

## SOME NOTES ON THE PLEISTOCENE HISTORY OF THE CINCINNATI REGION.

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### INTRODUCTION.

Dr. Leverett's paper, "The Pleistocene of Northern Kentucky,"<sup>1</sup> reports the work of a pre-Illinoian glacial advance in the region of Cincinnati. So far, it has not been correlated definitely with either of the earlier glacial stages. Dr. Leverett has outlined two small areas south and west of Covington, Kentucky, on the west Cincinnati quadrangle which are covered with a deeply weathered drift which he attributes to a pre-Illinoian glacier. He considers that enough till is present in the glacial material and that the deposits show sufficient decomposition to warrant the interpretation that an ice sheet earlier than Illinoian pushed its way over the highest hills (up to 900' + A. T.) in that part of northern Kentucky, at least. This would be a happy circumstance in view of the presence of many large erratics scattered over parts of northern Kentucky beyond the boundary of the Illinoian ice. Dr. W. R. Jillson, who has reported many of these large boulders<sup>2</sup> has suggested that they were brought into Kentucky by a pre-Illinoian ice sheet, but Dr. Leverett's paper is the first to report boulder clay in Kentucky attributed to an early Pleistocene ice in that state.

It is the opinion of the writer of this paper that the glacial material described by Dr. Leverett and attributed by him to the presence of an ice sheet, is water-laid instead of ice-laid, that it was deposited by flowing water rather than by ice. It is also believed that the outwash which covers most of the high land (above 800' A. T.) in that part of northern Kentucky which appears on the two Cincinnati quadrangles and beyond the border of the Illinoian ice is probably of the same age and origin as that found in the very restricted areas outlined by Dr. Leverett. It is thought that the material was furnished

<sup>1</sup>Leverett, Frank. Kentucky Geological Survey, Series VI, Vol. 31, 1929.

<sup>2</sup>Jillson, W. R. "Glacial Pebbles in Eastern Kentucky," Science, Vol. LX, No. 1544, 1924. "Glaciation in Eastern Kentucky," Pan. Am. Geol., Vol. XLII, 1924. "Early Glaciation in Kentucky," Vol. XLIV, pp. 17-20, 1925. Also Ky. Geol. Sur., Vol. 30, 1927.

by an ice sheet as well as by the northward-flowing rivers of Kentucky and that the record points to a period when the highest hills of that part of Kentucky were covered with water—glacial water from melting ice and river water which flowed into the region and had to flow away. The question of age seems to be a matter of some uncertainty. Certain facts make these deposits appear to be of pre-Illinoian age and other circumstances, as will be discussed later, make them seem more plausibly of Illinoian age.

In the area near Covington, there was seen by Dr. Leverett a 3-4 foot layer of boulder clay and another is reported by the present writer which was 8-10 inches thick, but which disappeared within a few feet laterally as the excavation was continued. Both were underlain and overlain by sand and gravel and surrounded on all sides at like elevation by the same sort of water-laid deposit. Neither had any important areal extent, as will be shown later. There was also noted on the surface at 900' + A. T. a sandstone boulder, perhaps 8 inches long and 5 or 6 inches thick. The boulder clay embedded in gravel is considered insufficient to justify the interpretation that northern Kentucky was overridden by a pre-Illinoian glacier. The one boulder scarcely constitutes a difficulty.

#### DESCRIPTION OF MATERIALS.

The glacial material southwest of Covington, Kentucky, mapped by Dr. Leverett as drift and till of pre-Illinoian age, varies considerably from place to place within a small area. In some places it is chiefly gravel, in others sand and in some places it is largely silt-like in character.

In an exposure where the material is mostly gravel, the pebbles in the upper 20-25 feet are much decomposed, many crumbling easily, and to the same depth the deposit as a whole is of a very dark brown color streaked with black along the cracks. The upper part is quite clayey, probably due to the decomposition of feldspar rocks, and has been used for molder's sand. A few chert and quartz pebbles remain. Lower down the pebbles are more solid and range in size from tiny ones to two or three inches in diameter. Many are undoubtedly of glacial origin. Such a deposit can be seen near Amsterdam road about three-quarters of a mile northeast of Ft. Mitchell. The highest elevation is 900' A. T. by the topographic map and the deposit seems to slope down the

hillside to an elevation of about 820' A. T., where it overlies a fine calcareous sand carrying many cemented masses of sand in concretionary form. It was a few feet above this sand at an elevation of perhaps 840' A. T. that the thin band of boulder clay was seen by the writer. The band of boulder clay seen by Dr. Leverett was about a quarter of a mile south of this point exposed in a street excavation in the same ridge.<sup>3</sup> Dr. Leverett does not recall any other place where boulder clay was seen by him. The street excavation is now somewhat slumped and shows no boulder clay.

