The Preglacial Valleys of the Upper Mississippi and its Eastern Tributaries.

Harry M. Clem.

So far as the writer is aware, there has been no attempt to compile a map showing the results of researches upon the preglacial drainage of the region indicated in the title. The following paper addresses itself to that task, together with a brief discussion of the reason for believing that certain streams shown on the map were preglacial. Only the briefest outline can be given in this short discussion, which merely undertakes to pioneer the large field lying before it.

The attempt has been made to map accurately the preglacial channels of the area in question, but this may not always have been attained, for several reasons. The literature is not adequate in all the fields of the area, and often the statements made are not so clear as might be desired. The word "probable" is very frequently used and renders mapping difficult, if not impossible. Occasionally, authors differ, and in such cases the one which seemed to be the better authority is followed, and the dissenting theory mentioned in the text. No attempt has been made to give a critical discussion of the different theories. Any reader who may desire more detailed information than this paper furnishes can find all that is of importance in the accompanying bibliography,[1] or he may look there for correction or verification of any points in the discussion with which he may disagree.

The greater portion of the region covered in this paper is so deeply buried in drift that only the major details of the ancient preglacial topography are apparent. The multiplicity of minor topographic details that give final expression to the landscape are so completely buried from sight that it may never be known how the ancient surface appeared before the advent of the glacier. Only by a multiplicity of borings could a general idea of the details of that buried topography be obtained, and that is impossible except where some deep-seated natural resource induces men to sink deep wells. Thus innumerable small valleys have been obliterated and

[1] Not published here.

lost to history. The larger valleys generally remain sufficiently unobscured to enable geologists to trace their courses, either continuously or at intervals close enough together to enable a safe inference to be made concerning their previous courses. The larger the valley the better chance it had in general to leave behind itself traces of its former course, for, occupying the lowest part of the surface and carrying great quantities of water, it was automatically kept open by drainage from the melting ice. Yet even the largest river trenches were in imminent danger of defacement. Such an instance is found in Jay and Adams counties, Indiana, where there are signs of a huge valley whose bottom is buried beneath nearly 400 feet of drift and no traces left of its existence on the surface. Another case is that of the preglacial Mississippi where it turns southeastward to the Illinois valley just below Clinton, Iowa.

The map shows large hiatuses wherein there are no preglacial streams indicated, but they certainly exist buried in several hundred feet of drift. West and south of the basin of Lake Michigan and between that basin and the Lake Erie depression in northern Indiana and Michigan no details are shown, and only a few larger courses suggest probabilities of preglacial existence. The depth of the drift and the absence of deep-seated natural resources do not encourage the digging of a sufficiently large number of deep wells to permit the construction of a topographic map of the preglacial surface. Enough, however, is known to assure us that the ancient drainage lines were quite different in many details from the present systems.

Without further preliminaries we shall discuss the pros and cons regarding the claims of the streams shown on the maps to a preglacial ancestry. For the sake of convenience of treatment, the area is divided according to the several smaller drainage basins which make up the greater Mississippi basin. This will be found convenient because there are wide elements of correspondence between the present and the preglacial drainage basins, as a glance at the generalized map will show. The basin of the Great Lakes, which seems to cut out a portion of the Mississippi basin, and which is separated by a very low primary divide, over which the lakes drained in the Ice Age, is discussed briefly.

THE PREGLACIAL DRAINAGE OF THE UPPER MISSISSIPPI BASIN.

The preglacial divide of the northern side of the Upper Mississippi basin is not definitely determined. It can be pretty definitely located at

Huron, N. D., where there is a col and a constriction in the James river, a preglacial divide, over which the reversed headwaters of that stream now run southward. From Huron eastward its location is a matter of speculation backed up with slender evidence. From here it may have turned south across the present Mississippi valley somewhere near "military ridge," as Hershey (46) would have it, and then eastward, or it may have turned north some distance east of Huron along the east edge of the basin of the Red river, but this will be discussed more fully later. "Between the Rock river drainage line and Lake Michigan there is a somewhat less elevated belt of limestone, which extends curvingly in a direction east of south into western Indiana." (Leverett, 64:16.) Somewhere in eastern Illinois or western Indiana a spur ran south, probably near the present divide between the Wabash and Illinois system separating the preglacial as well as the present basins. The location of the divide north through Wisconsin is not well known, but there is no doubt that it was east of the present "driftless area."

Even if it were possible and profitable, space does not admit of a detailed discussion of secondary divides, which can generally be inferred from the location of the preglacial valleys. After calling attention to the fact that the present Mississippi river has evidently a system of drainage widely different from the system or systems which were operative in preglacial times within the region now drained by it, Leverett says: "Besides opening a new channel at each of the rapids, the stream apparently is occupying sections of two or more independent preglacial valleys." (64:461.)

As to the course of the Mississippi above St. Paul, Chamberlain suggested, in 1879, that it is post-glacial (19:253), but that it probably follows the preglacial channel in short stretches. Hershey, in 1897, agrees with the suggestion.

