DEPARTMENT OF THE INTERIOR

BULLETIN

OF THE

UNITED STATES

GEOLOGICAL SURVEY

No. 58

WASHINGTON
GOVERNMENT PRINTING OFFICE
1890

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

THE GLACIAL BOUNDARY

IN

WESTERN PENNSYLVANIA, OHIO, KENTUCKY, INDIANA, AND ILLINOIS

BY

GEORGE FREDERICK WRIGHT

WITH AN INTRODUCTION BY THOMAS CHROWDER CHAMBERLIN

WASHINGTON

GOVERNMENT PRINTING OFFICE

1890

CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF GLACIAL GEOLOGY,
Washington, D. C., May 23, 1889.

SIR: I have the honor to transmit herewith for publication as a bulletin of the Survey a paper prepared by Prof. G. Frederick Wright on the glacial boundary in western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois, to which I have prefixed an introduction reviewing certain questions of wide interest and debatable interpretation.

Very respectfully,

T. C. CHAMBERLIN,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

INTRODUCTION.

By T. C. Chamberlin.

The following paper is one of a series of important contributions to glacial geology, issued under different auspices, whose objects are to set forth the extent of the northern ice-borne drift with greater precision and detail than have been before practicable. In a general sense, the extent of the drift of the Atlantic border region and of the interior has long been known, but more or less lack of precision respecting its limits and marginal character has prevailed. In the western part of our territory definite knowledge has been much more limited and misconceptions of some gravity have obtained. No other state of knowledge was to be expected in view of the vast stretch of territory involved and the multiplicity of broad questions forced upon the attention of the earlier geological surveys, whose functions were rather to determine the salient features of a score of diverse formations than to trace out into complete detail any selected one. But about a decade ago (1876) a movement in the direction of more careful delineation of the outer margin of the drift was initiated by Profs. George H. Cook and John C. Smock, of the New Jersey Survey, and this was followed, at short intervals, by similar work on the southern border of New England by Warren Upham and other volunteers; across Pennsylvania by Profs. H. C. Lewis and G. F. Wright, under the auspices of the Geological Survey of that State; and across Ohio and Indiana by Prof. Wright, through the aid of the Western Reserve Historical Society. The present bulletin includes the extension of this work of delimitation to the Mississippi River, under the auspices of the U. S. Geological Survey. West of the Mississippi considerable progress has been made by Profs. R. D. Salisbury, J. E. Todd, and myself in delimiting the northern drift and determining the character of its border, but the details yet await publication. In the main the consecutive tracing of the border of the drift has not been attempted in that region, but determinations have been made at frequent intervals along the margin in connection with other work, deemed, at the present stage, more important.

All those who have been engaged in these recent and more careful studies of the border of the drift, though they have come to the study from different associations and under different auspices, have given

assent in greater or less measure to the doctrine of the glacial origin of the drift, and have employed its working hypotheses. All are not, however, equally exclusive in their employment of these hypotheses. At present a portion of the investigators incline to the view that all the marginal deposits, save, obviously, the water-washed gravels, sands, and clays, are of direct glacial deposition, while others are undecided respecting *certain portions*, doubting whether they were deposited directly by land ice or indirectly by floating ice in bodies of water marginal to the great ice field.

There are also important differences of view respecting the unity of the marginal deposits and the continuity of the history of glaciation. Some of the investigators appear to give adhesion to the belief that the entire margin was produced at practically the same time and by the same great field of ice, while others entertain the confident belief that different portions of the margin were produced at different times and by independent ice invasions, or, at least, ice advances. These divergences of belief and these withholdings of belief constitute a wholesome intellectual environment which it is not desirable should be replaced by complete unity of interpretation until such unity shall be compelled by the force of evidence. It is essential, however, to its wholesomeness that the fact and the nature of the divergences should be distinctly understood wherever confusion or misapprehension are liable to be introduced into the literature of the subject, and wherever the general reader, who has not traced critically the growth of opinion, may otherwise be misled.

Certain of these divergences of view and certain more specific differences of opinion, to which attention will presently be called, exist between the author of this paper and myself, in view of which Prof. Wright in transmitting this paper indicated that it would cause him no surprise if I should express dissent from some of the views advocated in this bulletin. It seems to me consonant, therefore, with a full appreciation of the obviously great value of the data here presented, to call attention to certain points of divergent interpretation.

The first difference of opinion springs from the marked diversities which the character of the drift border presents.[1] In the Atlantic and Appalachian regions the margin is generally marked by ridged accumulations, bearing the specific characters of a terminal moraine, whereas in the Mississippi Valley and on the plains west of it the drift ends in a thin margin, unmarked by specific terminal ridging. The bordering

[1] The diverse characters of the drift margin appear to have been first clearly distinguished on the border of the driftless region of the Upper Mississippi, and were specifically discussed by my associate, Prof. R. D. Salisbury, before the Wisconsin Academy of Science in 1884, who set forth the contrasted facts that along certain stretches the margin consists of thick-ridged accumulations, constituting definite terminal moraines, while along other stretches the drift ends in attenuated edges. The subject is more fully brought out in our joint paper on the driftless area of the upper Mississippi Valley, in the Sixth Annual Report of the U. S. Geological Survey.

moraine at the east departs from the extreme limit of drift, according to our present knowledge, as I interpret it, in western Pennsylvania. There the outermost moraine[1] lies a few miles back from the limit of drift, the extreme edge being formed of thinly dispersed erratics. Westward from this there is a wider departure of the two, and in the immediate valley of the Mississippi the terminal moraines thus far identified lie remote from the border. I have elsewhere assigned reasons for believing that these are the essential equivalents of the ridges which lie along the border in the Atlantic region. However this may be, I entertain the view that the drift sheets of the interior which terminate in attenuated borders—and I hold that there are more than one of these—are more ancient than the drift which terminates in the recognized ridged moraines. I conceive that these differently disposed drifts indicate somewhat widely separated epochs of glaciation, attended by differences of orographic attitude and differences in the specific methods of action and in the phases of deposition.

If there be any truth in these views it becomes important to distinguish the differences in the character of the border, for they have significance beyond the mere fact of variation in the manner of deposition. While not disposed to urge the acceptance of these views beyond the point to which they seem to be borne out by specific evidence—which can not, obviously, be here cited—it seems important that the differences in the nature of the border be duly weighed, and that pending the demonstration of the truth the mind of the reader be withheld from the unconscious acceptance of the impression, which has somewhat obtained, that the border is a historical unity.

Respecting the question of mode of formation it is most important that the criteria of discrimination between deposits held to be formed directly by land ice and those held to be formed by floating ice should be rigorously scrutinized. The criterion of *striation*, as urged by the author of this bulletin, appears to me to be thoroughly trustworthy where the scorings are developed in sufficient abundance and perfection to afford ample facilities for discrimination. In the Atlantic and Appalachian regions and over large portions of the interior the phenomena of *striation* are adequate and decisive, but near the border, in the plain region of the interior, striation is relatively rare and feeble. Besides, there are very numerous instances of unabraded, rotten-surfaced rock, covered with the ancient residuary material, and even old soils remain unremoved. This appears to force the alternative of either dismissing the land-ice theory for these areas or of maintaining that land ice may creep over extensive tracts without forcefully abrading the surface, even when already incoherent from disintegration. While I incline to the latter alternative somewhat strongly, it appears to me to be in the interest of ultimate progress to distinctly recognize the differences between such areas of feeble abrasion and those which exhibit

[1] Using the word here only in the sense of a terminal *ridging* produced by a glacier.

strong glacial rasping, and also to recognize that while the land-ice hypothesis is unassailable in the one region, its support is relatively weak and perhaps altogether insufficient in some portions of the other; and further to recognize that while the glacial theory may be true in the main it may be false in the particular.

The evidence afforded by the tills seems to me yet to need adjudication. While, generally, unassorted, unstratified bowlder clays are strong presumptive evidence of glacier origin, there seems yet to be reason to believe that almost precisely similar deposits may be produced by the droppings of floating ice. Certainly the presence of glaciated pebbles and bowlders is not distinctive, for floating ice derived from the edge of an adjacent or distant glacier would bear material precisely like that carried within the glacier itself. That it might be unstratified in its deposition appears to be supported both by theoretical considerations and by observations on deposits which are so sandwiched between assorted and laminated material, so graduated into such material, and so bordered by beach lines and surfaced by plane topography as to afford strong evidence of glacio-natant origin. Having, without much satisfaction, puzzled over the problem for several years in the endeavor to find trustworthy lines of discrimination between bowldery clays of glacier and of glacio-natant origin, respectively, I am inclined to regard this line of proof as of doubtful character in its general application, though the specific nature of individual deposits may disclose their origin with reasonable certainty.

Evidence drawn from the topographic relations of the margin of the drift is of the first order of importance. In the present case the undulations of the margin over heights and across valleys constitute the strongest feature of the evidence. The free manner in which the border line rises and falls in crossing the Appalachian Mountains and the bordering hilly districts is scarcely less than demonstrative in itself. In the plainer regions of the Mississippi Basin similar evidence, though less pronounced in character, carries corresponding weight. Relying chiefly on this argument, a qualified assent seems required to the view of Prof. Wright that the extent of the ice was essentially coterminous with the extent of the drift.

Other criteria of discrimination between the products of land ice and of floating ice, respectively, are assignable. Among these the peculiar character of the products of drainage, particularly the overwash aprons and the moraine-headed gravel trains, have the highest value. Where these are strong and sharply developed, nothing can be more convincing of glacier origin, and nothing more fatal to the glacio-natant hypotheses. But if phenomena of this class are clearly developed in the debatable territory, they have not been determined with sufficient definiteness to be a source of appeal. On the contrary, the most notable attendant phenomenon is the loess-like silt that overspreads the margin and the adjacent regions, both within and without the border The graduation

of this into the till of these districts—*not everywhere*—I esteem one of those features which demand a conservative attitude respecting the part played by creeping ice and by floating ice, respectively.

As a check in the opposite direction, it is to be noted that there is, thus far, a lack of evidence of shore lines, or of definite horizontal limitations of the supposed subaqueous products, such as might reasonably be expected under the hypothesis of subaqueous deposition.

While, therefore, on the whole, the evidence seems to me quite strongly to support the view advocated in this paper, that the advance of the land ice was essentially coincident with the margin of the bowldery drift, such a view seems tenable only on the hypothesis that the land ice was competent to creep out upon a plain without forceful action upon it, and without notably plowing up material at its edge.

This seemingly necessary qualification respecting the marginal action of the ice must be carried with us as we turn to the consideration of the supposed glacial dam in the vicinity of Cincinnati. I assent to the view of Prof. Wright and of the earlier students of the drift south of the Ohio River, notably Dr. George Sutton,[1] that the ice sheet probably pushed across the river and landed the bowldery drift south of it essentially in its present position. But there is a lack of evidence that this involved forceful or vigorous action, for striation and abrasion have not been detected, and the amount of transported drift is trivial. The glacial action here appears to have belonged to the ineffective class above alluded to. *The fact, therefore, that the ice bridged the chasm of the Ohio does not necessarily carry with it the view that it blocked that chasm to the exclusion of the river.* It does not follow that there was a permanent glacial dam at that point, competent to backset the water to the height of the five or six hundred feet requisite to give it some other outlet. It may be admitted as extremely probable that the temporary damming of the stream by ice gorges was of frequent occurrence, and still be held that, in the main, the water maintained a tunnel under the overbridging ice. Such tunnels are not uncommon beneath existing Alpine glaciers, where they push across the mouth of tributary valleys. There is a wide distinction to be drawn between the obstruction caused by the thin extremity of a glacier creeping across the channel of a stream, and those instances (so numerous on the northward slopes during the later stages of glaciation) in which an enormous mass of thick ice, if not the great body of the glacier itself, pushed against the ponded waters. The Mergelen Lake, of Switzerland, is one of the few known instances of an ice-dam and body of water of the former order, and we have in it some indication of the competency of ice to act as a permanent dam under such conditions. The great Aletsch Glacier flows across the mouth of a tributary valley and dams back a brook, forming a little lake, to which the name Mergelen See is given. The glacier extends past the mouth of the tribu-

[1] Proc. Am. Assoc. Adv. Sci., 1876, pp. 225-231; Geol. Survey Indiana, 1878, pp. 108-113.

tary about 9,500 meters, and proves itself competent to form a temporary dam, but not a permanent one, though the depth of the backset water is here only about fifty feet. This comparatively slight depth of water, giving a pressure of little more than an atmosphere and a half, periodically bursts its way out beneath the ice, and discharges itself in destructive floods down the valley. In the supposed ice-dam at Cincinnati, the pressure reached, by hypothesis, sixteen or seventeen atmospheres, or about two hundred and fifty pounds to the square inch, while the ice reached across the gorge scarcely more than twice the distance that the Aletsch Glacier passed beyond the mouth of the valley in which the Mergelen Lake lies.

Besides the great difference in the depth of water, there is the important fact that the Ohio Valley at all times bore a stream of great volume. In proportion as the ice encroached upon its channel, its current must have been accelerated, and its scouring ability increased, and with that arose an increased tendency to cut for itself a special narrow and deep channel less readily invaded by ice. Besides, the current must have been charged with sharp silt, derived from the glacial grinding on the north side of its basin, while the water from its southern side probably at all times retained some melting power, which, added to the heat of friction developed by the constricted and forced current, augmented its ice-cutting power and aided it in maintaining itself against the ice encroachment. Its situation in the bottom of a deep gorge, running transverse to the ice movement, and lying from four to six hundred feet below the plateau on which the overriding ice chiefly rested, also gave it an advantage in maintaining itself against the thin and relatively inert margin of the ice. Thus several conditions favored the stream in its struggle with the supposed encroaching glacier.

There would, however, seem to have been every requisite condition for the formation of gigantic ice-gorges at the time of the vernal breaking up of the river ice, and on other favoring occasions. But as soon as such an ice-gorge becomes an effective ice-dam, if it ever does—which is doubtful—it destroys the conditions of its own creation; first, by stopping the current that produced it and held it in place; and, secondly, by lifting the ice by the rise of the ponded water. It seems improbable that a lake so ponded would rise to a height of five or six hundred feet without lifting such a dam of blocks piecemeal, or even bodily. Certainly, with the known tendency of solid ice to form bergs, it could not be supposed to remain long.

But, as a matter of fact, it would probably never become a complete dam, and would soon be threaded by innumerable tunnels, whose gradual enlargement would lead to its destruction. Meanwhile, the escaping waters, though greatly reduced, might still be able to maintain a tunnel under the glacier, which, though it might be correspondingly reduced by the encroachment of the ice, would again be enlarged by the

powerful current forced through it when the ice-gorge weakened or lifted.

It appears far from clear, therefore, that the existence of a permanent ice-dam was a necessary or even probable consequence of the slight crossing of the gorge by the glacier. Temporary and partial blocking I should deem an extremely probable and frequent occurrence, but not a permanent damming.

I am perhaps influenced in this view by a study of another region where the similar question of glacial damming has arisen. I refer to the driftless area of the upper Mississippi, which is surrounded on all sides by a deep sheet of drift. On the south, along the Mississippi, which was its drainage outlet, the country is occupied by drift for 250 miles; not merely a sprinkling of dispersed bowlders with exceptional patches of till, as in the trans-Ohio region, but a general mantle of drift. The driftless area has been diligently searched for evidence of temporary as well as permanent submersion. Along the western border there are scattered erratics and a mantle of loess, but over the central and eastern portions erratics are absent, except in extremely rare instances of probably human transportation. There is a very thin discontinuous distribution of fine silt mingled with the residuary soil and only distinguishable from it in most cases by the microscopic detection of minute particles of crystalline silicates and other minerals which are common to the drift and loess but not known to occur in the purely residuary soil. These foreign particles may, perchance, be wind-drift importations, or they may be the results of transient submersion; such a submersion as was possibly due to the temporary blocking of the outlet by ice. The distribution of the loess, however, does not form an argument for this view, for it spreads over the drift southward, reaching entirely across the glaciated tract. Whatever may be the truth respecting these trivial silt deposits, there has been found no proof of general and permanent submersion of this region by ice-damming, notwithstanding the conditions seem to have been exceptionally favorable therefor, and notwithstanding the further fact that the depth of water requisite for the submersion of most of the area is less than that postulated for the supposed Cincinnati dam.

But these theoretical considerations are less to our present purpose than a consideration of the direct evidences of the existence or non-existence of an effective blockade of the river at that point. Among the crucial tests of such a hypothesis may be enumerated the existence of lacustrine deposits and high shore-marks in the valley above, *but not below*. In an ideal case such lacustrine deposits and shore-marks should be present immediately above the dam, but not present within the area occupied by the dam nor immediately below. Terraces and supposed lacustrine deposits two or three hundred miles above are less conclusive, because of the possibility of intervening agencies.

A second crucial test of the hypothesis is to be found in the existence or

non-existence of the abandoned channel through which the supposed ponded waters discharged themselves. It must be quite evident, upon consideration, that the ponded waters could not have had a permanent outlet across the ice itself, for such a stream as the Ohio, fed during the summer season with relatively warm waters from the southern half of its large basin, must quickly have cut a channel through the barrier. As yet no such outlet has been found, or, at least, determined to be such, and the hypothesis lacks this very important support.

These considerations lead up to the much discussed terraces of the upper Ohio, Monongahela, and Alleghany valleys, which have been thought by Professors Wright, White, and Lesley to have had their cause in the supposed ice-dam, and in turn to afford evidence of its existence. As a widely different interpretation of the origin of the chief terraces of these streams seems to me required, it is the part of candor to specifically set forth this divergence of view in transmitting this bulletin to the scientific public.

I look upon the determination of the origin of these terraces as chiefly a question of identification of structural species, quite analogous to the identification of species of plants and animals. Terraces formed by bodies of standing water are specifically different from those formed by flowing water, and the question here is, Have these terraces the inherent characters of lake and sea terraces or those of river terraces? The following are among the specific differences which should enable us to distinguish the class to which they belong. They are drawn with special reference to terraces in a system of branching, narrow valleys, as in the case in hand. They would require some amplifications and qualifications for a different habitat.

Lacustrine terraces are horizontal, while fluvial terraces slope in the direction of the river flow. In the case of terraces formed by rivers that have nearly reached their base plains the slope is obviously slight, but the basis for discrimination still remains. The intervention of crust movements may obscure, but can scarcely obliterate, the distinction, for in a system of tortuous and branched valleys, as in the present case, the system bears in itself the data for the elimination of the distortion.

Limiting attention for the moment to constructive terraces, it is the rule that lacustrine terraces are built throughout the entire circuit of the lake, while fluvial terraces are built only in favoring lodgment spots, as the concave bends of the meandering stream. The tendency in the one is to uniformity of distribution; in the other to local aggregation. Both tendencies are subject to important modifications, but these modifications are likewise distinctive. The two more important modifications are caused by (1) the difference in the extent of the sweep of the waves, and (2) by the material brought in by tributaries.

(1) Other things being equal, lacustrine terraces (whether wave-cut terraces or wave-built terraces) are greatest opposite the longest sweep

of the waves, and, the sweep being equal, are greatest opposite the sweep of predominant winds. The strength of development of lacustrine terraces corresponds, therefore, to the stretch of water opposite to them and to their relation to prevailing winds. In river terraces wind action is overshadowed by other agencies, and the above correspondences are wanting. The more extensive the series of terraces and the more varied their positions relative to the extent of water surface and to the direction of winds the more pronounced these distinctions.

(2) Tributary streams and ravines, by pouring in detritus, form local enlargements of the terraces of lakes, and usually also of rivers, but the special disposal of the material is different in the two cases. In a lake a delta terrace is formed symmetrically about the entrance of the tributary—subject to the accidents of the situation—the material fanning out equally to the right and to the left and being thrust out in front into the lake by the force of the entering stream. In a river the material thrown in by a tributary is carried down stream and may be entirely borne away. In any active river the formation of the delta is checked on the upper and front sides and its growth directed down stream in a more or less bar-like fashion.

(3) In the lacustrine class, the wave-cut terrace, the sea cliff, and the wave-built terrace are situated together, the material for building the last being derived from the erosion of the others. On the other hand, the river-cut cliff is usually at the convexity of the river bend or at least at some point where it impinges on the adjacent highland; while the correlative river-built terrace is in the concavity of the bend below, or at least in some suitable lodgment spot, invariably down stream.

(4) The material of lake terraces is usually different from that of river terraces. In narrow land-locked lakes very little attrition of shore material is possible, and the terraces either consist of fine material or of little-worn rock fragments. Moreover, the little wearing observed is of the beach order rather than that of stream-rolling. On the other hand, the material of river terraces is stream-rolled and current-assorted alluvium. This distinction fades out in proportion as the river, by the slackness of its stream, approaches stagnant, lake-like conditions.

The foregoing statements have reference to temporary lakes occupying river valleys for a limited time, and so merely developing terraces along their slopes, but not filling up their beds. If the entire bed was filled up, and the terraces, instead of being formed directly by the lake or stream, were carved out by subsequent erosion and the question becomes one of deposition and marginal erosion, and not of terrace formation, some of the above criteria become inapplicable while others gain in force. The evidence from cliffs and rock shelves becomes stronger because in the longer lapse of time involved the differences between the laws of lake-cliff formation and of river-cliff formation more fully expressed themselves.

So, also, the distinction of material becomes more pronounced; for as

the filling of a lake progresses it retires from the bordering slopes and isolates itself in its own deposits, and the material becomes more and more distinctive and more fully assumes the lacustrine phase of assortment and lacustrine habit of stratification and thus distinguishes itself from fluvial deposits.

These statements of criteria lack both in fullness and in qualification. The distinctions will not always be sustained in a rigid application, under all conditions and in every local instance. Absolute and invariable distinctions will not be expected by experienced students of nature. But these criteria hold good in the main, and in the present instance they are regarded as entirely decisive.

TERRACES OF THE UPPER OHIO RIVER DISTRICT.

With a view to some preliminary determinations having bearings upon the crust changes, time relations, and drainage conditions of later Tertiary and of Quaternary times, Mr. G. K. Gilbert and myself spent twenty days in the fall of 1885 in a joint reconnaissance of the terraces and related phenomena of the Monongahela, Alleghany, Upper Ohio, and tributary valleys. Mr. Gilbert, as geologist in charge of the Appalachian division of the survey, approached the subject in search of light upon the former attitudes of the surface and possible orographic changes, and brought to the study a large experience and an acknowledged acumen in the analysis and interpretation of fluvial and lacustrine phenomena. My own approach was from the glacial side. Our impressions throughout were in the closest harmony, and I have Mr. Gilbert's assent to the views involved in the following statements:

The terraces of the upper Ohio River district embrace five classes, viz:

1. The high horizontal benches of Stevenson.
2. The upper river terraces.
3. The lower river terraces.
4. The slender horizontal terraces.
5. The structural or differential degradation terraces.

Discussion has previously related chiefly to the second class.

I. THE HIGH HORIZONTAL TERRACES.

These, so far as I am aware, were first described by Prof. J. J. Stevenson, from the résumé of whose observations[1] the following quotations are taken:

Looking now at the observations recorded in the foregoing part of this paper, we see that, although very fragmentary, they show the existence of two sets of benches, in one of which, the higher, the individuals have an almost unvarying level, whereas

[1] Proc. Am. Philos. Soc., vol. 18, 1880, p. 302, 303. Also Second Geol. Survey, Pennsylvania, KKK (Report of progress in the Fayette and Westmoreland district, Part II, the Ligonier Valley), 1878, p. 260.

in the other or lower set the members have no definite altitude with respect to tide, but vary much, as do the beds of the streams along which they are found. Arranged in tabular form we have, first, the benches of the higher series:

	Feet above tide.
1. Chestnut Ridge, Seaton Road	2,580
2. Chestnut Ridge, National Road	2,400
3. Top bench of Somerset County	2,323
4. Middle bench of Somerset County	2,288
5. Bottom bench of Somerset County	2,123
6. Bench near Confluence	1,820
7. Sixth bench near Loyalhanna	1,690
8. Fifth bench near Loyalhanna	1,570
9. Fourth bench near Loyalhanna	1,520
10. Third bench near Loyalhanna, also at Hillsborough and Beallsville	1,475
11. National Road, Washington County	1,445
12. National Road, Washington County	1,420
13. Second Loyalhanna bench, also National Road near Beallsville and Hillsborough	1,380
14. National Road east from Brownsville	1,350
15. Tenth bench of Stewartstown series	1,290
16. Intermediate bench, Dunbar Creek, Possum Creek, Greensburgh	1,270
17. Ninth bench of Stewartstown series, First Loyalhanna bench	1,225 to 1,240
18. Eighth bench of Stewartstown series	1,195
19. Seventh bench of Stewartstown series	1,130
20. Sixth bench of Stewartstown series	1,100

The elevation of low water at Pittsburgh, as used by the city surveyor's office, is 699 feet above mean tide. * * *

The variations in level exhibited in individual benches of this series are so slight that they may be due either to petty variations of the barometer, or to errors in reading it, or to the fact that, in every case, the highest point on the bench was sought, so as to determine the top of the detrital deposit. As that deposit, though very thin, has suffered more or less from erosion, one could not, even with perfect instruments, obtain a series of measurements which would tally accurately. The extreme of variation, even in No. 17, where two benches are confounded, is scarcely 18 feet, so that one is fairly justified in regarding the benches as practically horizontal and parallel.

The deposit on these branches sometimes contains a little clay, but sand greatly predominates. No rolled or polished fragments of stone occur, and such fragments as are present belong altogether to rocks found in the immediate vicinity. Nothing shows that running water had ever passed over those plains, so that if the water were in motion its effects must have been confined within a limited space.

Typical portions of these terraces were examined by Mr. Gilbert and myself, but not with sufficient detail nor over a sufficient extent of ground to justify us in publishing any opinion regarding them, especially as it does not concern us here; for, if I have not altogether misunderstood the advocates of the Cincinnati ice-dam, this series of terraces is not included among those ascribed to that agency—indeed, this series has not, I think, even been alluded to in the papers on that subject.

Manifestly there are insuperable objections to such reference, for, in the first place, the lowest of these is higher than the summit of the supposed dam, and, in the second place, the vertical range of the series itself is twice that of the ice obstruction. A series of terraces reaching

from 1,100 feet to 2,580 feet above tide could not rationally be referred to an ice-dam ranging from 440 feet (low water in the Ohio at Cincinnati) to 950 or 1,000 feet above tide. A dam of 500 feet would scarcely make a series of terraces having a vertical range of 1,430 feet.

II. THE HIGHER RIVER TERRACES.

These have been described and discussed, either locally or areally, by Prof. J. J. Stevenson,[1] Prof. I. C. White,[2] Prof. J. P. Lesley,[3] Mr. H. Martyn Chance[4] and Prof. G. F. Wright.[5] The whole system has not yet, however, been thoroughly examined, and a complete and entirely satisfactory discussion is not yet possible, but the leading features are determinable. The term "river terraces" was applied to these by Professor Stevenson, and indicates the interpretation which he placed upon them. A similar view was evidently entertained by Mr. Chance for the portion which he has described. In this view we also concur, and hence retain the name. It seems necessary, however, to distinguish these from a lower series of river terraces of separate origin and history. Among the distinguishing characteristics of the higher river terraces are the following:

(1) *They slope with the present streams.*—This tendency is well expressed by Stevenson:

> The river terraces fall down stream and are covered by irregularly bedded sand, clay, or gravel, containing transported fragments, which have been rounded by the action of running water. When followed up the streams these terraces show differences among themselves in degree of slope, so that each is merged successively into the next higher, until that which at the mouth of the stream is the river "bottom" becomes the only terrace, and is lost at last in one of the lower horizontal benches.[6]

In the following table an attempt has been made to collect all observations at command relative to the chief upper terrace of this series on the Monongahela River, and also the uppermost limit of pebbles, as these constitute the most trustworthy and significant data:

---

[1] Second Geol. Survey Pennsylvania, K, Green and Washington Dist., 1876, pp. 11–19; KKK (Ligonier Valley), 1878, pp. 251–263; Proc. Am. Philos. Soc., Phila., vol. 18, 1880, pp. 289–316; Am. Jour. Sci., 3d series, vol. 15, 1878, pp. 245–250.

[2] Second Geol. Survey Pennsylvania, Q, Beaver River Dist., 1878, pp. 9–14; also, QQ, 1879, p. 10–12; Proc. Am. Assoc. Adv. Sci., thirty-second (Minneapolis) meeting, 1883, pp. 212, 213, and Science, vol. 2, 1883, pp. 319, 320.

[3] Second Geol. Survey Pennsylvania, Q, 1878, pp. xxiv, xli.

[4] Second Geol. Survey Pennsylvania, VV, Clarion County, 1880, pp. 17–21.

[5] Boston Soc. Nat. Hist., 1887; Am. Naturalist, vol. 18, 1884; Am. Jour. Sci.

[6] Stevenson: Proc. Am. Philos. Soc., vol. 18, 1880, p. 314.

Table of observations on the upper pebble-bearing terraces and upper observed limit of pebbles on the Monongahela River, given in descending order.