It is hardly possible that it was the same lens of boulder clay which was seen in the two exposures, because it does not appear in a deep excavation (perhaps 25 feet vertically) between the two points. Neither band of boulder clay appears in two other exposures (30-40 feet vertically) at like elevation within a quarter of a mile to the east.

At other places at the same elevation (above 800' A. T. and covering the highest hills which are about 900' A. T.) the same dark brown, deeply leached deposit consists of sand, either coarse or fine and showing unmistakably horizontal bedding indicative of water as the agent of deposition. One mile southwest of Covington along the Lexington pike are two such exposures. The material is fine sand in the lower part and coarser sand and gravel toward the top. One exposure shows 32 feet of sand and gravel and is leached of its lime to a depth of 23 feet. The leached portion is very compact and very dark brown except near the surface where the color is grayish. The other exposure is deeper, perhaps 40 feet, but is otherwise identical in appearance. There is nothing in either that could be mistaken for boulder clay and they are within a quarter of a mile east of the ridge where the layers of boulder clay were seen, and at a like elevation.

In Devou Park in Covington, much of the material is very silt-like, but it contains residual pebbles of chert near the surface, and layers of gravel and sand below show it to be water-laid also. The elevation is 860' A. T. by the topographic map and the depth of the exposure is over 40 feet by measurement. It is not fresh enough to give a chance for actual measurement of the depth of leaching. The entire depth seems to be leached, but this is probably deceptive. This exposure

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<sup>3</sup>Report of this location is contained in a private communication from Dr. Leverett.

was referred to formerly as loess,<sup>4</sup> but this view must be abandoned when one considers the sand and gravel present.

It is more or less irrelevant to the subject matter of this paper, but it seems improbable to the writer that any loess exists in the vicinity of Cincinnati, either north or south of the Ohio river. All the silt-like material found on the surface of the glacial mantle seems to contain residual pebbles and to grade downward into regular glacial material where the exposure is deep enough. The pebbles in loess-like material have been referred by some writers to the work of crawfish. This seems to the writer untenable as well as unnecessary. The pebbles are so uniform and constant in their distribution, that one is led to doubt whether crawfish are sufficiently ubiquitous to account for them. At any rate, the decomposition of both gravel and boulder clay would yield a silt-like material near the surface, besides the residual pebbles.

On the weathered surface of all this mantle southwest of Covington, whether the material is mostly fine silt or sand or gravel, there are scattered an abundance of small pebbles. So many of these are of white quartz that one is reminded of the Pennsylvania conglomerate of Kentucky. One would expect that the Kentucky rivers would bring their load into such a ponded area, and to find Kentucky rocks mingled with those from Canada in the resulting deposits. This is probably the explanation. Of course, the quartz pebbles could also have been brought by the ice from the Pennsylvanian conglomerate of Ohio.

In addition to the water-laid material described above which is to be found within the areas marked by Dr. Leverett, there is to be found on most of the upland south of Cincinnati which lies outside the Illinoian ice border deposits of sand and silt, some of it gravelly. The highest level east of the Licking in the east Cincinnati quadrangle is around Cold Springs where the land rises to 880' A. T. by the map. In many places on all this land over 800' in elevation there is to be found sand or sandy silt or fine gravel, all decomposed, all dark brown and all stained to considerable depth with black. This tallies precisely with the major features of the deposits described above which are to be seen west of the Licking river. No deposits have been noted east of the river which are not leached of their lime.

<sup>4</sup>Fenneman, N. M. "Cincinnati and Vicinity," Ohio Geol. Sur. Bulletin 19, 1916, p. 138.

However, no exposure is known to the writer where a sufficient depth is penetrated to find the unleached lower part, if it exists. Dr. Leverett infers on page 13 of his paper<sup>5</sup> that these sands east of the Licking are to be correlated with the Ohio River Formation of Tertiary age, but it seems to the writer that they are to be referred to the same conditions which are responsible for like material at a like elevation and with a like relation to drainage west of the Licking. These deposits, then, are also regarded as a part of the deposit due to Pleistocene flooding. Good examples for study can be found in Ft. Thomas near the intersection of Grand Avenue and Highland Avenue, along the road one mile east of Cold Springs, and near Alexandria, a few miles south of the border of the east Cincinnati quadrangle. It is shown also at many other places along the ridge roads in Campbell County.

West of the Licking river, too, and outside the areas outlined by Dr. Leverett are to be found deposits of brown sand on the high ridges. This can be seen in many places on the high land around Hebron, Kentucky, in the west Cincinnati quadrangle where wells are reported which yield soft water. Since this sand correlates in appearance and elevation with that to the east, it is probably of the same origin.