Hershey has the following to say concerning the preglacial valley above St. Paul: "The high upland area which trends north and south on its eastern side at some distance from its immediate border, continues without a change for many miles to the north, passing to the east of Lake Phalen. Although deeply covered with drift, it is undoubtedly based on an upland area of rock. To the west of it, and in the direct line of continuation of the old Mississippi valley, there is a topographical depression which trends for many miles to the northwest. It is occupied in places by lakes, the most important of which is lake Phalen. This, in my opinion,

will probably be found to be the ancient course of the Mississippi river. That it is the position of a preglacial valley is indicated by a deep well at the St. Paul Harvester Works, situated in the present topographical depression, which penetrated rock at 235 feet beneath the surface or 628 feet above the sea, which is 55 feet beneath the present low-water level of the Mississippi river at St. Paul. The lake Phalen depression is separated from the head of the Mississippi cañon valley by a moraine which is evidently based on a comparatively low surface, for it does not rise nearly as high as the drift to the east or west. As seen from the opposite side of the valley, its escarpment or bluff at the head of the old cañon valley shows such topography as is usually produced by the erosion of drift. In short, all the evidence favors this lake Phalen depression as the position of the pre-glacial continuation of the Mississippi cañon valley." (46: 263.)

From the southeastern corner of St. Paul to Leclair, Hershey believes with other geologists that the valley is pre-glacial. In the vicinity of Dubuque, however, he thinks that the valley is proportionately too small for the stream which it carries, that the preglacial stream flowing past Dubuque could not have been larger than the present Rock river, or possibly no larger than the Pecatonica. The valley is cañon shaped and narrow and the rock floor is about 300 feet below a deep filling of drift. The divide is suggested to be somewhere between La Crosse and Prairie du Chien, particularly where "military ridge" is traversed by the present river. (46:266.)

Hershey believes that the stream north of this supposed divide flowed toward central Minnesota instead of away from it, but that the reversal came early, before the Ice Age, probably at the end of the Ozarkian, by an uplift in the north, or, as an alternative view, it may have "resulted from the disturbance of other drainage systems by the accumulating northern ice. For instance, it is quite possible that the Kansan ice-sheet had advanced across the outlet of the supposed northwardly flowing ancestor of the upper Mississippi river, obstructing its flowage, and after the production of a great extra-glacial lake, turning the drainage of the entire region over the lowest point on the divide which intervened between it and the headwaters of the southwardly flowing central Mississippi river, long before it glaciated the country south of the 'driftless area.'" (46:267.)

Leverett accepts this hypothesis, or at least he quotes it and offers no objections. (64:461-2.)[1]

The question of the preglacial course below Clinton, Iowa, is not yet fully settled. Leverett discusses the problem fully in his writings (58, 60, 62, 63, 64), and lately Carmen has spent some time in the Clinton region, but his paper is not yet published (16). The number of wide channels between Clinton and Muscatine, and the depth of drift renders the problem very complex.

A quotation from Leverett (Monograph 38, pp. 466-7,) will give a fair idea of the location of the preglacial course below Clinton: "Udden's special investigation has led him to the conclusion that the praeglacial line must have been along one of two courses, either southeastward through the Meredosia slough and Green river basin to the Illinois at the bend near Hennepin, or directly westward through the Wapsipinnicon basin to the mouth of Mud creek, and thence southwestward along the Mud creek sag to the Cedar; thence the course may have been by way of the present Cedar and lower Iowa, or more directly southward to the Mississippi just west of the meridian of Muscatine. Udden has collected well data along the Mud creek sag showing that a buried channel occurs there whose rock floor is more than 100 feet below the level of the Mississippi river at Clinton, and perhaps sufficiently low to have carried the drainage of the preglacial stream whose valley has been traced southward to Clinton. The data are scarcely sufficient to fully establish the connection of this channel across the Wapsipinnicon basin, for there are very few deep wells in the basin. Another feature which throws some doubt upon this connection is the narrowness of the deep portion of the channel along the Mud creek sag.

"Turning to the southeastward course, one finds a broad depression or lowland tract leading from Clinton through to the Illinois river. This lowland, except at the outer moraine of the Wisconsin drift in Bureau County, stands only a few feet above the level of the Mississippi, and yet apparently carries a heavy accumulation of drift. The drift is largely sand and there has been no necessity for sinking wells entirely through it.

[1] It may be well to say here that such constrictions in the valley of the Mississippi occur wherever the river crosses resisting strata of rock, such as the Lower Magnesian, and the Galena, Trenton and Niagara limestones, and it may be possible that the river has always been running south, being unable to cut its valley so wide in the more resistant beds. Hershey's theory is interesting but not well established.

They have, however, penetrated 40 to 50 feet without striking rock. The bed rock gradually descends from each side toward the middle of the lowland, and some of the creeks coming into the lowland occupy large and deep channels which have been only partially filled with drift. This rather throws the balance of evidence in favor of the view that the preglacial stream flowed southeastward into the Illinois.