Locality.	Upper pebble-bearing terrace.		Upper observed limit of pebbles.		Observer.
	Above river.	Above tide.	Above river.	Above tide.	
	Feet.	*Feet.*	*Feet.*	*Feet.*	
Morgantown, W. Va	275	1,065	.....	.....	I. C. White.
Between State line and Georges Creek	280	1,055	.....	.....	J. J. Stevenson.
Greensborough	275	1,050	.....	.....	Do.
Mouth of Muddy Creek	260	1,025	.....	.....	Do.
Carmichaels (abandoned channel)	250	1,015	.....	.....	White.
Pumpkin run	300	1,063	.....	.....	Stevenson.
Brownsville (2 miles above)	230	970	250	990	Chamberlin.
California (1 mile above village)	180	920	215	955	Gilbert.
Opposite Wood's run (sloping shoulder)	180	920	200	940	Gilbert and Chamberlin.
Old Troytown	180	920	195	935	Do.
Fayette City (back of)	180	920	200	940	Do.
Between Fayette City and Belle Vernon (abandoned channel—oxbow).	200	940	.....	.....	Do.
One mile back of Belle Vernon (abandoned channel).	195	935	220	960	Chamberlin.
Opposite Belle Vernon	180	940	185	945	Gilbert.
Belle Vernon	180	940	.....	.....	Stevenson.
Monongahela Cemetery	190	920	200	930	Gilbert and Chamberlin.
West Elizabeth	185	905	210	930	Do.
McKeesport	190	910	205	925	Do.

The grouping of the terraces in this way is not intended as a mode of assertion that they form a single simple series. Under the view that they are river terraces it is by no means necessary to suppose that they are strictly equivalent to one another. On the contrary, it is rather the habit of streams to form different sets of terraces along their course as the result of the unequal resistance of the strata, of the modifying effects of tributaries, and of other agencies which effect unequally the progressive deepening of the river bed. The observations in the Monongahela do, however, seem to show with some degree of force that there is a general equivalence and that the whole series declines, and this is presumably representative of a declining limit of action on the part of the depositing agency. It is not, of course, insisted that the observations are either exhaustive or that the altitudes are strictly accurate, all being barometric determinations.

The tributaries of the Monongahela River bear terraces which are significant, but concerning which the data are more limited. The more applicable of the observations of Profs. Stevenson and White are here cited.

Respecting Georges Creek, which enters the Monongahela River a few miles north of the West Virginia line, Prof. Stevenson says:[1]

Along this stream the third and fifth benches of the Stewartstown series are persistent, but rise so that at Smithfield the fifth is 304 and the third 200 feet above the river at the mouth of the creek. * * *

Between Smithfield and Uniontown the third, fifth, and sixth benches are seen to be persistent along the east side of Brush Ridge, which marks the course of the Saltsburg axis. But in ascending the creek, the fifth has shown a constant increase in elevation, so that as the divide between Georges and Redstone Creeks is approached, that bench takes the place of the sixth, and finally becomes merged into the seventh.

Of the benches on the Youghiogheny River the same writer says:[2]

At McKeesport the river "bottom" is 765 feet above tide; from that point it is continuous to Connellsville, at the mouth of the Chestnut Ridge Gap, where it is 894 feet above tide.

Opposite Connellsville a fine bench is seen at barely 200 feet above the stream, which is covered by a thick coat of débris containing many huge fragments, all of them having rounded surfaces. The same bench occurs at Perryopolis, where at one time sand was obtained for glass-making.

This terrace rises much more slowly than the river bed above Connellsville, for at Ohiopyle Falls it is barely 140 feet above the river. While this bench was the bed the river flowed directly across the neck of the peninsula at the falls.

The railway elevation of Ohiopyle is given as 1,237 feet above the ocean, but what is the relationship of this to the river or to the terrace is unknown to me. The terrace at Connellsville is 1,066 feet, while the upper limit of pebbles at the mouth of the Alleghany is 925 feet high, showing a very notable fall down-stream.

Prof. I. C. White makes the following statement respecting some of the upper tributaries of the Monongahela River, which seems to conflict with the general tenor of the above data, and which will be referred to in another connection:[3]

The other tributaries of the Monongahela on which the writer has noticed clay and other deposits of the fifth terrace are Decker, Dunker, Whitely, Muddy, and Ten-Mile Creeks, and in each case the deposits disappear at the same absolute level at which they cease along the river.

It may be remarked, however, (1) that the criterion here observed is not rolled pebbles, but clay and other deposits, making it uncertain whether the terraces belong to the system under consideration or to some other; and (2) that these are all small streams contiguous to each other, whose terraces might have approximately the same upper limit under either the fluviatile or lacustrine hypothesis.

Respecting Chartiers Creek, a stream running parallel and contiguous to the Monongahela and emptying into the Ohio, the following statement is made:

---

[1] Second Geological Survey, Pennsylvania, KKK, p. 256.

[2] Ibid., p. 259.

[3] Paper read before the American Association for the Advancement of Science, Minneapolis, 1883.

A terrace continuous along Chartiers Creek from Cook's station to Bridgeville, and on which Grafton station stands, shows the following slope of its level:

	Feet.
Cook's station terrace, above creek at Cook's station	25
Bridgeville terrace, above creek at Bridgeville	75
Cook's station terrace, above Creek at Bridgeville	205
Fall of Chartiers Creek itself	180
Fall of the terrace level itself	130

This shows that no one of these terraces is by any means on a dead level. These Chartiers Valley terraces continue to its head, and contain limestone drift from the south.[1]

On Montour's Run [a parallel stream running northerly and emptying into the Ohio] a similar terrace is seen, which is even more marked than that on Chartiers Creek. It is traceable along the stream for several miles between Findlay and North Fayette townships of Alleghany County, and falls less rapidly than the bed of the run, the difference being about 35 feet in 4 miles. It shows many rolled and water worn fragments, even so far from the river as Findlay township. Between Robinson and Moon townships of the same county it is much interrupted, and the attempt to determine its relation to the river series was not altogether successful. It seems to be connected with the one occupying the third place in the list already given.[2]

Passing to the Alleghany River, it should be borne in mind that it runs in a course almost directly opposite to that of the Monongahela and associated streams, and is thus extremely well situated for the purpose of the present discrimination, for, on the fluviatile interpretation, its terraces must slope in a contrary direction. The data at command are embraced in the following table:

Table of observations on the upper pebble-bearing terraces and the upper observed limit of pebbles on the Alleghany River, given in descending order.

Locality.	Height of upper pebble-bearing terrace.		Upper limit of pebbles.		Observer.
	Above river.	Above tide.	Above river.	Above tide.	
	Feet.	*Feet.*	*Feet.*	*Feet.*	
Warren	230	1,395	250	1,415	Chamberlin.
Tidioute	295	1,390	.....	.....	Do.
Oil City	260	1,270	.....	.....	Gilbert.
Parker	250	1,105	275	1,230	Gilbert and Chamberlin.
Abandoned channel near Parker	250	1,090	.....	.....	H. M. Chance.
Abandoned channel near Parker (col of "oxbow").	260	1,115	.....	.....	Gilbert and Chamberlin.
Bellevue, on the Ohio, 5 miles below Pittsburgh.	310	1,005	.....	.....	I. C. White.
Middletown, on the Ohio, 12 miles below Pittsburgh.	250–280	940–970	.....	.....	Wright (this paper).
Do	350	1,040	Occasional pebbles.		Stevenson.

[1] Second Geological Survey of Pennsylvania, Q, p. 26.

[2] Ibid., K, 1876, p. 15.

The two localities on the Ohio River have been added to the Allegheny series because they contain northern drift pebbles in common with the latter. By comparison it will be seen that the fall from the pebble limit at Warren to the pebble-bearing terrace at Tidioute, a distance of 21 miles, is 25 feet, the descent of the present stream being 78 feet. From Tidioute to Oil City, a distance of 35½ miles, the fall is 120 feet, the present descent being 113 feet. From Oil City to the upper pebble limit at Parker, a distance of 49½ miles, the fall is 140 feet, the descent of present stream being 125 feet. From Parker to Bellevue, a distance of 87½ miles, the fall is 125 feet, the present descent being 165 feet.

The foregoing facts, if they justify any conclusion at all, sustain the view that the terraces of the Allegheny River flowing from the north slope southward, while those of the Monongahela flowing from the south slope northward toward their common axis, the Ohio River, precisely as the river terraces do to-day, and at gradients not greatly different.

(2) *The material capping the terraces is distinctly fluvial.* In narrow, winding lakes, such as those must have been which occupied these river valleys if such lakes existed at all, there could have been no great wave force, and consequently no considerable coarse-rolled material, and from the nature of the case, such rounded material as may have been produced must have possessed the well-known characteristics which distinguish lacustrine from fluvially rounded material. But the capping of the Monongahela terraces, and more notably that of the Allegheny terraces, contain large quantities of coarse, well-rolled, and I do not hesitate to say, distinctively river-rolled, material ranging from the finer grades up to bowlders 1 or 2 feet in diameter, and occasionally larger. I measured one 1¾ by 2¾ by 3 feet. Prof. Stevenson records one whose dimensions were 1 by 2 by 4 feet. Both of these were on the Monongahela terraces, where the average coarseness is less than that of the Allegheny terraces. It is true that associated with this coarser rolled material there is much that is finer and indistinguishable from lacustrine material, but that is usually true of fluvial deposits. Such fine material may be said to be an inevitable element of alluvial deposits of low slope, since portions of the river flood must necessarily be relatively stagnant. In the deposits of the great floods of the Ohio at the present day a considerable proportion is of the fine, silty, quasi-lacustrine character.

There are also associated with these terraces deposits of stony clay, not very far removed in kind from the stony clays of the glacial drift, save that the embedded stones are not glaciated. This formation is susceptible of misinterpretation, but its true analogue may be seen in the banks of the present Monongahela, throughout the lower half of its course. The material there is very largely composed of a stony clay concerning whose origin there is no room for doubt. The overflows of the flood season bear out upon the submerged flats chiefly silt, but ice, stumps

of trees, and other buoyant material bear occasional stones, which are deposited with the accumulating fine material, forming a stony clay or loam. This is not at all an unusual or phenomenal deposit, but on the contrary is a typical form of flood deposit in streams of low gradient, especially in the higher latitudes, where the aid of river ice is annually afforded.

(3) *These terraces are rock platforms.* The chief terraces are rock-cut, and, as stated by Stevenson—

> At every locality where an exposure occurs it was seen that the terrace is merely a shelf worn out of the stratified rock, on which the river has spread a thin layer of detritus. From the bottom of this layer to the next shelf below there is rocky escarpment, never one of detritus.[1]

It would be a misinterpretation to infer from this language that there are continuous rock shelves cut along the whole face of the bluff; they are precisely the opposite of this, being broad platforms of rock at certain points and entirely absent at others. These platforms are not infrequently from a quarter to a half mile or more in width. To have cut these back by the simple wave action of a narrow, land-locked, hill-sheltered lake would have required a lapse of time which I must leave the reader to estimate for himself. To my own mind, such a work under the conditions of this case is simply impossible, since the excavated material, together with the concurrent inwash from the surrounding country, must have completely silted the lake up before such an amount of erosion, or anything approximate to it, could have taken place.

(4) *The form and distribution of the terraces is of the fluvial, not lacustrine, order.* The distinction between lacustrine and fluvial terraces in respect to form and distribution was indicated in the statement of general criteria. In the last paragraph this feature was incidentally touched upon. The rock shelves, instead of lining the hillsides throughout, and being broader opposite the longer and more forceful sweep of waves, as they should have been had they been produced by a temporary lake, usually have their greatest development in bends of the stream, or in similar dynamic situations, where they have escaped subsequent erosion. It appears to us perfectly clear from an inspection of the ground that the chief of these platforms are but portions of the bottoms of the ancient river which were left in the subsequent cutting down of the channel. The most convincing evidence of this will appear under the following heading, but such broad platforms as occur at Brownsville, Yorkville, Bellevue, New Brighton, and elsewhere, with their rock bases and their rock faces, appear to us to admit of no other interpretation.

(5) *Abandoned channels—"oxbows."* But the most specific evidence of this is found in the abandoned loops of the ancient river, which, after their necks had been cut across by the stream, were left as irrefutable evidences of the status of the streams at the time they were

[1] Second Geological Survey, Pennsylvania, K, 1876, p. 17.

formed. An excellent description of one of these, near Parker, on the Alleghany River, has been given by Dr. H. M. Chance,[1] as follows:

In driving east from Parker along the road leading to West Freedom, a strikingly broad and open valley is seen, and in it a small, sluggish stream, entirely disproportionate in size to the breadth of the valley.

At Hagerstown the wagon-road crosses this valley, which here bears off to the northeast, but bending around to the southeast it is again crossed by the road one mile from West Freedom.

Leaving the main road and following the valley for half a mile toward the southeast a summit is reached, on the south side of which another stream heads and flows * * * through a valley similar to the first. The divide is in swampy ground.

At Perryville the north side of the valley is steep and the south side of more gentle contour, but at Hagerstown the reverse is seen, while throughout the back of the bend, on either side of the summit, the inside of the loop presents gentle slopes facing the more precipitous rock-covered declivities surrounding its outer border.

The summit of this old valley is about 1,090 feet above ocean level, or 250 feet, more or less, above low water in the Alleghany River at Parker. It has been cut down into—if not entirely through—the Homewood sandstone, which outcrops in the valley wherever the side slopes are steep enough to expose it.

The valley is filled throughout by a deposit of river silt containing a small percentage of glacial drift, evidently reworked and redeposited by fluviatile action. This silt consists of sand, gravel, and clay beds irregularly, though truly stratified—the counterpart of the silt found along the present channel of the Alleghany River. The coarser gravel beds in which water-worn fragments of the Coal Measure and conglomerate rocks largely predominate, are sometimes consolidated by a calcareous cement, thus being converted into recent conglomerates, similar to those seen along Oil Creek Valley.

A short distance below Hagerstown the stream cuts through the drift into the subjacent rocks, through which its descent is very rapid to the Alleghany River near Parker. The same feature is noticeable on the opposite side of the loop, where the stream cuts through the drift near the Monterey road-crossing.

The almond-shaped hill inclosed by this valley and the Alleghany Valley rises nearly one hundred and fifty feet above the drift deposit. It contains the ferriferous lime-stone and its underlying coal-beds.

A magnificent view of both sides of the valley and the included island may be obtained from the summit of the road leading to West Freedom, at a point one-half mile west from that town.

That this old valley was once part of the Alleghany or Clarion River channel can not be doubted. It evidently formed an oblong loop or bend that was probably cut through by an excessive undercutting erosion on the two opposite sides of the neck or narrowest part of the loop, just as the river is now slowly eating its way through the neck of Brady's Bend. This action may have been facilitated by the ice riding over the neck of the loop.

As soon as the river found a vent through the loop the old channel was abandoned; but during high water, and before the river had appreciably lowered its level, this old bend must have been a back channel, with more sluggish current than the new cut. Under these conditions it was probably filled with the drift it now contains.

But the present level of the Alleghany and Clarion Rivers is at least two hundred feet beneath bed-rock in the old channel, and as the river is now flowing on a false bottom fifty feet, more or less, above the true bottom of the valley, it is evident that the old channel is two hundred and fifty feet above the true bottom of the Alleghany River at Parker; or, in other words, the Alleghany River has eroded a valley two hundred and fifty feet deep, and subsequently refilled it to a depth of fifty feet since the old channel was abandoned by the main stream.

[1] Second Geological Survey, Pennsylvania, VV, 1880, pp. 17–20.

As the silt filling the abandoned water-course contains some glacial drift—pebbles worn from the Eozoic rocks of Canada—it follows that the river did not entirely abandon this channel until the commencement of, or some time subsequent to, the glacial period. The river, then, must have accomplished the erosion of this deep gorge and a partial refilling of it since the commencement of the glacial epoch, or possibly in less time.

The observations of Mr. Gilbert and myself support those of Mr. Chance in all essential particulars. Above the ancient channel the hills rise by relatively gentle, well graduated slopes, indicative of protracted erosion of the whole surrounding country, while the valleys below this horizon, with scarcely an exception, present steep declivities and often vertical rock cliffs, indicating rapid and relatively short erosion. In other words, the topographic contours above and below this horizon stand in sharp contrast, and of themselves indicate diverse histories.

The similar abandoned channel between Fayette City and Belle Vernon, on the Monongahela, presents almost identical characteristics. At Fayette City, where the present channel diverges from the ancient one, a rock face appears in the cross-section of the latter, and again at Belle Vernon, where the old channel is crossed by the new, there are steep rock faces on both sides, showing conclusively that the old channel is rock-bottomed. Besides these evidences, in themselves conclusive, the creeks that flow in the abandoned channel cut down through the alluvium into the rock along considerable stretches in the lower portions of their courses. The bed material of this old channel seemed to us to be clearly fluviatile, and not lacustrine. Among this material are rounded masses, one, two, and even three or four feet in diameter.

As in the preceding case, from this old river bottom the hills rise by harmonious, well-graduated erosion slopes to the adjacent summits, 200 or 300 feet above, while below this horizon the slopes descend with steep declivities, and often precipitous faces. The plain of this abandoned channel is a horizon of demarkation between long continued general erosion above, and relatively rapid vertical cutting below. The ox-bow at Carmichael's we did not see, but from the description of Profs. White and Wright there seems no ground to doubt that it is in every way similar in character. So, also, doubtless, is Teazes Valley.

To us these are clear and unequivocal instances of abandoned river valleys, and their testimony respecting the origin of the terrace plains, of which they are the largest and best preserved remnants, is of the most unequivocal and decisive character. The fragmentary terraces left by the erosion of the stream along its general course, where it has followed approximately its ancient route, are but minor portions of a continuous river bottom, or of a series of river bottoms, formed during the progressive cutting down of the rivers.

It seems highly probable that these abandoned loops at Carmichael's, Belle Vernon, and Parker are to be correlated together and to be connected with the broader, more deeply covered rock terraces that line

the Monongahela, Allegheny, and upper Ohio Rivers, for in each of these instances there lies upon the ancient rock bottom a bed of fluvial material ranging up to 40 or 50 feet in thickness, and from these terraces there likewise spring the characteristic curves of ancient erosion sweeping over the uplands, while equally characteristic slopes or cliffs of rapid erosion lead down to the present river bottoms. The occurrence of subsidiary terraces does not essentially modify the truth of this generalization.

III.—THE LOWER RIVER (OR MORAINE-HEADED) TERRACES.

The third group of terraces are sharply distinguishable from those which have just been considered, first, in the fact that, instead of being rock platforms covered by fluvial material, they are made up bodily of coarse alluvium, mainly gravel. They have their chief development in the rivers entering the Ohio from the north, and when traced up they are found to head on one of the moraines of the later glacial epoch, or at least of a later glacial epoch following at a considerable interval an earlier one. The uppermost of these terraces has for its surface plane the ancient flood deposits of the glacier-fed streams. The lower terraces have been cut out of it by subsequent erosion. Near the moraine this upper glacial flood surface may be traced continuously, rising somewhat rapidly as the moraine is approached, and passing gradually into a series of undulations which merge into the gravelly knobs and basins, and thence into the unassorted hills of the moraine. This relationship was satisfactorily observed by Mr. Gilbert and myself, separately or jointly, on Conowango Creek, near Russellburg; on the Little Broken Straw, near Freehold; on the Big Broken Straw, near Horn's Siding; and on Oil Creek, near Hydetown. On Sugar Creek, French Creek, and Sandy Creek phenomena of similar significance appear, but they are less clear in their import. On Beaver River and Little Beaver Creek analogous features are more satisfactorily displayed.

The streams of gravel starting in these morainic heads run down through the rock channels cut below the old river bottom as above described. The surfaces of these later glacial gravel streams are generally much below that of the earlier terrace deposits, but as they slope more rapidly there is no constant difference. An interval of from 100 feet to 200 feet may be taken as representative. These later glacial gravels extend below the present river beds, reaching depths varying from 40 feet to 250 feet or more, showing a considerable depth of channel before this late filling. These terraces reach their greatest height above the present stream, so far as observed, at the junction of the Beaver River with the Ohio. There the terrace rises 127 feet above the Ohio, according to a lock-level measurement by Mr. Gilbert.

Similar moraine-headed terraces occur in Ohio on the Muskingum, Scioto, and Mad Rivers and their tributaries, and seem to have their

equivalents in terraces on the lower stretches of these rivers and on the Ohio. In other words, there is a general system of deep valley gravels, starting from the moraines indicated and sweeping down the valleys, growing progressively finer in material. Out of these glacial flood deposits a system of terraces has been cut by subsequent erosion. The still later glacial episodes seem to have introduced modifying elements, but these are unimportant in this connection.

General remarks on the two systems of river terraces.—The time and manner of origin of the moraine-headed terrace plains are placed beyond question by their morainic connections. They are clearly the products of the streams that issued from the glacier during the moraine-forming epoch. The carving of the terraces out of these plains was chiefly a subsequent work, of relatively minor importance in the present discussion. The coarseness of the gravels of this series indicates vigorous drainage, which in turn implies an open valley and at least a fair gradient below. It is equally evident that terraces of a much higher level and different gradient could not have been formed at the same time. Minor side-valley terraces might have been formed at flood stages, but only to the height of the maximum floods, and these must have had the same slope as the broad flood plains.

It is clear that the upper gravel-bearing terraces were not formed at the same stage as these moraine-appended ones, for they are not only of a different type, being alluvium-covered rock platforms, but they stand high above most of the morainic heads of the later deposits and show much greater antiquity in the erosion of their surfaces. For example, at Warren the old gravels have an altitude of 1415 feet above sea-level, with a terrace at 1395 feet, while the moraine-headed flood deposits of the later epoch at Russellburg, eight miles upstream, occur at about 1275 feet. On the Beaver River the moraine-headed gravel stream has an elevation of about 830 feet, while along the valley below pebbles referred to the earlier epoch range from 900 to 950 feet, and ten miles below there is a wide rock-based terrace at about 885 feet. But these higher gravels contain pebbles of granite and other crystalline rock, whose presence is only to be accounted for through glacial agencies, and the explanation of their origin must embrace that element. It is not far to seek.

Outside of the moraine with which the lower series connects itself there lies a tract of attenuated drift, consisting of scarcely more than scattered bowlders,[1] dispersed indifferently over the highlands or

[1] I. C. White: Second Geol. Survey, Pennsylvania, Q, 1878, p. 10; QQ, 1879, p. 9, and QQQ, 1880, pp. 15-17.

T. C. Chamberlin: "The bearing of some recent determinations on the correlation of eastern and western moraines." Am. Jour. Sci., August, 1882, p. 96.

H. C. Lewis: Second Geol. Survey, Pennsylvania, Z, 1884, pp. 45, 71, 170, 171, 177, 179, 180, 186, 195, 200-202.

G. F. Wright: The glacial boundary in Ohio, Indiana, and Kentucky, tract No. 40, Western Reserve Hist. Soc., 1884, pp. 227, 228.

gathered in colonies. In the passing allusion cited below, I expressed doubt whether this extra-morainic drift, was an appendage of the moraine or an older drift, here barely emerging from beneath a later one, but which, farther west, extends far out beyond it. Subsequent studies over a wide extent of territory convince me that the latter is the truth. The evidence of this, even in western Pennsylvania, is of itself somewhat strong, but can not be discussed at length here.

Mr. J. F. Carll has presented convincing evidence that the drainage of the present upper Alleghany Basin was toward the Erie Basin in preglacial times, and that it was turned into its present course during the ice invasion.[1] Mr. Carll rested his admirable discussion with the establishment of the general proposition respecting drainage reversal, without attempting to distinguish between the episodes of the invasion. But the facts above cited show that this reversal must have taken place much anterior to the formation of the outer moraine, for the floods of that date poured down through a canyon already cut from 40 to 100 feet below the present river-bottom with the result of partially filling it with glacial gravel, as shown by the following table taken from Mr. Carll's report.

Table showing altitude above ocean level of the ancient floor of the Alleghany River.[2]

Locality.	Railroad levels.	Depth of drift.	Ancient floor.
	Feet.	*Feet.*	*Feet.*
Warren, Warren County, Pa	1,200	100	1,100
Irvineton, Warren County, Pa	1,168	60	1,108
Tidioute, Warren County, Pa	1,113	50	1,063
West Hickory, Venango County, Pa	1,092	45	1,047
Tionesta, Forest County, Pa	1,060	50	1,010
President, Venango County, Pa	1,048	40	1,008
Henry's Bend, Venango County, Pa	1,035	45	990
Oleopolis, Venango County, Pa	1,032	45	987
Walnut Bend, Venango County, Pa	1,023	40	983
Rockwood, Venango County, Pa	1,016	50	966
Oil City, Venango County, Pa	1,008	50	958
Franklin, Venango County, Pa	988	40	948
Cochran, Venango County, Pa	982	40	942
Fosters, Venango County, Pa	970	40	930
Scrubgrass, Venango County, Pa	945	40	905
Emlenton, Venango County, Pa	905	45	860
Parker, Armstrong County, Pa	889	50	839

Combining these with preceding data, three fluvial planes are to be noted: (1) the rock floor, which, lying 1,100 feet above the sea at Warren, declines southward, as shown in the above table; (2) the moraine-headed terrace plane which starts at Russellburg, eight miles above War-

[1] Second Geol. Survey, Pennsylvania, Report III, 1880, pp. 330-355.
[2] Ibid., p. 337.

ren, at about 1,275 feet, and apparently about 250 feet above rock bottom, and likewise declines southward; and (3) the upper erratic-bearing terrace plane, which, starting at Warren at 1,395 to 1,415 feet, and having at Tidioute, near the ancient divide, an altitude of 1,390 feet, declines to 1,115 feet at Parkers. The time sequence of these three planes is clear. The high terraces must have been first formed as shown by Mr. Chance. The rock channel, whose bottom represents the cessation of excavation, was eroded after the high terraces were formed and before the later gravels were poured into it. The moraine-attached gravel planes were manifestly last in formation.

The higher glacial gravels antedated those of the moraine-forming epoch by the measure of the erosion of the channel through the old drift and the rock, whose mean depth here is about 300 feet, of which, perhaps, 250 feet may be said to be rock. The excavation that intervened between the two epochs in other portions of the Alleghany, Monongahela, and Upper Ohio Valleys is closely comparable with this.

In view of these facts it seems scarcely less than proven that it was the earlier invasion of ice that reversed the drainage and partially filled the valleys with débris, forming the capping of glacial gravel that rests upon the upper terraces.

As we read the history of events, the salient features were as follows: The erosion of the valleys proceeded with relative slowness during the stages immediately antedating the time at which the streams reached the base plane represented by the bottoms of the abandoned channels on the Alleghany and Monongahela Rivers, and the degradation of the surrounding country was relatively great as compared with the downward cutting of the streams. This became more and more pronounced until the streams (in these portions of their channels) reached base planes of erosion, after which they began to build up their bottoms by the fluvial deposits of which we now find remnants. This proceeded until forty feet or more of basal debris was accumulated. This building up of the bottoms of the streams while the degradation of the surrounding country was still in slow progress, afforded exceptionally favorable conditions for changes in the courses of the streams. The two-fold process was especially adapted to bring low necks within the limits of overflow at flood stages, or to cause the disseverance of narrow necks by lateral corrasion. It does not surprise us, therefore, that several important changes took place nearly coincidently during the prevalence of these conditions.

From the fact that the fluvial material in these abandoned channels and on the corresponding terraces in the Monongahela Valley is wholly local, or southern, while among the analogous material of the Alleghany there mingle crystalline erratics of Canadian derivation, and from the evidence given above, we draw the inference that the partial filling was coincident with some stage of the earlier glaciation, presumably a late stage. This view gathers some support from the now well

sustained belief that a general depression and slackening of drainage accompanied the earlier glaciation.

Following this episode of valley-filling and earlier glaciation there was a prolonged epoch of rapid erosion of the valley bottom, which was apparently coincident with an interglacial epoch, and was, perhaps, the result of the resilience of the land after the glacial depression. During this epoch the rock gorges were cut down to the rock bottoms that now lie forty feet or more below the present river bottoms. Then came the later invasion that halted at the outer terminal moraine, whose overloaded floods, like those of the preceding glacial incursion, filled the valley bottoms with glacial alluvium; only, in this instance, in harmony with the more vigorous character of the later glaciation, the filling reached, at some points, 300 feet. Since that time there has been another stage of reexcavation, giving origin to the lower gravel terraces.

This is doubtless far from being the whole history of events, and may be divergent from the truth in minor phases, but I believe with some confidence that it represents the general truth respecting the history of the abandoned channels and chief terrace deposits of the system of benches under consideration. Were not this introduction already almost inexcusably long, I should desire to give expression to my belief in some minor episodes and to qualify these bald outlines.

