THE GENESIS OF THE OHIO RIVER.

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This paper presents the views of the author relative to the development of the Ohio River. An attempt is made to reveal the general pre-glacial drainage lines, and to show how the present Ohio River came into being through glacial derangement of the pre-glacial drainage, at and near the margin of the glacial limits, between the Mississippi and the Kanawha rivers. The paper is based very largely upon surface phenomena as they appear to an amateur. The data and interpretations presented are not claimed to be free from error, but it is hoped that the paper has sufficient merit to attract the attention of geologists who may more fully present the data and who are capable of calling attention to and correcting faulty conclusions, where such occur.

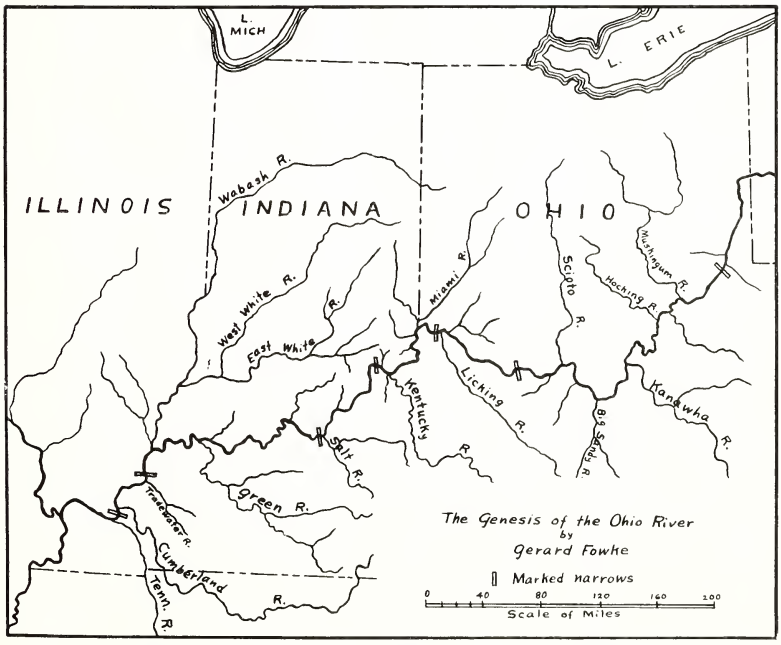

Fig. 1. A portion of the Ohio River drainage system, showing locations of narrows which mark the sites of sags or notches in former major divides between pre-glacial stream systems.

[1] The author is under especial obligations to Prof. C. A. Malott for his careful revision and correction of this paper, for his valuable suggestions and for the preparation of the accompanying maps.

"Proc. Ind. Acad. Sci., vol. 34, 1924 (1925)."

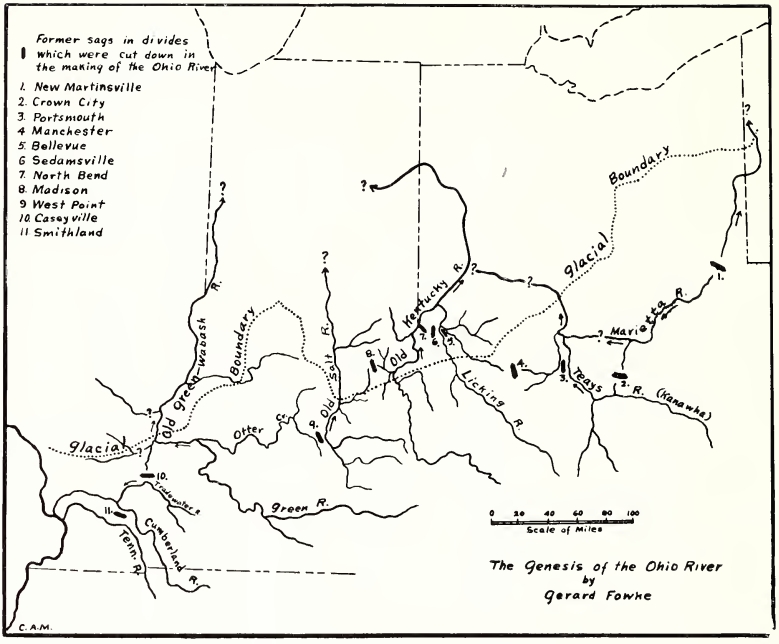

Fig. 2. Sketch map showing probable northward flowing stream systems which were obstructed by glacial ice from the north. These stream systems were combined to make the present Ohio River by ponded waters breaking down the divides between them. Their northern portions are now chiefly obscured under thick drift deposits.

The Ohio follows a course more devious and irregular than that of any other river of its size and importance. From Pittsburgh, the general direction of the stream is northwest to the mouth of Beaver River; thence southwest and west to Yellow Creek; south to Fishing Creek; southwest, then northwest, to the Muskingum; southwest to the Little Kanawha; west to the Little Hocking; south to Ravenswood; from there, by a tortuous course to Letart Falls; then northwest to Pomeroy; southwest to the Guyandotte; west to the Big Sandy; northwest to the Little Scioto; southwest to the Kinnickinnick; north of west to the Great Miami; south to Sugar Creek; southwest to the Kentucky River; west to Madison; southwest to Salt River; northwest to Blue River; southwest, with many abrupt short curves, to Cloverport; northwest to Anderson Creek; southwest and west to the Wabash; south to the Tradewater; south of west to Golconda; south nearly to the Tennessee; northwest to Grand Chain; finally, southwest to the Mississippi.

Within these general trends are numerous minor curves and bends, some of them very abrupt. There are several stretches, notably those between Hockingport and Pomeroy, Ohio; between New Richmond, Ohio, and Warsaw, Kentucky; between Leavenworth and Tell City, Indiana; between Newburg, Indiana, and the mouth of the Wabash—where a steamboat following low water channels will have its prow directed, within a few miles' run, toward nearly every point of the compass.

The diversity of the topography along the river impresses the traveler. From the head of the river until well below Vanceburg the stream flows between high hills, mostly of sandstones and shales, sometimes with steep gradients from base to summit, again more gently sloping or with a succession of elevations within a short distance. In places, vertical bluffs overhang the river bottom or rise above masses of talus descending steeply to the water's edge. On the Kentucky side, opposite the mouth of the Scioto, a hill of the latter description has an elevation of nearly 600 feet above low water. Near Manchester the rock formations become different; sandstones disappear, only shales and limestones occur, and from here to the mouth of Salt River the hills are generally lower than those in the sandstone area, with rounded dome-like or truncated-conical tops where they are cut off by ravines from the adjacent uplands. At Salt River the Ohio passes from a lowland into an upland, cutting through a high sandstone escarpment capped with limestone, known in Kentucky as "Muldraugh's Hill" and in Indiana as "The Knobs" or the Knobstone Escarpment. The bordering hills are high and precipitous. A few miles below here it enters a tortuous trench in heavy bedded limestones, with steep hills or vertical bluffs and narrow bottom lands on either side, almost to Cloverport. Then, to Shawneetown, the hills gradually recede from the stream and diminish in height. Below Shawneetown they are somewhat higher, steeper, and closer to the river, until near the mouth of the Cumberland. From Metropolis down, the country flattens.