"It should be observed that in case the southwestward route proves to have been the course of the Mississippi, the present line of the stream departs from it only a few miles and enters the same old valley below Muscatine, which it occupies above Clinton. But in case the southeastward route proves to have been the preglacial course from Clinton, the preglacial valley above Clinton finds its continuation down the Illinois instead of down the Mississippi, and the present Mississippi passes from one drainage system to another in its course between Clinton and Muscatine."

Carmon gives many more interesting details, but he concludes with Leverett and Udden: "It is quite possible that in one or the other of these courses the preglacial Mississippi flowed. Both appear to have rock floors to carry the waters of the streams which excavated the Mississippi valley above Clinton, but the data are not complete enough to allow us to decide which of these two courses was the real one" (16). Carmen gives an interesting discussion of the changes produced by each ice invasion upon the Mississippi and a reading of this will help detract from the complexity of the situation in this region.

From Muscatine southward the Mississippi is flowing in a broad preglacial channel except for a few miles above Keokuk, Iowa, where it is flowing in a post-glacial gorge known as the Lower Rapids (63). The old drift-filled valley which has been studied by C. H. Gordon (41), is about twice as wide and 100 feet deeper than the present valley, and lies to the westward in Lee county, Iowa[2] (Fig. 1). Below Keokuk the Mississippi follows the preglacial channel.

Not much space can be devoted to a discussion of the tributaries because the map shows the ones that can be mapped with any certainty, and the reference in regard to each one are full.

Regarding the preglacial history of the Minnesota valley, Upham says (131): "There is evidence . . . . in the terraces of modified drift

[2] Leverett also gives a map and cross sections of this channel. See bib. 62, 63, 64; also J. E. Todd, 114.

along the Minnesota valley, that in large part its erosion was effected in preglacial time and during stages of retreat and readvance of the ice-sheet previous to the final departure." In an earlier article he says that the valley was eroded in the Lower Magnesian and Calciferous formations, before the Cretaceous subsidence, was re-elevated, and, in the first principal epoch of glaciation, covered with a "thick, unbroken, moderately undulating expanse of till" and partly re-excavated by an interglacial stream which, guided by the slope determined by preglacial erosion, coincides along much of its way with the old valley eroded in these strata before the Ice Age (119:109).

The St. Croix river has been discussed by Berkey, R. T. Chamberlin (18), Elftman (30), and Upham (121, 132) and others. Chamberlin thinks the preglacial course from the Dalles of the St. Croix was east to the preglacial Apple river; while the other writers would have it to the westward. The streams of the driftless area in Wisconsin, Minnesota, Iowa and Illinois are preglacial (20, 45-47, 64).

The Wisconsin river is in the preglacial channel below Prairie du Sac. Below Kilbourn City, according to Salisbury and Atwood (89), the preglacial course is east of the present stream, through the Lower Baraboo Narrows, and the Devils Lake Gap of the quartzite ridges on either side of Baraboo, Wisconsin. According to Fenneman (33), a preglacial tributary of the Wisconsin passed northwest through Kegonsa and Mendota lakes. Fenneman finds sections of preglacial channels marked out by the lake basins in southeastern Wisconsin, as shown on the map.

In Illinois, outside of the thick Wisconsin drift which obscures the preglacial valleys of the northeastern part of the State, the preglacial valleys can be fairly easily traced. Outside of the triangular area whose vertices are at Clinton, Hennepin and Rockford, the directions of the present and the preglacial drainage systems are coincident. In this triangular area, the changes have been considerable (62, 64). The preglacial valley of Rock river from Janesville, Wisconsin, to the edge of the Wisconsin drift southward is easily traced, but beyond that the drift rises 100 feet above the preglacial bluffs and its course can be traced only by borings. Its bed is found to be a little lower than that of the Mississippi to the west, descending 210 feet in a distance of 100 miles south from the Wisconsin border. It probably was tributary of the preglacial Mississippi if that river joined the present Illinois.