Recurring to the question of the relationship of these terraces to the supposed ice dam at Cincinnati, it becomes obvious that, if the foregoing identifications are correct, the phenomena do not admit of explanation by such an obstruction. In a different way they find their elucidation in the conditions that accompanied the ice invasions. That there were at least two incursions of ice, that both had the habit of filling up the bordering valleys with their drainage matter, that a depressed condition of the land and a slackened drainage were coincident with certain stages of each, and that there was a prolonged interglacial interval of erosion, are indicated by a wide range of phenomena. In support of the lower gradient of the streams, which is the leading feature of the explanation of the much-discussed higher river terraces, there may be cited, on the one side, the extensive deposits of the loess on the lower Ohio, the Wabash, the Illinois, the Mississippi, and the Missouri Rivers, as shown by the concurrent observations of numerous geologists, and, on the other side, the yellow gravels and the brick clays of Philadelphia, the bowldery deposits about the Delaware and Chesapeake Bays, and the Columbia formation of the Potomac and adjacent regions, as worked out respectively by Messrs. H. C. Lewis, F. D. Chester, and W. J. McGee.

So, also, in confirmation of the very considerable erosion which took place between the invasions, there is, on the one hand, the great erosion of the Missouri Valley from the Great Falls, in Montana, to southern Dakota, in the course of which, for long stretches, it has manifestly cut

its entire channel of from three hundred to eight hundred feet in depth since the early drift epoch, and, on the other hand, the erosion of the Atlantic streams, notably that of the Potomac, where the entire gorge from below the Great Falls has been excavated in obdurate crystalline rock since the earlier glacial epoch, as shown by McGee.

In short, both in the great interior basin, on the one side, and on the Atlantic coast on the other, as shown by independent observations, there appear to have been prevalent the two great features of which we find additional evidence in the terraces of the upper Ohio and its tributaries, viz: first, a general depression coincident with the earlier ice invasion, and, second, a prolonged interval between invasions, marked by greater erosion.

Respecting the argument of Prof. Wright, that the high state of preservation of the vegetal deposits indicates a recency incompatible with the great lapse of time which the erosion of the valleys implies, I have only to remark that I know of no criterion by which the minimum rate of decay or lithification of vegetal deposits takes place when the material is buried in clay or constantly submerged by ground-water. The whole tenor of the study of fossil remains is to emphasize the fact that the preservation has been extraordinarily perfect under certain conditions, while under others the completeness of the destruction has been equally phenomenal. It appears to me that the rate of decay and of lithification of buried vegetal material is a problem rather than a proof. Very fresh-looking wood is found in the *Tertiary* deposits of the lower Mississippi Valley.

IV. THE SLENDER HORIZONTAL TERRACES.

A system of slender terraces, lying along the slopes of the hills back of Wheeling, W. Va., has been observed by Mr. W. J. McGee, of the U. S. Geological Survey. With them he is inclined to correlate some of the terraces of the Monongahela River and some of its tributaries, which have been examined by him. These terraces are far from being constant, and commonly occur only at localities obviously favorable for their formation and preservation. There are usually two, but rarely three or more members, all within a vertical interval seldom exceeding fifty feet. They differ entirely from the preceding classes, being merely slender bands of slope-wash lodged along the sides of the hills, reaching a thickness of perhaps ten feet, measured normal to the hill slope, and having sloping surfaces. So far as observed they maintain a horizontal position. They seem to be just such accumulations as might gather on the margin of a ponded stream in a comparatively limited interval of time. The mean altitude, on both the Ohio and the Monongahela, is about one hundred and fifty feet.

As indicated in a quotation made above, Prof. I. C. White finds on several of the tributaries of the Monongahela clayey terrace deposits, which disappear at the same absolute level at which they cease along

the main river. It may be that these clayey terraces constitute a horizontal system equivalent to those observed by Mr. McGee, while the rock benches and alluvium-capped terraces of the region belong to the ancient river system, and that in this discrimination lies the reconciliation of seemingly inharmonious observations. The data at command are far too limited to warrant a confident conclusion. These observations should stimulate a further search for this class of terraces, and in this search it is supremely important that these slender, slope-wash terraces should be distinguished from those which have heretofore been the chief, if not the exclusive subjects of discussion in this region, and with which they have little in common beyond the bald fact of being terraces.

V.—THE STRUCTURAL TERRACES.

The fifth series of terraces which mark the slopes of the upper Ohio and its tributaries are obviously structural or degradational, being dependent upon the unequal resistance of the paleozoic strata that form the hill-slopes of the river valley. They are horizontal where the strata lie horizontally and inclined where the strata lie inclined. Their origin is obvious.

SUMMATION.

Summing up the subject of the terraces, it is to be remarked (1) that the highest series of terraces are horizontal, but have elevations the lowest of which is above the reach of the supposed Cincinnati ice-dam, and the range of which, according to Prof. Stevenson (on whose observation the determination of the whole series rests), greatly exceeded the total range of the ice-dam, and that the two, for other and obvious reasons, can have no causal relationship; (2) that the upper series of pebble-bearing terraces carry evidences that to us are clear and decisive that they are fluviatile in origin and that they were contemporaneous with the earlier glacial epoch; (3) that the lower series of gravel terraces are demonstrably connected in origin and in time with a later ice incursion, during which was formed the outer moraine which has been so carefully traced by Profs. Lewis and Wright across northern Pennsylvania; (4) that the slender horizontal terraces observed by McGee (and perhaps certain portions of those observed earlier by Prof. White, but not separated in discrimination from the fluvial terraces), may be the relics of the work done by the waters ponded by the glacial obstruction at Cincinnati; but too little is yet known of these to justify more than this suggestion; and (5) that the structural terraces are evidently due to differential degradation and have obviously no relationship to the question under discussion.

THE GLACIAL BOUNDARY IN WESTERN PENNSYLVANIA, OHIO, KENTUCKY, INDIANA, AND ILLINOIS.

By George Frederick Wright.

INTRODUCTION.

The following is a preliminary report of progress concerning my investigations relating to the glacial boundary in western Pennsylvania, Ohio, Kentucky, Indiana, and Illinois. But as, according to instructions, the work is supplementary to what had already been done in the same field, it has been necessary to give a summary statement of facts previously discovered and published.

The main problem has been to determine by actual observation the exact southern line along which the signs of the so-called direct glacial action cease to be apparent. To accomplish this it has been necessary to examine personally a belt of territory along the whole distance sufficiently wide to demonstrate that the phenomena denominated "glacial" actually exist down to the line, and that they do not exist south of the line.

The phenomena chiefly relied upon as proofs of direct glacial action are the existence of striated surfaces of rocks in place, the occurrence of the unstratified deposits called "till," and the discovery of transported bowlders in such positions as to preclude their deposit by water action. The sufficiency of this proof can be evident only from the report itself. As there may be occasion to question the character of the deposits called "till," I have inserted in the text cuts from photographs of several fresh perpendicular exposures in different places.

STRIATED SURFACES OF ROCKS IN PLACE.

There is no question that an exposed surface of rock might be striated by the action of a vast mass of floating ice in shallow water. Icebergs whose lower surfaces barely graze the rock beneath, and which are moved along by strong and steady currents of water, might produce striæ which are in a general way parallel with each other over extended surfaces of level country. But that the striation char-

acterizing the greater part of the drift-covered portion of North America could not have been produced by floating ice is evident from a variety of considerations.

In the first place, striated surfaces are found in situations where it is impossible to suppose there could have been any currents of water in which ice could float; and the striæ in these places correspond in all respects with those ordinarily found in other situations. For example, limiting myself to observations of my own, in Davidson township, Sullivan County, Pennsylvania, there are numerous and well-defined striæ upon the exposed surfaces of Pocono sandstone, lacking only a few hundred feet of being as high as the highest summit of the Alleghany Mountains, and not far from 2,000 feet above the sea. The direction of the striæ is here S. 9° W.

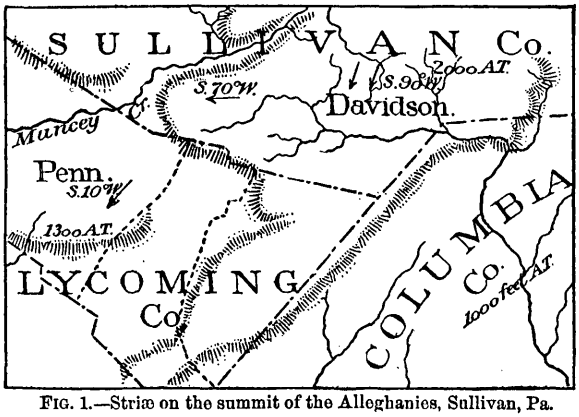


FIG. 1.—Striæ on the summit of the Alleghanies, Sullivan, Pa.

A few miles west in the valley of Muncy Creek, there are other striæ at a lower level, whose direction is evidently determined by that of the valley which bears in some places S. 70° W. At a still lower level, and farther down the creek after it emerges from the Alleghany escarpment (which here, as elsewhere, bears from NE. to SW.), in Penn township, Lycoming County, the striæ turn again to a more southerly direction, bearing S. from 10° to 20° W. There is here no chance for a current of water moving over the Alleghanies to produce all these striæ; for every appearance indicates that they were contemporaneous, and water which would barely suffer the ice to graze the surface in Davidson township, Sullivan County, would be too deep in Penn township, Lycoming County, to allow a floating body of ice to graze the surface there, which is at least 700 feet lower than the other in Davidson township. Nor would there be any opportunity for a current of water to set over Penn township from the north, since the escarpment of the Alleghany is only two or three miles distant in that direction, and it is in all places from 700 to 1,000 feet above it.

Nor could this striation be the result of a local glacier, since Davidson township has no higher land to the north in which a local glacier

could form. On the other hand, everything coincides with the supposition that a continental ice-movement from the north here surmounted the Alleghanies, and that its force was nearly spent at this point. The striæ on the unobstructed surface of Davidson township represent the normal movement of the ice in that vicinity, while the variations in direction down Muncy Creek show the disturbing influence of a local valley near the margin, down which the semi-fluid mass would press in obedience to its laws of motion.

This is but an instance of what may be found in various other places in the mountain regions of Pennsylvania.[1]

Phenomena similar to these just described are also not infrequent northward, making it evident that the striæ now exposed to observation were those produced by the last movements of the ice near its margin and during its period of final retrocession. Each forward movement of the ice, like that of a plane or rasp, would obliterate the marks of the previous movement.

In the region coming more immediately within the limits of the present report, namely, that lying west of the Alleghanies and extending to the Mississippi River, the observed striæ near what I have taken to be the limit of direct glacial action have been comparatively rare; still they are sufficient to illustrate the same general principle. In the places where these marginal striæ have been observed there is usually either a barrier which would obstruct the progress of a current of water flowing in the direction of the striæ, or, where there is no barrier, there is such a sudden cessation of glacial deposits as could not have occurred if the transporting agency had been floating ice. The water deep enough to have floated bergs to the locality of these striæ, and to the limit of glacial deposits not far beyond, would, in the absence of barriers, have transported this glacial débris still farther south.

Again it is noticeable that these marginal striæ very uniformly point at right angles to the marginal line itself in the locality where they occur, so that in repeated instances I was able from the direction of the striæ to prophesy the direction of the nearest point in the margin of the glaciated area.

For example, the striæ in Mercer and Lawrence Counties, in western Pennsylvania, have a general direction S. 45° E., which is very nearly at right angles to the line marking the limit of direct glacial action a few miles away.[2]

Again, in Highland County, Ohio, the average bearing of striæ is S. 26° E., at right angles again to the glacial margin a few miles away.

At Woodsdale, Butler County, Ohio, about 20 miles north of Cincinnati, well defined striæ occur, running nearly N. and S. These are of

[1] For further particulars respecting other places in Pennsylvania see Second Geol. Survey, Pennsylvania, Z, containing the report of H. Carvill Lewis and myself upon the terminal moraine in that State, especially the reports on Monroe, Luzerne, Columbia, and Lycoming Counties.

[2] Op. cit., p. 189.

additional interest as showing the degree to which the ice movement at this point was independent of the local topography. The striæ here observed were upon the south side of the Miami River (whose general course is here NE. and SW.), and 75 feet above low-water mark. The direction of the striæ is diagonal to that of the valley, which is here a mile or more in width, but nearly at right angles to the general course of the glacial boundary, about 20 miles to the south.

Near Vandalia, Owen County, Ind., well marked striæ appear running from S. 40° to 50° E., some bearing still more to the east. Here, again, the limit of direct glacial action (which is but a few miles away), after having swung from Clark County, near the Falls of the Ohio, at Louisville, Ky., to the north as far as Morgan County, is now for a long distance passing in a SSW. direction toward Posey County.

The point farthest south at which striæ have been observed east of the Mississippi is near the southwest corner of Williamson County, Ill., about latitude 37° 35′.

This is near the apex of a great southern loop in the glacial boundary, which extends but a few miles farther to the south; and the direction of the eastern set of striæ, in Williamson County, is S. from 10° to 15° E., while that of the western set, about 12 miles distant, in Jackson County, is S. 5° W. The striæ are here undeniable and most clearly marked

SUMMARY OF FACTS CONCERNING THE UNSTRATIFIED DEPOSIT CALLED TILL.

PRELIMINARY REMARKS.

Full descriptions of till and its associated deposits are given by President T. C. Chamberlin in his preliminary paper on the Terminal Moraine of the Second Glacial Epoch.[1]

It is sufficient here to remark, in general, that the agency through which the drift deposits are supposed to have been distributed is one which is capable of producing very complicated results. During the whole existence of the continental glacier, especially at certain seasons of the year, there must have been connected with it a great amount of water action; and through the agency of the enveloping sheet of glacial ice, water must have been set free in places and under conditions very different from those in which it would be a modifying agent after the ice had withdrawn. In all those valleys whose natural drainage is to the north there would be a period, both during the advance and during the retreat of the ice, when temporary lakes would exist in its front. In all such places, of course, there would be opportunity for that peculiar stratification of the material characterizing the deposits distributed by water. It is easy to see that these conditions would exist to a marked degree in Ohio north of the water-shed.

[1] Third Annual Report U. S. Geol. Survey, 1883, pp. 295–310.

On the other hand, south of the water-shed, where the main drainage lines were always open to the south, it would be rare that any large confined body of water could have existed for any great length of time. But wherever there was an ice front at any level there must have been, especially during the period of retreat and during the summer months, a vast amount of water set free even upon the high lands, which in its impetuous course would sort the material and deposit terraces and deltas of sand, gravel, and pebbles in positions that are quite impossible in the present condition of things. My observations have been particularly directed to the effects of this complicated agency south of the water-shed between the Ohio and the lakes, and more particularly near the southern margin of the region over which the marks of the direct action of glacial ice are unmistakable. In conducting these observations I have incidentally traversed nearly the whole region between the lakes and the Ohio in every direction, and have carefully zigzagged the whole marginal line from the Alleghanies to the Mississippi, crossing and re-crossing it at short intervals (usually from one to two miles), extending my observations over a considerable belt of the territory beyond the limit assigned by me to direct glacial action. An incidental branch of the investigation, and one which in interest and importance is so great that it well-nigh overshadows the main inquiry, pertains to the effects during and towards the close of the glacial period of water action along the valleys opening to the south, and which lie for the most part outside the glaciated region. With a remarkable uniformity these valleys contain immense deposits of gravel, which line their sides to a level far above the reach of present streams.

GENERAL DISTRIBUTION OF TILL AND ITS RELATION TO BURIED CHANNELS.

The distribution of drift material over the glaciated region south of the water-shed between the lakes and the Ohio is more uniform than it might seem to a local observer. As Prof. J. S. Newberry[1] long ago pointed out, glacial action in Ohio was superinduced upon a country whose minor topography had been shaped by the long-continued erosive action of running water. These preglacial streams had everywhere eroded channels through the sedimentary rocks hundreds of feet in depth, and south of the glaciated limit these channels are still the marked feature of the country.

North of the line the channels have ordinarily been filled with till so as completely to obliterate them. According to Prof. Newberry the Cuyahoga River (flowing north and emptying into Lake Erie at Cleveland) occupied in preglacial times a bed 200 feet beneath its present bottom, since borings along its bed for twenty miles above its mouth penetrate that depth before reaching the rock, while the rocky escarpment on each side of its present narrow valley now rises from 200 to

[1] Report Geol. Survey, Ohio, vol. 1, pp. 34, 37, 44, 172, 175, 177, 205, 418, 433, 461

300 feet above it. Previous to the glacial period this river must therefore have occupied a narrow trough from 400 to 500 feet deep. Prof. Newberry had also called attention to a buried channel occupied in preglacial times by Rocky River (a stream emptying into Lake Erie a few miles west of the Cuyahoga), but which was filled up by glacial débris, so as to compel the stream to seek another channel in the lower part of its course. Recently Dr. Gould, of Berea, Ohio, has traced this buried channel a distance of more than twenty miles, connecting it with the wide, deep valley still occupied by the stream in Medina County. The course of the buried channel is traced partly by gathering a record of wells which fail to reach a rocky bottom for 50 or 100 feet below the ordinary depth, but more especially by noting the repeated places at which the present stream in its winding course crosses and recrosses the old valley. Where this occurs the present stream flows between rocky banks both above and below the line of the buried valley, and has a rocky bottom; but in the short space occupied by the old valley itself the stream now flows between banks of till nearly 100 feet high, and has a muddy bottom.

Thus, in the main, all the valleys down to the glaciated limit in Ohio, Indiana, and Illinois have been obliterated, and the whole region has been reduced to a comparative level by the action of the ice; so that the glacial boundary is found to be practically the limit of the prairie region in these States, though as the Alleghanies are approached from the west the comparatively higher elevation of the country, and the consequent increasing depths of the river channels, makes the till in increasing degree insufficient to fill them.

The maximum for the average depth of the glacial deposit over the area in Ohio north of this boundary line is estimated by Mr. E. W. Claypole[1] to be 56 feet. No one at all familiar with the region will be disposed to think this estimate exaggerated.

Recent activity in Ohio and Indiana in boring for gas and oil has given us more definite knowledge of the depth of the glacial deposits over that region than was before possible. The result is to prove that Prof. Claypole's estimate of an average depth of 50 feet is altogether too moderate.[2] Prof. E. Orton furnishes me in advance the figures which he is to publish in his forthcoming report upon the subject. These figures represent the depth of the glacial deposit in fifty-three of the counties of Ohio as determined by the borings in one hundred and twenty-two wells. The average depth of the glacial deposit is found to be upwards of 90 feet (93 feet+). In some of the wells the depth of the glacial deposit was truly phenomenal, as in St. Paris, Champaign County, where in one well rock was not reached until a depth of 370 feet, while in another 530 feet was penetrated by boring, and the well was aban-

[1] See Proc. Am. Assoc. Adv. Sci., 30th (Cincinnati) meeting, 1881, p. 151.

[2] As to the possibilities of error in such calculation, see the driftless area by Chamberlin and Salisbury, Sixth Annual Report U. S. Geol. Survey, p. 207 et seq.

doned before rock was reached. In Dayton, Montgomery County, the glacial deposit was found to be 247 feet deep; in Cridersville, Auglaize County, 300 feet; in Newark, Licking County, 235 feet; in Lebanon, Warren County, 256 feet; in Osborn, Greene County, 207 feet; in Hamilton, Butler County, 214 feet. The average in various counties is also significant. In Auglaize County six borings give an average depth of 141 feet; in Butler County, four borings average 116 feet.

With reference to the correctness of this representation, it should be remarked that borings prosecuted in this manner are more likely to give an underestimate than an overestimate of the real facts; for, as is well known, it is much easier and less expensive to drill through the sedimentary rocks than through deep deposits of till and looser drift, so that the aim of the prospectors is to begin their wells at points where the rock will be reached at as small a depth as possible. But so completely have the preglacial lines of erosion been obliterated in Ohio that it is impossible to make certain calculations as to the proximity of the rock to the surface. In the deepest drift (530 feet in Champaign County) special effort was made to locate the boring where the superficial deposits were shallow; but, as the result proved, the surface indications were deceptive and a serious mistake was made, involving the contractor in financial disaster. It should, however, be observed that the deep well of St. Paris lies in the line of the terminal moraine of the second glacial epoch, as indicated in the report of President Chamberlin, where the depth of glacial deposits is supposed by him to be exceptionally great.

CHARACTER OF THE MATERIAL COMPOSING THE TILL.

A uniform characteristic of the surface deposits covering the glaciated region is the intermingling of a great variety of material from widely separated regions to the north.

The significance of the facts observed can best be perceived by comparing observations from extreme portions of Ohio. We will therefore put side by side the deposits in Oberlin, Lorain County, Ohio, and those near Oxford, Butler County.

Oberlin lies 12 miles south of the lake and 252 feet above it, being about 30 miles north of the water-shed. The general surface of the country is remarkably level, though rising gradually to the south; the divide between Black River and the Killbuck, in Harrisville, Medina County, being but 84 feet higher than the general level in Oberlin, while the divide between the Maumee and the Wabash, near Fort Wayne, Indiana, is seven feet lower than Oberlin, and the summit between the Sandusky and Scioto Rivers, in Wyandot County, and between the Mahoning and Grand Rivers, in Trumbull County, do not vary ten feet either way from that already mentioned in Medina County. The drainage sum-

mits between the Cuyahoga and the Tuscarawas, and between St. Mary's and Laramie Creek, are from forty to sixty feet higher still.

FIG. 2.—Map showing glacial boundary in Ohio.

The following table[1] will be convenient for reference:

Lowest summit between the waters of Lake Erie and the Ohio River:

	Feet above tide.
Mahoning and Grand Rivers, Champion, Trumbull County	918
Cuyahoga and Tuscarawas Rivers, Summit Lake, near Akron, lowered four feet by the canal	975
Black River and Killbuck, Harrisville, Medina County	911
Sandusky and Scioto, Tyamochtee, Summit, Wyandot County	908
St. Mary's and Laramie Creek, Shelby County	952
Maumee River and Wabash, near Fort Wayne, Indiana	825

The following data are of value in connection with the above table:

	Feet.
Elevation of Lake Erie above tide	575
Elevation of Oberlin above tide	827

[1] Prepared by Col. Charles Whittlesey for annual report of the Secretary of State to the Governor of the State of Ohio (Ohio statistics) for 1879, p. 574.

It thus appears that there could have been no confined body of water over the northern part of the State of sufficient depth to float icebergs of any great size. So that, from the nature of the case, we could not expect to find in this region any extensive deposits from that source; and, least of all, any great amount of striation which could be attributed to floating ice, and with this conclusion the character of the drift in this region corresponds.

The rock nearest the surface in Oberlin is the Waverly sandstone, which in places is but slightly covered by drift, but in other places has suffered extensive erosion, and wells penetrating the drift thirty or forty feet fail to reach the rock. The strata are here dipping toward the southeast at a rate of nine feet per mile.[1] Eight miles to the northwest occurs the line of the outcrop of these sandstones, where are the celebrated Amherst quarries, at an elevation of about one hundred and seventy-five feet above the lake. The lower shelf between these quarries and the lake is occupied by Erie shale, concealed only by a thin covering of drift.

The 175-foot level is marked by a ridge of sand and local gravel, with occasional collections of well-rounded pebbles from three to four inches in diameter. Pieces of fresh wood (supposed to be sycamore), much water-worn, are frequently found from fifteen to twenty feet below the surface of this ridge, and are specially abundant in the level country immediately south of it. Towards the lake there are other series of ridges at lower levels, and in various places where I have observed it, there is in such situations a marked increase of granitic bowlders upon the general surface between the ridges, as if the washing of the waves had carried away the fine material leaving upon the present surface only the bowlders that were originally scattered through a deeper deposit of till, such as characterizes the whole country to the south of the ridges. The geological formations of this vicinity are shown by the following record of a recent boring:

Record of an artesian well at Oberlin.

	Feet.
Yellow clay	11
Blue clay	10
Red clay	10
Sandstone	10
Red shale	74
Blue shale	24
Black and blue shale	737
Limestone	15
Total	891

From this statement of the situation, the significance of the following facts concerning the composition of the drift at Oberlin will be apparent. From a number of wells dug during the spring of 1886, and

[1] Whittlesey, Ibid., p. 575.

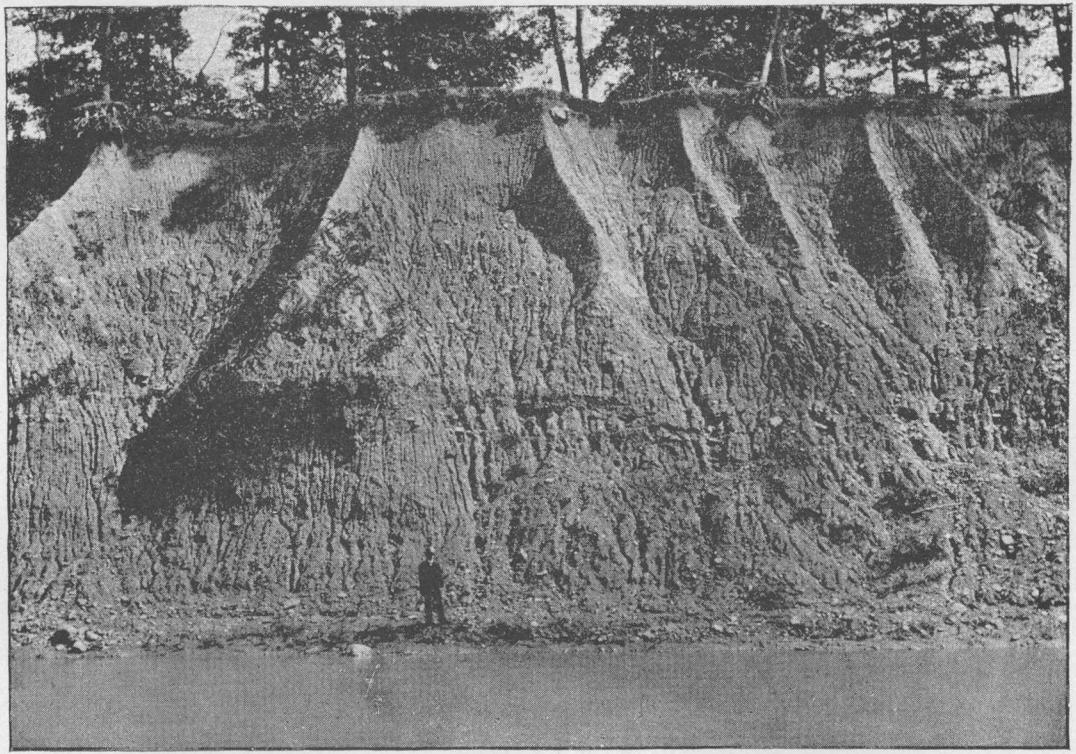
penetrating the superficial deposit from fifteen to twenty feet, it is evident that it can not have been a deposition in water. Granitic bowlders brought from northern Canada, two feet and more in diameter, are frequently found at all depths in the deposit. Fragments of Corniferous limestone (finely polished and scratched), whose horizon is several hundred feet lower than the situation in which they are found, occur in the drift at all depths. The mass of the deposit is, however, a very tenacious clay, formed by the mechanical comminution of the extensive deposits of shale whose outcrop is to the north and at a lower level. A specimen of this clay, freshly taken from 15 feet below the surface, consisted of about 55 per cent of material so finely comminuted that it was readily held in suspension in water. The remaining 45 per cent consisted of fragments more or less angular, and from one-quarter of an inch in diameter down to the finest sand. Both of these portions effervesce readily in acids, showing that lime is present in the form of carbonate, and that therefore the clay is the result of mechanical comminution and not of chemical disintegration[1]. We give in a note the result of both a mechanical and a microscopical analysis.[2] Among the materials composing this deposit there are granitic and quartzite fragments from northern Canada, Corniferous limestone from below the level of Lake Erie[3], fragments of Erie shale, sometimes two or three inches in diameter, and pieces of Amherst sandstone. All these ingredients are intimately mixed together without any signs of stratification. There are, however, at irregular intervals, belts of stratification in the till wherever I have observed it. For example, in one of the wells mentioned in Oberlin a vein of quicksand a foot or more in thickness was encountered at a depth of 12 feet, but with compact blue till both above and below it.

It is evident that there is no way in which the material composing the till just described could have come into the position it now occupies except by a true glacial movement. The lower level occupied by the strata of the shale (which appears in the till at Oberlin in fragments as well as in finely comminuted particles) demonstrates that the transportation could not have been by floating ice, since with a water level low enough for the shale to have been frozen into the cakes of ice there could not have been depth enough to float it over the higher lands to

[1] See Pres. T. C. Chamberlin, in Am. Jour. Sci., 3d series, vol. 27, 1884, pp. 378–390.

[2] In thirty-eight grains of the material are twenty-one grains of suspended matter and seventeen grains of matter too coarse to be suspended in water. Under the microscope the suspended matter betrays its mechanical origin.

[3] These limestones, however, crop out to the northwest at Sandusky, and to the north on the other side of the lake. But taken in connection with the other facts apparent, we are warranted in drawing the inference that these limestone fragments are from the direction of the ice-flow as indicated in the abundant striæ of the vicinity; and there is no reason why they should not have come from the level of other fragments with which they are associated.



SECTION OF TILL AT LANE'S MILL, NEAR DARRTOWN, BUTLER COUNTY, OHIO.

the south, where it is now found. This inference is confirmed also by a comparative study of drift deposits in the southern portion of the State.