It would appear that a river having the length of the Ohio, with as many large tributaries, would flow through a valley whose breadth would at least to a slight degree become greater from the source to the mouth. Variations in bottom slope and in the hardness of the rock formations bordering the stream, would have some influence upon this feature; if these alone were concerned it would be comparatively easy to determine which portions should be wider and which narrower. There is also a natural diversity due to lateral erosion or side-cutting. This sometimes has a rhythmic alternation which may produce nodes analogous to those of a vibrating string fastened at the ends; the current may swing by turns to either side above or below the node, but at that particular point, it will hold practically the same channel. Narrowing due to this cause may be noted at various points along the Ohio; but there are also variations which can not thus be accounted for. The valley as a whole, will progressively widen for a greater or less distance —there is no regularity in the changes—then narrow almost to a gorge or canyon; then widen again; and such alternations are to be found along the entire length of the river.

The width of bottom lands must vary according to the position of the hills by which they are restricted; but their elevations above the water, and the number of terraces, are independent of the breadth. At some places almost the entire area between the hills is under water in great floods; at other places only a small portion may be submerged. Occasionally there is only one level; but in most places there are distinct terraces, sometimes as many as five rising successively between the river and the hill.

Especial interest attaches to the fact that in portions of the valley, particularly in the interval between Portsmouth and Madison, a number of creeks and ravines flow the wrong way in relation to the prevailing drainage; that is, the course of these feeders between the points where they rise and where they discharge is directed up instead of down the river. This occurs only where the river valley is becoming narrower below the junction point of such tributaries.

A majority of the creeks and rivers discharging into the Ohio from the north flow through valleys whose width is out of all proportion to the size of the stream draining them. Some of these valleys are much wider, and a few of them have buried rock floors much deeper than the main stream has where they enter it or at some point farther down.

A study of all these phenomena led Prof. W. G. Tight, then of Denison University at Granville, Ohio, to the conclusion that the Ohio as a continuous river, in the upper 400 miles of its course, did not exist prior to the beginning of the glacial epoch, and that its origin was due to the breaking down by glacial floods of barriers between older streams of whose channels the new-born waterway took possession. Some of these had flowed in the same direction as the Ohio, or "down stream," as we would say in present conditions; others were headed "up stream"; while still others had flowed in channels which were cut across in such manner that the upper portion and the lower portion of the former valley are now found on opposite sides of the Ohio. Tight found his first clue in the relief map of the State of Ohio. From the general trend of lowlands and highlands he was convinced that the early drainage of eastern and central Ohio had been toward the north instead of toward the south and west. He brought this conception to public notice in papers read before the Ohio Academy of Science about 1895; later he published the results of his completed researches in Professional Paper No. 13 of the United States Geological Survey. It is sufficient for present purposes to state that Fishing Creek, in West Virginia, flowed northward from near New Martinsville, through the upper Ohio to Beaver, Penn., where it joined the Monongahela and found its outlet in the direction of Lake Erie; that the Kanawha flowed westward from St. Albans, past Huntington, to Wheelersburg, Ohio, where it turned north; that the Kinnickinnick and smaller streams, down to Manchester, flowed eastward, then northward through the present Scioto Valley and joined the Kanawha in the vicinity of Waverly. From here the old river is easily traceable to the north line of Ross County, beyond which point it is obliterated by glacial drift. Tight believed that it flowed northwestward toward the upper Wabash. Possibly it joined the buried channel mapped by Bownocker; or it may have continued northward toward the western end of Lake Erie.

There is general agreement now among geologists that a divide existed at Manchester, Ohio, from which the water flowed eastward, as just described, and westward toward Cincinnati. Before this fact was known, however, Prof. Joseph L. James[1] of Cincinnati pointed out that the Ohio formerly made a loop to the northward from the mouth of the

[1] A Brief History of the Ohio River, Popular Science Monthly, April, 1891.

Little Miami, nearly to Hamilton and then down the Great Miami to its present channel. His interpretation is followed by some later writers. James bases his conclusions upon the width of the old valley and the slight depth at which bed-rock is found below Cincinnati. He believed this to be the only place along the Ohio where the river so nearly reaches solid bottom; but similar floors have since been discovered. He was also of the opinion that the river divided at the mouth of the Little Miami, one branch following the present Mill Creek, and the two joining north of Cincinnati; it is now known that this was not the case.

Leverett[2] and Fenneman[3] have adopted James's theory. Fenneman seems to have done his work in this region entirely independently of those who had already studied the region quite thoroughly, as he makes no mention of them; neither does he refer or allude to any report or map published previously to the time of his researches, although his map is in some respects almost a facsimile of one published in the Cincinnati Commercial-Gazette in February, 1899.

J. A. Bownocker, "History of the Little Miami Valley," in Ohio Acadamy of Science, Special Paper Number 3, 1900, shows various changes in drainage conditions. The lower end of the Little Miami was only a small creek beginning at Foster's above Loveland. All the drainage above this was reversed, or toward the north; it finally fell into the Great Miami, some of it at Middletown, some near Tippecanoe. The East Fork of Little Miami is a pre-glacial valley of great age, being wide and deep. It flowed west through the drift-filled valley north of Cincinnati to Mill Creek basin somewhere near Carthage, and so into the Great Miami. The latter flowed north past Piqua and up the valley of Loramie Creek to the vicinity of Berlin, where it joined another (buried) stream. This has been traced as far to the westward as Grant County, Indiana, directly toward the Wabash below Huntington. Beyond here its course is not known. It seems almost certain, though not yet established, that this is a continuation of the deep valley in Champaign County, Ohio.

A paper by the present writer, read before the Ohio Academy of Science in 1897, published in The Bulletin of Denison University, Vol. II, 1898, was the first to point out that the Licking River of Kentucky, in pre-glacial time, flowed northward in the Great Miami Valley. No suggestion was made then as to its course beyond Dayton; but the buried channel described by Bownocker offers an outlet. Owing to insufficient investigation and hasty preparation, that article contained some entirely erroneous statements, which met with prompt and just criticism. They were corrected in a later report published in Special Paper No. 3, 1900, of the Ohio Academy of Science.

Opportunity for access to the general literature of the subject having been restricted, other reports or papers not mentioned herein may have been overlooked; any omission is not intentional.

[2] Leverett, F., Monogr. 41 U. S. Geol. Surv., 1902, pp. 116-118.

[3] Fenneman, N. M., Geology of Cincinnati and Vicinity, 4th Series, Bull. 19 Geol. Surv. of Ohio, 1916, pp. 113-124.

Professor Tight's[4] work along the upper portion of the river is very thorough. The present paper is concerned chiefly with the Ohio below Manchester or that portion not considered in detail by Tight.

The names of the present streams will be given to the older streams flowing through the same valleys, except where this might result in confusion as to which one is meant; in which case another name will be adopted. For example, that part of the Ohio between Manchester and the Little Miami will be called Manchester River.