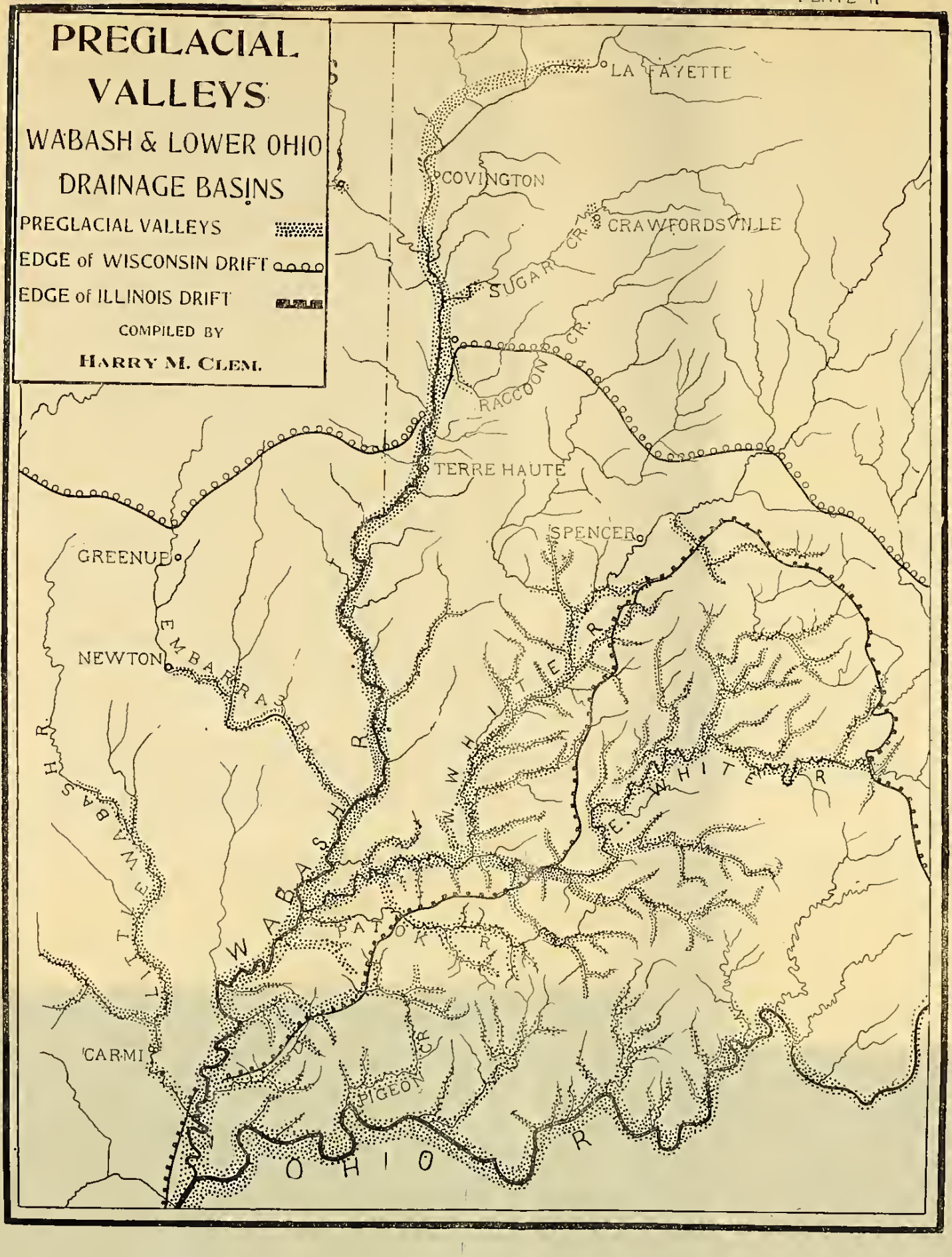
Chamberlin (19), Upham (125, 128), and Spencer (94) have postulated a preglacial outlet of Lake Michigan through Illinois to the Mississippi, but no such channel has been found. Cache basin in southern Illinois is interesting, because it may be a portion of the preglacial Ohio, as deposits of clay indicate, but why or when it was abandoned is not known (64).

A glance at the map of Iowa shows a correspondence in location and direction between the preglacial and the modern drainage lines. The geological survey of the State of Iowa is not yet completed. The breaks in the preglacial valleys on the map indicate either that the river is not running in a preglacial channel or that it has not been studied. Space will not permit a detailed statement as to which of these two facts is indicated, but a study of the references will make it clear.[3] In the eastern part of the State the preglacial drainage has been obscured by drift and the flow of the temporary interglacial Mississippi across them, while in the northwest the drift alone has defaced the ancient valleys.

In Missouri but little study has been devoted to the preglacial conditions of the State. J. E. Todd (111) has given the following summary of the preglacial drainage in the Missouri Geological Survey: "The Kansas River may have flowed at a higher level, which is indicated by the Weston rapids, and it may be guessed that its course was eastward as far as Chariton County, then possibly northward by the buried channel found in Linn County and Putnam County, although that channel may not be deep enough. All that is now known is that there were deeper channels in Iowa whose beds are lower than the bottom of the present channel of the Missouri river near New Frankfort. Reference is made to the Washington channel discovered by Calvin, and further discussed by Bain. The La Mine and its tributaries may have flowed north and joined it. The Osage and Gasconade may have similarly gone northeast into the valley of the Illinois, the former by way of the valley of the Auxvasse or Big Muddy to the valley of the Salt River and northeast, passing somewhere near Quincy, the latter by the lower course of the Missouri. It may be considered more likely by some that the Kansas river passed Moberly and joined the Osage, or that all these streams may have had nearly their present courses to the present junction of the Osage and Missouri[4]."

[3] See bibliography, 7, 12, 15, 41, 71, 81, 90, 103, 118, 139.

[4] For references on the tributaries of the Mississippi see: 1, 2, 3, 7, 8, 14, 15, 16, 25, 30, 33, 41, 44, 45, 46, 57, 58, 62, 64, 68, 70, 71, 81, 90, 103, 118, 146.