The accompanying illustration (plate I) shows perpendicular exposures of till on the banks of Four-mile Creek, at Lane's Mill, west of Darrtown, in the northwest part of Butler County, Ohio. The height of the bank is 65 feet. About half way up from the bottom there is a stratum about two feet thick, which is partially stratified; but both above and below this stratum the deposit is true till, being very compact and containing a great variety of rocky fragments, showing distinct marks of glaciation. The larger portion of the rocky fragments consists of local limestones, and these are abundantly striated. In size these fragments range from two feet in diameter down to minute particles, which are readily held in solution in water. The finer portions effervesce readily in acids. This locality is also that in which fragments and logs of cedar wood are found mingled with the till. Near the left-hand corner a large red-cedar log was found a few years ago in so fresh a condition that it was manufactured into utensils of various sorts, and it still retained its peculiar odor. Fragments of wood are seen projecting from the till both above and below the stratified layer.

I could not detect any essential difference between the till at this locality and that described at Oberlin, except what would be accounted for by the difference of composition arising from the difference in the local material which has been ground up to constitute the matrix. In both cases the material is largely the product of mechanical rather than chemical disintegration. Also, whatever we may say about the stratified stratum in the middle of the bank (shown in plate I), the great masses above and below are clearly the direct deposits of a glacier and not deposits from floating ice. A second view (plate II) from a locality east of Darrtown, is of a similar perpendicular exposure. The unstratified character of the deposit is apparent. The clay and semi-angular fragments are indiscriminately mixed. There is also a well-marked tendency in the flat limestone fragments in the lower portion of the deposit to arrange themselves horizontally. This arrangement, it is true, would, according to mechanical principles, be that which would obtain in case the flat fragments were of uniform thickness and fell through any considerable depth of water. But the chances of their being of uniform thickness and the improbability of their having fallen through great depths of water are such that we may take the horizontal arrangement as proofs of direct glacial deposit rather than of deposit from floating ice.

These instances are but illustrations of what occurs at numerous points not far from the border of the glaciated region as marked in my map. Essentially the same characteristics are found at Avondale station,

within the limits of Cincinnati itself, and at North Bend, on the north bank of the Ohio River, 20 miles west of Cincinnati, in a deposit 150 feet deep.

SOURCE OF BOWLDERS IN THE TILL.

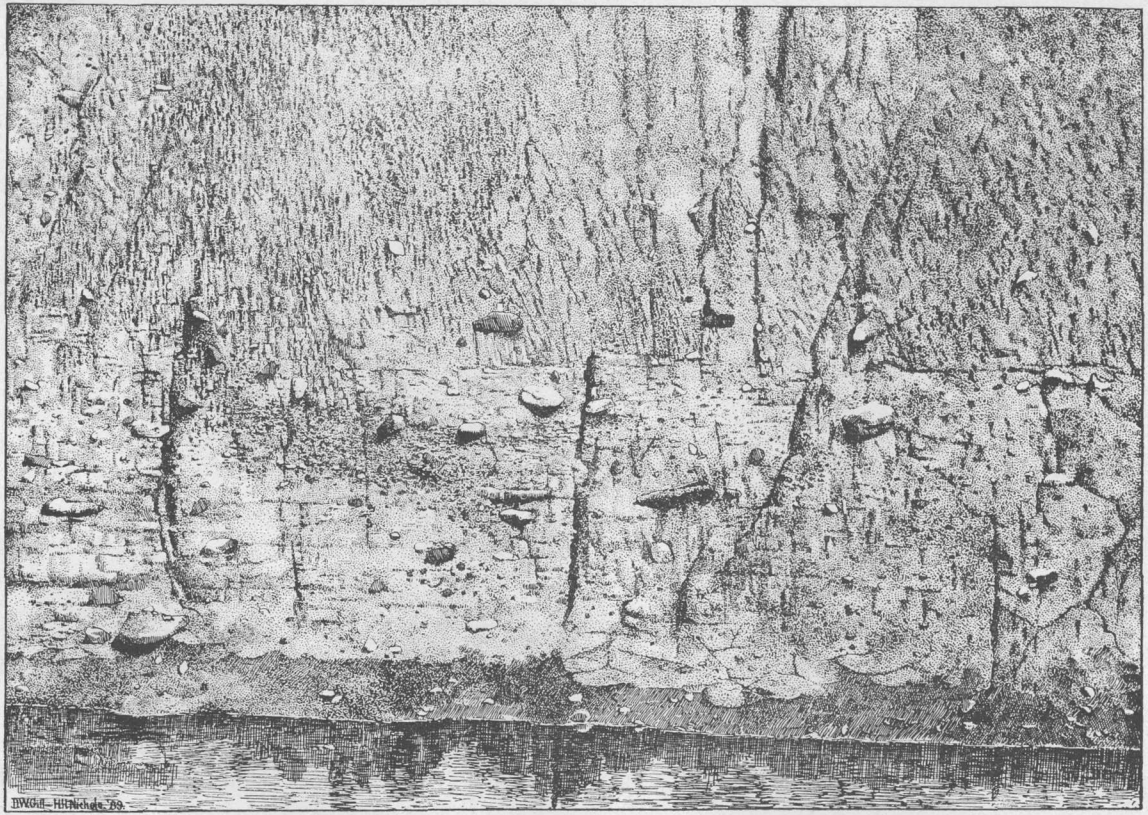
The northern origin of much of the material composing the deposits near the margin of the glaciated area is unmistakable, and some of it is surprising both for the distance it has been transported and for the size of the masses transported.

As yet there has been no systematic and complete comparison of the bowlders found near the glaciated margin and the rocky masses to the north, for the purpose of definitely locating the origin of the transported material, and there is such a degree of superficial resemblance between the granitic formations in different localities that no comparison will be satisfactory until the specimens have been both chemically analyzed and examined under the microscope. Still, a superficial examination reveals much of consequence.

In general it is manifest even to the casual observer that everywhere east of the Mississippi River the material composing the till is of northern origin. In Essex County Massachusetts, the bowlders are readily traced to localities in New Hampshire, some of them but a few miles away, and others from the White Mountain region, one hundred miles and more distant. My attention was early attracted throughout that region to bowlders of porphyritic gneiss containing very large and characteristic crystals of feldspar. The nearest ledges containing this class of rock are in the vicinity of Lake Winnipiseogee, in New Hampshire, seventy and more miles away, where the rock is a marked feature. So the whole mass of drift covering Plymouth County, Massachusetts, and that forming the hills of Cape Cod and of the islands to the south, is evidently of northern origin, and much of it from no great distance. Plymouth Rock is a bowlder from the direction of Boston. Prof. N. S. Shaler is able to trace the bowlders removed from a small mountain in the north of Rhode Island, and to estimate their amount with such accuracy as approximately to determine the extent of erosion taking place under a movement extending from that point to the terminal moraine. The material occurs in a triangular-shaped area to the south with its apex at the mountain. (See his forthcoming report.) The bowlders scattered over the surface of the moraine in Long Island consist largely of granite, gneiss, hornblende rock, mica slate, and red sandstone, which are easily recognized as from well-known localities in Rhode Island, Connecticut, and Massachusetts.[1]

Prof. Dana has also described many bowlders in the vicinity of New Haven which have been transported from well known trap-dikes, sixteen miles or more distant, and in a northeasterly direction. One

[1]Natural History of New York, part 4, Geology, part 1, p. 165 et seq.



EXPOSURE OF TILL SOME MILES EAST OF LANE'S MILL SECTION.

of these, called Judges' Cave,[1] on West Rock, 365 feet above the sea, must weigh a thousand tons.

A remarkable train of bowlders in Richmond, Massachusetts, near the summit of the Berkshire Hills and extending several miles was long ago described by President Hitchcock and Sir Charles Lyell, and more recently and accurately by Mr. E. R. Benton.[2]

In New Jersey, according to Prof. Cook, the bowlders are readily traced all along the morainic margin, as belonging to well known outcrops, of trap, blue limestone, and crystalline rocks to the northwest. Near Drakestown, in Morris County, there is a mass of blue limestone which had been worked for years as a quarry without suspecting that it was but a bowlder. "As exposed it measures thirty-six feet by thirty feet, and the quarrying has gone twenty feet in depth. Its vertical diameter is unknown. Around it there are many gneissic bowlders and other drift materials."[3] This mass is about one thousand feet above the sea level, and its native place must have been some miles to the north.

In Pennsylvania the distance from which the glacial material near the border of the glaciated region has been transported becomes at once more evident, because of its unlikeness to the local rocks. West of the Blue or Kittatinny Mountains there are no crystalline rocks in the State. Nor are there any such rocks to the north nearer than the Adirondacks in New York, or the highlands in northern Canada. Yet, granitic, gneissoid, and hornblendic bowlders abound all along the glaciated border, and are an important means of determining the glacial limit. In the valley between Blue Mountain and Pocono Mountain, Monroe County, and on the summit of the Pocono plateau, 2,000 feet above the sea, granitic bowlders from one to three feet in diameter are abundant, though mingled with great piles of local fragments. The granite must have been transported a distance of 250 miles at least, and carried over the summit of the Alleghanies lying to the northwest, and across the valley of the Mohawk in New York. The northern tributaries of the West Branch of the Susquehanna, likewise, bring down into that stream numerous granitic pebbles, showing that the glacial deposits in Lycoming County contain material from the far north which has been carried bodily over the summit of the Alleghanies. On proceeding west, the granitic mountains from which that material could come gradually recede to the north, thus increasing the distance between such bowlders and their possible original home. From Salamanca, New York, southwestward to Cincinnati, the whole country is literally covered, down to the glacial limit, with granitic, gneissoid, and hornblendic bowlders. Near Salamanca such bowlders abound at ele-

[1] See Am. Jour. Sci., 3d series, vol. 26, 1883, p. 347.

[2] Lyell's Antiquity of Man, pp. 355–362; Bull. Mus. Comp. Zool., Harvard Coll., vol. 5, no. 3, 42 pp. with map.

[3] Geol. Survey New Jersey, annual report State geologist for 1880, p. 30.

vations not far from 1,900 feet above tide and 700 feet above the Alleghany River. In Beaver County they are numerous on the hills to within 6 or 7 miles of the Ohio River, and several hundred feet above it. In Columbiana County, Ohio, a granite bowlder was found measuring 13 by 11 feet and 8 feet out of ground. Others were noted measuring 8 and 5 feet in diameter. In the same vicinity the till contains finely striated fragments of local sandstone, showing direct glacial action on the rocks of the vicinity. In Holmes County, mingled with fragments of granite in the till, were finely polished and striated pebbles of Corniferous limestone, which must have been brought from the other side of the water-shed, in the vicinity of Lake Erie, which is 100 miles distant. Near Lancaster, in Fairfield County, there is a granitic bowlder measuring 18 by 11 by 6 feet out of ground. In Ross County, near Adelphi, Chillicothe, and Bainbridge, granitic bowlders are found on the hills from four to six hundred feet above the valleys, that is, up to one thousand to twelve hundred feet above tide. A hornblendic bowlder 5 by 3 by 2 was noted 550 feet above Bainbridge. In Brown and Clermont and Hamilton Counties granitic bowlders abound on the hills down to the very edge of the trough of the Ohio. Here, also, are numerous bowlders of jasper conglomerate from the region north of Lake Huron or near the lower end of Lake Superior. The variegated pebbles of red jasper and of darker quartzites form a striking feature in the rocks of that northern region. The bowlders of this material found in the vicinity must have been transported nearly six hundred miles. Several bowlders of this description, from two to three feet in diameter, were found in Boone County, Kentucky, a number of miles south of the Ohio River, and between five and six hundred feet above it. Bowlders of this jasper conglomerate are very abundant in Michigan, are not infrequent in northern Ohio, and occur in various localities in southern Indiana—one being observed near Nashville, Brown County, Indiana, near the highest land in the State (about eleven hundred feet). Granitic and hornblendic bowlders are very abundant in Illinois as far south as Carbondale, Jackson County, near latitude 37° 35′ north. The bed rock is also here distinctly striated, showing the transportation of bowlders must have been independent of any stream of water. The distance from this point to the parent ledges can not be less than 600 miles to the north.

REGULARITY OF DISTRIBUTION OF TILL NEAR THE MARGIN.

(1) DISTRIBUTION OF THE TILL EAST OF THE ALLEGHANIES.

NEW ENGLAND.

Over New England the natural inequalities of the country are partly responsible for the irregular distribution of the till.[1]

In New Hampshire the phenomenon of a sloping mass of till south of a ledge of rock is frequently to be noted. But, as if to check too hasty a generalization respecting the manner of their formation, it has

[1] Chapter by Warren Upham, Geology of New Hampshire, vol. 3, 1878, pp. 285–333.

also to be noted that in about one-third of the instances in which deposits of till slope up against a rocky eminence the till is on the northern slope in the direction from which the ice came. Moreover, these accumulations sometimes slope both ways, and what is more remarkable still, often surmount in symmetrical form low rocky elevations whose surface is finely polished and striated by glacial action. So often do these lenticular-shaped[1] masses of till surmount low rocky eminences that Prof. Shaler at one time endeavored to explain their origin on the theory that they were but the remnants of a deep ground moraine which had originally covered the whole surface, but, during a supposed depression of the country to the sea-level, had been eroded by the waves wherever they were not protected by the rocky elevations at their base.[2] But these lenticular hills, or drumlins, abound in certain portions of southeastern New England[3] and in central New York south of Lake Ontario.

In southeastern New England these lenticular accumulations "vary in size from a few hundred feet to a third or a half mile in length, with usually about half or two-thirds as great width. Their height, corresponding to their area, varies from 40 or 50 feet to 150 or 200 feet. But whatever may be the size of these hills, they are singularly alike in outline and form, usually having steep sides, with gently sloping, rounded tops, and presenting a very smooth and regular contour."[4]

The prevailing direction of the longer axis of these hills is the same as that of the glacial striæ in their vicinity. In composition drumlins do not differ materially from the ordinary deposits of till in the same region. The material is for the most part unstratified, the clay is very compact; striated stones are commingled with the clay in every portion. There are, however, in these hills, as in the till as ordinarily arranged, occasional layers of stratified material, so that water for domestic purposes is usually found by sinking wells of no great depth. The bowlders upon the surface of the lenticular hills are also both larger in size and more angular in shape than those in the lower part of the deposit. I have not observed anywhere in Ohio, Indiana or Illinois, any marked tendency of the till to assume this lenticular shape. Nor have I been able to detect any generic difference between the composition of these hills and the general deposit of till over the portion of these interior States which I have surveyed. At the same time, it is perhaps worthy of note that the total deposit in the interior States averages a much greater depth than in New England. In Ohio, as already remarked, a reasonable calculation makes the average depth

[1] Hence called by Prof. C. H. Hitchcock "lenticular hills," but Prof. Shaler thinks it best to retain the name "drumlins," given to similar accumulations in Ireland.

[2] See Proc. Boston Soc. Nat. Hist., vol. 13, pp. 196–203.

[3] See Upham, Geol. New Hampshire, vol. 3, pp. 285–309; glacial drift in Boston and vicinity, Proc. Bost. Soc. Nat. Hist., vol. 20, pp. 220–234.

[4] Upham, Geol. New Hampshire, vol. 3, p. 288.

of the till upwards of 56 feet, while in New Hampshire Mr. Upham estimates that the whole deposit if evenly spread out would not exceed an average of 10 feet. But Mr. Upham now informs me that he thinks his early estimate much too small. This difference may be accounted for in two ways: first, the rocks from which the till of New England is derived are mainly crystalline, and hence of firmer texture than those from which the material of the till near the margin of the glacial limit in the interior is derived. The sandstones, shales, and limestones of the interior would much more readily yield to the disintegrating influences of glacial action than the granite and gneiss of the east would do. In the second place, the depth of the deposit is ordinarily greater over the southern portion of the glaciated region than over the northern, so that the deposits in Massachusetts are noticeably greater than those in New Hampshire for which Mr. Upham made his calculations.

The region under my immediate investigation in the interior States perhaps corresponds, in its proximity to the glacial margin, more nearly with the southern portion of New England.

The extreme southern portion of New England and Long Island are characterized by massive and irregular deposits of glaciated material. The backbone of Cape Cod consists of a line of hills from one to three hundred feet in height and from one to three miles in breadth, flanked on the southern side by extensive deposits of water-worn material. In contour and composition these hills very much resemble the kettle moraine of Wisconsin as described by President Chamberlin. According to my own observation, however, the terminal deposits in southern New England are composed of less water-worn material and contain more striated stones than the corresponding formation in Wisconsin. But like the kettle moraine, this line of deposits on the southern border of New England, abounds in kettle-holes of all sizes and is composed of transported material loosely thrown together. That the deposit on Cape Cod is not truly terminal, however, appears from the fact that the islands to the south are composed of similar deposits. Nantucket, Martha's Vineyard, the Elizabeth Islands, and many smaller islands between, are but the summits of submerged morainic deposits of unknown depth.[1] Farther west this same line of morainic hills continues, appearing near Point Judith in Rhode Island, and running to Watch Hill, and thence through Plum Island and Fisher's Island to the north shore of Long Island as far west as Port Jefferson, where it disappears. The parallel lines of hills, after forming the irregular outline of No Man's Land, Block Island, and the eastern part of Long Island from Montauk Point westward to Sag Harbor and Roslyn, continues to be the chief feature of the country as far as Fort Hamilton and Staten Island, south of New York City.[2]

[1] For description see Upham, Geol. New Hampshire, vol. 3, pp. 301–305, and B. F. Koons, Am. Jour. Sci., 1884, 3d series, vol. 27, pp. 260–264; 3d series, vol. 29, 1885, pp. 480–486.

[2] See Upham, Am. Jour. Sci., 3d series, vol. 18, pp. 86, 198.

NEW JERSEY.

Across New Jersey the accumulation of loose and glaciated material brought from the north is well marked down to the very margin of any signs of glaciation whatever. But the terminal deposit is not relatively so excessive as along the region eastward through Long Island and Cape Cod. On crossing the Delaware River at Belvidere, and throughout the whole region westward, the relative inferiority of the extreme marginal deposit is still more marked, except in a few localities, which may best be mentioned in this connection.

PENNSYLVANIA.

In Northampton County, Pennsylvania, just west of the Delaware River, the character and extent of the glacial deposit continues very much as in New Jersey. Near Middagh's, the most southern point of glacial signs in the county, the deposit is certainly as much as fifty feet in depth, and is, without question, till. This is about six miles west of the river, and is 625 feet above it. Nearer the mountain, not far from Bangor, the marginal deposit is, even at a still greater elevation, from one to two hundred feet in thickness, and for a mile or more is dotted with kettle-holes.

Monroe County spans a section east and west from the summit of the Blue Mountains to the summit of Pocono Mountain and the western border of the Pocono plateau looking towards the Lehigh River, a distance of 30 miles. The elevation of the Blue Mountains is in round numbers 1,400 feet above tide; that of the Pocono plateau, 2,000 feet. The valley between them is about eight miles wide, and is but 620 feet above tide. At Saylorsburgh, in the middle of this valley, there are extensive kettle-holes, and the deposit of till is very deep (Prof. Lewis estimates it as "several hundred feet") and covered with large bowlders, some of which are from the Adirondacks, 250 miles away. Five or six miles away, on the summit of the Pocono plateau, 1,400 feet higher, the marginal deposit is equally remarkable. For many miles in width a level, sandy plain extends in all directions. The soil over that portion of it situated south of the glaciated region is thin, being composed simply of the superficial disintegration of the compact Pocono sandstone. Upon going north in Tunkhannock township, one suddenly strikes into a glacial accumulation (near the boundary of Tobyhanna township), which is remarkable at once for its length, its height, its composition, and the abruptness of its southern margin. For a distance of about twelve miles the accumulation forms a marked feature of the landscape, and is known in the locality as "Long Ridge." This is truly morainic in character, is one hundred feet or more high, consists of a confused collection of bowlders (some of granitic character from the far north), and incloses near its margin numerous small lakes which have no outlet. These are neither more nor less than kettle-holes, and they are specially remarkable from the fact that some of

them are near the eastern margin of the plateau, which here forms an escarpment of several hundred feet. A little farther west this moraine so obstructs the outlets of several small streams flowing northward as to form small lakes to the south of it.[1]

Luzerne County.—It is unnecessary to do more than merely mention a few other places in Pennsylvania where the abruptness and amount of the terminal accumulations are noteworthy. But it may be well to note that upon the western flanks of the mountain in Luzerne County, between the Lehigh and the Susquehanna Rivers, the southern-margin of glacial action is very sharply defined, so that, according to Prof. Lewis,[2] the southern limit of the glacier can be determined to within a few yards. The accumulations in the valley of the North Branch of the Susquehanna, above Beach Haven, are also very large, and are unquestionably a direct glacial deposit, as can be seen to good effect by comparing them with the material near the river, at and below the intersection of the glacial border, where extensive terraces, 75 feet high, line the stream for one-fourth a mile on either side. Beach Haven is but 530 feet above tide.

Columbia County.—Another striking mass of glaciated material in the same vicinity occurs in Sugarloaf township, Columbia County. This is in the valley of Fishing Creek, west of Shackshinny Mountain. The valley is filled from side to side with a heterogeneous collection of large sandstone and conglomerate bowlders (some of them six feet in diameter), mingled with unstratified finer material, and to a depth of seventy-five feet or more. This deposit extends several miles south on the east side of the valley, but is entirely absent south of this point on the western side. The elevation of the valley is about one thousand feet above tide. The Alleghany Mountain rises 1,100 feet higher four miles to the north. This is but four or five miles south of the striæ on the summit of the mountain, mentioned on p. 40. A few miles west of this point the signs of glaciation cease.

Lycoming County.—On the summit of the Alleghany Range, near Ralston, in Lycoming County, the deposits are thick on the highlands east of Lycoming Creek, and about eight hundred or one thousand feet above it. But the narrow valley itself contains nothing but water-worn material, both to the south and for several miles to the north of Ralston.

NEW YORK.

In Cattaraugus County, New York, the terminal deposits are specially abundant in the township of Great Valley south of Ellicottsville and upon the hills south of Randolph. Great Valley, just south of the village of Peth, is filled with till from side to side (about one-eighth of a mile) to a depth of at least 60 feet and for a long distance. Scratched fragments and pebbles of granite and gneiss are abundant in the de-

[1] Second Geol. Survey Pennsylvania, Z, pp. 74–78. [2] Ibid, p. 103.

posit at this point and to the north, but to the south there is nothing in the valley except water-worn material arranged in regular terraces. At Steamburgh, about 20 miles further west, in the old valley east of Randolph, wells penetrate the stratified gravel 70 feet without reaching rock, and probably would have to go much deeper to reach it. This was probably, according to Prof. Carll,[1] the preglacial outlet of the Upper Alleghany River, which is known not to have flowed at that time south of Warren, Pennsylvania, since its upper and buried channel is much deeper than that below Warren.

(2) DISTRIBUTION OF THE TILL WEST OF THE ALLEGHANIES.

GENERAL REMARKS.

In considering the glacial deposits of western Pennsylvania and of eastern and southern Ohio it is important to bear in mind the ordinary elevation of the country above tide and its preglacial condition. From Salamanca, New York, to Cincinnati, Ohio (a distance in a straight line of about 380 miles), the general course of the glacial boundary is southwest, and is approximately parallel with the axis of the Appalachian Mountains, and continues throughout not far from the northwest outcrop of the Appalachian coal-fields, being inside the line of outcrop as far as Knox County, Ohio, and from thence to the Ohio River in Brown County, passing over a country characterized by extensive outcrops of Waverly sandstone. Over all this region preglacial erosion had been most extensive, as is evident to a superficial observer, from the long, deep channels cut by all the streams through the coal measures outside the glacial limit, and where there has been little to disguise the effect of this long-continued erosion. The Ohio River, from Louisville, Kentucky, up to Pittsburgh, Pennsylvania, occupies a valley of erosion averaging about a mile in width, and bordered on each side by parallel horizontal strata of rock rising in nearly perpendicular bluffs from three to five hundred feet in height. The same trough continues in similar proportions up the Alleghany River to near its source, except that it is narrower and in its upper portions deeper. Furthermore, deep as is this valley, there is abundant evidence that before the glacial period it was still deeper, it having been filled up, as estimated by Newberry,[2] more than one hundred and fifty feet by a postglacial river deposit. For example, at Cincinnati the gravel and sand have been repeatedly penetrated to a depth of more than one hundred feet below the bottom of the river without reaching the rock. At New Philadelphia, Tuscarawas County, Ohio, borings show that the old bottom of the Tuscarawas River was 175 feet below its present depth. Near New Castle, Pennsylvania, the bottom of the old trough of Beaver Creek is shown to be 150 feet below the present bottom.

[1] Second Geol. Survey Pennsylvania, III, pp. 330–439.
[2] Geol. Survey, Ohio, vol. 2, pp. 1–80.

In the same manner all the streams tributary to the Ohio occupy narrow, deep valleys of erosion, entirely devoid of waterfalls, showing that in all cases they have been at work in their present valleys from the very earliest times. The difference between the elevation of the country about Salamanca and that at Cincinnati corresponds very nearly with the fall of the Alleghany and the Ohio Rivers between those points. The Alleghany River at Salamanca is 1,360 feet above tide. The country to the north and west is about 1,900 feet above tide. The Ohio River at Cincinnati is 447 feet above tide. The elevation of the surrounding country is between nine hundred and one thousand feet above tide. North of the glacial limit there is every reason to suppose that preglacial erosion had produced effects corresponding to what is now visible throughout southeastern Ohio, southwestern Pennsylvania, and West Virginia. But to a great extent these preglacial channels have been completely filled up with till, so as to make important changes in the line of drainage and to give an entirely different aspect to the whole glaciated region from that borne by the country outside of the limit. Indeed, as remarked above, the glacial boundary throughout southwestern Ohio and the whole of Indiana and Illinois corresponds very closely with the boundary of the prairie region in those States, so that the natural scenery, the character of the soil, the water supply, and nearly all the elements determining the vast agricultural interests of those States have been produced by the ice movement during the glacial period. The till which is spread over this area represents what Newberry calls "the grist" of the continental glacier, and altogether constitutes an immense mass, amounting in Ohio alone to a stratum averaging more than sixty feet in depth over about twenty-five thousand square miles. As compared with the deposits in New England, this is so nearly uniform in its deposition that it has been beyond my power, if not my province, to trace any extensive system in the irregularities which appear. The results of the attempt to trace such a system are given by President Chamberlin.[1] I will content myself with briefly indicating the approximate amount of deposition along a belt from ten to twenty miles wide, forming the southern and eastern margin from Salamanca, New York, to the Mississippi River, taking the counties in order.

PENNSYLVANIA.

Warren County.—In the Conewango Valley above Warren, in Warren County, the glacial accumulations are very marked, filling it from side to side, forming a well-defined ridge rising abruptly about seventy feet on its northern side, near Ackley Station. For about two miles the material of this deposit is clearly till, but it gradually changes into water-worn material, which is spread along the margin of the stream as a regular terrace. This morainic deposit rises diagonally upon the flanks of the

[1] Preliminary paper on the terminal moraine of the second glacial epoch, Third Annual Report U. S. Geological Survey, pp. 330–335, 339, 341.

hill to the east for a long distance and to a heighth of several hundred feet. Upon the west side of the valley the glacial deposits are deep all over the northern tier of townships from Pine Grove westward, and they appear as if pushed up to the watershed between Lake Erie and the Alleghany, which is here 1,900 feet above the sea, more than 1,200 above the lake, and about 700 above the Alleghany.

The till in many places is certainly twenty-five feet in depth, and extends in a continuous sheet northward as far as Jamestown, New York. It is pushed far up upon the northern slope of Pike's Ridge, in Sugar Grove township, Pennsylvania, to a height of about four hundred feet above the country to the north. In the southwest part of the county granitic bowlders and striated stones are numerous upon the high land in the southern part of Deerfield township. This is several miles nearer the Alleghany River than the line as determined by Prof. Lewis and myself in 1881 for the Pennsylvania Survey.

Venango County contains a glacial deposit of considerable depth near its western border; but the deep accumulations are for the most part in the valleys now occupied by streams. Here also, as in Warren County, the glacial limit must be put several miles nearer the Alleghany River than as delineated by Prof. Lewis and myself in 1881. Granitic bowlders and striated pebbles abound in Cherry Tree, Oakland, Sugar Creek, and Sandy Creek townships, at an elevation of about six hundred feet above the river and about one thousand seven hundred feet above tide.

Crawford County lies wholly within the glacial limit, and with the exception of its southeastern portion is uniformly and deeply covered with till.

Mercer County also lies wholly within the glaciated area, and is deeply covered with till, except upon its higher summits, which contain numerous glacial striæ.

Butler County.—The glacial limit barely grazes the northwestern portion of Butler County, passing through Mercer, Slippery Rock, and Worth townships. Granitic bowlders are numerous down to very near the margin.

Lawrence County is completely enveloped in till, with the exception of the two southeast townships. The depth of the till, even upon the higher lands, as at Mount Jackson, certainly approaches 50 feet.

Beaver County.—Till is pretty deep over the extreme northwestern part of Beaver County, in Darlington township. Bowlders and thin deposits of till are found upon the highlands ten miles farther south, to within about ten miles of the Ohio River, but none could be found upon the high land beyond those points. The bowlders found in the terraces at the mouth of Beaver Creek were transported down the stream by water.