The sands and gravels here discussed occur generally on high land, usually above the 800' contour. One exception to this rule deserves to be mentioned, where waterlaid deposits in this part of Kentucky occur at about 700' A. T. On the little 700' A. T. hill immediately east of Newport, Kentucky, on the east Cincinnati quadrangle is a leached deposit of fine sand resting on the bed rock. It is about ten feet thick and shows horizontal bedding.

Sand and gravel showing horizontal bedding all over the highest land surface can mean only one thing and that is flowing water at that level, not necessarily and not probably at that great an elevation above sea level. Some sort of flooded condition must have maintained from which the water had to flow away. A melting ice sheet would furnish the proper kind of temporary flood and would furnish the Canadian rocks found in the gravels, while the rivers which naturally flow northward in Kentucky would add their quota to the foreign material brought by the glacier. Of the sand, further study

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<sup>5</sup>Leverett, Frank, *loc. cit.*

may show what part belongs to the northern and what to the southern origin.

If a flooded condition covered the 900' contour south of Covington, it must have covered a wide area in Kentucky and one might expect to find water-laid deposits anywhere that was land surface after the flood receded and from which the material was not washed away either then or later. If the age shall prove to be pre-Illinoian, it is not known to the writer over which divide the accumulated waters discharged. A great area of north central Kentucky is now lower than 900' A. T. If these deposits can be referred to Illinoian time, it is probable that the ponded water was poured through the col at Anderson Ferry.

One mile west of Cold Springs and three-quarters of a mile east of the valley wall of the Licking river is an exposure of boulder clay at the surface which merits attention. The elevation is 840' A. T. by the topographic map and the depth of the exposure is about five feet, though a little less than half of this can be said to be vertical and free from slump. All that can be tested is free of lime. The material is very compact, but neither darker in color nor more decomposed in appearance than ordinary Illinoian boulder clay. The upper part is loosened by decomposition only to a depth of 12 or 18 inches, another circumstance which points toward its being of Illinoian age. There are many small pebbles, chiefly of quartzite and one quartzite was found which was about three inches across. At other places within a mile north of this point on the high level east of the Licking, glacial pebbles were found on the surface in plowed fields. Though this is beyond the border of the Illinoian ice as mapped,<sup>6</sup> it is believed to be of Illinoian age and to occupy a significant position relative to the sand and gravel around Cold Springs.

North of the Ohio river there is to be found some water-laid material on high land covered by till. At Kennedy Heights at an elevation of 840' A. T. coarse water-laid sand is covered with a brown, leached boulder clay. This can be seen well at the end of the Kennedy Heights car line at Kennedy Avenue and Montgomery Road. The boulder clay there is about six feet deep, contains no lime and few pebbles. Two large quartzite boulders were found in place in an excavation about

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<sup>6</sup>Leverett, Frank, *loc. cit.*, p. 15.

ten feet deep. It is not known how much sand there is beneath the till. The excavation showed several feet.

This sand covered with boulder clay probably represents the ice which furnished the gravel for the deposits south of the Ohio which are discussed above. Unfortunately, the depth of the boulder clay is not sufficient for definite conclusions as to its age.

#### DEPTH OF LEACHING IN GLACIAL MATERIALS IN RELATION TO THEIR AGE.

All glacial materials which have traveled across the state of Ohio will have become limy. When exposed to the weathering of rain water, the lime will be leached from the surface downward and the depth to which this leaching has been accomplished is the best indicator of the age, modified naturally by the kind of material. Laminated clays will be least readily penetrated, boulder clay next, and sand and gravel most readily. The depth of leaching, then, will increase in this order for any given length of time.

The great depth of leaching shown in the glacial deposits southwest of Covington in addition to the decomposition of the rocks and the very dark color is the best criterion for recognition of great age.

Wisconsin gravel at Red Bank in the eastern edge of Cincinnati shows a leaching of the lime to a depth of 55 inches and in a kame south of Hamilton, Ohio, the gravel was free of lime to a depth of 46 inches. There is very little gravel of Illinoian age exposed at the surface near Cincinnati. The outwash is in most places covered with boulder clay. However, at Mariemont and Madisonville in the abandoned trough of the Ohio east of Cincinnati are places where gravel and not boulder clay form the top of the deposit. An exposure along the road in Mariemont shows a lens of gravel at the surface with boulder clay on either side of it at the same elevation and all a part of the regular valley fill. It must represent the course of a stream on the ice. In this gravel it was found that the leaching has reached a depth of 14 feet from the surface. The color in the leached zone is dark brown streaked with black and the pebbles are decomposed quite like the deposits south of Covington. However, in the gravel and sand deposits along the Lexington pike, the leaching shows a depth of 23 feet from the surface. Since leaching must proceed more slowly with depth, this

may be a great enough difference to indicate that the age of the Kentucky deposits is pre-Illinoian.