PREGLACIAL VALLEYS
WABASH & LOWER OHIO DRAINAGE BASINS
PREGLACIAL VALLEYS
EDGE of WISCONSIN DRIFT
EDGE of ILLINOIS DRIFT
COMPILED BY
HARRY M. CLEM.
LA FAYETTE
COVINGTON
CRAWFORDSVILLE
SUGAR CR.
RACCOON CR.
TERRE HAUTE
SPENCER
GREENUP
NEWTON
EMBARRAS R.
WABASH R.
WHITE R.
E. WHITE R.
WHITE R.
WABASH R.
PATOKA R.
CARMI
PIGEON CR.
OHIO R.

THE PREGLACIAL DRAINAGE OF THE BASIN OF THE WABASH AND LOWER OHIO.

About one-half of the drainage basin of the Wabash river is so deeply buried under glacial deposits that there is very little similarity between the modern watershed and the watershed of the preglacial streams that discharged through the lower course of the Wabash. The preglacial rock surface was probably very rough, for the drift varies within short distances from a few feet to over 200 feet in depth.

The Wabash river at Lafayette is flowing in its original channel. Below Lafayette the preglacial channel runs westward and then southward, meeting the present Wabash at Covington. Below Covington the present river follows the ancient channel. Nothing is known of the upper portion of the preglacial Wabash above Lafayette. A study of the drift covered rocks reveals a divide extending south along the west side of Lake Michigan, and curving to the east into Indiana. It is from 100 to 200 feet above Lake Michigan and is deeply sculptured by preglacial streams and thoroughly drift covered. It has been suggested that the Lake Michigan basin was the headwater portion of the Wabash in preglacial time. On this point Leverett says (62): "The headwater portion of the Wabash stream forming the preglacial Wabash may prove to have been in the Lake Michigan basin. But if so the connection with the Wabash is through a very much narrower trough than that occupied by Lake Michigan. Borings at both North Judson [497 ft.], Winamac [490 ft.] and Monticello [467 ft.], Indiana, situated near the line connecting the heads of Lake Michigan with the preglacial valley at Lafayette, go to a level about 100 feet below the surface of Lake Michigan before entering rock. But within a few miles east of this line rock ledges have an altitude as great as the surface of Lake Michigan, while immediately west of this line they rise 90-125 feet above that level. This trough can not have, in the vicinity of Monticello, a breadth of more than ten miles. Monticello is situated near the middle of the trough. The probabilities are, therefore, against the existence of a much deeper channel in it."

Leverett (65) suggests that the old channel which passes into Grant County from Ohio may be a headwater portion of the preglacial Wabash. The modern Wabash has not completely excavated the ancient valley to its full width above Terre Haute, but below that city the excavation is more nearly complete.

Not much need be said about the tributaries of the Wabash, for Leverett has very fully discussed them. The details have not been worked out, and what is known was that most easily determined. Usually it is the lower portions of these streams and the lower portions of their tributaries that are well known, the headwaters being usually post-glacial and the preglacial valleys covered with drift.

The course of White river below the north line of Greene county, with slight exception, is so completely covered with drift that the course of the preglacial stream can not be ascertained. For a few miles below Martinsville the present stream follows a preglacial valley. The river below Spencer flows for a few miles in a narrow, shallow channel among the hills and ridges, there being no definite preglacial drainage lines to control its course. It occupies a preglacial valley from the mouth of Raccoon creek down to Worthington, where it joins a wider valley two to two and one-half miles wide, which trends south. From this point to its mouth, the course of the stream is nearly coincident with a broad preglacial line.

Bean Blossom creek, which Leverett has not included in his map of the preglacial drainage of Indiana, is undoubtedly preglacial. This is the conclusion of Dr. E. R. Cummings and V. F. Marsters, both of Indiana University, who have worked in this region (69).

The Patoka is very interesting on account of the fact that it is a composite of the headwaters of four different stream systems. For short distances it follows a preglacial channel and then it suddenly crosses rock surfaces which were formerly cols between the preglacial streams. The three upper stream systems emptied northward in preglacial time into the White river. During the advance of the Illinois ice-sheet the mouths of the stream were dammed, and lakes were formed. The water in the upper or eastern lake flowed into the next west over some low sag in the divide and this into the third. Whether the lake drained south over a sag into the Ohio or drained westward to the Wabash through some sub-glacial channel is not settled, but Leverett inclines to the latter (64: 101-2).

The Ohio river (65: 183) below Madison is thought to be preglacial through its entire course along southern Indiana, except probably for a short distance at Louisville, as J. Bryson (12) and C. E. Siebenthal (91) have discovered. This is Leverett's conclusion also, but he says further, "A course about as direct is found in a line leading west from Madison, Indiana, along the Muscatatuck, to the East White and White rivers and

thence down the Wabash to the Ohio. That there was an ancient westward drainage along the East White river is shown by the presence of Tertiary gravel near Shoals, Indiana, that was brought from the east. But the East White has a smaller channel than the neighboring part of the Ohio, and no channel has been discovered near Madison to connect the Ohio with the Mascatatuck Valley. It, therefore, seems a less favorable course than that down the Ohio" (65: 112).