OHIO.

Columbiana County.—The northern half of Columbiana County is deeply covered with till, while it is entirely absent in the southern half.

Within two miles of the southern boundary of the deposit, in the most western township, the till is thrown up into hummocks, and incloses kettle-holes of moderate size upon the highest land, constituting at that point the water-shed between the Mahoning and the Tuscarawas rivers. Wells are reported as penetrating the till 50 feet without reaching rock. Throughout the country, especially in the eastern part, granitic bowlders are found upon the high lands along a belt four or five miles south of the deeper deposit.

Stark County is deeply enveloped in till all over its northern and western half, while the southeastern part is completely devoid of glacial marks. Two or three miles west of Canton there is a remarkable series of ridges and kettle-holes, ending in Buck Ridge, which rises 85 feet out of an extensive gravel plain, with a base of 570 feet, and ascending from the east side with a slope from 18° to 25°. This kame—for so it properly is—is coarsely stratified, and contains many granitic pebbles and bowlders. One bowlder, about the middle of a cross-section half way up, measured nearly five feet in diameter. To the north the ridge continues to an indefinite distance, inclosing large kettle-holes. One of these was 300 feet long and 40 feet deep, with the bifurcated edges of the ridge as its rim. This seems to be the southern extension of the large kame-like deposits which abound between Akron and Ravenna, upon the water-shed between the Cuyahoga and the Nimishillin, about twenty-five miles to the north. The numerous lakes throughout that region are all "kettle-holes." The extreme southwestern part of Stark County is deeply covered with till, and there is an immense kame-like accumulation near the Tuscarawas River, and rising 154 feet above it, in the southern part of Bethlehem township.

Holmes County.—The northern half of Holmes County is deeply covered with till, while it is completely absent in the southern half, and the line is very sharply defined. The Killbuck River divides the county into two equal portions east and west, occupying a valley about a mile in width, and about 500 feet below the general level. The southern half of the county is very much broken, being everywhere cut up into deep gorges by the streams. Throughout the northern half, these gorges have been entirely obliterated by the glacial deposits. Deposits of till from twenty-five to thirty feet in depth appear at numerous places near the highest land in the county. In a broad place where these small streams unite in the valley, five miles north of Millersburgh, is a kame-like accumulation rising 125 feet above the stream, containing scratched stones. Near Millersburgh a cut in the till showed a very fresh appearance 20 feet below the surface, there being no signs of oxidation at that depth. There are extensive terraces on the Killbuck River near Killbuck post-office, rising 120 feet above the river.

Knox County.—All but the extreme eastern portion of Knox County is deeply enveloped in till. The glacial boundary is here running a few degrees west of south. At Danville, wells were reported penetrating

126 feet (probably in a preglacial channel) through yellow clay, blue clay, gravel, quicksand, and cemented gravel without reaching rock. The railroad cut shows glaciated material from twenty-five to forty feet deep for a distance of about 400 yards. This is on the extreme eastern limit of the glaciated area.

Licking County is enveloped with till to a depth of fifteen to thirty feet west of the two eastern tiers of townships, and the fringe of scattered glacial deposits outside is narrow.

Perry County lies wholly outside of the glaciated region, with the exception of the northwestern township, where, at Thornville, the glacial deposit upon the hills south of the old reservoir is certainly 35 feet in depth. Large bowlders are numerous.

Fairfield County is deeply covered with till, with the exception of its three or four southeast townships, which in places very near the margin is certainly 40 feet in depth at an elevation of 450 feet above the canal at Lancaster.

Ross County.—The glacial limit passes through Ross County diagonally from northeast to southwest. The accumulations at Adelphi, in the extreme northeast corner of the county, in the valley of Salt Creek, are in general very fresh in appearance and show an exposure of 188 feet. The same formation rises to 200 feet a mile or two west. A few scattered pebbles of granite were found three or four miles outside of this limit upon hills 400 feet above Salt Creek, and glacial accumulations are continuous in the Scioto Valley to Circleville. In Green township, in the eastern part of the Scioto Valley, there are immense kame-like ridges of gravel largely composed of limestone fragments, rising 150 feet (barometer) above the plain. Near Lattas P. O., in Twin township—550 feet (barometer) above the Scioto Valley at Chillicothe—a well upon the farm of J. McConnell penetrated till 31 feet (12 feet yellow clay, 4 feet blue clay, 10 feet yellow clay, 5 feet gravel). Three miles north of this is a broad valley 400 feet lower. Wood was found in this well in the clay 13 feet from the surface. Scattered glacial deposits upon the summit are found three or four miles farther south; but the deposit continues at a great depth to the west as far as Highland County.[1]

Highland County is completely enveloped in till, with the exception of its southeast corner. Over the northern and western half the deposit is deep, but rather thin southeast of Hillsborough. A mile or two south of Hillsborough there is an extensive deposit, about 40 feet thick, of cemented gravel containing granitic pebbles, having nearly the elevation of Hillsborough itself, which is 500 feet above Chillicothe, and 700 feet above low water at Cincinnati, 1,135 above tide.

Brown and Clermont Counties are deeply covered with till over their northern portion, and glacial deposits are more or less marked down to the Ohio River as far east as Eagle Creek, Brown County. In the south-

[1] For further particulars concerning the deposits in this county along Paint Creek see p. 93.

ern part of these counties the till is pretty generally of a reddish color, showing thorough oxidation. Lewis and Pleasant townships, in Brown County, on the Ohio River, abound in these deposits of till down to the very margin of the trough of the Ohio, where the general level is from 400 to 450 feet above the river. Numerous deposits within a mile of the escarpment were noted from ten to twenty feet in depth, and contained granite bowlders three or four feet in diameter.

Nearly the entire water-shed, many miles in width, east and south of the East Fork of the Little Miami, and occupying and covering the western part of Highland, the northern part of Brown, and the southern part of Clermont County, and lying from 400 to 500 feet above the Ohio River, is covered by a level and uniform deposit of loamy soil, fine and light colored at the top, with gravel toward the bottom from three to seven feet deep. Granite is a frequent constituent of the gravel, the surface is a dead level, and the land is difficult to drain. The deposit is similar in every essential respect to those afterward to be described in the southeastern counties of Indiana and over a large part of the southern portion of the glaciated region in Illinois. The fine deposit at the surface is in these counties thin, being scarcely ever more than two or three feet in thickness, and resembles in composition the upper part of the loess appearing so extensively in Illinois and farther west.

Hamilton County.—Clearly marked glacial deposits are by no means continuous over Hamilton County, but they are scattered over it in a somewhat perplexing manner. In Anderson township, in the southeastern corner of the county, upon the Ohio River, much of the elevated portion of the country (375 feet above the river) is covered with till from 15 to 20 feet in depth, and granitic bowlders are abundant. In the southern sections of Columbia township, cuts in till are frequent from 30 to 40 feet in depth. At Avondale and Walnut Hills, in the upper part of the city of Cincinnati (from 250 to 350 feet above low-water mark), cuts in till from fifteen to twenty feet in depth are exposed. In this there is no appearance of stratification; granitic fragments up to 20 inches in diameter are abundant, and in general are not water-worn; striated fragments of local rock and Corniferous limestone from the northern part of the State are also abundant. Upon the western side of Mill Creek no distinct deposits of till could be found upon the highlands in the townships bordering the Ohio, nor in Green township, still farther to the north. The region, however, is covered pretty generally with a deposit from six to ten feet in depth, consisting of fine clay, of a whitish yellow for the first three or four feet from the surface and a reddish color below, with some gravel near the bottom, and occasionally a striated pebble. The general elevation above the river is not far from 400 feet. At North Bend, in Miami township, a preglacial valley, formerly connecting the Big Miami with the Ohio, is filled with till to a height of 160 feet above the river. Striated pebbles in this are numerous. Colerain and Springfield townships, in the northern part of the county,

are, over their southern portions, pretty generally covered with from ten to fifteen feet of clay comparatively free from pebbles; but in their northern part, near Pleasant Run, deposits of true till are deep and abundant.

Butler County, to the north of Hamilton County, is everywhere deeply enveloped in till, fresh sections of which, near the city of Hamilton, contain undecayed specimens of wood, and show as little signs of oxidation as anything in the northern part of the State.[1]

KENTUCKY.

Campbell, Kenton, and Boone Counties form a sort of promontory looking towards the north, with the Ohio River on the east, north, and west sides. Since the direct glacial deposits come down to the river banks in Clermont and Brown Counties on the east in Ohio, and in Dearborn, Ohio, Jefferson, and Clarke Counties in Indiana, it becomes of special interest to note the facts over the intervening portion of Kentucky with care.

Campbell County.—The hills in Carthage precinct facing the river to the east and opposite New Richmond, Ohio, about twenty-five miles above Cincinnati, are enveloped with a deposit of till from ten to fifteen feet in depth in which granitic bowlders are numerous. This extends to an elevation of from 350 to 400 feet above the river opposite New Richmond, but none could be found upon the hills in the southern part of the precinct. Nor could any till or granite pebbles be found upon the summit between the Ohio and Licking Rivers in this county from Alexandria to Dayton (the general level being about 400 feet above the river). The soil, from six to ten feet deep, is clay, being yellow near the surface, but dark gray below. A deposit of sand near Alexandria upon the summit is a decomposed remnant of sandstone.

Kenton County.—A détour from Visalia northwest towards Florence (over elevations ranging from three hundred and fifty to five hundred feet above the river) discloses no glacial signs until reaching the Boone County line, three miles southeast of Florence. Here seven miles south of the Ohio, there suddenly appears a stiff clay deposit containing numerous granitic pebbles three or four inches through (see specimens 91 and 92). From this point northward towards Florence granitic bowlders abound. Five were measured which were each upward of two feet in diameter. The covering of the soil was only from two to three feet (the elevation is about five hundred feet above the Ohio).

North of this, a railroad cut at Erlanger (475 feet above low-water mark in the river), shows clay six feet, containing small pebbles of quartzite, limestone and granite.

From Erlanger to Covington a deep deposit (from twenty to twenty-five feet) of loess merging into loam, with some gravel at the bottom, everywhere appears along the road.

[1] See p. 49.

Boone County.—One and a half miles southwest of Florence a bowlder of jasper conglomerate, three and a half feet in diameter was found in the headwaters of a small stream emptying into Gunpowder Creek (elevation about five hundred feet above the river at Cincinnati). Two miles west of Florence there are other bowlders of this jasper congolmerate with thirty or forty granitic bowlders, many of them two or more feet in diameter. These also are in a branch of Gunpowder Creek and 500 feet above Cincinnati. This conglomerate is identical in composition with that found in place on the south shore of Lake Superior and to the north of Lake Huron, the bowlders from which are widely scattered over Michigan, Indiana, and northern Ohio.

One mile east of Hebron there is a deposit of till 12 feet or more in depth, and 450 feet above the river. The whole surface of the country about Hebron is covered with a loamy deposit containing occasional scratched stones and pebbles.

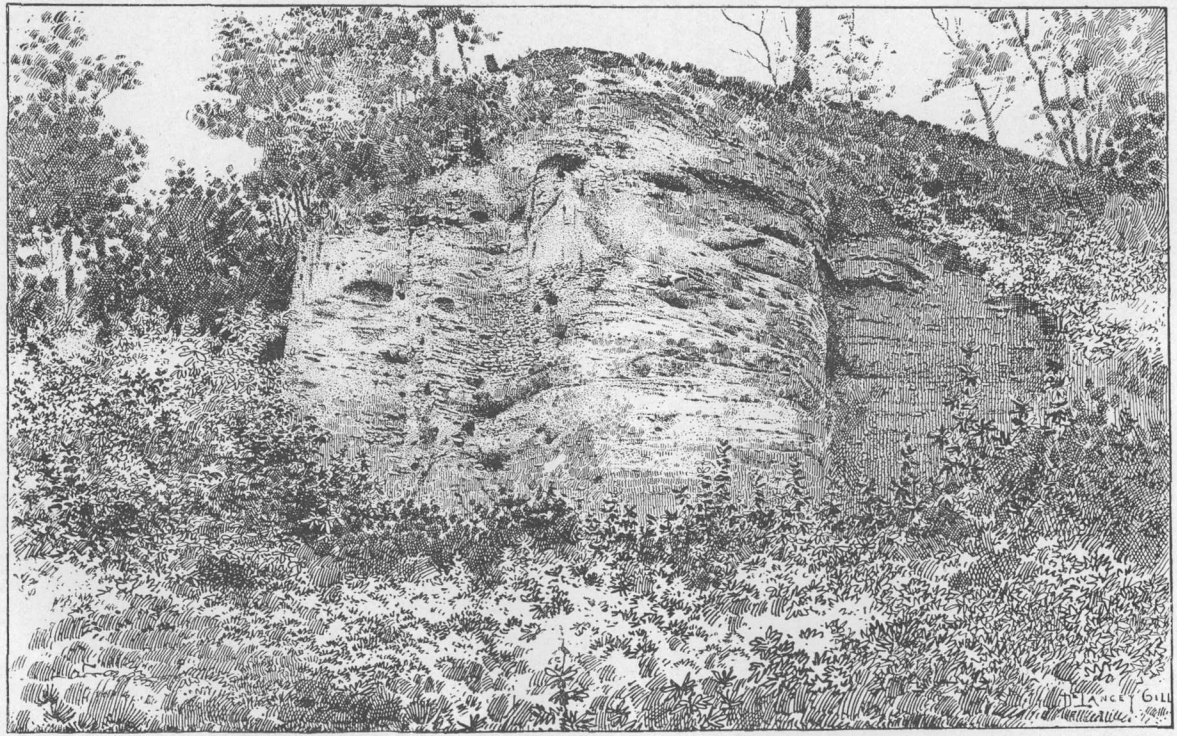
From Petersburg to Big Stone Lick the summits of the bluff, up to about 450 feet, and perhaps higher, are enveloped with a loam containing numerous granitic and other pebbles. There is no appearance of stratification. Near the headwaters of Middle Creek, at an elevation of 300 feet above the river, six miles southeast of Petersburgh and three miles east of Belleview (Grant post-office), the washed pebbles of this gravel are cemented together by an infiltration of lime, forming perpendicular exposures of 50 feet, where cut through by the streams. The pebbles are mostly lime rock of the Cincinnati series, but some, a foot or more in diameter, are granitic.

An extensive deposit of this loam appears on the highlands south of Gunpowder Creek, two miles northeast of Big Bone Lick, by Big Bone Baptist Church, near the junction of Hamilton and Union precincts, 500 feet (barometer) above the river.

A section made still farther south, from Glencoe to Warsaw, in Gallatin County, failed to disclose similar deposits there.

Similar to the conglomerate at the headwaters of Middle Creek is that facing the river at the mouth of Woolper Creek, known as Split Rock (see plates III and IV), which show the cliffs of conglomerate across the creek from Split Rock.

The pebbles in the cemented masses are mostly of limestone, and are very coarse, individual pebbles frequently being from three to four feet in diameter. Granitic pebbles are infrequent. One was found, however, measuring two feet in diameter. The cliffs of this conglomerate, at the mouth of Woolper Creek, rise 185 feet above low water, and the material is cemented together by an infiltration of lime. Kamelike ridges extend for two miles south of Woolper Creek, on the way to Belleview. These are composed of rather fine material, and are 160 feet above the river. The terrace upon this, the Kentucky side of the river, for two miles or more below Woolper Creek, is remarkable for its height, being more than 100 feet above the river, and 56 feet higher than the high-water mark of January, 1883.



CLIFF OF POST-GLACIAL CONGLOMERATE SOUTH OF WOOLPER CREEK, NEAR SPLIT ROCK, KENTUCKY.

Trimble County.—South of Madison, Indiana, on the opposite side of the river, in Kentucky, the level-topped table-land (450 feet, barometer, above the river) is covered for several miles with a yellowish loam or loess, two to five feet, graduating into a stratum containing a large number of flint chips, but no granitic pebbles. There were, however, some quartzite and compact red sandstone pebbles, giving some signs of glaciation; also near the river a few granitic pebbles were found 440 feet (barometer) above the river.

INDIANA.

In Indiana the glacial boundary line still continues to bear in a southerly direction through Ohio, Switzerland, and Jefferson Counties, grazing the edge of Kentucky again opposite Madison, and reaching its southernmost point near Charlestown, in Clark County.

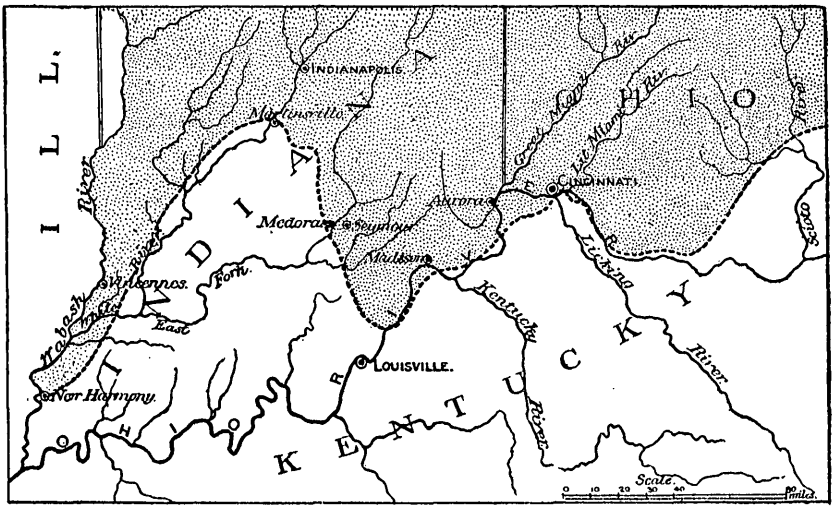


FIG. 3.—Map of southern Indiana, showing glacial boundary.

From here it bears again to the north through Scott and Jackson Counties to the line between Bartholomew and Brown, and follows this to the northeastern corner of Brown. There again it turns to the southwest, touching the northeast corner of Monroe, where it again bears north for 10 miles, to near Martinsville, Morgan County. Here the line turns west and south, passing diagonally through Owen, Greene, Knox, and Gibson Counties, and into Posey County to New Harmony.

Dearborn County.—At the Junction of the Miami and the Ohio, just above Lawrenceburgh, the valley is between two and three miles wide, and the level-topped highlands on the west rise to an elevation of 500 feet. Thin deposits of till were found upon these highlands with scattered granitic bowlders over the whole southern part of the county. The intervale upon the Ohio is here bordered on the west by a stratified terrace of water-worn material from one-fourth to one-half mile wide, 80 feet above high-water mark, largely composed of pebbles two or three inches

in diameter. Opposite Lawrenceburgh remnants of this appear on the Kentucky side, and it continues at a similar height on the east bank for some distance up the Miami, in Ohio.

Ohio County.—At Hartford, Ohio County, south of Laughery Creek, a deposit of clay, gravel, and small granitic pebbles (thrown up into small ridges and knolls) rises upon the north slope of the plateau to a height of 250 feet. Gold is found in this deposit. Upon the table-land 450 feet above the river, granitic bowlders, from two to three feet in diameter, occasionally occur.

Switzerland County.—Upon the highlands, one-half mile back from the river, at Florence, York township (elevation 350 feet above the river), there is no appearance of glaciation, the clays being all residuary. An extensive terrace on the east side of the river is 100 feet above low-water mark. The highlands in Jefferson and Craig townships, northwest of Vevay (475 feet above low water), are covered with a deposit of reddish clay, from two to three feet thick, abounding in granitic pebbles.

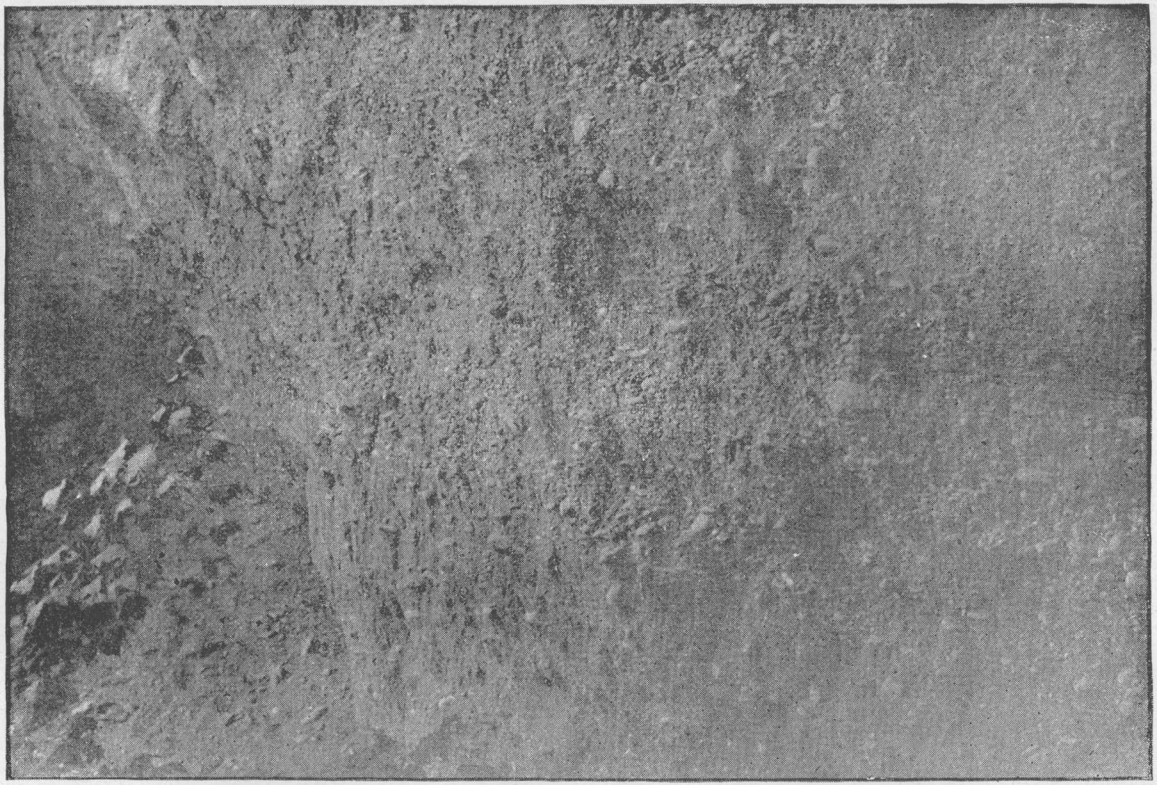
Jefferson County.—On the edge of the level-topped highlands, at North Madison, 475 feet above low-water mark, there is a deposit of clay 20 feet deep, light yellow for a few feet below the surface, then reddish in color, with much flint and many small pebbles, some of which are of granite and are striated, especially through the lower half of the deposit. The fine material gradually merges into the coarse, and there is no stratification. The flint comes from the decomposition of limestones in the region further north. Detours made from here (30 miles north to Osgood, Ripley County; 25 miles northwest to Vernon, Jennings County, and 15 miles west-northwest to Paris, Jennings County) show that the whole table-land is covered with a formation similar to that described. This is of varying degrees of thickness, being sometimes 30 feet and more in depth on the highland. Granitic bowlders and striated stone pebbles are abundant, but there are no knobs or ridges of drift.

Hanover and Saluda townships are of the same elevation and present the same features with the region north of Madison. Granitic bowlders are abundant on the surface, sometimes two or three feet in diameter, and the till is occasionally from twenty to thirty feet deep upon the highlands, with granitic bowlders near the bottom.

Ripley County.—At Milan (about five hundred and fifty feet above the river at Aurora), a well, according to Prof. Borden[1], gives the following section:

	Feet.
1. Light-colored clay soil	10 to 14
2. Yellow clay, with flint, gravel, and fossil-corals	12
3. Blue glacial clay	12
4. Coarse, yellow sand, with recent shells and water	8
5. Blue clay, muck, containing roots and limbs of trees	8
Total	54

[1] Seventh Annual Report, Geol. Survey, Indiana, for 1875 (1876), p. 195.



A NEAR VIEW OF CLIFF OF POST-GLACIAL CONGLOMERATE SHOWN IN PLATE III.

Jennings County.—In Bigger township, in the southeastern corner of Jennings County, wood was reported from two wells in hard blue clay, 12 and 30 feet below the surface.

Prof. Borden reports the following section[1] from a well at Paris Crossing:

	Feet.
1. Light-colored clay, with deeper shades below	10
2. Ocher-colored clay, with flint pebbles, increasing in hardness towards the bottom	19
3. Very hard bed clay and gravel	2 to 3
4. Blue drift clay, very sandy, with water; also limbs, twigs, and roots of trees, continued to the depth of	7 to 10

Clark County.—Through Washington, Bethlehem, and Owens townships, the characteristics described in Jefferson County continue. Large striated granite bowlders, three to four feet through, abound near Bethlehem, about half way up to the summit from the river. Some till appears as far south as Charlestown; but thence to Jeffersonville, and turning northwest across the northeastern corner of Floyd County to Wood Township, Clark County, and thence on northwest through Washington and Lawrence Counties, no till or transported bowlders are to be found. Glacial deposits are found only on returning east to Brownstown, Jackson County. A prominent feature of the country from the eastern part of Floyd County to the northeastern part of Brown County are the knobs of Waverly sandstone, rising several hundred feet above the surface to the east, and dipping gently westward so as to underlie the coal which is in the western part of the State, corresponding to similar formations dipping in the opposite direction in the Scioto Valley of Ohio.

Scott County and the southeastern part of Jackson I have not examined, but have assumed that the limit lies east of the knobs just named.

Jackson County.—Till with granitic pebbles and striated stones was found two miles southeast of Brownstown, bordering the sandstone knobs. North of Brownstown, six miles across the intervale between the East Fork of White River and White Creek, till rises about fifty feet from the plain against the foot hills. But the highlands in Salt Creek township show no glacial deposits.

Bartholomew County.—In the southwestern corner of Bartholomew County till, abounding in granitic pebbles and striated stones, runs up on the highlands to within about two hundred feet of the summit of the sand hills; but it is absent from the southeastern corner of Brown County. Sections in Ohio township show it to be at least forty feet in depth, and it continues, like a flat-topped terrace, eastward toward the East Fork of White River. Harrison and Union townships are covered with till from the east to within about two miles of the Brown County line, where it ceases upon the flanks of the sandy knobs, at a height of about two hundred feet above the valley. Sections show this to be at least fifty feet deep.

[1] Seventh Annual Report, Geol. Survey, Indiana, for 1875 (1876), p. 172.

Decatur County, to the east, is completely enveloped in till, but neither in that county nor in any south of it was my own attention called to anything like moraine hills, such as were described in the Eastern States, though I drove from Clarksburgh, in the northeastern corner of the county, to Greensburgh, and thence south through Osgood, Ripley County, to the Ohio.

Johnson County.—The southern part of Johnson County is completely enveloped in till, the deposits being sometimes ninety feet and more in depth.

Brown County.—The sandy knobs stretching northward from Floyd County, attain in Brown County, south of Nashville an elevation of 1,147 feet above tide. No glacial deposits were found upon these knobs along the eastern border of the county until reaching the extreme northeastern corner.

Till continues from Johnson County into the northeastern part of Hamblin township, Brown County, and rises to within about three hundred feet of the summit of the knobs. There are no granitic bowlders in the beds of the streams running east from the knobs, but many very large ones are found near the glacial margin, one being five feet in diameter. Gold is also found here, as in Ohio County.

The northwestern part of Hamblin township and the northern part of Jackson township are covered with deep deposits of till, being fifteen or twenty feet deep at Georgetown, and rising to an elevation of 200 feet above Bean Blossom Creek. In the valley of Big Salt Creek, at Nashville, there is no till; but a few granitic pebbles and bowlders are to be found. Northwest from Nashville, near the water-shed between Big Salt and Bean Blossom Creeks, and on the south slope, bowlders of granite and jasper conglomerate, from three to five feet through, were found. Till also was encountered at Needmore, Jackson township.

Monroe County is wholly free from any glacial deposit, except in the extreme northeast corner.

Morgan County.—Jackson township is completely enveloped in till, often from thirty to forty feet in depth. At Morgantown, wood is reported as found in a well one-fourth mile from the creek, 30 feet below the surface. At Mahalasville, the glacial deposit terminates on the northeastern side of the valley of Big Indian Creek, in kame-like hills 107 feet high. The gravel in this hill is mostly fine, but contains bowlders of decaying granite, two and a half feet, at different elevations. The valley of White River at Martinsville, Washington township, is about one and one-fourth miles wide, consisting mostly of intervale. Till appears on hills east of Martinsville, but there is none southwest.

Jefferson township is covered with deep deposits of till to about one mile south of its center, where it suddenly ceases.

Ray township contains glacial material only in its extreme northern part.

Putnam County is completely enveloped in till.

Owen County.—In Owen County the glacial line turns again to the southwest, running through Harrison, Taylor, Montgomery, Morgan, Lafayette, and Jefferson townships.

The southeastern part of Harrison township is unglaciated; but glacial deposits are continuous over the northern part of the township.

In Montgomery township till and bowlders in moderate amount appear at Santa Fé, and are continuous north ten miles to Cloverdale.

Till, with abundant granitic bowlders, also covers the highest hills in the northeastern corner of Morgan township, and three miles to the southwest.