Before the present drainage system had its beginning, three separate projections of the Kentucky highlands extended into what is now Hamilton County, Ohio. The first of these was that upon which the upper part of Cincinnati is built; its boundaries were Manchester River, Licking River (Mill Creek), and the East fork of the Little Miami. The second peninsula was immediately below the Licking; it comprised the area from Mill Creek almost to North Bend and northward nearly to the Hamilton County line. The third protuberance was the narrow ridge lying between the Ohio and the Great Miami, below North Bend.

In each of these was a low place, or sag, each of which was destined to be entirely cut away by glacial floods. The first was at, or near, Bellevue; the second just west of Sedamsville; the third, a short distance below North Bend. The names of these villages will be given to the sags and to the divides of which the sags were features. (See figure 3.)

Manchester River, which had its beginning 75 miles southeast of Cincinnati followed a somewhat irregular course to the Bellevue hill, where it turned toward the north to join the East Fork. The width of the valley varies considerably at different places. These variations are not due entirely to erosion by the main stream. Large creeks entering from either side cut out valleys for themselves, and the two excavations, uniting, set the outside bordering hills so much the farther apart. The heavy deposits of sand and gravel which sometimes entirely cover the low spurs and ridges projecting from the intermediate hills strengthen the impression of greater width. To avoid repetition, it may be said that similar conditions are found from one end of the river to the other.

Between the Bellevue and the Sedamsville headlands, the Licking River flowed northward through the present Mill Creek Valley. The Manchester-East Fork joined it near Carthage and the combined waters reached the Great Miami Valley in the southern part of Butler County.

Between the Licking River and the Sedamsville divide, some small ravines trend upstream, that is, in a direction opposite to the flow of the Ohio.

Below Sedamsville a small stream which we will call Sedamsville Creek, flowed northwest to the North Bend promontory. Here it turned north, past Cleves, into the valley of the Great Miami. The latter stream is insignificant in comparison with the size of the depression which it occupies. Separated from the Ohio for several miles only by a narrow rocky ridge, the tip, so to speak, of the North Bend extension from Kentucky, it enters the former near Lawrenceburg. There is a striking con-

[4] Tight, W. G. Drainage Modifications in Southeastern Ohio and Adjacent parts of West Virginia and Kentucky, Prof. Paper 13, U. S. Geol. Surv. 1903.

trast at their junction between the constricted valley of the larger stream and the wide bottom lands bordering the tributary. Viewed from the top of the hill, the relative importance of the two rivers seems to be entirely reversed.

This wide expanse between the bordering hills, with extensive high bottoms on one side or the other, continues to the mouth of the Kentucky River. Below this, the stream rapidly contracts until at Madison, Indiana, solid rock rises abruptly from the water on the Indiana side; a very narrow trip of alluvium separates the river from the Kentucky highland directly opposite. There is but one explanation possible for this; namely, that the Kentucky formerly flowed eastward and north-

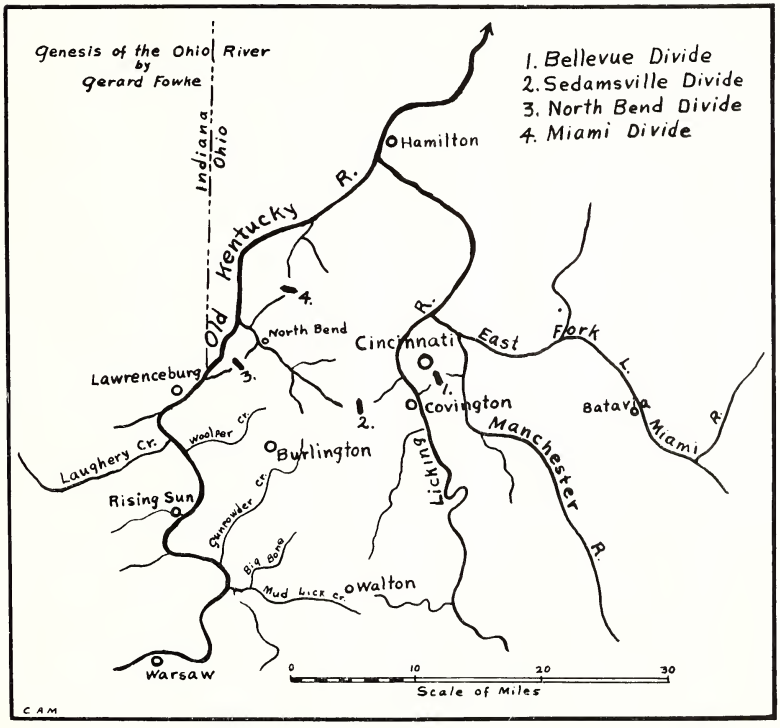

Fig. 3. Probable pre-glacial drainage lines in the Cincinnati region, showing the locations of the Bellevue, Sedamsville and North Bend divides or sags which were cut down to form the present route of the Ohio River when the pre-glacial drainage was obstructed by glacial invasion from the north. The site of the Miami divide is now occupied by the Big Miami River.

ward to the mouth of the Great Miami. It did not however, pass on up that stream as it now exists, but flowed north to near Harrison. Here it turned northeast through Dry Fork, crossed the Butler County line not far from Fernald, and passed on into the extensive valley south of Hamilton.

For distinction, this former channel from Carrolton to Hamilton will be called Old Kentucky River.

Briefly summarized, then, pre-glacial conditions in this region were about as follows:

1. The Kanawha, carrying directly or indirectly the drainage between New Martinsville and Manchester, flowed northward through a part of the Scioto Valley toward either the Wabash or Lake Erie.

2. Manchester river joined East Fork of the Little Miami and followed around the northern margin of the Bellevue extension.

3. Licking River, passing between the Bellevue and Sedamsville divides directly across the bed of the present Ohio, absorbed the Manchester-East Fork and continued north into Butler County.

4. Old Kentucky River crossed Hamilton County, Ohio, into Butler County and joined the Licking.

5. The trunk stream formed by the Manchester-East Fork, Licking and Old Kentucky branches went on north and united with the buried river described by Bownocker. This may have been the Kanawha, though probably it was made up from drainage lines of the western part of the State of Ohio having no immediate connection with the Kanawha. (See figures 2 and 3.)

Malott[5] coincides with the view that a divide existed at Madison; Leverett, Fenneman, and others, decline to admit it, adhering to the belief of James that the Licking curved around near Hamilton and reached the Ohio by way of the Great Miami. The whole question, at present, hinges upon topographic evidence. The Manchester, East Fork, and Licking, admittedly flowed north; all the tributaries coming into the Ohio from either side, as far as Madison, except Woolper and Gunpowder in Boone County, are directed up the Ohio. The Little Miami, the Great Miami, the Whitewater, with their various tributaries, have their channels, here and there, in narrow gorges or close to rock bottom, thus showing their post-glacial origin as they now exist. The Bellevue and Sedamsville divides are further proven by the heavy drift deposits at the site of the Cincinnati waterworks and those on which the city of Cincinnati is built; their composition and stratification show they were laid down in quiet water. The North Bend divide is proven by the narrow valley and the extensive drift deposits between North Bend and Cleves.