Both Tight and Leverett agree in placing the head of the preglacial lower Ohio near Madison, Indiana, thus making it a very humble stream compared with the conditions of today.

THE PREGLACIAL DRAINAGE OF THE BASINS OF THE UPPER AND MIDDLE OHIO.

Much work has been done in this basin, and much has been written about it, and maps of local areas have been made to cover most of the State, but no general map has ever been compiled. The bibliography, as is apparent, contains a great many excellent references to this region. Leverett (65) and Tight (109) give the most complete discussion of the subject, and several other geologists have carefully discussed limited areas of the basin; and in view of the fact that so much has been written on the subject only a few necessary points will be given here.

The Ohio river is remarkable in many respects, for it presents much variety in width, depth and other characteristics. The valley varies in width from six miles, where the walls are low and gentle, to one mile, where steep bluffs enclose it, and its depth ranges from less than 100 feet to 800 feet. Its bed presents a succession of riffles where its channel runs over rock and shoals where the bed is upon a filling often 75 feet deep. The number of narrow places where the bluffs are steep is remarkably large, as is shown on the maps (Pls. IV, V) by the term "col" and at such places the valley is young. Between the cols the present valley is frequently crossed by old, wide valleys that extend for miles on either side. Many of the tributaries, especially below Portsmouth, enter in opposite directions to their general course and many that rise close to the main river, flow around for miles before entering, a fact indicating the recent origin of the Ohio (109: 34). Much of the same may be said of many of the tributaries, such as the Muskingum, Hocking, and the Allegheny, for they are, too, "things of shreds and patches," having been produced by the union of portions of various stream systems.

The location of the primary divide, if the preglacial drainage lines have been established correctly, can be followed in a general way by a glance at the maps (Pls. IV, V). The portion of the divide, and the most important portion, between the Wabash and Erie basins has not yet been satisfactorily located. Upon its accurate determination depends most of our knowledge of the outlet of the drainage of southern and southeastern Ohio. Some general facts concerning it will appear in the following discussion. From near Mt. Vernon east and southeast to New Martinsville the divide is well located, and the area northeast and north drained to the northward. The present Ohio is seen to fall into two divisions on this basis.

The portion of the Ohio above New Martinsville reached some northern outlet by three different streams (Pl. V). These are easily located, with a few minor exceptions, for the preglacial cols are usually apparent. Carll (17) called the attention to a narrowness of the Allegheny valley at Thompson's gap and shows that the rock floor of the valley, now covered with drift, sloped northward from the divide, and he concluded that the headwaters of the Ohio once drained northward by this valley. He concluded that the outlet was through the Cassadaga valley, but Chamberlin and Leverett made later studies, found the Cattaraugus creek valley the deeper and more direct route to Lake Erie and concluded that the outlet was by that valley (65: 129-30; 21: 101: 159-60).

Another prominent col just north of Parker separates another section of the Allegheny which included the Allegheny to a little below Oil City. French creek reversed to Meadville and an old valley continuing northward to some preglacial valley in the Erie basin were the main stream in the system, for here is an old, wide rambling valley in which Cussewaga creek flows south to join French creek. Leverett accepts this outlet, showing that the drainage could not have been up French creek above Martinsville, because of a col in French creek valley a few miles northeast of Meadville (65: 134-8).

The next lower section of the preglacial system, whose main stream was the Beaver reversed, and the Grand, is variously known as the Spencer (35), Old Lower Allegheny, Pittsburg (109) and Grand river (21). It has been well studied and most authors agree upon its course. The drift is deep north of the source of the Beaver; but the old gradation plain slopes north to Sharon and then upward farther north. A depression

descends westward to Youngstown on the Mahoning. Borings at Niles and Rome reached level at 70 feet above Lake Erie, showing that the old Grand valley grows deeper in the north (65: 149-51).

They are marked off by the meridians of New Martinsville and Columbus and include a mass of detail that, in most cases, is very difficult to map from the text. The area south of a line between New Martinsville and the mouth of Newark river has been studied thoroughly by Tight and mapped in detail (Pl. V and 109) and well discussed. The changes here are quite profound but they can be read with little difficulty.

Theh Muskingum has offered much difficulty to its own solution, especially within the deeply drift-covered areas. Leverett (65: 158-65) gives the most concise summary of the preglacial conditions of the basin, but Tight (109, Pl. I) gives a similar general outline, and with local writers discusses the region.

The Blue Rock col is sufficiently plain to separate that part of the present stream into north flowing and south flowing portions. The north flowing part might have gone north along the present Muskingum or northwest up the Licking, but Leverett favors the latter (65: 161). Tight is especially responsible for the section drained by the Licking reversed and the preglacial Newark (104: 152, Pl. I; 91: 160) and of Vernon river.