In Lafayette township the deposits of till are thin, but extensive throughout the northwestern half. Three miles south-southwest of Vandalia, striæ were found running up hill nearly east and west in the outcropping sandstone strata. Five miles to the west, in Marion township, well-defined striæ were found running S. 40° to 50° E.

Till appeared in the northeastern corner of Jefferson township, and for three miles to the southwest; but there was none in Franklin township.

Greene County.—From Switz City, westward, no glacial deposits appear for four miles; but they begin to be seen in Stockton township, and are continuous to the western border of the county, being from fifteen to twenty feet in depth. Scratched pebbles and granitic bowlders are abundant.

Sullivan County is completely enveloped in till.

Knox County.—East of Vincennes, on rising from the broad gravel terrace of the Wabash, and one and a half miles from it, sand-hills rise about one hundred feet. A mile farther on, hills rising one hundred feet are covered with loess, which completely envelops everything. But in Harrison township, seven miles southeast from Vincennes, cuts of fifteen or twenty feet through the loess revealed an irregular deposit of true till. The hills are here from one hundred to one hundred and fifty feet above the valleys, but the depth of the till could not be ascertained.

Daviess County.—Nothing like till was found in the southern part of Daviess County in a drive from Washington to Petersburgh, Pike County.

Gibson County.—At Princeton, Patoka township, there is a deposit of till thirty or forty feet deep, with granitic pebbles, one of which was a foot and a half through. There were also numbers of striated pebbles in this bank. Loess, ten or twenty feet deep, covers rounded slate hills to the east. No granite pebbles were to be found in the eastern part of Princeton township and the western part of Columbia.

At Owensville, Montgomery township, loess is everywhere on the surface, with blue till underneath containing granitic and scratched pebbles. Till also appears at Fort Branch, in the southern part of

Patoka township. Wells are reported as penetrating red and blue clay 20 feet. Eastward to Barton township no glacial material could be found.

Vanderburgh County.—Extensive detours in Vanderburgh County disclosed everywhere the loess resting upon the rocks in place, and the streams utterly devoid of gravel.

Posey County.—Robb township, in its eastern part, is so deeply enveloped in loess that the character beneath could not be determined. The hills are about two hundred feet above the Wabash (estimated). In the northwestern corner of the township, facing the valley of Black Creek the loess is underlaid by till, which is certainly 20 feet deep. Scratched stones and granitic bowlders were numerous. This exposure continues for a mile and a half. Black Creek, which flows through this deposit, contains much granitic gravel. Granitic pebbles and striated stones occur also on the hills between Black Creek and the Wabash.

One-half mile southeast of New Harmony a section shows 15 feet of loess overlying till of an unknown depth, but with no sharp line of demarcation between them. The trough of the Wabash is here about five miles wide.

ILLINOIS.

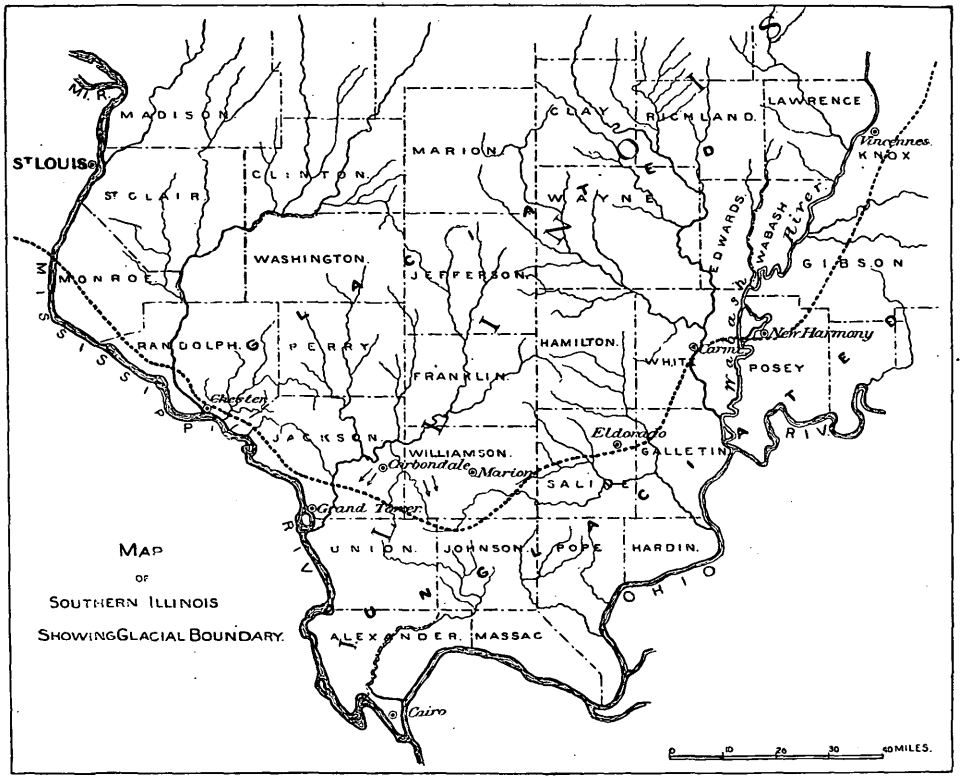
The glacial boundary in Illinois (see Plate V) first appears in White County near Phillipstown, and bears in a general southwesterly direction through Gallatin, Saline, and Williamson Counties, whence it bears northwest through Jackson, Randolph, and Monroe Counties, forming the east border of the Mississippi bottom-lands. But nowhere in this region are the glacial deposits thrown into ridges and hills as in the Eastern and Northwestern States, and they are everywhere buried, to a greater or less extent, by loess.

White County.—At Phillipstown the bluff facing the Wabash bottoms, opposite New Harmony, Ind., shows from twenty to thirty feet of till at the bottom, merging gradually into loess of about the same thickness. One-half mile west, compact blue till, containing fragments of rock and small bowlders, appears at 10 feet below the surface.

Hawthorn and Emma townships are an extensive sandy plain not more than twenty or thirty feet above the Little Wabash.

Throughout Carmi and Heralds Prairie townships till with all its characteristics everywhere appears under the loess on the west bank of the Little Wabash. A characteristic section in the southwestern part of Heralds Prairie gives 11 feet of loess and 35 feet of till. No sharp line of demarcation between the two could be found. Granitic bowlders 5 feet through occur in Carmi township. Mr. James Chilton reported a nugget of copper as found in section 28.

Gallatin County.—In Gallatin County glacial deposits are found only in Bear Creek, the northwestern township, where at Omaha station a considerable deposit occurs with granitic pebbles three or four inches through, which gradually merges into the loess above, and is reddish


MADISON
CLAY
RICHLAND
LAWRENCE
St LOUIS
MARION
Vincennes
KNOX
CLINTON
St CLAIR
WAYNE
EDWARDS
WABASH
WASHINGTON
JEFFERSON
GIBSON
MONROE
RANDOLPH
PERRY
HAMILTON
New Harmony
WHITE
POSEY
FRANKLIN
Chester
JACKSON
WILLIAMSON
Eldorado
GALLETIN
Carbondale
Marion
SALINE
Grand Tower
UNION
JOHNSON
POPE
HARDIN
ALEXANDER
MASSAC
Cairo
MAP
OF
SOUTHERN ILLINOIS
SHOWING GLACIAL BOUNDARY.
0 10 20 30 40 MILES.

in color. A detour to Shawneetown, and thence to Equality, disclosed no clearly marked glacial deposits.

Saline County.—Just north and west of Eldorado station, and 75 feet (barometer) above it, till, red in color, is exposed similar to that at Omaha, Gallatin County, but is absent to the southeast.

Till is abundant on the road from Eldorado to Raleigh. The soil is red, and the granitic pebbles are much decomposed. At Raleigh the loess is more of a yellow cast.

An extensive detour in Harrisburg township disclosed no glacial marks. The loess was more red in color.

Numerous exposures of till at least ten feet deep appear in the northern sections of Brushy township. Granitic bowlders two feet through are frequent. This is south of the Middle Fork of Saline River, the bottom-lands of which are about fifty feet below the general level.

Williamson County.—Till six to ten feet deep with the same amount of loess overlying, is exposed at Attila (120 feet above Marion). A similar deposit appears throughout the eastern part of Crab Orchard township. Striated stones are abundant. A trap-bowlder, two and a half feet, was observed. The color of the loess was yellow; the depth from five to ten feet.

At Sarahsville is an exposure of till covering several acres. Sections show 10 feet of loess, then 20 of till, in which are granitic bowlders two and a half feet in diameter. The material is of various colors, red, orange, and yellow, and without stratification.

Deposits similar to that at Sarahsville continue to Creal Spring and Sulphur Spring, 200 feet above Marion, but they cease near the line of Johnson County, reappearing farther west on recrossing the Williamson County line.

Till is abundant in the southern portion of Grassy township, but disappears just before crossing the Union County line (at an elevation of 400 feet above Carbondale). In section 30, near the southwestern corner of the township, is a half acre of till like that at Sarahsville, where, on the sand rock exposed underneath, are distinct striæ already referred to (p. 42) as the most southern point in America at which striæ have been observed east of the Mississippi.

Jackson County.—Deposits of till are frequent in the northeastern and northern part of Makanda township, but do not extend to the higher lands in Union County. A striated surface was uncovered near the road, one and a half miles southwest of Carbondale; direction of striæ, S. S. 5° W. This is in section 29, Carbondale township. The covering of till removed was from eight to fifteen feet.

Ridge township contains a fine exposure of till with abundant granitic pebbles, from six to eight inches in diameter, in section 1, T. 10 S., R. 1 W. From ten to fifteen feet of till is overlaid by the same amount of loess (165 feet above Carbondale). There is no till in the southern and central portions of the township, which is exceedingly rocky and

rough, though loess from ten to twenty feet is everywhere found; but till appears in the nortwestern portion of the county in sections 5 and 8, T. 7 S., R. 4 W. (360 feet above Carbondale). Two miles west from this point the rocky bluff descends perpendicularly to the Mississippi, about four hundred feet below.

Randolph County.—The hill back of Chester (310 feet above the river) is covered very deeply with loess, in some places 100 feet. No till was observed within the city limits, but granitic pebbles were found in gulleys (210 feet above the river) north of the city. At Welga station, five miles back from the river, till abounds in great quantities with frequent granitic and striated bowlders two feet in diameter. A fresh section here shows six to ten feet of loess, graduating rather suddenly into a gravelly stratum about ten feet in thickness resembling true till, resting upon soil filled with local fragments.

The contour of the country seems to have been largely determined by the direct glacial deposits, as the loess rested like a blanket of pretty even thickness over all, adjusting itself to previous irregularities.

MISSOURI.

A detour through Missouri from opposite Grand Tower to Perryville and to the river bank opposite Chester, Illinois, disclosed no sign whatever of glacial action, though everywhere there is a covering of loess, the general elevation being 300 feet above the river. The river valley all along is from five to seven miles wide.

Jefferson County.—Extensive detours in Jefferson County disclosed no true glacial phenomena there.

At De Soto (300 feet above the river) there was no loess on the hills, but everything was covered with a red residual clay full of local fragments.

St. Louis County.—West from Carondelet station there are no hills much more than 100 feet above the river, and all are covered with a blanket of loess about 20 feet deep. Sections show that this sometimes rests upon the unevenly eroded surface of the limestone, but sometimes also upon a thin stratum of well-rolled gravelly soil with an occasional granite pebble, but nothing like till was discovered.

Between Carondelet station and the business part of St. Louis, on the turnpike, numerous quarries and sink-holes, about one hundred and fifty feet above the river, show at the bottom of the loess a stratum of red clay a foot or more thick, containing granitic and other pebbles up to three inches in diameter. The depth of the loess is about twenty feet.

Near Forest Park, on the road to Ferguson, a section shows loess about 20 feet, with gravel from two to three feet at the bottom containing granitic and finely striated pebbles two or three inches in diameter. I found similar sections also near Hyde Park. This gravelly stratum was extensively uncovered in 1883 near the brick yards in the neighborhood of Shaw's Botanical Garden. Here many granitic and striated

pebbles were found. The upper terrace of the limestone was much eroded, and the gravelly stratum rested directly upon it. No striæ was discovered upon the limestones in place, but thin fragments of limestone striated upon one surface were found. This is three miles back from the river (elevation about one hundred and fifty feet).

GENERAL REMARKS.

The Illinois Central Railroad from Chicago to Cobden, in the southern part of the State of Illinois, discloses but few glacial phenomena of interest to the transient traveler, though southward from Mattoon the color of the soil in the deeper cuts seems to be more distinctly red than to the north. The surface is covered with a fine, light colored silt, compact and without gravel and from one to two feet thick. Below is a reddish clay of undetermined depth, containing fine gravel of chert, quartz, limestone, and granite.

At Centralia sections fourteen feet deep showed white clay, three to five feet, with tough yellow clay containing quartz pebbles below. At Ashley a section of twelve feet showed two feet of white clay without grit, graduating into yellow clay containing an increasing amount of fine gravel with bowlderets and striated fragments lower down. At Du Quoin wells from seventeen to twenty feet in depth have two feet of loess with three to four feet of gravelly soil, with many striated and granitic pebbles lower down. Fragments brought up from the rock in place were striated. In Cobden, seven miles south of the glacial limit (and 350 feet above Carbondale) there is no loess and there is no sign of glaciation; but there is much compact clay (see specimens 34 and 35).

At this point it will be profitable to give a more summary and explicit statement of the form of the glacial deposits over the glaciated margin traversed between the Alleghanies and the Mississippi River. As before remarked (page 55), a distinct, continuous terminal moraine along the southern margin of the glaciated region is not easily traced west of the Delaware River. Across the State of Pennsylvania the marginal accumulations worthy to be called a moraine (that is, consisting of knobs and ridges of any considerable height with inclosed kettle-holes), are found only at infrequent intervals, as already described (pp. 55–57). West of Pennsylvania such marginal accumulations are still more infrequent. The only places in the whole distance of the marginal belt surveyed between Pennsylvania and the Mississippi River in which I have encountered the features of a terminal moraine, such as exists south of New England and across the State of Wisconsin, are suggested, are the following:

In Columbiana County, Ohio, extensive ridge accumulations are found near Palestine on the eastern edge of the county, on one of the branches of Little Beaver Creek. These ridges were evidently formed by streams of water which issued into the valley from the ice-front, and in their composition resemble kames. In the western part of the county, at New Al-

exandria, upon the higher land in the county, and about 3 miles back from the border of the glaciated region, the deposits of till are as much as 50 feet deep, and are marked in a moderate degree by the knobs and kettle-holes characteristic of a true moraine.

In Stark County, next west, ridged accumulations of great size (85 feet high) with large kettle-holes occur within a mile of the extreme border of glaciation. These ridges are on a scale which compares favorably with the Kettle Range in Wisconsin, and the material, like that of the Kettle Range, is pretty largely water-worn. (See above, p. 60.)

In Holmes County, though the glacial margin is sharply defined, and the glacial deposits are of considerable depth over the whole northern part of the county, there are no ridged accumulations of marked size except in the valley of the Killbuck, a few miles above Millersburgh. (See above, p. 60.)

In Knox County no extensive ridged accumulations were anywhere observed, though the depth of the glacial deposit is considerable down to within a short distance of the margin.

In Licking County in the vicinity of Wilkins Run, in Mary Ann township, there is an extensive marginal accumulation of terraces and kames, some of which are 92 feet high. A little farther to the south, also in Newark township, and very near the marginal line, the glacial deposit is marked by small hummocks and ridges at an elevation of 200 feet above the valley. In the southeastern part of Licking township, near the reservoir, there are extensive kame-like ridges from 15 to 30 feet above the level of the valley, which here drains through Jonathan Creek into the Muskingum. To what extent the base of these ridges is covered by deposits of loam and peat could not be ascertained.

Thorn township, Perry County, presents in its northern part a continuation of the phenomena in Licking township just described. The reservoir occupies a kettle-hole on the water-shed between a branch of Licking River and Jonathan Creek.

In Fairfield County the glacial limit is marked by ridges and hummocks of till at least 50 feet in depth, on the east side of Rush Creek. This is on land 200 feet above the valley. At Berne station there are hills of gravel from 50 to 60 feet in height brought down by the streams which drain the glaciated area in Pleasant township. In Hocking and Madison townships of this county the accumulations of till are very marked, being in some cases 40 feet in depth, at a height of 450 feet above the Hocking River, at Lancaster. Muddy Prairie, so-called, seems to be an immense shallow kettle-hole very near the margin.

In Ross County, at Adelphi, in the northeastern corner of the county, near the head of the valley of Salt Creek, the marginal accumulations are more marked than anywhere else in the State. Here, on the east, facing Salt Creek, they show a perpendicular section of 188 feet, and extend southwesterly through Colerain and Green townships, for sev-

eral miles to the Scioto Valley. The knobs, ridges, and kettle-holes are marked at various places within a mile of the southern limit of glacial signs. In Green township, on the eastern edge of the Scioto bottoms, kame-like ridges of gravel rise from 100 to 150 feet above the general level. West of the Scioto, at Lattas, in Concord township, ridges and knobs from 50 to 60 feet in height are numerous, resting on the flanks of the hill which faces to the northwest. The ice, however, surmounted this hill (which is about 400 feet above the general level to the north), and extended 3 or 4 miles, reaching the narrow valley of Paint Creek, in which, near the junction of Cat Tail Run, there are immense kame-like accumulations.

In Pike County the depression in the col between Bainbridge on Paint Creek and the headwaters of Baker's Fork of Brush Creek is filled to an indefinite depth by deposits of till, showing numerous ridges, knobs, and kettle-holes. This is on the extreme margin, and is about 200 feet above the bottom-lands of Paint Creek, and is flanked on the south by a level-topped loess deposit, extending for 2 or 3 miles. (For a fuller description of this, see pp. 92–96.)

Through the southeastern corner of Highland County and the northwestern of Adams, the terminal accumulation is less marked than in Ross County; still the boundary of the glaciated region can be readily determined. In neither of these counties, nor in Brown or Clermont Counties, were there any ridged accumulations which could be properly called moraines, and I think that the same is true of Clinton County, and also of Hamilton, though the till is from 10 to 20 feet deep in the neighborhood of Walnut Hills station in Cincinnati, and 350 feet above the river, while at North Bend a preglacial channel extending from the Miami to the Ohio is filled by till to a height of 160 feet.

In Indiana the glacial deposits in the glaciated portion of Jefferson, Clarke, and Scott Counties are comparatively scanty. The deposit is much deeper over Dearborn, Ripley, Decatur, Jennings, and Bartholomew Counties, but though I traversed them in every direction, I nowhere encountered in them any ridged accumulations which properly could be called moraines. In Johnson County, however, where the boundary approaches the higher lands of Brown County, ridges and knobs of till were encountered in two or three places, and to some extent in the western part of Morgan County, but nothing of the sort appeared in Owen, Clay, Greene, Sullivan, Knox, White, Gibson, and Posey Counties.

In Illinois nothing like a moraine was encountered in any portion of the State which I traversed, which included Randolph, Perry, Franklin, Jackson, Williamson, Saline, Gallatin, and White Counties.

HYPOTHESIS OF A GLACIAL DAM AT CINCINNATI.

INTRODUCTION.

From the facts already stated it seems evident that the ice of the glacial period came down to the north bank of the Ohio River all the way from Brown County, Ohio, to Madison, Indiana, a distance, as the river runs, of more than one hundred miles, while it is equally clear that at points south of Cincinnati glacial ice extended across the river into Kentucky from six to ten miles. The acceptance of this conclusion raises some most interesting questions in speculative geology. The interpretation of the facts will depend upon whether the glacial deposits upon the north and south sides of the Ohio River belong to the same period or to different periods widely separated in time. The question also involves that as to whether the deposits upon the south side of the river were made before or after the Ohio had worn its present valley.

Upon the supposition that the long, narrow trough of the Ohio River (described on p. 57) was preglacial, the glacial deposits upon the south side at Cincinnati imply an ice dam between five and six hundred feet in height. Such an obstruction in the present condition of the valley would set the water back so as to submerge Pittsburgh to a depth of about three hundred feet, and affect the Alleghany River as far up as Oil City, and the Monongahela nearly up to Grafton, West Virginia.

Soon after the first announcement of these facts[1] Prof. I. C. White published a paper upon the terraces of the Monongahela River, which seemed to him in a remarkable degree to confirm the theory of an ice dam at Cincinnati.[2] To judge of the value of these individual facts it is necessary to take a more comprehensive view of the whole matter than has heretofore been possible, and to speak somewhat in detail of the terraces throughout the whole valley of the Ohio and its tributaries.

THE LOWER TERRACES OF THE OHIO AND ITS TRIBUTARIES.

The valley of the Ohio River above Louisville is characterized by two sets of terraces, the lower of which is very persistent throughout the whole course and is especially developed wherever tributaries from the glacial region enter it. So uniform is the increase in the height of a terrace in the Ohio Valley immediately below the mouth of its tributaries, coming from the glaciated area, that there can be no hesitation in attributing their deposition to the vast flow of water down these tributaries into the Ohio during the period in which the ice extended into their headwaters. The deposits in the Ohio below the mouth of Big

[1] Am. Jour. Sci., 1883, 3d Series, vol. 26, p. 326.

[2] See Proc. Am. Assoc. Adv. Sci. 32d (Minneapolis) meeting, 1883, p. 212, and The Glacial Boundary in Ohio, Indiana, and Kentucky, G. F. Wright (Western Reserve Historical Society), 1884, pp. 81–86.

Beaver Creek in Pennsylvania, are typical of what elsewhere occurs, and may therefore be described with considerable minuteness.

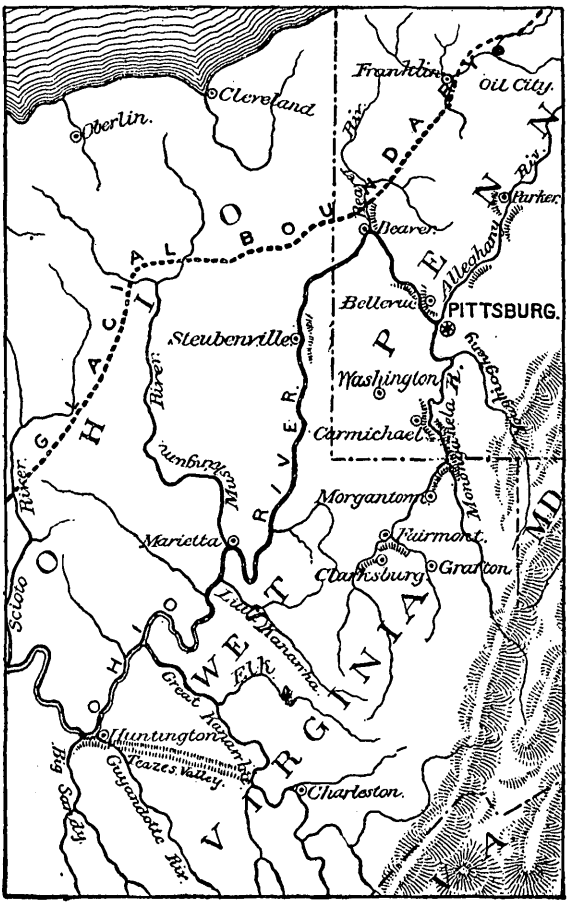


FIG. 4.—Map of the tributaries of the upper Ohio.

The towns of Beaver and Rochester, Pennsylvania, are built upon a terrace which is 120 feet above the level of the Ohio and but eight or ten miles south of the glaciated region. The composition of that part of the terrace occupying the terrace upon which Beaver is built, and down stream from the junction of Beaver Creek and the Ohio, differs remarkably from that upon which Rochester is built, on the angle up stream from the junction. In the angle below the junction of the streams the terrace is composed of rounded pebbles of quartzite, gneiss, and granite, some of them, even near the surface, being two feet in diameter. In the angle above the junction granite pebbles are exceedingly rare, and pebbles of any kind more than two or three inches in diameter are scarce. The explanation is evident. To use Prof. Dana's terms when speaking of the Connecticut River and the White River,[1] the Ohio is the great *distrib-*

[1] See Am. Jour. Sci., 3d Series, vol. 22, 1881, p. 466.

uter and the Beaver is here the principal *contributor*, of drift material. The Ohio does not itself have direct access to the bowlders which had been transported by glacial ice, it being wholly outside of the glaciated region. The drainage basin of the Beaver is, however, strewn with glacial débris down to within a few miles of the Ohio; and, as the granite bowlders of that area were borne along by the swollen torrents at the close of the glacial period, on reaching the onward but less rapid current of the larger Ohio they would naturally be deposited at the junction of the streams and in the lower angle.

The one hundred and twenty to one hundred and thirty foot terrace, upon which the city of Beaver is built, continues upon the north side of the Ohio River downward to Vanport, two miles, where it crosses to the south side and continues below to Raccoon Creek. Here it reappears upon the north side and continues to Six Mile Run, reappearing upon the south side a little above Industry. From Industry down three or four miles it is again upon the north side, reappearing on the south side one mile from Georgetown, two miles from the Virginia line, where, according to my leveling, it is 112 feet above the river, and contains numerous granitic bowlders two feet or more in diameter. It is evident that the whole valley from Beaver to Georgetown, 14 miles, was once filled with coarse gravel and pebbles to a height of about one hundred and twenty feet, the material being much coarser at Beaver than at Georgetown. A well-marked terrace, also containing granitic pebbles, is found on Little Beaver Creek, one mile from its mouth, and 130 feet above the Ohio.

Below the mouth of Little Beaver Creek, as far as Marietta, at the mouth of the Muskingum River, there is no tributary entering the Ohio which could have been charged with glacial floods or with glacial material. There is, therefore, as might be expected, a gradual but marked diminution below this point in the extent of the terrace deposits. At Steubenville the extensive terrace upon the east side, according to my measurement, is but 95 feet above low water, and at Martin's Ferry, opposite Wheeling, the extreme height of the terrace is 102 feet. In both these places the granitic pebbles are numerous, but are smaller than higher up the river. From Martin's Ferry to Marietta I have not examined the banks of the river. This increase in the height of the terrace was remarked by Sir Charles Lyell,[1] who estimates it as 60 feet high at the mouth of the Great Kanawha, and about eighty feet high at Georgetown.

The Muskingum River, which enters the Ohio at Marietta, is lined with terraces all the way up to its headwaters in the glaciated region. It was therefore an important contributor to the glacial drift of the Ohio. Consequently at Rockland, about twelve miles below Marietta, and where the Ohio turns at right angles to the west, we find a marked increase in the glacial terrace. Blennerhasset Island is but fifty or sixty

[1] Travels in America, second series, vol. 2, p. 224.

feet above low-water mark, and is occasionally completely submerged by floods. The terrace at Rockland, however, is nearly 50 feet above the present high-water mark. About five miles below, opposite Little Hockhocking, a terrace appears again upon the south side of the Ohio, corresponding in general elevation and character to that at Rockland on the north side. The terrace at Ironton is 90 feet, while at Portsmouth, below the mouth of the Scioto, another chief contributor of glacial drift, the terraces on both sides are 110 feet.

There are no other specially marked terraces at any considerable distance above the present high-water mark until reaching Cincinnati, just below the mouth of the Little Miami River, which was one of the most abundant contributors of drift material from the glaciated region. Here we find the upper terrace, upon which the main part of the old city of Cincinnati is built, to be about fifty feet above the present high-water mark, or 120 feet above low water. Twenty miles below, at Lawrenceburgh, Indiana, near where the Ohio is joined by the Great Miami (another most important contributor from the glaciated region), the terraces rise to 112 feet above low-water mark, or about eighty feet above the flood plain. The terraces here are of equal height upon both sides of the Ohio; but upon the west side are much broader, extending into the valley from one-fourth to three-fourths of a mile from the foot of the bluff. The valley itself between the bluffs is here about three miles wide. Farther down the river the upper terraces are of diminished height. At Warsaw, Kentucky, about 20 miles below, the highest terrace is ninety feet above low water, or about thirty feet above high water. At Madison, Indiana, 20 miles still farther down, the upper terrace is 85 feet above low water. From these facts it is evident that there is no need of supposing the Ohio Valley to have been filled up through its entire course with gravel to the height of the terraces where the streams enter from the glaciated region. But just below the mouth of each of those streams there was an excessive deposit, which formed a bar or slight dam, as is the case now in the Mississippi at the mouth of its present tributaries. The Ohio, then, at the close of the glacial period, would have presented a series of long pools, one stretching down to the vicinity of the mouth of the Beaver, where the water must perceptibly have shoaled for several miles. A second pool ended at Marietta, at the mouth of the Muskingum; a third pool extended to the mouth of the Scioto at Portsmouth; a fourth to the vicinity of Cincinnati. Below the mouth of the Great Miami there was no contributor of glaciated material to obstruct the channel with its excessive deposits until reaching the mouth of the Wabash. There can be no question that this series of high terraces belongs to the closing stages of the last glacial epoch, if there were two epochs. The present flood plains are deposited in a channel which has been worn out of these larger deposits of the glacial period. And, as already noted, these glacial terraces are but parts of a still deeper de-

posit filling an old preglacial channel which was one hundred and fifty or two hundred feet deeper than the present trough.