REVIEW OF ILLINOIAN AND WISCONSIN GLACIAL  
HISTORY AT CINCINNATI.

Omitting for the moment consideration of the work of a pre-Illinoian glacier it may be well to review briefly the events of glacial history in northern Kentucky and southern Ohio which are more recent and therefore more clear. The water-laid deposits described above with one exception known to the writer are not lower than 800' A. T., which seems to indicate that the drainage at that time was scarcely lower. After that, presumably, and before Illinoian time, the streams were able to entrench themselves more than 400 feet below this level. Such a deep valley now abandoned and partially filled with glacial deposits can be seen northeast of the city of Cincinnati. It is about two miles wide with a rock floor at about 370' A. T. and with walls rising sharply to 860' or 880' A. T. It was carved, no doubt, by the ancestral Ohio which carried during that time the Scioto and Kanawha drainage. The basin of Cincinnati in some parts and the valley of Mill creek west of the city have a rock floor of equal elevation and must therefore belong to the same period of active stream erosion. These valleys and others were partially filled with Illinoian outwash and boulder clay. This is evident in a definite terrace level along the present Ohio river and in the above-mentioned abandoned valley which is 600' to 660' A. T., the higher level to the north as one would expect. It consists of outwash capped with a variable thickness of boulder clay.

Some valleys east of Cincinnati were filled in the same way to a level of 700' to 720' A. T., as for example the valley of the Little Miami river north of Milford, Ohio, east Cincinnati quadrangle, the valley of East Fork, east of Milford, and the valleys of Dry Run and Cluff creek south of the Little Miami and southwest of Milford. It is not known how widespread this higher terrace is nor just how it correlates with the 600' + A. T., terrace ascribed to Illinoian age.

It has been assumed that the Illinoian ice also overrode the hilltops in the vicinity of Cincinnati and a small area in northern Kentucky, because there is everywhere more or less of glacial material on the highest levels. This is in most places a thin veneer (three or four feet thick) in which case it is entirely



leached of its lime, contains few pebbles and these of chert, quartzite and basalt, and is remarkably silt-like in character. It does not seem to be loess, however, because of the constant occurrence of pebbles. Such a veneer can be seen at many places along the ridge road from Cheviot to Cleves in the west Cincinnati quadrangle. In other places the boulder clay on high levels is thick enough to show the typical Illinoian soil profile<sup>7</sup> with a high content of lime at about four or five feet from the surface. This can be seen, for example, in the C. & O. railroad cut at Summit, one mile south of Westwood, in the west Cincinnati quadrangle or near Crescent Springs, Kentucky, also in the west Cincinnati quadrangle.

It seems certain that it was the Illinoian glacier which obstructed the northward course of the Ohio river at Cincinnati and caused ponded water to cut through minor divides east and west of the present city and so establish the present course of the Ohio from the mouth of the Little Miami river to the mouth of the Big Miami. Such a conclusion seems justified from two lines of evidence, though another fact is hard to explain. Dr. Leverett<sup>8</sup> says that the col at Manchester seems to have been cut through during a pre-Illinoian glaciation and that the great amount of water poured through the channel of the Ohio was able to cut the very deep and very wide valley northeast of the city of Cincinnati. This trenching with abrupt valley walls was accomplished before the advance of the Illinoian glacier. The great width of the valley in contrast to the narrow abandoned curves of the river which originally headed near Manchester preclude the possibility of the former having been cut by the same stream as the latter. But the great amount of ponded waters added to the water of the Kanawha and Scioto systems is another matter and of a magnitude corresponding with the width of the abandoned valley. The lapse of time between the early ice which caused the Manchester divide to be broken and the Illinoian ice which caused the augmented Ohio to abandon its northward course toward Hamilton must have been considerable and the trenching during this time seems to have amounted to 400 feet, at least, near Cincinnati.

Another line of evidence which seems to date definitely this relative order of events along the Ohio river is the occur-

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<sup>7</sup>Leighton, M. M. *Journal of Geology*, Vol. XXXVIII, No. 1. 1930.

<sup>8</sup>Leverett, Frank, *loc. cit.*, p. 26.

rence of water-laid coal and mica in a river terrace in the abandoned valley.<sup>9</sup> The level correlates with the regular glacial filling of the old valley (600' ± A. T.) and the sand in which the coal and mica occur is overlain with the usual capping of boulder clay. The coal and mica must have come from the coal fields of eastern Ohio or Kentucky and the water which brought them must have flowed through the Manchester narrows. The Illinoian ice must have advanced from the north, constituting an obstacle which the water was unable to surmount.