Leverett, in Monograph 41, U. S. Geol. Survey, pp. 114-118, notes evidence in several places in this region of a drainage system apparently much older than the one now under discussion, and predicating a different elevation of the land. For example, "A gradation plain on the immediate borders of the Ohio . . . is that of an abandoned channel which leads from Eagle creek . . . northward to the Ohio River. It stands fully 200 feet above the Ohio, and has a width of about one-half mile." This is at the head of Sugar Creek, apparently a former extension of Eagle Creek. The latter rises in central Kentucky, flows north almost to the Ohio, then suddenly turns southwest into the Kentucky. Above the angle, the line of flow is directly up the Ohio from the sharp bend above Warsaw. Leverett notes similar "gradation planes" near Grant's bend on the Licking; at points farther up the Licking; near the mouth

[5] Malott, C. A. Handbook of Indiana Geology, Pub. 21, Indiana Dept. of Conservation, 1922, p. 137.

of Indian-Kentuck Creek; connecting the Eagle Creek (Sugar Creek) plane with the South Fork of Big Bone Creek. As to the last, "Its size is more in harmony with that of Big Bone Creek, and markedly less than the portion of Eagle Creek with which it connects." Similar gradation planes he says, are well defined on the Big Blue and Litt Blue rivers of Indiana. As these planes are not drift-filled depressions, but have solid rock bottom, they are entirely independent of glacial movements. Leverett also points out (p. 118) an apparent contradiction to the theory of northward drainage of the Kentucky. "Gunpowder and North Fork of Big Bone point very strongly down the Ohio." He could have added that Woolper Creek has a slight trend to southward, entering the river at such an angle that it might have flowed in either direction. These facts need explanation.

The dividing ridge between the Licking and the old Kentucky maintains its high level to the hills bordering the Ohio. The crest or watershed is almost exactly along the line of the Southern Railway to Walton, then bears more to the west. Gunpowder Creek rises along this crest in numerous branches the longest being that which heads near Constance, on the Ohio, and flows south past Limaburg. The natural slope, owing to the curvature of the crest prevented it from bearing to the west; farther down, shorter drainage lines assisted in compelling it to continue south. Woolper Creek, rising more to the west, took the shortest course to the old Kentucky. Big Bone Creek is made up of a large number of very small tributaries which head anywhere and flow in any direction; its entire drainage is confined to a few square miles, so it is insignificant. It falls into Mud Lick, a larger creek, one branch of which flows north, the other north of west. These streams are so small as to be negligible were it not for the fact that the first three seem to flow in the wrong direction; but a study of the topography shows they were compelled to follow their present channels notwithstanding the former general slope of the valley. They seem more important than they are, because of the very heavy drift deposits in their lower portions.

Laughery Creek, on the Indiana side, flows for several miles in a direction exactly opposite to that of the Ohio above their junction. The two streams do not seem to join properly but this is due to the drift deposits on the Kentucky side which fill the original channel. The upper part of Laughery flows south, owing apparently, to a post-glacial condition of the same nature as that which influenced Paint Creek in Ross County, Ohio. Tributaries of Laughery, near the point where it changes its course from south to northeast, interlock with those of Indian-Kentuck Creek, but the divide between the two is unbroken.

Indian-Kentuck, which enters the Ohio at Brooksburg, formerly turned to the southeast and united with the Little Kentucky just below Carrollton. They held to the east and joined the old Kentucky which at that time followed a valley now abandoned, and reached the present Ohio three miles above Carrollton. When the glacier closed this passage the old Kentucky passed through an opening or sag where Government Dam No. 1 is now located, into the Little Kentucky. When the glacier receded the detritus at the former outlet debarred the stream

from resuming its course and forced it to remain where it is. From the high hill east of Carrollton, enclosed by the Kentucky, the Ohio, and the abandoned valley, a good view can be obtained of the natural easy, curve of the old valley from Worthville to Vevay.

As further evidence that a divide existed at Madison, the terraces extending from Lawrenceburg to Carrollton may be cited, including the great conglomerate deposit known as "Split Rock"; some of these rise fully 200 feet above the river. They represent material carried by floods and floating ice into the lake formed by the divide holding back the water. It was during this period, too, that the tributary streams were partially silted up as we now find them. Much of the sedimentary filling in the lower Kentucky, however, is not glacial but local; native rock weathered down and carried by river floods into the water which had backed up from below.

A well on the river bank at Carrollton, at the eastern end of the town and several hundred yards out from the hill, starting at an elevation of 60 feet above low water, reached bed-rock at 135 feet.

The exact sequence of events leading to present conditions has not yet been fully worked out. A provisional explanation will be offered.

If the old Kanawha turned in the direction of the Wabash, as suggested by Tight and Bownocker, the old Kentucky joined it somewhere north of Dayton. With the blocking of the extreme northern outlet by the ice, wherever and whenever this may have occurred, all the water it carried was turned into the Kentucky. As a result, a lake was formed which covered the entire drainage area between New Martinsville and Madison, to a level somewhat above that of the hypothecated sag in the divide at the latter place; for, until the passage-way was widened and deepened, the water could not escape as rapidly as it would accumulate.

When the mouth of the old Kentucky was closed, the outflow of the old Kanawha was turned into the Scioto, thence through a low place in the divide at Manchester, and into the Manchester-East Fork River. This is what would have happened, also, in case the course of the old Kanawha had been northward toward Lake Erie, as it may have been.

When the Licking was closed by the advancing ice north of Cincinnati, the divide just west of Sedamsville was surmounted and all the floods from above passed into the old Kentucky by way of North Bend and Cleves.

Some time after the Licking was closed the ice advanced across the Manchester-East Fork River north of Cincinnati, and the ponded waters broke over the Bellevue divide. Perhaps at about the same time the North Bend Promontory was reached, and this divide was cut through just southwest of North Bend, and the newly created Ohio had an open route, about as at present, from Pittsburg to Louisville.

The Great Miami with a reversed water flow now has possession of the old Kentucky in Ohio, except that portion from the Butler County line to near Cleves. This latter portion of the old Kentucky was filled with drift to such an extent that it has never been cleared out. The Miami River passed up Taylor Creek, a northward flowing tributary of

the old Kentucky, and thence over a divide near Miami into a small southward flowing stream entering the old Kentucky, reversed, in the vicinity of Cleves.