All the southerly flowing streams which rise in the glaciated region are marked at the points at which they enter the unglaciated district by terraces of exceptional height (but never exceeding 160 feet), containing many granitic pebbles, and gradually diminishing, both in height and in the size of the pebbles, as they recede from the glacial boundary. Such terraces are specially noticeable at the following localities:

In Pennsylvania, on the Delaware River, at Belvidere; on the Lehigh River, at Bethlehem; on the Susquehanna, at Berwick; on Fishing Creek, below Benton; on the Loyalsock, above Montoursville; on Lycoming Creek, below Ralston; on the Conewango, below Ackley Station; on Big Broken Straw Creek, at Spring Creek; on Oil Creek, at Titusville; on French Creek, above Franklin; on Big Beaver Creek, at Chewtown.

In Ohio, on the middle fork of Little Beaver, at New Lisbon; on the east branch of Sandy Creek, a tributary of the Tuscarawas, at East Rochester; on the Nimishillen, just below Canton; on the Tuscarawas, near Bolivar; on Sugar Creek, another tributary of the Tuscarawas, at Beech City and Deardoff's Mills; on the Killbuck, another branch of the Tuscarawas, below Millersburgh; on the Mohican, above Gann's Station; on the Licking, at Newark; on Jonathan Creek, near Thornville (the last eight all empty eventually into the Muskingum); on the Hocking River, at Lancaster; on the Scioto, a few miles above Chillicothe.

In Indiana, on the east fork of the White River, at Seymour, and on the Wabash, near New Harmony.[1]

THE UPPER TERRACES OF THE OHIO AND ITS TRIBUTARIES.

Disconnected with the lower set of terraces, there is another, which is far more difficult of interpretation, and which stands at a much higher level. We will note the places where this upper set of terraces is most conspicuous, beginning below Cincinnati and going towards the source of the river.

I am inclined to reckon, as belonging to this series of upper-terrace formations, the conglomerate (described on page 64) near Woolper Creek, a few miles above Belleview, in Boone County, Kentucky, and 25 miles below Cincinnati. What is here known as Split Rock is but a dismembered portion of a level-topped terrace of cemented gravel rising 185 feet above low-water mark, and extending back from the river from one-half to three-quarters of a mile, and a mile or two along the sides of the valley. A deposit precisely similar occurs a mile and a half back from the river, near the headwaters of Middle Creek, about three hundred and fifty feet above low-water mark.

[1] For fuller information on this subject, see Am. Jour. Sci., July, 1882, pp. 8-14; Geol. Survey, Ohio, vol. 5, pp. 761-762.

I am inclined also to classify with the upper terraces some cemented gravel containing granitic pebbles, and similar to this at Split Rock, found on Bracken Creek at its junction with the Ohio just above Augusta, Kentucky, about fifty miles up the river from Cincinnati. The summit of this is about two hundred feet above low-water mark. The pebbles of the conglomerate are very coarse, and numbers of them are granitic and from three to four inches in diameter. A similar conglomerate occurs upon the opposite bank, near Higginsport, Ohio.

Going up the river, an instructive remnant of the higher terrace was found on the east side of the Ohio River a little below Steubenville, Ohio, opposite the lower ferry, and about twenty miles above Wheeling, West Virginia. At this point the representative of the lower terrace previously described is about one hundred feet above low-water mark, and is well developed. But farther back from the river, upon the West Virginia side, numerous granitic pebbles occur at an elevation of 50 feet higher, and included in an extensive deposit of sand, whose upper limit is 285 feet above low-water mark, or about one hundred and eighty-five feet above the lower terrace. Just to the north of this point the rocks in places project to the river's bank, at an elevation of four or five hundred feet above the river; thus during excessively high water favoring the formation of the deposit just described.

The remnants of the upper terrace below Steubenville correspond both in general character and in elevation above the river to three others between the mouth of Beaver Creek and Pittsburgh, of which one is at New Brighton, on the east side of the Beaver not far from its junction with the Ohio. Here there are remnants of a terrace preserved upon a rocky shelf and containing many rounded pebbles of granite 215 feet above the Beaver, and 260 feet above the Ohio. This is several miles outside the extreme limit of direct glacial action. The pebbles are at the bottom of a thin deposit of cream-colored clay which is used for brick-making.

A similar terrace exists back of Middletown, Alleghany County, on the south side of the Ohio River, 12 miles below Pittsburgh. Here, at the height of from two hundred and fifty to two hundred and eighty feet above the river, rolled fragments are abundant; and among them an occasional pebble of granite.

A third noteworthy remnant of a terrace between the mouth of the Beaver and Pittsburgh occurs at Bellevue, in Ohio township, Alleghany County, Pennsylvania, on the north side of the Ohio, about five miles below the mouth of the Alleghany River.[1] Here, upon a shelf of rock facing the river, in a perpendicular cliff, between two hundred and fifty and three hundred feet in height, there is the remnant of a terrace whose surface is 310 feet above low-water mark and containing many granitic pebbles. This terrace is about half a mile in width. A well

[1] See I. C. White, 2d Geol. Survey, Pa., Q. p. 175.

sunk from the surface was reported to me as passing through 20 feet of tough clay and 25 feet of sand, coarse gravel, and quicksand, showing pebbles at the bottom a foot or more in diameter. At that level springs come out facing the river. Facts concerning analogous terraces on the Monongahela are detailed in the next section.

THEORETICAL EXPLANATIONS.

Here we may well pause to consider the theoretical elements of the problem, and ask, by what combination of forces known to be in operation could this terrace of gravel at Bellevue, which incloses pebbles of northern drift, be deposited nearly three hundred feet above the present level of the Ohio River, and 1,000 feet above tide? The granitic pebbles must by some means have been brought down the Alleghany River from as far up as Franklin, a distance of 125 miles. To account for this terrace and some others which I shall presently mention, there are only three possible hypotheses, each involving in some form the aid of the glacial theory. These hypotheses are (1) that during or since the glacial period the whole region of the upper Ohio passed through a period of subsidence, the limit of which is marked by these upper terraces; (2) that there has been some local obstruction like that of the supposed Cincinnati ice dam; (3) that the upper terraces were formed during an earlier glacial epoch when the rocky beds of the streams occupied a higher level than now.

That these upper terraces are coincident in date with, or subsequent to, a glacial epoch is clear from the fact that the granitic elements entering into their formation could have been brought into the headwaters of the Alleghany River only by a movement of glacial ice from the distant north. After being left by glacial ice in this region, they were within reach of streams of water which could transport them an indefinite distance towards the Gulf of Mexico. Such granitic pebbles from the glaciated region are, at the present time, transported by flowing water far down the Ohio River, and even into the Mississippi. But, whether rolled along upon the bottom or transported upon floating ice, they can now be deposited along the stream only to the height of the present flood-plain, which is nowhere more than seventy feet above the bottom. The present problem is how to account for them in terraces 300 feet above the river.

THE UPPER TERRACES THE REMNANTS OF A DISTINCT GLACIAL EPOCH EARLIER THAN THAT PRODUCING THE LOWER.

There is no question but that these facts may be accounted for on the theory that there have been two glacial epochs, in each of which the ice extended into the headwaters of the Alleghany; and that these high terraces were formed during the first glacial period, as the present flood-plain of the river is formed, but when the bed of the river was between two and three hundred feet higher than it is now. This, how-

ever, would involve the supposition that sufficient time elapsed between the first glacial period and the second for the Ohio and its tributaries to wear down their channels through their rocky bed, and along their whole length to a depth of between three and four hundred feet. If we accept without question the theory of two glacial periods so nearly equal in extent and separated by such a vast interval of time, this is the easiest way to account for the facts as so far presented.

But without questioning the fact of two distinct glacial epochs, we may question the propriety of accounting for this terrace by a glacial epoch so far back in time as this theory supposes. From the Falls of the Ohio at Louisville, Kentucky, to the head of the Alleghany, for a distance of about one thousand two hundred miles the stream has lowered its bed through the rocks to a depth of more than four hundred feet below the bottom of the terraces in question. For the testimony is unequivocal that the rocky bottom of the Ohio River from the Beaver down is not far from two hundred feet below its present bottom. The time necessary for this amount of erosion is enormous.

FACTS ADVERSE TO THIS THEORY.

Now, there are many facts which would seem to forbid such an enormous lapse of time between the deposition of these upper terraces containing granitic pebbles and the formation of the lower terraces containing similar material, as before described. In the first place, vegetable and animal remains of recent species are found in a very fresh state of preservation in river deposits of the Ohio Valley corresponding in age with the upper terraces in question.

Terraces on the Monongahela.—The first instance has been carefully described by Prof. I. C. White, and occurs on the Monongahela River, near Morgantown, West Virgina. The trough of the Monongahela, which joins the Alleghany at Pittsburgh to form the Ohio, is in every way similar to that of the Alleghany, with the single exception that the terraces which line its banks at heights corresponding to those of the Alleghany and the upper Ohio, contain no pebbles of northern drift but consist wholly of material which is native to the valley itself. At numerous places, as Professors White [1] and Stephenson have pointed out along the Monongahela, and as I myself have since observed, there are extensive deposits of pebbles and bowlders from two to three hundred feet above the river, especially near where the tributaries enter. Many of these deposits may well enough be regarded as the river pebbles left in the channel when it flowed on a rocky bottom two or three hundred feet higher than at present. Such places may be noted at Belle Vernon, Brownsville, and Masontown, in Fayette County, Pennsylvania, and Greensborough, in Greene County, Pennsylvania. But, in the opin-

[1] See The Glacial Boundary in Ohio, Indiana, and Kentucky, G. F. Wright (Western Reserve Historical Society) pp. 82–84.

ion of Prof. White, the deposits near Morgantown, West Virginia, can not be so easily explained in this manner. I transcribe Prof. White's description, premising that his familiarity with the region is greater than that of any other competent observer.

In the vicinity of Morgantown, terraces of transported material occur at the following approximate (measured by barometer) elevations:

Terraces.	Feet above river.	Feet above tide.
First	30	820
Second	75	865
Third	175	965
Fourth	200	990
Fifth	275	1,065

The first terrace is the present flood-plain of the river, consisting principally of fine sand, mud, and gravel. * * *

All of the other terraces have thick deposits of transported material, wherever the original contour of the surface has favored its preservation from erosion. From the top of the fourth terrace Mr. Keck dug a well through seventy feet of clay, gravel, and bowlders without finding bed rock. He also encountered logs of wood in a soft or semi-rotten condition near the bottom.

Many other wells on the third terrace have been sunk to depths of 20 and 30 feet without reaching bed rock. * * *

Owing to the considerable elevation—275 feet—of the fifth terrace above the present river bed, its deposits are frequently found far inland from the Monongahela, on tributary streams. A very extensive deposit of this kind occurs on a tributary one and a half mile northeast of Morgantown, and the region, which includes three or four square miles, is significantly known as the "flats." The elevation of the "flats" is 275 feet above the river, or 1,065 feet above tide. The deposits on this area consist almost entirely of clays and fine sandy material, there being very few bowlders intermingled. The depth of the deposit is unknown, since a well sunk on the land of Mr. Baker passed through alternate beds of clay, fine sand, and muddy trash to a depth of 65 feet without reaching bed rock. In some portions of the clays which make up this deposit, the leaves of our common forest trees are found most beautifully preserved. Whether or not they show any variations from the species growing in that region the writer hat not yet had time to determine, but when a larger collection has been obtained, this subject will receive the attention that it deserves, since if the date of the glacial epoch be very remote, the species must necessarily show some divergence from the present flora.

Of animal remains the only fragment yet discovered in this highest of terraces is the tooth of a mastodon, dug up near Stewartstown, seven miles northeast from Morgantown.

More recently Prof. White[1] contributes other interesting facts which concern the terraces farther up the Monongahela, and which can best be quoted in this connection:

Owing to the nature of the topography, and the country rock along the draining streams, the region along the upper Monongahela has these terrace deposits in better preservation than any other with which the writer is acquainted, and this is especially true of the West Fork branch of that stream. It is along this line that the existence of a great submergence which covered the country with a thick coating of

[1] Am. Jour. Sci., 3d series, vol. 34, 1887, pp. 378, 379.

transported material up to a certain level, is most conclusively shown. In the region of Morgantown, on the main Monongahela, these terrace deposits end at about two hundred and seventy-five feet above low water, or 1,065 feet above tide, while at Fairmount, 26 miles above, there is a vast amount of this terrace material thrown down about the junction of the Valley and West Fork Rivers, and the upper limit of the same is a little over two hundred feet above low water, which is here 850 feet above tide.

About twenty miles farther up the river (West Fork), near Shinnston, the upper limit of the terrace material is found at 160 feet above the water, but here the latter has an elevation of about eight hundred and eighty-five feet above tide.

At Clarksburgh, where the river unites with Elk Creek, there is a wide stretch of terrace deposits, and the upper limit is there about one thousand and fifty feet above tide, or only 130 feet above low water (920), while at Weston, 40 miles above (by the river), these deposits cease at 70 feet above low water, which is there 985 feet above tide. It will thus be observed that the upper limit of the deposits retains a practical horizontality from Morgantown to Weston, a distance of 100 miles, since the upper limit has the same elevation above tide (1,045–1,065) at every locality.

These deposits consist of rounded bowlders of sandstone, with a large amount of clay, quicksand, and other detrital matter. The country rock in this region consists of the soft shales and limestones of the Upper Coal Measures, and hence there are many "low gaps" from the head of one little stream to that of another, especially along the immediate region of the river, and in every case the summits of these divides, where they do not exceed an elevation of 1,050 feet above tide, are covered with transported or terrace material, but where the summits go more than a few feet above that level, we find no transported material upon them, but simply the decomposed country rock.

A fine example of one of these bowlder-covered divides may be seen at the mouth of the Youghiogheny River, back of McKeesport, Pennsylvania. The "divide" in question is one between the waters of Long Run, which puts into the Youghiogheny two miles above McKeesport, and that of another little stream which heads up against it, and flows into the Monongahela within the city limits. The divide between these two water-ways, although 275 feet above the level of the river, is almost imperceptible in a broad and bowlder-covered valley through which there is not the slightest doubt that the waters of the Youghiogheny once flowed during the epoch of submergence.

Another typical illustration of these terraces in the valley of the Monongahela occurs at Carmichael's, Greene County, Pennsylvania. Carmichael's is about five miles west of the river and (as shown in the accompanying map) about the same distance from an angle in the stream which it makes in turning to the north. The village is built on what is called the "Glades," which extend about two miles in one direction and three in the other. The Glades are about two hundred and fifty feet above the river, and from one to two hundred feet below the general level of the country, and are connected by a pretty well defined channel at about the same level with the river both above and below. Above, this old river channel is continuous with one on the east side near Masontown—the two old channels forming a sort of a double ox-bow in the reverse direction from those in the present bed of the stream, and about two hundred and fifty feet above it. The whole course of this old channel is marked by rounded pebbles, such as are found at the bottom of the present river, and these are covered more or less with several feet of loam. The glades at Carmichael's are simply an enlargement in this old channel. But at Carmichael's a log of wood

was reported to me as found buried 30 feet in the sand. Much quicksand is found from 15 to 20 feet below the surface. It hardly seems possible that wood should have been preserved in such a situation during all the immensely long period required for the river to lower its bed through the rock to its present level. Many of the river pebbles may belong to the earlier period, but after eliminating the effects of that early cause it is difficult to resist the conviction that most of the fine loam and quicksand, together with the buried wood, belong to a much later period of deposition. It is easy to see that with the water standing at about that level throughout the whole valley, wood and clay and sand would come down from the higher reaches of the river and be deposited in such sequestered places. Any cause that can be shown to have acted in recent times to raise the water to that level will furnish the most natural explanation of the facts.

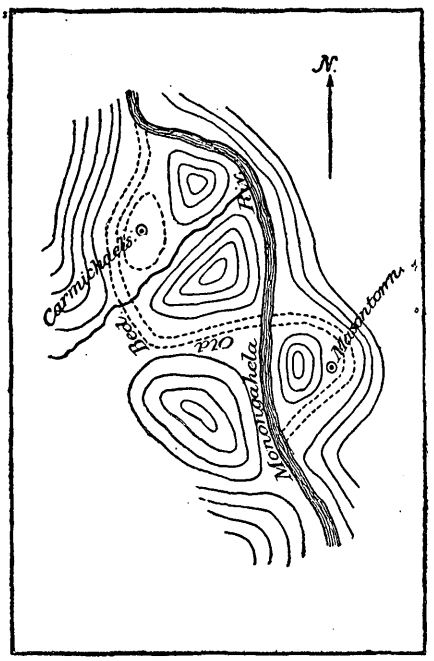


FIG. 5.—Map of the old channel of the Monongahela, between Masontown and Carmichael's, Virginia.

Wood has been found also in a similar situation in the remarkable terrace on the Alleghany River, near Parker, Pennsylvania. Here also there is a sort of a double ox-bow at a level of about two hundred and fifty feet above the present bed of the river. But, unlike the gravel at Carmichael's, the gravel here is partly composed of granitic pebbles, though far outside of the region of the direct action of glacial ice. Like that at Bellevue, on the Ohio, this gravel bears unmistakable evidence of having been deposited during the glacial period. The wood was reported as dug from quicksand in a well two miles east of the Alleghany, near the eastern limit of the high deposit containing the pebbles just mentioned. It should be noted, however, that the absolute level of this deposit at Parker is somewhat higher than that at Bellevue, but it scarcely differs at all from that of the fifth terrace described by White as extending from below Morgantown, West Virginia, to Clarksburgh.

River deposits in Teazes Valley, West Virginia.—Still another instance of wood which has been preserved in a deposit of the glacial age is worthy of minute description. In this case I have the advantage of having found it myself. The locality to which we are now transferred is that of Teazes Valley, Putnam County, West Virginia. This valley runs

from the Kanawha River, a little below Charleston, to the Ohio at the mouth of the Guyandotte, near Huntington. The valley is clearly enough a remnant of early erosion, when the water of the Upper Kanawha took that course to join the Ohio. The valley is very clearly

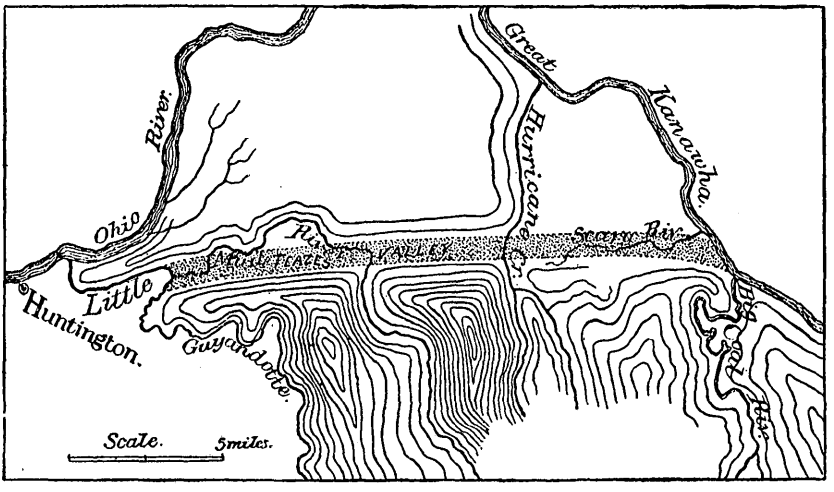


FIG. 6.—Map of Teazes Valley, West Virginia.

marked, being about a mile wide and from two to three hundred feet lower than the hills on either side, and having a remarkably level floor throughout the greater part of its course. The bottom of the valley is filled throughout with a deposit of river pebbles covered many feet deep with a mixture of sand and clayey loam. (See Plate VI.) In some places this loam is from thirty to forty feet deep, extending for several miles without interruption, as at Long Level, about the middle of the valley. Here a section about one-half mile long and 25 feet deep shows at the top a stiff stratum of clay containing wood at a depth of seven feet. Immediately below is sand containing much iron and cemented together by the infiltrations of the ore. The stratum above containing the wood had never been disturbed, and the wood, a small specimen of a knot of some coniferous tree, is remarkably fresh in its whole appearance. It is scarcely possible that it should have remained in such a position during all the time required for the erosion of the Ohio Valley and its tributaries from the level of Teazes Valley to its present level, 250 feet below. Besides, there are many other things going to show that the deposit was in slack water rather than on the banks of a running stream. Unlike the deposits of a river on its banks, in this case the silt extends clear across the valley, covering everything to a uniform depth, except where it has been removed by subsequent irregular erosion. A single cut in this silt, shown in Pl. VI, is one-half mile or more in length.

Another evidence of the recent date of this deposit of river silt as compared with the erosion of the valley, appears in the relation of the

transverse valleys to it. Mud River and Hurricane Creek are two small streams rising some little distance to the south of the valley, but now either joining or crossing it at a level sixty or seventy feet lower than that of the rocky bottom of the valley (see map of Teazes Valley). Mud River joins the valley at Milton, and then turns west and follows its course to the Guyandotte. But its level even above where it now joins the valley is 120 feet lower, and this a channel worn in the solid rock. Hurricane Creek is a still smaller stream, and crosses the valley within a few miles of its eastern end, emptying into the Kanawha some miles farther down. Where it crosses the Teazes Valley its bed is sixty or more feet lower down in the rock than that on which the pebbles and silt rest throughout the valley, and these deposits come down on the rocky shelf bordering the Hurricane in a way to show that it could not have remained where it is during the time required for so small a stream to wear down so extensive a channel.

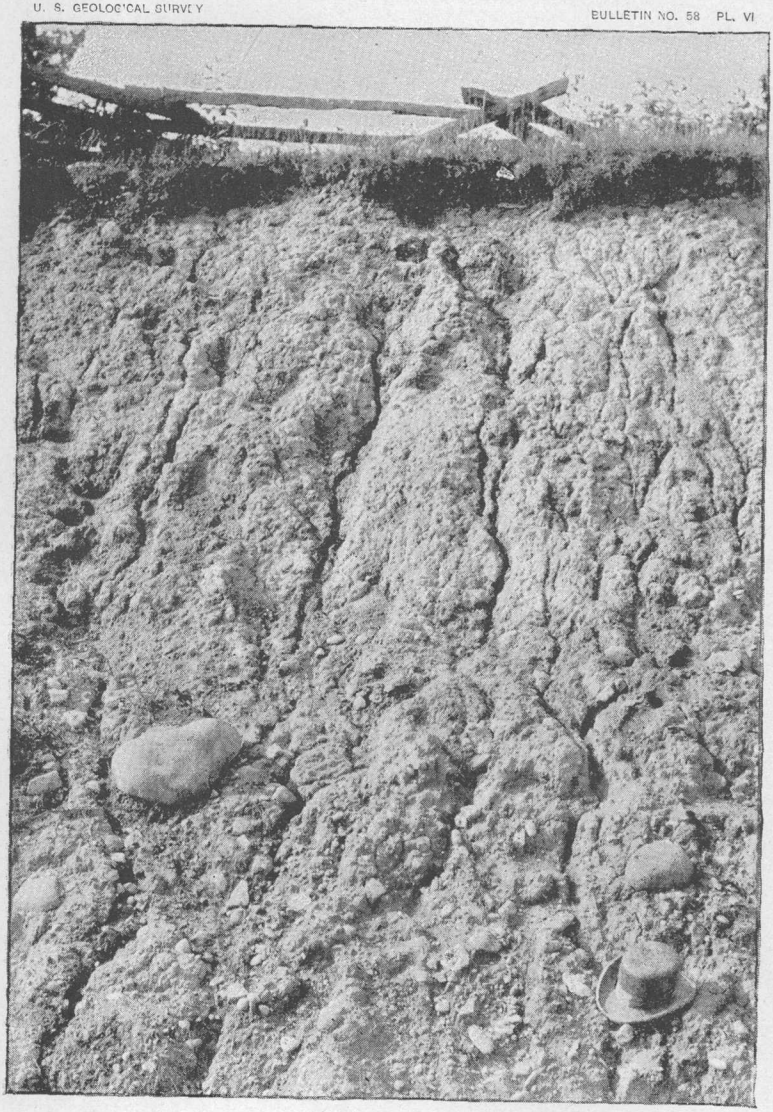
The old river valley in Boyd County, Kentucky, back of Ashland, is really a continuation of Teazes Valley, which then continued down as far as opposite Hanging Rock, just below Ironton, Ohio. It was the river pebbles in this part of the old valley, just back of Ashland, which deceived some of the earlier observers, and led to the impression that there were signs of the actual presence of glacial ice in this county in Kentucky. On close examination, however, it appears that the pebbles are all regular river pebbles, and moreover are all from the valley of the Kanawha. Especially there is to be noted a dark-colored flint peculiar to the mountains of West Virginia.

Terraces on the Big Sandy.—But wood is not the only perishable material whose preservation is significant. Pebbles of the soft sandstones of the coal measures are almost equally perishable, and Prof. I. C. White reports accumulations of these at various points at high levels on the southern tributaries of the Ohio. One such instance is on the right bank of the Big Sandy, 10 miles above its junction with the Ohio. Here Professor White[1] has described a deposit of rounded and flattish bowlderets from two to four inches in diameter and 450 feet above the stream (950 above tide). "These rounded bowlders of local coal measure sandstone [in the opinion of Prof. White] could hardly have resisted the elements during the long time since the Big Sandy Valley existed at this 400-foot level."

The hill on which they occur is a topographical summit for the immediate vicinity so that this does not represent the highest deposits of such a nature in the region. A similar deposit occurs on the Guyandotte, at the mouth of White Oak Creek, where a bed of bowlders was observed by Prof. White extending up to 150 feet above the river, or to 925 above tide.[2]

Terraces on the Elk River.—A still more significant collection of such

[1] Am. Jour. Sci., 3d series, vol. 34, 1887, p. 375. [2] Loc. cit.



SECTION OF DEPOSIT NEAR HURRICANE, IN TEAZES VALLEY, WEST VIRGINIA.

material near the junction of the Elk with the Kanawha is thus described in a communication to me by the same experienced observer:

Where the Kanawha meets the Elk at Charleston, West Virginia, a great bed of bowlder trash extends to 225 feet above the river (780 feet above tide), among which are large numbers of metamorphic rocks from the Blue Ridge region of Virginia. Many bowlders go much higher, while some extend to 390 feet above the river, or to 945 feet above tide.

One of the best pieces of evidence for the glacial dam that I have found, outside of Teazes Valley, may be seen a short distance up the Elk River, at the summit of the divide separating the waters of two small streams, which both empty into the Elk thus:

Here we find a deposit of clay, bowlders, and other trash on the summit of the divide, and how it could have got there except from backwater of some kind covering the surface there I am at a loss to understand.

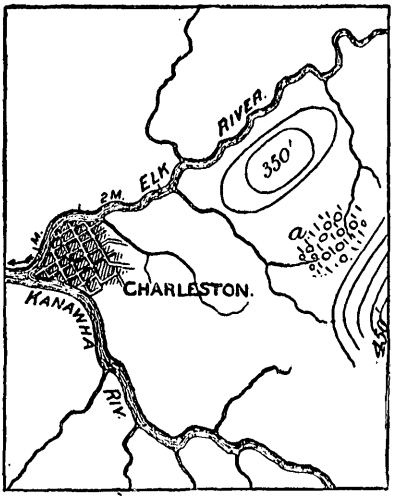


FIG. 7.—Outline map of Elk River, West Virginia.

Another instance of possibly still greater significance has been reported by Professor White since the above was in type. It occurs on the water-shed between the west branch of the Monongahela and Middle Island Creek, which empties into the Ohio some distance above Marietta. The Parkersburgh branch of the Baltimore & Ohio Railroad makes a cut in this summit about fifteen miles west of Clarksburgh, West Virginia. There is here "a broad level summit, having an elevation of 1,100 feet, in a gap of probably 300 feet below the inclosing hills. That gap, or valley, is covered by a deposit of fine clay. The cut through it is about thirty feet, and one can observe the succession of clays of all kinds and of different colors, from yellow on the surface down to the finest white potters' clay at the level of the railway where the cut reaches bed-rock, thus proving that the region has been submerged." This submergence would carry a water-level up the Alleghany Valley so as satisfacorily to explain the phenomena there attributed by some to a first glacial epoch. Speaking of the theory of President Chamberlin, that all these deposits in the Monongahela Valley were connected with the formation of the benches which slope downward, and were the result of erosion, Professor White claims "that subsequent to the erosion of these benches all of them were covered with lacustrine deposits. The proof of this is found in the fact that along the Monongahela and its tributaries there is at the summit of this lacustrine level a deposit of clays and bowlders and erosion debris of every description, beginning at 1,100 feet above sea-level and extending down to the present flood-plain. Now, on the Baltimore and

Ohio Railroad (at the point before described) there is, it seems to me, an absolute proof of this submergence, because the old valley slopes there on the one hand into the Ohio and on the other into the Monongahela, and yet the summit has 30 feet of a clay deposit, and on this summit, and on other tributaries of the Monongahela, these clay deposits cease at altitudes of 1,075 to 1,100 feet, and above that level there is no deposit—there is simply the decomposed shale and rocks in place. Why should these clay deposits cease near that prescribed level if there has been no submergence during the later history of this valley?"[1]

Terraces in Bath County, Kentucky.—Mr. G. H. Squier has also furnished me facts of a similar character concerning deposits in the upper portion of the valley of Licking River, Kentucky. In Bath County he found over an extensive region of low table-land, between Slate Creek and Licking River, and for some distance to the north, large numbers of water-worn pebbles, composed of white quartz, chert, black shale, and sandstone, and, most remarkable of all, fragments of water-worn coal. These are spread, not over the low table-land and in the valleys, but over the lower hills; but do not extend vertically as high as the water-shed. The pebbles of sandstone and coal must have been brought down the streams at least twenty miles, and it is evident that they could not have been left upon this table-land and these low hills by running water They are just such deposits as would occur during the existence of a temporary lake into which floating ice from the east could bring and deposit the materials in the situations indicated.

