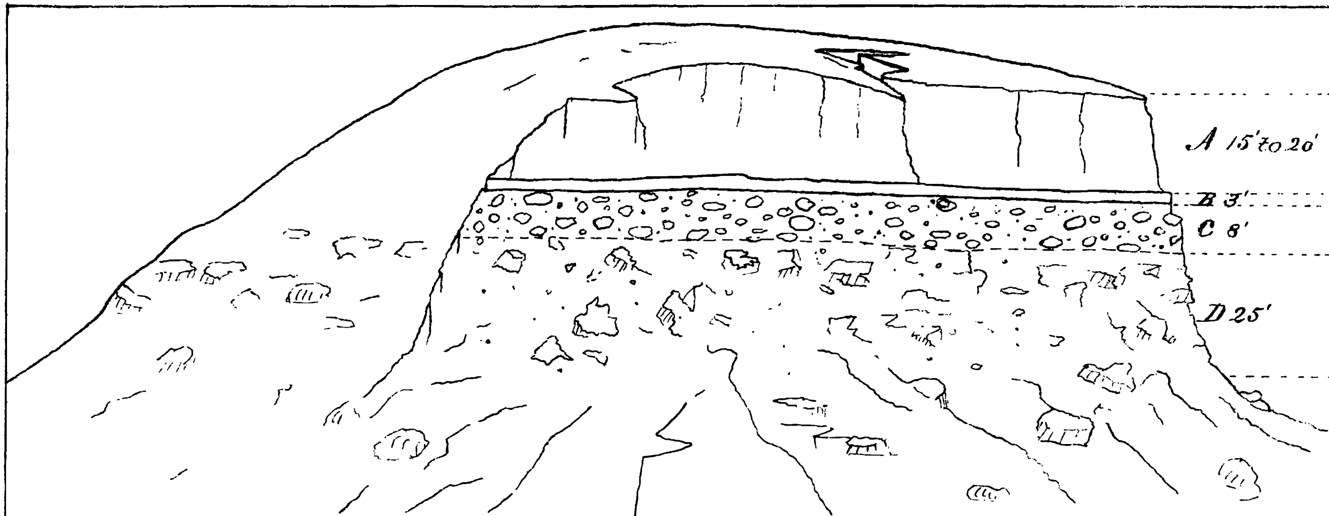


Warren's Rep't. Bridging Miss. R. *Diagram D.*



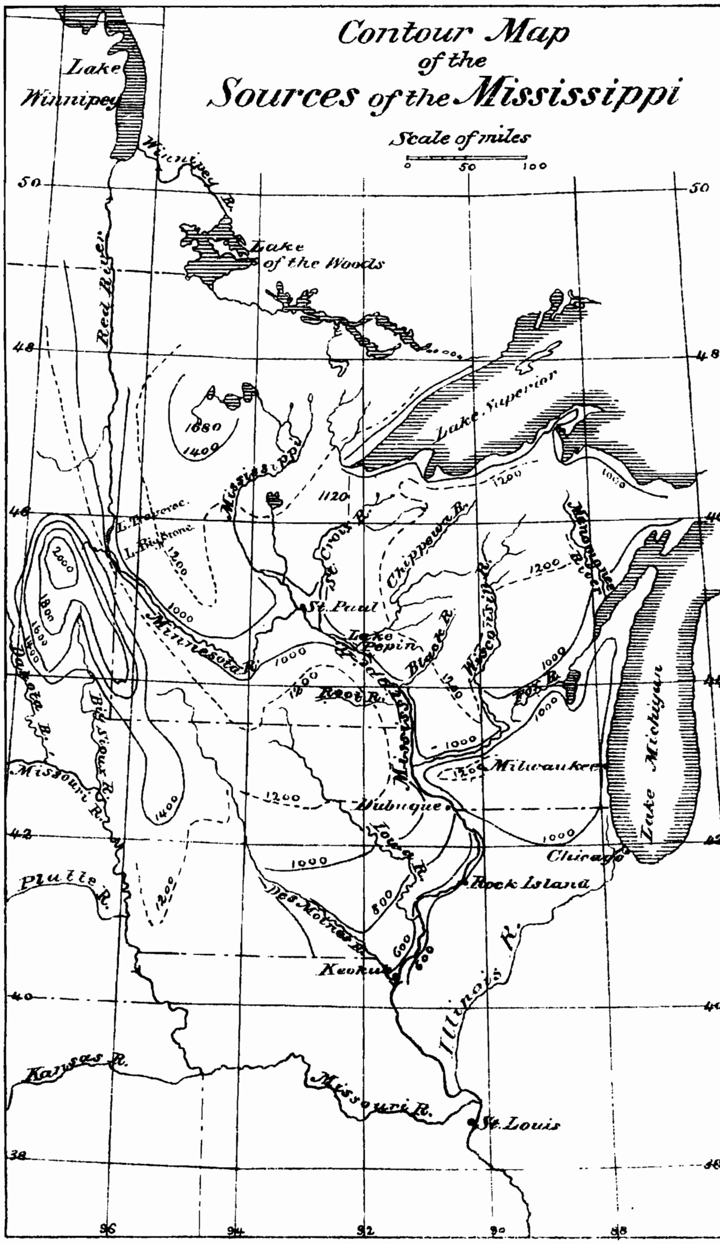
Warren's Rep't. Bridging Miss. R. Diagram E.





Section of Mississippi River Bluffs at Warsaw Illinois

A is a very fine yellow sand and clay widely developed. B is a bluish clay and fine sand C is rounded hard bowlders from small gravel up to 400 lbs., mixed with sand. D is composed of angular blocks from over a ton weight down to small stones, mingled without order; with coarse and fine sand and clay, showing no selection or sorting. The rocks are trap, porphyry, granite gneiss or syenite, hard brecciated limestone &c. The upper carboniferous shales in vicinity exhibit local displacements


Contour Map
of the
Sources of the Mississippi
Scale of miles
0
50
100
Lake Winnipeg
Winnipeg R.
Lake of the Woods
Red River
Lake Superior
Mississippi
1680
1400
1120
1200
1000
2000
1800
1600
L. Traverse
L. Big Stone
St. Croix R.
Chippewa R.
Wisconsin R.
Menomonee River
St. Paul
Minnesota R.
Lake Pepin
Black R.
Root R.
Fox R.
Dakota R.
Big Sioux R.
Missouri R.
Milwaukee
Dubuque
Lake Michigan
Chicago
Iowa R.
Rock Island
Platte R.
Des Moines R.
Keokuk
800
600
Illinois R.
Kansas R.
St. Louis
50
48
46
44
42
40
38
96
94
92
90
88