Much difficulty was experienced in determining the location of the preglacial channel which carried the drainage of the present Muskingum after it reaches the headwaters of the present Rocky river. Todd (117), a local writer who has a paper on the preglacial drainage of the Rocky basin and an area south, favors an outlet down the preglacial Rocky, but Leverett (65: 165) believes that it flowed east into the old Cuyahoga (Pl. IV), although he admits that the evidence of a slope in the rock floor in that direction is meager. He also favors the idea that the upper Tuscarawas was continuous with the preglacial Cuyahoga.

The system of preglacial drainage (Pls. IV, V) collected into Portsmouth river—the lower Scioto reversed—is fully discussed by Tight, Leverett and others and is established. Newark, Vernon and Portsmouth rivers united somewhere southwest of Columbus, but it is not well known just where. After the union of these rivers the direction of their united valleys is not yet determined. Leverett (65: 103-4) says on the question: "'Four possible courses were suggested for the discharge from the southern end of the Scioto basin: First, southward, down the Scioto from Waverly

to the Ohio and thence down the Ohio; second, northward, along the axis of the Scioto basin to Lake Erie; third, northwestward across western Ohio, along one of the several deep valleys brought to light in that region by the oil and gas wells, eventually to the low tract on the lower course of the Wabash or the basin of Lake Michigan; fourth, northeastward past the Licking reservoir and an old valley east of Newark to the Muskingum at Dresden, and thence northward along or near the present valley of the Muskingum, Tuscarawas, and Cuyahoga to the basin of Lake Erie at Cleveland." (65: 102-4.) Leverett later found an oxbow channel at Lucasville, which seemed to testify strongly against a southern discharge, and a divide now crossed by the Tuscarawas between Zoar and Canal Dover, which renders a northeast discharge impossible. It seems worth while to quote Leverett concerning the difficulties of the other two routes: "The northward route along the axis of the Scioto basin encounters a general rise in the bordering plain of about 200 feet in the 100 miles between the south end of the basin, near Chillicothe, and the continental divide near Marion, north of which there is an even greater descent to the Lake Erie basin. If the course of drainage was northward across the divide, and if the divide has not suffered recent uplift, there must have been channeling in it to a depth of about 300 feet. That an axis of uplift exists in this part of the continental divide is shown by the arching of the rock formations over it; but its extent and its date are not yet determined.

"The northwestward route leads across the limestone belt on the west side of the Scioto basin, whose general level is about 200 feet above the continental divide at the north end of the basin and 500 feet above the gradation plain near Chillicothe. To pass through that region the channeling would be so much greater than is required for a northward course along the axis of the basin, that one can scarcely resist ruling out the northwestward course. Yet from what is found on the lower Ohio, where the stream passes directly across the low Devonian shale area into the knobstone and sandstone formations that now stand much higher, such a ruling may be unwarranted. The presence of the low basin occupied by Lake Erie offers an additional argument in favor of the northward route. This basin would be reached by that route in less than half the distance required to reach a similar low track in the Wabash region, or the Lake Michigan basin by the northwestward route. Each of these routes falls within regions so heavily covered with glacial deposits that the course of the channels can be

traced only by means of borings, and these are so few and so poorly distributed as to be inadequate to our needs."

Tight favors a northwestward discharge of the Portsmouth river and so maps it in Plate I, Professional Paper, No. 13 (109).

Bownocker has studied the deep borings of west central Ohio and finds evidence of a deep channel running from Anna to Celina, north to Rockford and west into Indiana, as far as Grant county, where no borings by which it may be traced are found (10, 11). This old channel may be a continuation of the preglacial stream in question (Portsmouth river), and Leverett suggests that it may be a tributary of the Wabash (65: 183-4; see 109, p. 23 and Pl. I), but adds: "The size of the valley indicates that it drained at most only a few counties of western Ohio."

Between Manchester, Ohio, and Madison, Indiana, the Ohio crosses three cols, which means that it is the united parts of four basins. The Licking and Kentucky rivers are thought by both Bownocker and Fowke to have been united to form a single stream at Hamilton. Fowke and Tight think that from Hamilton it flowed northward along the Great Miami reversed. Leverett, who opposes the idea, states, "It is probable that the old drainage south from the latitude of Dayton followed nearly the course of the present line to the Ohio. . . . The old Ohio was entered by the Great Miami near Hamilton. The latter stream makes slight departures from the line of the old Ohio below Hamilton, the old Ohio channel being in part farther west than the Great Miami." (65, p. 184.)

Fowke believes that the old channel between Hamilton and the mouth of the Kentucky was eroded by the Kentucky river, instead of the Ohio. He says: "In other words, that stream, instead of following the present Ohio as it does now, or flowing across Indiana, turned to the east and north and joined the Licking at Hamilton. There is no other channel through which it could have gone. . . . From Hamilton northward the old river bed is filled with drift and has not been traced. There can be no doubt, however, that it joined the old Kanawha (Chillicothe) north of Dayton, probably in the neighborhood of Piqua." (36). The preglacial head of the Ohio is by this theory placed at Madison, Indiana.