Certain facts are hard to fit into such a picture of past events. The Illinoian glacial fill in the abandoned curve toward Hamilton rises from about 600' A. T. at Cincinnati to 660' A. T. north of Glendale in the Mason, Ohio, quadrangle. At Cincinnati, this is nearly 300 feet lower than the divide at Anderson Ferry, five miles west of Cincinnati, which was broken, presumably, in order to let the ponded water escape to the west. It is difficult to think that such a valley deposit is sufficient record for a front of ice which is to be credited with changing the course of such a great stream and causing its waters to spill over a 900' ± A. T., divide. If a real glacial dam was ever built up in this valley, what has become of it? How could the same glacier be responsible for an orderly valley deposit built of outwash covered with boulder clay, at 600' + A. T., and for the boulder clay on the highest hills near Cincinnati (900' + A. T.)?

As to the absence of the glacial dam, another possibility presents itself. If the stream continued northward at Hamilton, Ohio, as has been stated by Tight and Fowke and Malott, instead of southwestward, as believed by Dr. Leverett and Dr. Fenneman, the dam may be considered to lie north of Hamilton where much of the original topography is, no doubt, covered with drift.

After Illinoian time, a period of trenching followed before the advance of the Wisconsin glacier to within five miles of Cincinnati on the north. All valleys which were low enough to receive it were filled with outwash to a level of 530'–560' A. T.

Since Wisconsin time, the drainage has been carried to a lower level than this outwash, so that both these glacial deposits are to be seen as dissected terraces in most of the big valleys around Cincinnati.

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<sup>9</sup>Brand, L. S. "The Occurrence of Coal and Mica in Pleistocene Deposits near Cincinnati," *Ohio Journal of Science*, Vol. XXXII, 1932.

South of the Ohio river at Cincinnati there are the typical Illinoian deposits in the valleys east of the mouth of the Little Miami river and on the uplands as well, both east and west of the Licking in that area over which the ice advanced. As outlined by Dr. Leverett, this border shows a deep indentation to the north at the mouth of the Licking. As far as known to the writer, there are no alluvial terraces along the Licking river which correlate with the 600' outwash of Illinoian age north of the Ohio river. Such terraces of Wisconsin age are a distinct feature and correlate perfectly with the 530' A. T., Wisconsin outwash level at Cincinnati. The absence of such alluviation during Illinoian time may mean that the Licking was not there then. This opinion was presented by Louis Desjardins of the University of Cincinnati in a paper given before the Kentucky Academy of Science in 1931. It has been assumed by Dr. Leverett and Dr. Fenneman, however, that the Licking flowing northward carved the pre-Illinoian valley directly west of Cincinnati which is now occupied by the Mill creek flowing southward. In that case the valley south of the Ohio river must have been cleared since that time.

#### AGE OF KENTUCKY DEPOSITS.

Definite conclusions concerning the age of the high-level outwash in northern Kentucky probably await further field observations. If one is inclined to consider these deposits as of pre-Illinoian age, certain facts seem to substantiate that position.

1. The Kentucky sands and gravels are leached, decomposed and discolored to a greater depth than those of known Illinoian age also exposed at the surface. The difference appears to be a matter of depth alone, however, as the discoloration, the decomposition of pebbles, and the clayey content in the upper part appear the same in both.

2. The Kentucky deposits are limited to the highest levels. If deep valleys had existed at the time of this deposition, it is difficult to see how later erosion could have been so selective as to leave the material only on the high levels. It is certain that valleys as deep as 370' A. T. had been carved before Illinoian time, because such valleys were filled with Illinoian deposits. Such reasoning would seem to date these high-level sands and gravels as pre-Illinoian and to make them correspond in age with a topography older than the valley sides.

3. As above stated, the deposits under discussion are water-laid and higher than 800' A. T. The Illinoian terrace is also for the most part outwash with an upper limit of 600' = A. T. at its southern edge. It seems inconsistent that two definite levels for water-laid material could have been developed in the same glacial period with a difference in elevation of 200'. It would be more convenient to account for such discordant levels by referring the higher to an older glaciation. And again, if the Illinoian glacier has left a clearly-marked outwash level which is nearly 300 feet lower than the old Anderson Ferry col, as before noted, it is hard to suppose that such waters could have broken the divide. However, the present valley of the Ohio at Anderson Ferry is so narrow and steep-walled that it can not be referred to any very ancient time. If the sands and gravels near Covington are to be correlated in age with the cutting of the Anderson Ferry divide, it would serve to indicate the youth of both rather than the great age of both.

However, there are four more circumstances which should be pointed out in considering the age of these Kentucky deposits. After these considerations are weighed, it seems to the writer not impossible that the high-level sands and gravels near Covington may prove to be of Illinoian age, after all.