"Split Rock," at the mouth of Woolper's Creek, presents from the river, a vertical face of conglomerate about 160 feet high, mostly water-worn limestone blocks of local origin. This was formerly supposed to be the southernmost terminal moraine, but it is the result of a torrential discharge into practically dead water. Behind Petersburg there is an abandoned channel only a little above high flood mark; it extends in a direct line from the Great Miami toward Split Rock, and apparently it was through this that the debris was carried. The large rocks at the river front are soon replaced by gravel, this gives way to sand, and before the hill is reached there is only fine sand which shows the inclined or sloping lamination characteristic of the bottom of a pond which has been silted up by muddy running water. The final moraine is several miles south of here. Leverett[6], has depicted the limit of the ice in Kentucky. It crossed the Ohio at Utica, Indiana, opposite the mouth of Harrod's Creek, held a northeasterly course almost to Carrollton, thence to the bend at the mouth of Sugar Creek, northerly to Mud Lick near its mouth, then nearly east, and crossed the Ohio again in Campbell County. While the glacier was at this stage all the drainage of the Ohio and its tributaries above Mentor, Kentucky, was debarred from its natural outlet. It must have passed around the southern front of the ice; but there is no trace of a channel or depression through which it could have gone. It would seem quite probable, from looking at a map, that Eagle Creek had joined the Ohio through Sugar Creek; that it had been deflected westward by the ice-barrier; and that the Licking had pushed over the divide and found its outlet in this way. But there is no indication whatever of a channel on the summit; the rock formation confining the creek is unbroken and maintains its normal altitude to the depression at the head of Sugar Creek two miles below the turn of Eagle Creek, as noted by Leverett. This is sufficient evidence that if Eagle ever reached the Ohio it was so long ago that its present channel has since been cut down more than 200 feet through solid rock. Further proof of antiquity is found in the excessive amount of lateral erosion at Glencoe, where the valley is more than a mile wide. Except where the stream has cut a narrow deep channel close to the hill on the south, this valley has a level floor of solid rock only 10 to 14 feet below the surface upon which Glencoe is built. Nor is this accidental or local; half a mile or less above Glencoe, where the creek flows at the foot of the northern hillside, a similar rock floor extends from the hill on the south. The soil in Eagle Creek bottoms is from local sources, deposited for the most part when the valley was filled with glacial backwater. The same is true of the lower Kentucky. Where the overflow waters of the Licking went during the maximum ice advance is unknown.

A problem almost identical with that of the Licking is found when an outlet is sought for the overflow of the Kentucky. At Bond Mill the upper part of Salt River, flowing on solid rock, is headed straight for

[6] Monograph 53, U. S. Geol. Surv., Map VI.

the Kentucky. Before reaching Lawrenceburg, when within a short distance of its apparent destination, it turns abruptly westward and reaches the Ohio at West Point, below Louisville. There is unbroken bed rock to the top of the hill on the outside of the bend; and below here the valley, like that of Eagle Creek, is filled to a varying width with local drift.

The Madison divide was at the extreme upper end of the town. The valley is narrow, the hills steep, almost precipitous, to the top. There is very little drainage into the river; within two or three miles, on each side, there is a watershed which reverses the surface waters, on the north to Graham Creek and through that to White River, on the south through short creeks to the Ohio below the bend. On both sides of the river, the ravines are short and steep. Those in Kentucky have a fairly uniform slope from top to bottom; but on the Indiana side, although Indian-Kentuck Creek, above the divide has a regular descent through its several miles of length, all ravines below the divide down to Utica, are interrupted by high vertical cliffs of Niagara limestone, the cap-rock of the region. The limestones and shales underlying this are easily eroded, allowing it to break off in immense blocks. A similar process is going on in Elijah's Creek in Boone County, which enters the Ohio a few miles below Sedamsville; but as this is entirely in Cincinnati limestone it descends in a series of cascades instead of having a single high fall. Such conditions remind one of the hanging valleys around Ithaca, N. Y.

A short distance below the Madison divide, Crooked Creek, coming out of the upland from the north, followed the channel of the present Ohio to Utica where it joined Harrod's Creek. There seems to be still a remnant of the rock point between Crooked Creek and the ravine from the divide above; a well at the City Hall reaches bed-rock at 48 feet below the bottom of the river, while the Asylum well, a mile to the west, strikes it at 67 feet. Another well in the low ground between the last and the hill, found rock at practically the same level. As the Asylum well is near the middle of the valley, rock is probably at the same approximate depth clear across.

The top of the Asylum Hill is 416 feet above water in the Ohio. The railway station at North Madison is the same. The elevation of the City Hall is 96 feet; showing a depth of 144 feet of glacial drift at this point.

The extreme shortness and consequent steep gradients of the ravines on both sides of the river prove their recent origin and thereby strengthen the evidence that a divide existed here.

An interesting feature in this vicinity is "Lost Hill" a short distance below Madison. Originally it was a narrow ridge several miles long, projecting between Crooked and Clifty Creeks. The latter cut through it and left the lower end isolated.

After receiving Crooked Creek at Utica, Harrod's Creek continued a westerly course, skirting the hills north of Jeffersonville. Siebenthal, in the 25th Annual Report of the Indiana Geological Survey, 1890, p. 363, presents evidence of a buried channel along this route. At two squares from the river in Jeffersonville, bed-rock was found at 15 feet;

a fourth of a mile north at 80 feet. A well at the Silver Creek Cement Company's plant went (p. 262) 190 feet in clay and gravel without striking rock. Siebenthal thinks a mistake was made in the figures, but suggests a channel 90 or 100 feet deeper than at present oxbowing around from Flatwoods. It seems more probable that the channel he mentions was that of Harrod's Creek, and continued toward the west.

Conditions from Utica to West Point are very complicated and difficult to understand. According to Collett (Geol. Survey of Indiana, 1878, p. 300) there is a "depth of erosion beneath the city of Louisville of 175 feet below the present bed rock of the falls of the Ohio." On page 427 he says, "It is known that the Ohio River from near the mouth of Salt Creek to its upper tributaries, runs in a valley which has been cut more than 150 feet below the present river bed." James (Popular Sci. Mo., April, 1891, p. 746) quotes John Bryson in American Geologist, March, 1890, "in pre-glacial times the Ohio River divided above the city [Louisville], one branch flowing on the north and the other on the south of an island, the two uniting below the city. Well-borings show the rock in some places to be 150 feet or more below the present surface, and what are now insignificant streams were once large enough to carve valleys half a mile wide and many feet in depth. Where was once the island are now the falls." These depths appear to prevail below Louisville in the wide valley extending down to West Point. Owing to the great changes resultant from building and street making in the three cities, and the lack of deep drillings south of Louisville, an accurate reconstruction of pre-glacial conditions is not possible at present; but the indications are that Beargrass Creek ran to the east of the city and joined Harrod's Creek above Bryson's "Island"; and that another creek, now buried, headed near the Bullitt County line, flowed northward to Louisville, then westward toward New Albany. If this was the case, bed-rock should be found at no great depth along the divide separating Beargrass from the other creek, unless it was removed by glacial floods.

The vagaries of Salt River are confusing. Formed by the union of three forks, one from northeast, one from east, one from south, it flows west, then north to the Ohio which carries it abruptly west again through a narrow gorge when its logical course is by way of a wide, deep, open valley directly in line with its northern trend. The break through which it passes from its junction with the Ohio is manifestly the site of a former divide. If so, the only outlet for Old Salt River was toward the north through the present wide valley of the Ohio, nearly to New Albany, then along the foot of the "Knobs." Reinforced by Harrod's Creek, it continued to skirt the Knobs until these begin to bear to the west from the headland near Underwood. From here it pursued a general northerly course, about two miles west of the Pennsylvania Railway, to the junction of the two forks of the Muscatatuck River. It followed the present West Fork to the point where it emerges from the hills two miles northeast of Chestnut Ridge. From here, the old channel, filled with glacial debris, may easily be traced to the East Fork of White River somewhat more than three miles northeast of Seymour. (See figure. 2.)