The present course of the Ohio is due to the action of the ice-sheet which dammed the north flowing streams, forming lakes in the basins which overflowed at the lowest point in the divides between basins to the next lower neighboring basin. The lakes endured sufficiently long for the present Ohio to establish itself in the course which it now follows (36, 109).

THE PREGLACIAL DRAINAGE OF THE BASIN OF THE GREAT LAKES.

The Great Lakes have been so closely connected with the glacial history of the Mississippi basin, their origin is so closely connected with the preglacial Mississippi basin that it seems well to add a chapter to present briefly what is known about their preglacial history.

Newberry was one of the earliest writers to state the theory now so universally believed, that the antecedent of the Great Lakes was a great river system. According to him the first suggestion of the notion was given by deep borings in the valley of the Cuyahoga at Cleveland, which is a deep valley filled with drift (79). As early as 1882, in a summary of his work, Newberry mentioned, among other points, that he believed that "an extensive system of drainage lines which once traversed the continent, had been subsequently filled up and obliterated by the drift of the ice period." (79.)

Newberry thought the outlet of the lakes through Ontario was through a preglacial valley now occupied by the Mohawk river, and so mapped it in 1878. Spencer took exception to this idea, saying, "The Mohawk course will not answer, as the geological survey of Pennsylvania has shown that at Little Falls, Herkimer county, the Mohawk flows over metamorphic rocks." (79.) Lesley added that this rock divide was 900 feet above the floor of Lake Ontario.

Spencer began the study of the connection between Lake Erie and Lake Ontario before 1880, and in 1881 announced that he had found that the connection was through the Dundas Valley (94), and Newberry at once declared that he himself had prophesied the location of the connection where Spencer found it. Spencer thought that the outlet of the preglacial valley occupied by Lake Ontario could not be the St. Lawrence river, because the bed of the St. Lawrence river is of solid rock (94), nor the Mohawk, because of the rock divide at Little Falls. The channels through northern New York were unimportant and would not answer. The Seneca basin and the Susquehanna seemed available at first, for the deepest part of Lake Ontario is north of Seneca Lake, but too much subsidence would be required (94). After studying the beaches about Lake Ontario and noticing that they were tilted to the west, Spencer announced that the preglacial outlet was down the St. Lawrence (97, 100). Later he worked out the system of

channels which is shown in Fig, 4 (100, 101). Spencer suggested that Lake Michigan had a preglacial outlet to the south or southwest (93).

Upham (125, 128) took exception to Spencer's interpretation of the direction of the Laurentian preglacial drainage, and offered the theory that "A great trunk stream flowing south along the bed of Lake Michigan drew its chief tributaries on one side from the basins of Lakes Huron, Erie and Ontario, and the other side from the basin of Lake Superior." He held that during the latter half of the Cretaceous period nearly all the drainage area which now forms Minnesota and the drainage basin of the Missouri river was depressed and covered by the sea, while the contiguous area forming the Great Lakes region was dry land and continued so up to the coming of the Ice Age. The divide separating this area from the basins draining to the Atlantic, extended "along the Allegheny mountain belt and directly onward northeasterly to the Adirondacks, turning thence northwesterly across the Ontario highlands . . . to the present height of land north of Lake Superior." Spencer's preglacial stream system was, therefore, probably limited to the headwater streams now represented by the Lake Champlain basin and the Saguenay and Ottawa rivers.

Lately Grabau (43) has interpreted the preglacial drainage of the Great Lakes region in a manner different from Spencer and Upham. His theory briefly stated is this: The old surface of the pre-Cambrian rocks was worn away by long continued erosion and there were laid down upon them horizontally, but unconformably, the newer beds of Ordovician and Silurian rock. Then followed an uplift greater in the north, tilting the new beds southward with a dip of about 25 feet per mile. Following the uplift was a period of erosion, wherein the region "suffered an enormous amount of denudation, having been brought to the condition of a low nearly level tract or peneplain a little above sea level." Then the surface was submerged and beds of Devonian limestone, shales, and sandstones were laid down over it. The sea bottom became dry land and another cycle of erosion began. The uplifted beds formed a "broad essentially monotonous" coastal plain sloping gently southward. Consequent streams flowed southward down the slope. The great master streams developed were the Saginaw, Dundas and Genesee rivers, and probably some of the Finger lake valleys. As erosion proceeded, the sloping harder beds endured and cuestas were formed, having their steeper slopes to the north. Along the foot of the escarpments the subsequent streams flowed to the master streams. The Buffalo,

the Tonawanda and other large tributaries coming in at right angles to the consequent streams are the subsequent streams and some of their valleys are now the basins of the Great Lakes.

Short gullies, or tributaries to the subsequent streams, called obsequent streams, worked headward into the cliffs of the cuestas. Such a stream was the St. David's gorge, which, however, was not the preglacial Niagara, as was once believed by Scovell, Pohlman (84) and others.

The direction of preglacial drainage postulated by the theory above is in accord with the theories of Upham (128), Westgate (137), Russel (88), and also A. W. G. Wilson, who has worked the preglacial drainage of the region east and north of Lake Ontario in detail (140) (Plate VI).