1. The deposits are largely sand and it is believed that some of it has been carried a considerable distance by flowing water. Some of it may have flowed south only to be gathered up and carried northward again. Sand that has traveled far would be partially leached, at least, when it was deposited. This may be a factor in accounting for the greater depth of leaching in the sands and gravels in Kentucky than in like material of Illinoian age in Madisonville and Mariemont. Besides, the difference is not as great as one would expect (23 feet in the former and 14 feet in the latter), considering the great length of time which is ascribed to the interglacial period which preceded the Illinoian advance.

2. Drainage would be more perfect, the water table would sink lower, and leaching would proceed faster in gravel or sand on high land than in a like deposit on low land. The Illinoian gravel at Mariemont is not higher than 600' A. T. with the old valley wall rising to 880'-900' A. T. immediately above it. That on the Lexington pike is at an elevation of 900' = A. T., the highest level, thereabout.

3. The ridge of coarse gravel southwest of Covington lies

just where the Licking would have helped build it, if when the Illinoian ice covered the hills to the northeast and to the northwest it had continued to discharge its waters into the re-entrant angle. The angle between the two scallops in the ice border<sup>10</sup> besides the unusual coarseness of the material near the mouth of the Licking suggests this relation. The Anderson Ferry divide must have been almost 900' A. T. and it is the Illinoian flood which is credited with breaking it. Just upstream from this old divide and near the mouth of a strong northward flowing stream (the Licking) is exactly where such coarse waterlaid material would have been lodged before the divide was actually broken.

4. The smaller area of drift mapped by Dr. Leverett as pre-Illinoian (about a mile and a half north of Crescent Springs) and also the high-level sands around Hebron reported in this paper are north of the border of the Illinoian ice. If these sands and gravels are of early Pleistocene age, it is difficult to picture how the Illinoian ice could have overridden such horizontal and unconsolidated beds without either disturbing them or leaving any boulder clay on top. If the water which deposited the sands and gravels be thought of as contemporaneous with the thinning edge of the ice which left the boulder clay, the picture is less confusing. Dr. Leverett says,<sup>11</sup> "It is a singular circumstance that its apparent south limit and that of the Illinoian drift should be so nearly coincident."

#### ROCK BENCHES IN THE VICINITY OF CINCINNATI.

Since the sands and gravels discussed here are restricted to high levels, it probably means that at the time of their deposition only those areas were above the drainage lines, which furnishes a strong inference that their age is pre-Illinoian. If we omit the Newport sand at 700' A. T. which will be referred to again, the deposits described in this paper occur only above 800' A. T. This would indicate that at that time the drainage was relatively over 400' higher than the present major streams.

This level is in accord with the elevation of the highest and most prominent rock bench in the Cincinnati region both north and south of the Ohio river. At a glance over the two Cincinnati quadrangles, one is struck by the flat areas inside terrace-like loops of the 820' or 840' contour. This level is

<sup>10</sup>Leverett, Frank, *loc. cit.*, p. 15.

<sup>11</sup>Leverett, Frank, *loc. cit.*, p. 41.

even more striking in the field. It can be seen well, for example, all over Devou Park west of Covington where the 820' level makes finger-like projections toward the Ohio and Licking river valleys. East of the Licking, too, the valley wall rises steeply to about 840' A. T. where a marked level is apparent. It can also be seen around Dent, three miles northwest of Westwood or along the Ohio river east of the Little Miami river. These last two places are about twenty miles apart, so the level cannot be attributed to any stratigraphic dominance, because the strata rise eastward, at least three or four feet per mile toward the axis of the Cincinnati arch which crosses the Ohio river about 25 miles east of Cincinnati. The Bellevue member of the McMillan formation at Cincinnati has a total thickness of 15 to 25 feet and is not hard to recognize. The level of the top of the Bellevue at the University of Cincinnati is approximately 800' A. T. Near Dent at a distance of eight miles northwestward from the University the base of a Bellevue outcrop was found by aneroid to be 753' A. T. If the measurement was accurate this would show a rise of three or four feet per mile in a southeastward direction. It is probably a little greater in a more nearly eastward direction. This 800'-820' bench is also prominent north of Madeira, near Montgomery, around Reading and in other places in the northern part of the east Cincinnati quadrangle as well as south of the Ohio river in the extreme western part of the west Cincinnati quadrangle. These areas are also separated by as much as twenty miles. Such a level must be older than or of the same age as the Pleistocene water which flooded it and everything higher in this immediate vicinity.