The west fork of Muscatatuck, also called Vernon Creek, has a valley more than a mile wide to Weston, several miles above the point where it emerges from the hills and joined Old Salt River. East Fork, or Graham's Creek as it is usually called, flows partly in an old valley which may or may not be its original course.

At the junction of the two forks, Muscatatuck Valley is nearly three miles wide. All this low land is subject to overflow. Evidently the old channel had a considerable depth and was filled to its present level partly with sediment carried north by Salt River and partly by outwash from the glacier. Near Millport, south of Vallonia, the stream is on bed-rock, between rock walls. Here was a hill or ridge which retained a lake extending from the ice-front, past West Point and into Kentucky. The lowland or valley is now filled as far as New Albany with gravel, sand and clay, nearly all of local origin, much of it no doubt from the south. Erosion has worn the upland on the west into knolls and ridges. There is a small amount of glacial drift throughout this distance, which may have come from the north with a late glacial flow or may have been carried in by Harrod's Creek. No boulders were observed, or any gravel of a size to indicate other than a gentle current.

Muddy Fork, once a tributary of Salt River, now crosses its old bed at Bennettville, on the Monon Railway, to join Silver Creek. Both of these, after they leave the hills, are post-glacial streams, flowing mostly on solid rock.

The question naturally arises "What became of Salt River?"

Newsom, in the 26th Annual Report of the Indiana Geological Survey, 1901, pp. 294-6, describes and maps the drainage area of Muscatatuck and East Fork of White River. Before they unite, they flow in wide valleys; below their junction the stream flows through a comparatively narrow valley bordered by steep hills. He presents two hypotheses; one that the rivers held their present course, inherited from a previous erosion cycle; the other that "prior to the ice invasion the upper portion of East White River flowed either north or northeastward, or possibly emptied directly into the Ohio and at New Albany." As opposed to the latter supposition, he notes that "there are no narrows in the canyon to correspond with the position of the original divide between the east and west flowing streams." The "present flood plain of the valley varies in width from half a mile to over one mile, and would certainly seem to antedate the ice invasion."

But in various places in the Upper Ohio Valley, notably just above Portsmouth, and in the Scioto below Chillicothe, divides higher and more massive than any that could have existed in the White River country, were cut through and wider passages formed in them.

Ashley, in the 27th Annual Report of the Indiana Geological Survey, 1902, p. 64, says, "A comparison of the valley of White River along the north side of Washington County, or further upstream, with its valley a short distance above the mouth of Lost River will show a marked contrast, the valley being only a quarter of a mile wide in the latter region, as against several miles wide in the former region. How much of this difference is due to the rock through which it flows and how much to the earth movements and possible changes in channel?"

Ashley's last suggestion seems to fit the case. It is quite reasonable to infer that Old Salt River followed the East Fork northward to the buried channel outlined by Bownocker; that it carried with it the drainage of the valley now occupied by the various branches of the Muscatatuck; that with the reversal of drainage the water rose until East Fork was pushed through the hills of Lawrence and Martin counties; that when the ice had advanced to the hills below Seymour, the Muscatatuck broke down the divide at Millport; that when this outlet, in turn, was closed by the ice, the valley of Salt River was again filled, until the floods passed over the divide at West Point. As mentioned before, the waters of the upper Ohio when the glacier was at its most southern limit must have passed across Kentucky south of the ice; and yet no trace of such passage can be found. A divide at West Point surmounted and cut down will explain this.

During the extension of the ice-sheet to the south of the present Ohio, the overflow from Manchester into Licking, from Licking into Kentucky, and from Kentucky into Salt, could have taken place through the numerous depressions in the watersheds between these streams without making much impression at any one place. In fact, as all these rivers would rise to practically the same level there would be but little fall from one into another. All this water, after passing Madison, would be turned northward through Salt River and the East Fork of White River. When the outlet in that direction was closed, the Salt River Lake would back up at least as far as the Madison divide, perhaps go beyond it if the divide at West Point was the higher, as it probably was at this stage. But, sooner, or later, the rising water would have to pass over the latter; and when this took place the ice in Kentucky being exposed to running water on the east, south and west margins, would soon recede to such an extent that the lakes in the river valleys above could empty themselves rapidly through the new channel of the Ohio. The strong currents thus created would deposit much material in the lakes into or through which they passed; and this explains many of the high bottom-lands, especially those between Hamilton, Ohio, and Madison, Indiana, including the Split Rock conglomerate, most of which probably came out of the Great Miami.

This explication is not offered as a conclusive solution of the matter in question, but it is rather in the nature of a working theory. We do not yet know the rate of advance or recession of the glaciers; we do not know whether they reached all points of their southern limits at practically the same time, or whether there was a variation in their progressive movement; we do not know which of the northward flowing streams was first blocked off, or the order in which the divides were surmounted. But there is a reasonable certainty that the events herein recounted took place in somewhat the manner set forth, whatever may have been the order in which they occurred.

At Rock Haven, a few miles below West Point comes in Otter Creek whose valley offered a passage-way to the lower Ohio, or rather to that section of it which extends from here to Green River. We have now a new phase of the stream. It is best described by Ashley in the 27th Annual Report of the Indiana Geological Survey, 1902, p. 601:—

"If any region of land remains at one level for any length of time, erosion tends gradually to lower the valleys, then to widen them, thus reducing the height and steepness of the intervening hills, and if allowed to continue long enough, the land will become a flat base level, as it is called. If at any stage of the process, say when the area in question has been reduced to a gently rolling type of country, uplift takes place in any part of it, it is evident that the streams that rise in the uplifted area will have their upper courses in shallow valleys with gently sloping banks just as before the uplift. When, however, the stream reaches the edge of the uplifted portion, where it slopes down to the portion not elevated, or where it runs into the channel of a large stream that has cut down below the general level of the plateau, it will become a rapid stream and one that will erode and deepen its channel rapidly. A gorge will thus be started at the edge of the plateau or at the mouth of the stream, which will rapidly tend to eat its way back into the plateau."

This process is excellently shown at Elijah's Creek and at Madison, as noted above. The great preponderance of shale as compared with the thin-bedded limestone in the former, allowing rapid under-cutting and breaking down, has given rise to a series of cascades; at Madison the wearing away of the more easily eroded material in the lower portions has left high vertical cliffs at the top.

"The Ohio River," to quote Ashley again, p. 67, "presents somewhat similar problems. . . . At Leavenworth the river, ten feet above low water, is 1920 feet wide and the valley from bluff to bluff 3960 feet wide. The river continues in this narrow gorge-like channel to Cannelton or beyond, but 20 miles further west it is found flowing in a valley four or five miles wide. In this case the difference in the width of the valley would seem to be mainly due to recent uplift at the east. A study of the course of the Ohio, as well as of the courses of Blue River, Indian Creek, and other of the region, suggests very strongly that their present courses are largely a survival of their courses when flowing at the level of the upland or gradation plain then nearly at base level. Thus, take the horseshoe curve at Leavenworth, the two arms of the curve are separated by a high divide with bluffs as marked and precipitous as on the outside of the curve, indicating that the river has sunk its channel *in situ*. The same thing is very noticeable in following down Blue River where horseshoe curves abound, and in most cases the arms of the curve are separated by high divides."

Ashley's explanation of the canyon-like valleys in the vicinity of Leavenworth correctly describes the process of their formation, but his hypothesis of a "recent uplift to the east" is not tenable. The air-line distance from West Point to Tell City is only about 50 miles; consequently an elevation such as would be necessary to produce the rapid descent in the tributary rivers and creeks would result in marked disturbances of structure and dip in the strata. This evidence does not exist. Perhaps a better interpretation of the local conditions may be found in the heavy bedded and homogeneous character of the rock. These properties would compel small streams such as Old Otter Creek and its tributaries to maintain a high base level. With the wearing down of

the barrier at West Point and the consequent release of glacial floods, the volume of water passing through the gorge and also its velocity were vastly increased. The same causes that prevented the widening of Old Otter Creek would tend to confine the enlarged stream. A further hindrance to lateral erosion would be the immense blocks of stone falling from the cliffs as these were undermined; they would answer the purpose of revetments or riprap. Thus the principal corrasion would be at the bottom. The steep gradient, the narrow valley, and the volume of water, with the great quantities of boulders and gravel transported from above, would rapidly cut away the underlying strata, producing the canyon-like character of valley that we find there at present.

This narrow valley holds to Stephensport at the mouth of Sinking Creek, then there is a sudden widening for a few miles, including the outlet of Deer Creek above Hawesville. Between here and Anderson Creek at Troy there is an abrupt narrowing. The reason for these changes has not been discovered. From Anderson Creek down, the space between the bordering hills and the attendant width of the bottom lands steadily increases. Otter Creek, which name may be properly applied to the old main stream below West Point, joined Green River a few miles below Owensboro. (See figure 2). From here the lowlands extending to the Wabash are so wide that in places the hills can not be seen and the ancient channel is lost. At Evansville a rock ledge projects into the Ohio; at Henderson a rock ledge and bluff; at West Franklin a rock bluff. At Uniontown solid rock extends entirely across the river, passing under the bank on either side. In the bed of the river the stone over several acres is fractured as evenly as if artificially cut for paving or building purposes; it is exposed to the air at low water, there being an eroded channel through it barely wide enough to permit the passage of a steamboat. It is plain that very extensive lateral erosion took place here at some time in the past; but its cause and meaning are still to be deciphered.

All this means that at one time Green River held a westerly course to the north of Henderson and Mount Vernon, and joined the Wabash. Before tracing it further some observations in regard to the Wabash are necessary.

Leverett, in "Water Resources of Ohio and Indiana," 18th Annual Report U. S. Geological Survey, Part 4, p. 446, says:

"The Wabash from its source to Huntington is a narrow and shallow trench. Then it enters a valley much wider than that above Huntington, an old westward outlet of a glacial lake that occupied part of the basin of Lake Erie, and opened a post-glacial outlet for the Wabash. It follows this westward except for a few miles in the vicinity of Lafayette where it crosses or follows a pre-glacial valley for a few miles." Between Huntington and Covington "it has been compelled to do considerable excavation in rock." "Below Covington the stream follows very nearly the line of a partially filled pre-glacial valley."

Leverett says again in "The Illinois Glacial Lobe", U. S. Geological Survey, Monograph 38, p. 528, that the present Wabash River, with its eastern tributaries seems to have worked out a course which is to a

large degree independent of former drainage lines. It follows independently pre-glacial or recent channels, according to present topography. He also states (p. 530) that a boring in the abandoned channel west of Lafayette reaches rock at 300 feet; at Terre Haute rock is reached at 345 to 360 feet above tide. At Shawneetown, the rock floor was found at 240 feet above tide.

Malott, in "Physiography of Indiana", p. 76, says the "Wabash River below Lafayette or southward from the great bend follows an old pre-glacial valley. . . . Above [Lafayette] it was wholly obliterated." . . . "The main Wabash Valley from the vicinity of Huntington is largely the result of the drainage which existed during the runoff of glacial waters formed in the retreat of the continental glacial ice". (p. 110)—"From the vicinity of Delphi the Wabash Valley follows a broad pre-glacial valley." (p. 139)—"Certainly depression has taken place in southwestern Indiana, western Kentucky, southern Illinois, and southward to the Gulf of Mexico."

Below the Wabash, the valley soon begins to contract. At Shawneetown a rock ledge extends for some distance out into the river. On each side of the river is an extensive area of low, drift-covered land; well drillers report that bed-rock is reached in this at from 30 to 50 feet, although an occasional well east or north of Equality does not find rock until at a depth of about 200 feet. As the lower Saline flows in a narrow channel, almost a gorge, this indicates a pre-glacial course toward the Wabash.

Finally, there is a rock bluff on each side of the river at Caseyville, rising directly from the river shore; unmistakable evidence of a former divide separating Tradewater River from a short stream which flowed up the Ohio to the Wabash.

There seems to be but one explanation of all the features connected with the Wabash, and that is that it originally had a northern outlet. Whether this was toward Lake Michigan or Lake Erie, there is as yet no knowledge upon which to venture an opinion. There seems no escape from the conclusion that the Kanawha, the Licking, the Kentucky, and Salt Rivers extended northward and westward under the present drift-covered portions of Ohio and Indiana. It is not a reasonable supposition that all four of them would turn abruptly back on themselves after flowing hundreds of miles toward the north or northwest, and seek for a southern outlet. The pre-glacial Green and the Wabash from their junction, apparently took the same direction. (See figure 2.)

From the map, two rivers appear to offer a strong contradiction to this view; the Saline and the Little Wabash. The former has been referred to; it will be observed that all its upper tributaries except a few very small ones have an eastward bearing, toward Ridgeway and Inman. The well drillings also point to this course. When this outlet was shut off, the floods excavated the present channel to the Ohio.

The Little Wabash has a similar history. North of Carmi, Skillett Fork is in a wide valley, with a general easterly trend. A short distance above its junction with the main stream it is deflected sharply southward through a narrow gorge with solid rock sides and bottom.

The Little Wabash is in a similar gorge above the junction, the two thus carving an island out of the range of hills which bordered Skillett Fork on the south. The latter was the principal stream at that time, joining the Wabash near Grayville; the Little Wabash itself is post-glacial, as proven by the occurrence of rock at various places in its channel above Skillett Fork. It also has rock walls and a rock bottom a few miles below Carmi; but nothing definite can be learned here, as deep drift covers all the area between this stream and the main Wabash. Be this as it may, it is certain that all these streams were turned toward the Ohio when the ice reached the country south of the Great Lakes. Regardless of its early course, the Wabash was the first to offer an escape to glacial floods, and to carry this water to the south. The rivers above, in their turn, joined it.