Following this glacial advance which may have been partially responsible for depressing the land surface, there seems to have occurred uplift, possibly due in part to the withdrawal of the load. This causal relation is only a conjecture. The streams evidently entrenched themselves more than 400 feet before the Illinoian advance, but this was accomplished apparently with two interruptions. A second rock bench at about 700' A. T. is too marked to be missed and another at around 600' A. T. is less clear but unmistakably a marker for some sort of halt in rejuvenation.

The level of each of these rock benches correlates so closely with evidence of glacial outwash at that level, that the coincidence may be more than accidental. Uplift may have been

checked or actual depression brought about in each case by the advance of an ice sheet and rejuvenation quickened by uplift as the ice withdrew and its load of water was discharged through old or altered drainage lines. The period of outwash building would be a time when a great volume of water was being handled by the drainage and when a great supply of cutting tools was available.

At any rate a marked rock bench is clear in the field or on the map which is around 700' A. T. and, as said before, there is also a level-topped glacial terrace in the valleys east of Cincinnati which is largely outwash, capped with boulder clay. It is not known to the writer how extended this 700' A. T., glacial terrace may be found to be and it is only conjecture that it bears any relation to a rock bench of that elevation.

The 700' A. T., sand at Newport, mentioned earlier, lies on a rock bench and is probably to be assigned to this time of glacial outwash.

In Cincinnati the suburbs of Clifton, Hyde Park, and Avondale are largely built on a 700'+ A. T. bed rock level and overlooking many valleys are prominent 700'+ A. T. spurs. Near Miamitown in the western part of the west Cincinnati quadrangle are good examples and along the Ohio river near Cleves and Addyston. The long spur extending toward the Ohio river between Ludlow and West Covington is another excellent example.

This relation is suggested again in the correspondence between a less widely developed rock bench at an elevation of about 600' A. T. and the level of the glacial fill in the abandoned valley of the pre-Illinoian Ohio. In both Cincinnati quadrangles it will be found that most of the 600' A. T. loops in the contours represent glacial material, but in several cases these benches are of bed rock. In one case known to the writer, a single topographic bench is in part bed rock and in part sand. It is between Bellevue and Newport, Kentucky, a 600' A. T. spur known as the Spinx subdivision. Just west of the suburb of Clifton in Cincinnati there is a prominent ridge extending northwestward toward Cumminsville which is a bed rock bench with glacial material abutting against it. In West Covington there is a small abandoned oxbow of some earlier drainage which carved its stream bed only as deep as 600' A. T. before it was diverted. There is a 680' A. T. hill between the bed of the oxbow and the Ohio river on the north. At John's

Hill, about two miles south of Newport, is an abandoned tributary valley at 600' A. T. The record of drainage at 600' ± is largely obscured north of the Ohio river by the fact that glacial deposits are of the same elevation. It is possible that this lowest rock bench bears the same relation to the 600' A. T. Illinoian outwash as that outlined above for the 700' A. T. bench.

On the other hand it is possible that the two lower benches were cut during a halt in regional uplift due to other causes and that all the glacial outwash came later and bears no relation to the rock benches. However, if the Lake Champlain region has risen 400 feet since the withdrawal of the ice, presumably in response to the removal of load, it does not seem too fanciful to the writer to suppose that the area around Cincinnati may have had its regional uplift interrupted as above conjectured by advancing and retreating ice.

#### GLACIAL ERRATICS IN KENTUCKY.

Glacial boulders have been reported at many places in northern Kentucky beyond the border of the Illinoian ice, and some of enormous proportions and in baffling topographic positions. Those west of the Licking river are near enough the main drainage lines and low enough in elevation to offer no difficulties in view of the 900' A. T. gravel near Covington. The largest and the highest are those in the district of the knobs and coal fields of eastern Kentucky. This is in an area south of the old divide at Manchester, Ohio, extending into Lewis, Rowan, Carter, Elliot, and Morgan Counties. A particular boulder at Epworth in Lewis County is reported by Dr. Jillson to be 986' above sea level and is estimated to weigh 16 tons. A good many others have been reported in that section at around 850' A. T. One at Farmers in Rowan County weighs about three tons. It is because of these erratics that Dr. Jillson suggested that other evidence of a pre-Illinoian ice sheet in Kentucky might be found, but he reported no boulder clay or other evidence himself.

It seems to the writer of this paper that these erratics, lying as they do just where blocks of ice might have rafted them before the Manchester divide was broken constitute no insurmountable difficulty in the sequence of events. Dr. Leverett thinks the Manchester divide was broken at the time of a pre-Illinoian glaciation by the escape of flooded waters through a col. He thinks, however, that the divide at Man-



chester was not over 850' A. T. and so the Epworth boulder in particular could not have been rafted to its present position. If it was not carried to the knob where it now is by a floating block of ice, then an ice sheet must have been responsible for the work. However, no boulder clay or other evidence of the presence of an ice sheet has been reported for that part of Kentucky. It seems impossible that an ice sheet capable of carrying such enormous boulders could have over-ridden the region without leaving any other record.