The Tradewater River, which apparently should have turned toward the Wabash, followed the somewhat constricted valley of the Ohio to a point a few miles below Golconda, where it took a turn to the westward into Bay Creek and Cache River. The Kentucky hills then extended across the present valley, at Smithland, to Bay Creek on the north and to Metropolis on the west, deflecting the Cumberland up the Ohio to join Tradewater.

It is not clear why Bay Creek should have silted up, or why the divide at Smithland was cut away. There was a great depth of water here; on the hill behind the town, at an elevation of fully 100 feet above the highest terrace, a cut in a roadway exposes an old shore line of water-worn gravel and sand resting on native clay and limestone. There is not sufficient exposure to indicate whether it pertains to a lake or to a river.

The hills on the north side of Bay Creek extend in a fairly uniform curve from the Ohio to the Mississippi flood-land at Olive Branch; toward the west they are composed largely of stratified siliceous stone, which evidently replaces the original limestone. It is locally known as novaculite, to which it bears a much closer resemblance than it does to the chert so abundant in this region. The low lands north and west of Metropolis, drained by upper Bay Creek and lower Cache River, contain many knolls and ridges, remnants of a former deposit of chert gravel carried down by the Cumberland and Tennessee rivers. The chert gravel is entirely different from the novaculite in the bluffs to the north. As the way to the Mississippi, and so to the gulf, was open, it is not easy to account for the deep, quiet water in which this gravel accumulated. Had there been a land depression so considerable as to allow an extension of the Gulf of Mexico to submerge all this territory, there would surely be other evidence of it, here and elsewhere. It is not reported.

There is another possibility. It seems to be agreed among geologists that a subsidence occurred in the Mississippi Valley during the Glacial Epoch or at least during a part of that time, and that this was greater at the north than at the south. The gradient of southward flowing

streams would thus be diminished and their current rendered more sluggish. Wright states (Records of the Past, Jan., 1905, p. 15) that "for a considerable time during the closing stages of the Glacial Epoch, while the loess was being deposited, the lower Missouri was subject to an annual rise of water, in the month of August, amounting to 200 feet." This being true, it is evident that at the same time and from the same cause the Mississippi and the Illinois were similarly swollen, as were all the streams coming into the Ohio from the north. The warm, moisture-laden winds from the south, coming in contact with the cold air currents from the north, kept at a low temperature by the expanse of ice over which they blew, would give rise to torrential rains, producing tremendous floods in the Ohio's southern tributaries. When such floods occurred simultaneously, and united, each would retard the others and back them up as if they were opposed by a solid obstacle. That such was the case is shown by the elevation of loess below St. Louis, especially at Cape Girardeau, Missouri, where the city reservoir, at an elevation of 170 feet above flood level, is on a knoll of water-laid material whose summit was leveled off to provide the required space. Just how much the original height was thereby reduced, does not appear; but making allowance for this and for previous erosion by the elements through thousands of years, there must have been a flood height of more than 200 feet, perhaps as much as 250 feet. This would cause a rise in the Ohio sufficient to account not only for the gravel hills near Metropolis and the shore line on the hill at Smithland, but also for the sand and silt accumulations filling the depression left by earlier corrasion in the Ohio as far up as the Leavenworth gorge, and in its lower tributaries as well.

When the Wabash was debarred from its northern outlet, whenever and wherever that may have been, it must, for a time, have found or made its way westward or southward directly to the Mississippi. It is difficult to believe that the immense volume of water which drained into it from the north and the east could have poured through the gorge at Caseyville without enlarging it to several times its present dimensions, when we know that smaller quantities of water, hundreds of miles above, cut wider gorges through barriers of rock much higher, more massive, and more resistant, than that at Caseyville. At several points in Illinois deeply buried channels are reported, which have no connection with any existing system of drainage; the earlier post-glacial Wabash may have followed one of these—if there was more than one—until the advancing ice shut it off from that course and sent it back, reversed, into its present bed.

In this paper the Glacial Epoch is considered as a unit; the alternating periods, the advances and recessions, produced many changes of varying duration and of unequal importance; but on the whole the process of drainage reversal was continuous. It began with the blocking-off of the river whose place of final discharge was farthest to the north; and it ceased only when the present lines were established. In a sense it has not ceased yet, there being a few rock bottoms to reduce, as at Letart Falls, Fern Bank, Louisville, and elsewhere.

It is objected that the general slope of the land in the Ohio basin would render impossible any such drainage system as is here described. The objection is valid, on its face; but many undoubted changes of channel as radical as any indicated here, have taken place in other localities. Several tributaries of the upper Tennessee, as well as New River of West Virginia, rise on the Atlantic slope and break through mountains hundreds or even thousands of feet higher than their head springs, on their way to the Ohio; the Mississippi practically runs along a hillside; other examples could be cited. The rivers of the central valleys are by no means of recent origin; there has been ample time for extensive variations of level in different parts of their drainage area; so a study of their readjustments is not to be based solely on present topographical conditions. Further, in addition to alterations resulting from elevation or subsidence in the mass over a wide territory, there are minor variations due to differential warping.

In tracing buried channels by ascertaining the depth of bed-rock at different points, it is necessary to know whether the bottom of the well is in the deepest part of the old bed. It is also necessary to know how much the bed of the recent or present stream has been lowered by the corrasion or gouging of the bottom since glacial floods were first turned into it. It is recognized that deductions resulting from studying some of the factors, to the exclusion of others, may be quite misleading.

Preliminary to constructing dams in the Ohio, test holes were bored at short intervals across the stream to determine the character of material in which foundations were to be laid. There are 22 locations below Manchester. Omitting the dam at Louisville which is built on the ledge of the falls, there are ten sites at which rock bottom was reached. All other borings stopped in loose deposits. In regular order will be given the number of dam, the name of the nearest town, the depth of the hole (some of these are omitted), the elevation above sea-level of the bottom, and the character of the rock. These data are taken from Government charts.

33—Maysville, 27.8 to 29.7. 425.3 to 427.2.
Limestone or blue clay at nearly every boring.

34—Chilo. 30.1 to 38.3. 409.7 to 417.9.
Limestone at nearly every boring.

35—New Richmond, 27.5. 415.3.
Limestone boulders and yellow clay at this boring, which was well out in the river. Sand and clay in all the other holes.

37—Fern Bank. 20.81. 408.
Limestone all the way across.

38—Rising Sun. 39.0 to 58.5. 363.2 to 382.7.
Limestone at every boring.

39—Vevay. 33.3. 379.4.
On the Kentucky side about one-third of the dam is on bed-rock. Well out in the river limestone was reached at 384.7.

45—Stephensport. 329.7.
Sandstone.

47—Newburg. 300.4.
Coal.

50—Caseyville. 295.3.
Sandstone.

51—Elizabethtown. 297.6.
Limestone.

At Stephensport and at Newburg it is quite possible that the dams are not located over the deepest part of the old valley; drillings between the river and the farthest hill may not find rock at the depths given.