The water-laid material at 900' A. T. near Covington reduces to 86 feet the discrepancy between the altitude of the highest boulder and other water-laid deposits along the Ohio river. If the outwash near Covington is of pre-Illinoian age, it seems probable that this region was at a lower altitude at the time of this flooding than at present and that the amount of uplift since that time may have been as much as 400 feet. In such an uplift it would be odd if there were no differential shifting of relative elevations over an area as extended as that with which we are dealing (70-75 miles).

It is, therefore, the opinion of the present writer that it is within the range of possibility for the Epworth boulder to have come past the Manchester narrows in a block of ice and that the position of it and of the others on the eastern knobs appears to be a clue to this explanation. At least until further evidence is produced no one can consider that they have been transported by an ice sheet which seems to have left no boulder clay either on the hills or in the valleys. If it is there, we ought to find it.

#### CONCLUSIONS.

Most of the conclusions in this paper are qualified with alternative possibilities and may be altered after further observations. It has been thought not unprofitable, however, to add the field observations to those reported for the region with the recognition that much more field work is needed before a satisfactory chronology of events can be certain.

1. It is believed by the writer that evidence of a pre-Illinoian ice sheet in northern Kentucky is still lacking—that the glacial material on the uplands south of Cincinnati is water-laid and not icelaid. It seems clear that the material was furnished by an ice sheet (Illinoian or pre-Illinoian) and also by the northward flowing rivers of Kentucky.

2. The sand and sand-and-gravel deposits which occur on most of the land surfaces which are higher than 800' A. T. in the part of Kentucky which appears on the two Cincinnati quadrangles are thought to correlate in age and manner of deposition. It is thought that all these deposits covering a considerable area are to be referred to Pleistocene damming and that the deposits mapped by Dr. Leverett southwest of Covington are only a part of a more extended area of deposition.

3. The small amount of boulder clay seen imbedded in 30-40 foot deposits of gravel southwest of Covington is thought to have been rafted to its position by water also. The boulder clay is thought to have insufficient areal extent to be significant and entirely too little either vertically or horizontally to represent the spread of an ice sheet.

4. The silt-like material in Devou Park near Covington is reported to have gravel and sand layers and to contain many residual pebbles. It is believed that neither it nor any other deposit near Cincinnati can be called loess. The great numbers of residual pebbles which all the loess-like silt contains seem to preclude wind as the agent of deposition. It is thought to be due to the decomposition of glacial material into which it grades downward.

5. Waterlaid sand at 840' A. T. at Kennedy Heights overlain by a decomposed boulder clay is reported.

6. A glacial terrace is reported which is 700'-720' A. T. instead of 600'-660' A. T. as in the abandoned valley of the old Ohio. Both terraces consist largely of waterlaid material in the lower part, covered with boulder clay. The higher terrace occupies the valleys of the Little Miami and the East Fork, north and east of Milford, Ohio, and the valleys of Dry Run and Cluff creek south of Milford.

7. Three rock benches are reported for this region which show a striking correspondence in elevation with three known stages of glacial outwash. The 820'-840' A. T. bench is at the same elevation as the lower limit of the old-looking outwash in northern Kentucky. The 700'-720' A. T. bench corresponds with the level of the higher glacial (Illinoian?) terrace referred to above and the 600' A. T. bench which is less well developed is at the same level as the top of the Illinoian outwash in the southern part of the abandoned river valleys near Cincinnati. It is suggested that the advance and withdrawal of the load of ice may have had something to do with the halt and renewal

of stream erosion, besides furnishing a great volume of water heavily loaded with tools to do the cutting. An uplift of 400'  $\pm$  seems to have occurred between the earlier flooding and the Illinoian advance.

8. If the Manchester divide was broken in pre-Illinoian time, as Dr. Leverett thinks, by the escape of ponded waters, it seems not impossible that the large erratics which are to be found south and a little east were carried to their present position by floating ice blocks. It is suggested that the uplift which followed may have been somewhat differential and that relative elevations have been altered. At least the evidence for an ice sheet seems to be missing.

9. Depth of leaching in gravels of Wisconsin and Illinoian age are reported and also for the glacial material southwest of Covington. The figures are about 4 feet, 14 feet, and 23 feet respectively. One would like the last figure to be larger to make the deposits in northern Kentucky more convincingly ancient. It is suggested that their position would fit the conditions which must have existed in Illinoian time, and that they may, after all, prove to be of Illinoian age. Certainty as to their age seems to depend upon further field observations.

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