It may seem an insuperable objection to the foregoing theory of an ice dam, that at Oil City there is a terrace in the fork of the Alleghany with Oil Creek, which is 325 feet above the river, and that granitic pebbles appear in this. The low-water mark in the river at Oil City is about nine hundred and sixty feet above tide, which would make the elevation of this terrace 1,285 feet above tide. Also at Tidioute, about thirty miles farther up the river, glacial terraces are found on both sides of the river at just about the same absolute level. The solution of this difficulty may be found, on this theory, by supposing another ice dam in the Alleghany, at Franklin, Pennsylvania, and direct evidence of such an obstruction is not wanting. On reexamining the region with a view to correcting the glacial boundary as originally laid down by Prof. Lewis and myself, I found abundant evidence that former suspicions as to the incorrectness of our inferences were amply justified, and there can be no doubt that glacial ice at one time covered the hills down to the Alleghany River both above and below Franklin. Both above and below the angle of the Alleghany at that point I found granitic bowlders and scratched stones at elevations of from four to five hundred feet from the river, and farther east than the western angle of the river.

[1] Bulletin of the Geological Society of America, vol. I, pp. 477–479.

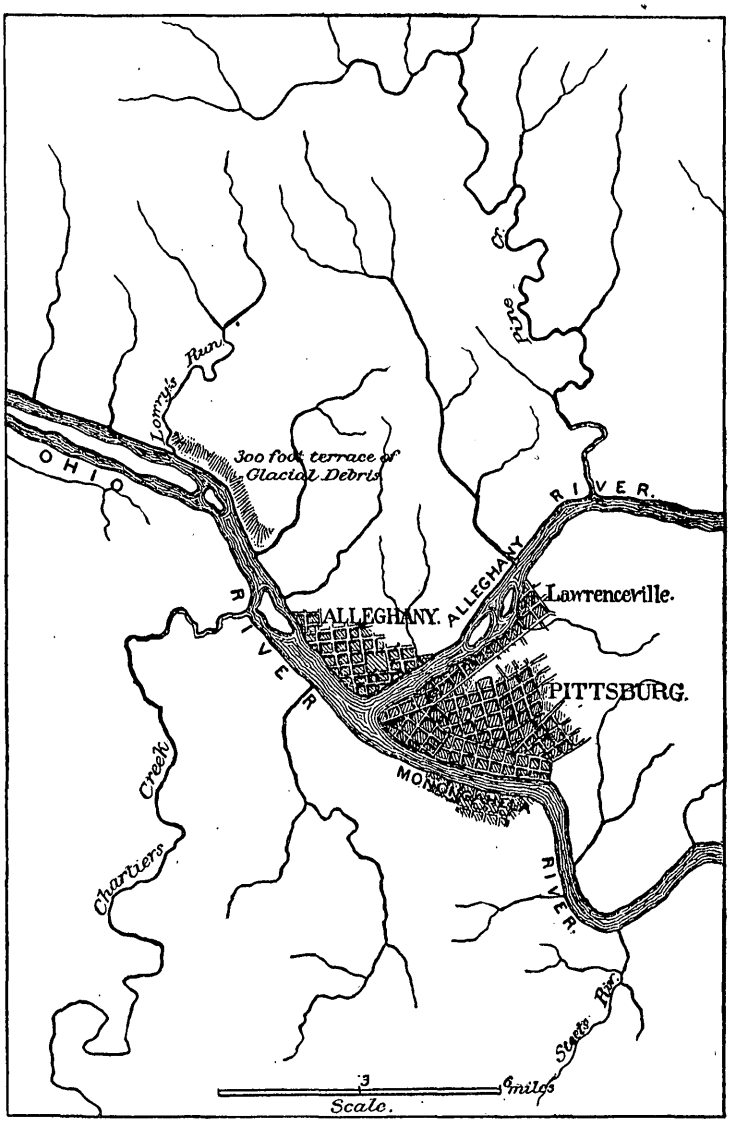


FIG. 8.—Map showing terrace at Bellevue, Pa., and the relation of Chartiers Creek to the Alleghany River.

Beech Flats, Pike County, Ohio.—Another crucial case is to be found in Pike County, Ohio, at the headquarters of Brush Creek. By reference to the accompanying map it will be seen that at the height of the glacial period the front of the ice rested at the northwest corner of Pike County, and that the divide between Paint Creek and Baker's Fork of Brush Creek is formed by the extreme portion of the direct glacial deposits. Before the glacial period there was a continuous depression connecting Paint Creek with the valley of Brush Creek, though not suffi-

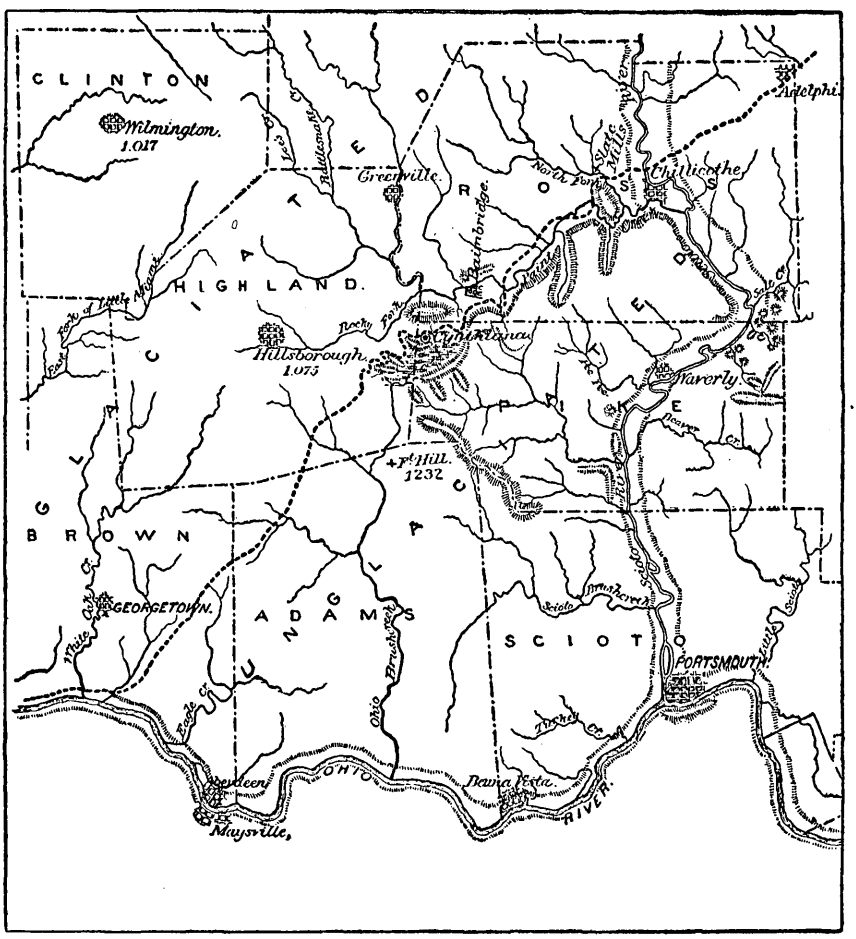


FIG. 9.—Map showing the still-water deposit between Paint Creek and Brush Creek, southern Ohio.

ciently low to make it the line of drainage. At a point about five miles south of Bainbridge, on Paint Creek, this depression is filled up, from side to side, to a height of about two hundred feet, with a true glacial deposit containing numerous northern bowlders and scratched stones. On the northern side, towards Paint Creek, this deposit exhibits every mark of a terminal moraine, with its characteristic knobs, ridges, and kettle-holes; while to the south of it there is an extensive plain, known

in the locality as the "Beech Flats." This, too, consists largely of transported material from the north; but it is level topped, and is considerably higher than the valley of Baker's Fork, which heads in it and runs to the south, emptying, finally, into the Ohio River. Its elevation is about nine hundred and fifty feet above tide.

The significance of this condition of things cannot be fully apparent without a discussion of the remarkable facts connected with the valley of Paint Creek between Bainbridge and its junction with the Scioto River. From examination of the map it will appear that the course of this creek below Bainbridge is in a northeasterly direction, parallel with and along the very margin of the glacial boundary. The valley of the creek is here about a mile wide, and is bounded on either side by steep banks leading up to the table-lands about five hundred feet above the stream. We cannot, as yet, be certain whether during the glacial period the ice extended to the southeast side of this valley for several miles below Bainbridge or not. But, as Prof. Orton[1] long ago pointed out, the preglacial outlet of Paint Creek was certainly for a time completely obstructed by ice. This preglacial outlet continued onward in a northeast direction till it was joined by the North Fork, at Slate Mills (shown on the map), where it turned to the right and pursued its course through a broad valley to join the Scioto below the present site of Chillicothe. It appears at a glance that, while the ice during the glacial period occupied the northeastern end of the valley, in the vicinity of Slate Mills, the drainage was compelled to seek a more southern outlet. A visit to the locality also makes it evident that after the ice had withdrawn, glacial deposits in that part of the valley presented a barrier to the occupation of its former channel by Paint Creek, compelling it to seek an outlet by a cut-off across a point of the table-land extending up to Slate Mills from the south. The evidence that Paint Creek has occupied this cut-off only since the glacial period appears primarily in the fact that the narrowness in that part of the gorge is in striking contrast to the other portions of the valley. It has not had time to enlarge as other portions of the valley have. Whereas other portions are about one mile wide at the bottom, this is not over 500 feet.

As before remarked, the table lands are here about five hundred feet above the valley of Paint Creek, and are built up of parallel strata of soft shale underneath and Waverly sandstone on the surface, the shale occupying here much the larger portion of the perpendicular height. It was Prof. Orton's opinion that this cut-off was formed by the action of the water which flowed along the front of the ice while it closed the lower part of Paint Creek Valley, in the vicinity of Slate Mills, and it has even been suggested that this might serve as a measure of the length of time during which the ice-front remained at this point, the problem being how long time would be required for the formation of

[1] Second Geol. Survey, Ohio, vol. 2, pp. 653–655.

such a gorge in such strata, the distance being in the neighborhood of two miles, and the strata being favorable to rapid erosion.

But, upon further examination and more mature reflection, it seems to me doubtful whether that can with certainty be called in its whole extent a postglacial gorge. The little stream seen upon the map to enter the cut-off at its southern angle is in itself an eroding agency of considerable importance, having worn back since the glacial period a tributary gorge no less than 600 feet in length; so that it is by no means impossible that the whole gorge across the promontory may have been formed by this and perhaps another stream flowing one to the east and the other to the west. If this cut-off had been thus formed in large part before the glacial period, then but a very short time would have been required to scour out the shale in the lower part of its bed, so that the extensive glacial deposits in the vicinity of Slate Mills should permanently turn the stream through the cut-off, where it now flows. As the result of my last visit to the locality, I am inclined to place the glacial boundary a little south of the cut-off, and make it follow the southeastern side of Paint Creek Valley up to Bainbridge. At any rate I have found granitic pebbles on the table-land for some little distance south of the cut-off.

My notes report that not only granitic but occasionally scratched pebbles were found upon the farm of Mr. A. T. Long, in Huntington township (400 feet above the level of Paint Creek), and that one sandstone fragment two feet in diameter was distinctly striated. More extensive deposits of gravel containing granitic pebbles were found at a level 150 feet lower than Mr. Long's farm, on either side of the water-shed between the creek above the cut-off and the creek below the cut-off, and from one-half to one mile distant, and all about one mile south of the cut-off. These deposits can be explained only in two ways. Either the ice extended upon the highlands one mile south of the cut-off (which is the more probable hypothesis) or water stood at that level while the ice-front was in the vicinity. As to the causes which might be supposed to have kept the water at that level, I will speak a little later.

Recurring now to the deposits south of Brainbridge, their true significance can be made to appear. Beech Flats is evidently a still-water deposit, for it is nearly level topped, slanting but gently to the south; it penetrates the side valleys for two miles south of the moraine-like deposits; it is of fine material like the loess; it is of considerable depth, being eroded by small streams in many places so as to show from ten to twenty feet in depth of homogeneous material; it ceases rather suddenly on the southern side, though there is no obstruction in that direction. No such deposit could have taken place in that position if there had been a ready outlet to the water down the valley of Brush Creek, for the valley does not materially contract in dimensions towards the south, and the descent, all the way to the Ohio River, is rather rapid, being not less than from six to ten feet to the mile. It follows that if the valley

had been open, a body of water large enough to have produced this loess deposit of which Beech Flats is constituted would have produced a torrent down Brush Creek of sufficient rapidity and size to have transported gravel and pebbles far down its course, forming terraces in that stream as in the other streams emerging from the glacial boundary. But there are no such terraces. In going three times over the field for several miles to the south, I looked in vain for any granitic pebbles along the stream.

Putting the facts connected with Beech Flats with those connected with the Paint Creek cut-off, near Chillicothe, there would seem to be but one adequate explanation, namely, the production of slack water (at a level from 900 to 1,000 feet above tide) by some such temporary obstruction as I have supposed in the Cincinnati ice-dam. This would permit a level-topped deposit of fine material immediately in front of the moraine, such as exists in Beech Flats, and would prevent the transportation of overwash gravel down the valley open in ordinary circumstances along Brush Creek. That at that time no line of drainage could have been opened through the Paint Creek cut-off is also evident from the facts presented. The main work of erosion through the Paint Creek cut-off, indeed, may have been, and probably already had been, accomplished in preglacial times by small streams. But the creek itself had doubtless continued in its original channel until the ice from the north reached Slate Mills, when the obstructed water must have begun pouring through the cut-off, and must have rapidly completed the work of erosion already well advanced by the work of the smaller streams. But if, as we have seen reason to believe, the ice continued to extend until it had passed the cut-off, so as to deposit the striated pebbles found on the farm of Mr. Long, one mile south of the cut-off, the outlet through this channel must for a time have been obstructed, and as there is no other lower place till reaching Cynthiana, the drainage ordinarily passing through the mouth of Paint Creek was turned into Brush Creek, when, if the way had been open, there would have been produced a torrent as in other valleys similarly situated.

But if one is not willing to grant that the granitic and striated pebbles to the south of the cut-off were deposited by an extension of glacial ice, but would maintain that these were carried thither by floating ice, he has still the problem of accounting for standing water at that level (not less than 1,000 feet above tide) on the Scioto side of the projecting table land as well as on the Paint Creek side. These deposits one mile to the west of Mr. Long's farm (on the southeast side of Paint Creek Valley and 250 feet above it) and similar deposits farther up the valley might at first seem to be the result of the more local ice-dam at the mouth of Paint Creek. But when considered in connection with the similar gravel deposits one-half mile to the east, in the watershed drained by Rolston Creek, which empties into Paint Creek below the cut-off, it seems more likely that both of them are to be connected with

the same cause, and that this cause is the one which produced the slack water in which Beech Flats were formed. Thus we seem to have in this fortunate combination a crucial test of the hypothesis in question in which the conditions are met in every important particular.

The theory is further confirmed by the fact that the lower portion of Paint Creek is so situated with reference to the glacial boundary that when the ice-front at this point had withdrawn but two or three miles, as it would very likely do contemporaneously with the withdrawal of ice from Kentucky, an ample outlet for glacial drainage would be opened into the Scioto 200 feet lower than the surface of the moraine between Paint and Brush Creeks; so that the natural necessity for a glacial outlet down Brush Creek would exist only so long as the ice closed up the mouth of Paint Creek. Just as soon, therefore, as the ice had retreated from the Kentucky hills south of Cincinnati so as to raise the blockade, and reopened the channel of the Ohio, it would doubtless also have retreated from the mouth of Paint Creek, and the line of glacial drainage through that into the Scioto and thence down the reopened Ohio would have been reestablished.

A theory which will so naturally account for so complicated a set of facts as these is well-nigh proved by this single instance. The only competing theory possible is that of a general subsidence of the country producing the same water level above Cincinnati which the ice-dam is supposed to have done. But this theory lacks such positive evidence as we have for the glacial dam at Cincinnati, and besides, it is not probable that a general depression of the country such as would produce still water at the head of Brush Creek would be of such short duration as is implied by the facts connected with this deposit, since any such general cause of obstruction would have been likely to reverse its action slowly, and so would have given time for the formation of numerous benches on the interior of the deposit toward the ice, whereas the terrace on that side is even more abrupt than on the other.

Freshness of the vegetable remains near the glacial margin.—The question of the occurrence of such an immense interglacial period as is implied in attributing the high level terraces just mentioned, as well as the glacial deposits in Boone County, Kentucky, to a first glacial epoch entirely distinct from that which covered the most of the area marked as glaciated, can not be settled without considering carefully the deposits of wood and peat found near the margin in widely separated localities all along the line.

One of the most instructive localities in which to study these deposits is in the region included in southern Montgomery and Butler Counties, Ohio. These deposits were first described by Prof. Orton, of the Ohio survey, in 1870.[1]

The most considerable deposit is found near Germantown, on Twin Creek, in Montgomery County, about thirty miles north of Cincinnati.

[1] Am. Jour. Sci., 2d ser., vol. 50, 1870, pp. 54-57.

SECTION OF PEAT AND DRIFT, GERMANTOWN, OHIO.

Here at a sharp angle of the stream there is exposed a perpendicular bank of drift 95 feet in height. Underneath this is a deposit of peat as much as 14 feet thick. The upper portions of the peat "contain undecomposed sphagnous mosses, grasses, and sedges." Both the stratum of peat and the clayey till above contain "abundant fragments of coniferous wood, which in many instances can be identified as red cedar (Juniperus virginianus)." (For the structure of the bank see Plate VII.) The composition of the drift deposit above the peat is as follows: Immediately above the peat there is from fifteen to twenty-five feet of true till. This has no sign of stratification, and abounds in striated stones. Next above occurs a band about ten feet thick of stratified material containing coarse gravel and a good deal of fine sand. Above this to the top the deposit is again true till, with, however, an occasional pocket of sand or thin layer of stratified material. But, both up the stream and down it, the cut terminates to appearance in vast gravel beds cemented together. Down the stream the stratum of peat rises so as eventually to come in contact with the band of stratified material before mentioned, the intervening till meanwhile gradually thinning out between them. The appearance is that of a saucer-shaped deposit of peat, such as would form in a kettle-hole, and which was subsequently filled and covered over with the advance of the glacier.

Whether it is necessary to interpret these facts as indicating two entirely distinct glacial ages or not will naturally be a matter open to dispute. That the facts indicate a somewhat prolonged interval between the first advance of the ice over the region and the second, can not well be denied, for the peat is clearly enough between two glacial deposits. But it may be well questioned whether an interval of a few hundred years would not suffice for the accummulation of the peat and the growth of the large cedar trees which, without doubt, flourished in that region immediately in front of the readvancing ice, and were rather suddenly overwhelmed by it. At any rate, the other localities in which fragments of wood are found imbedded in the till would show that there was not any great difference either in the conditions or the time of the first and second advances of the ice. Some of these other facts will now be noted.

The most extensive exposures of till containing woody fragments are in Butler County, Ohio, a few miles southwest of the deposit described above. One of these, near Darrtown, on Four Mile Creek, has already been spoken of on page 63. Upon reference to the description there the course of events would seem to have been as follows: A temporary retreat of the ice occurred, during which, for a short time, water was active in depositing material over the lower stratum of till, then there was a readvance in which a vast mass of unsorted material was pushed along over the stratified stratum without disturbing it. Above Germantown, in the bank described in the preceding paragraph, I thought I discovered as many as four such marks of successive advances

and retreats. Pl. VIII shows a section of till on a tributary of Four Mile Creek, near Oxford, Butler County, a few miles only from Darrtown. In this the unstratified character of the deposit is sufficiently manifest, and a piece of wood well preserved is seen projecting from the perpendicular exposure of the bank. This is about forty feet below the surface, and is where no land slide could have occurred. Equally good sections were afterwards seen in the same county on Aunt Ann's Run, near the city of Hamilton.

The wood in the instances next mentioned is found still nearer the glacial margin and they are of such a character and so numerous as to connect the previous instances with a glacial movement extending to very near the extreme margin of any signs of the direct action of glacial ice.

It is reported to me that a sycamore log was found at Morgantown, Morgan County, Indiana, 30 feet below the surface. This is, however, in a stratified deposit, but one which was evidently formed in connection with the last stages of the glacial period at that point. It is one-quarter of a mile back from the little creek running through the village, and the glacial limit is but a few miles south, on the higher lands of Brown County.

Near Seymour, Jackson County, Indiana, logs of wood are reported as occasionally found in digging wells in the village at a depth of 20 feet below the surface. Seymour is on a glacial terrace in the line of Collett's glacial stream, which was supposed to flow just east of the highlands in Brown County, and southward towards Jeffersonville. The wide terrace on which Seymour stands, and in which the logs are found, is about sixty feet above the present bed of the east fork of White River, running through the place. Black walnut logs are also mined from the banks of the river in low water. This instance is probably not decisive of the age of the buried wood, as the terrace may be the product of the so-called second glacial period. All agree that one of the later forward movements of ice in the interior came down as far as the northern border of Brown County.[1]

Other most decisive instances occur in Bigger township, in the southeastern corner of Jennings County, Indiana. Here, as already said,[2] wood occurs in one well 12 feet deep in true till, while near by wood was reported to me as found 30 feet below the surface in a well that failed to reach the rock at that depth. This is on as high land as there is in that region, and is about ten miles north of Madison, on the Ohio River, and about five hundred feet above it; and the signs of glaciation are abundant over the whole region. The well reported by Professor Borden,[3] at Paris Crossing, in Jennings County, as containing wood in blue drift clay 40 feet below the surface, is about twelve miles southwest of

[1] Preliminary paper on the Terminal Moraine of the Second Glacial Epoch by T. C. Chamberlin, Third Annual Rept. U. S. Geol. Survey, 1883, p. 333.

[2] See page 67.

[3] Seventh Annual Report Geological Survey, Indiana, for 1875 (1876), p. 172.

SECTION OF TILL SHOWING WOOD, ONE MILE SOUTH OF OXFORD, BUTLER COUNTY, OHIO.

the foregoing place. That at Milan, with muck and wood 54 feet down in what is evidently the true till of the region, is near the summit of Ripley County, Indiana, and is as far south as Cincinnati, and about twelve miles northwest from the river.

In Hamilton County, Ohio, Col. Charles Whittlesey reports thirty-five wells containing muck beds, leaves, or timber, from 300 to 500 feet above the Ohio River.[1] That at New Burlington is certainly in till.

In Highland County, Ohio, Prof. Orton reports many cases of the occurrence of such vegetable deposits. In the village of Marshall "eleven wells out of twenty reached a stratum of vegetable matter, with leaves, branches, roots, and trunks of trees." Marshall is on the very limit of glaciation. Similar instances were reported to me in the southern part of Highland County and in Clermont County.

In Ross County, near Lattas, Mr. J. M. Connell reported to me finding wood in a well on his farm. This is situated very near the extreme limit of glacial action, and is where it could not have been brought into position by water action. Mr. Connell's farm is 425 feet above the valley at Frankfort, two miles to the north, and 525 feet above the valley of the Scioto River at Chillicothe, 10 miles to the east. The till is massed up in great quantities against and upon the margin of the rocky plateau, here facing the north. The well described was in this marginal till upon the highest land, and passed through 12 feet of yellow clay, then through three or four feet of blue clay, then 10 feet of yellow clay, then gravel for five feet. About thirteen feet below the surface there was found a log of wood three or four feet long, and about three inches in diameter. This was in blue clay, and was accompanied with traces of muck.

I have omitted to mention many other places where wood is reported in what are perhaps preglacial channels serving as outlets to the south of the melting torrents, and which may have been transported a long distance from their native place. One such was reported to me in the valley of Raccoon Creek in Granville, Licking County, Ohio, and but a few miles from the glaciated border. This was found 94 feet below the surface of the terrace, which would bring it about forty feet below the present bed of the stream. A few miles farther up in this same valley red cedar logs were formerly found in great numbers beneath what I inferred were the glacial terraces along the valley; and the wood was so fresh that a flourishing business was for awhile carried on in manufacturing them into pails. Red cedar is not found growing in that region now, and the logs were evidently of the same period with those described as found in true glacial till in Butler County.[2]

Prof. Collett reports that all through southwestern Indiana there are found from 60 to 120 feet below the surface, peat, muck, rotted stumps, trunks, branches, and leaves of trees, and that these accumulations

[1] See Smithsonian Contributions for 1869, pp. 13, 14. [2] See above, p. 63.

sometimes occur through a thickness of from two to twenty feet. One mile west of Switz City, in Greene County, Indiana, a hickory log was reported to me as found 20 feet below the surface, but according to my observations, this was a short distance outside of the glaciated limit, and may have been of recent origin.

SUMMARY.

It will be profitable at this point to take a rapid survey of the facts bearing on the theory of a glacial dam at Cincinnati.

(1) The deposits in Kentucky south of the Ohio River, in Boone and Campbell Counties, seem to be such that only glacial ice could have deposited them. This being granted, the question then comes whether this extension of glacial ice took place before or after the erosion of the trough of the Ohio River. Bearing on this question we note that—

(2) The freshness of the glacial deposits in Hamilton County immediately north of the river, together with the perfectly preserved specimens of wood just enumerated from till in Jefferson and Ripley counties, Indiana, and in Butler, Hamilton, Clermont, and Highland Counties, Ohio, would seem to indicate that they belonged to a period much less remote than that when the Ohio was flowing in a rocky bed from three to four hundred feet higher than that now occupied. And it is scarcely probable that a second general glacial period, separated so far from the first, would be so nearly coincident in extent with the first as it must have been if the deposits south of the river belong to the earlier, and those north of the river to the later, period.

(3) The high terraces on the Big Sandy, in Teazes Valley, at the junction of the Kanawha and Elk Rivers, and near Morgantown, Fairmont, and Clarksburgh, in West Virginia, and at Carmichaels on the Monongahela, in Pennsylvania, can with difficulty be assigned to that remote period when the streams in those valleys flowed over rocky beds at heights corresponding to the height of the terraces. Slack water of some kind must be supposed to account for their evidently recent origin.

(4) The fine character of the sediment constituting the overwash in front of the moraine at the head of Baker's Fork of Brush Creek, in Pike County, Ohio, indicates a body of still water there at a height corresponding to that of the supposed Cincinnati dam. The absence of terraces, and indeed of any northern drift along the lower portions of Brush Creek, is additional proof of the same condition of things.

(5) Many of the high level terraces in the upper Ohio and its tributaries may be but remnants of river beds when the rocky bottom was at that level. But, since some of them were as evidently due to slack water deposition, when floating ice was abundant, simply considering them in themselves, it would remain to choose between two theories as to the cause of the slack water. The ice-dam theory has a rival in that of the general submergence of the Alleghany plateau to a depth of a thou-

sand feet or more. This has against it the enormous amount of change implied. It is an inordinate cause to introduce to account for so small a result. Furthermore, according to Prof. Lesley, there are not any corresponding terrace remnants on the east side of the Alleghanies, as there should be on this theory. Still, this is a point to be more fully investigated. The deposits of gravel and pebbles in the valley of the upper Potomac above Cumberland without much doubt mark former levels of the river bed and do not imply a submergence. I have not seen any definite descriptions of deposits farther south corresponding to these still-water deposits which I have attributed to the obstruction by the Cincinnati ice dam.

As the case now stands in my own mind, both the theory of continental depression and that of such an enormous period between two nearly conterminous fields of successive glaciation as is implied in attributing the deposits south of the Ohio and the high level terraces of the upper Ohio to a glacial period when the rivers flowed in rocky beds of corresponding height, must give place to the simpler theory that the ice, which all admit extended at no very distant date to the north bank of the Ohio for a distance of 50 miles, also extended at that time a few miles farther, and temporarily obstructed the channel, forming thus an ice dam of about five hundred and fifty or six hundred feet in height.

On this supposition, so natural in itself, all the facts are easily explainable. So confident have I become in the reality of this dam that I have not hesitated to use it as a means of putting myself in the line of discovering other facts which are the natural consequence of this. Many of the facts enumerated in this paper (as, for example, those connected with the headwaters of Brush Creek) were thus discovered. It was reasoned that they must exist from the nature of the supposition; and upon examination in proper localities it was found that they did exist according to previous calculation. I need not say that such experience is the most convincing proof of a theory.

THE LOESS AND ITS RELATION TO THE GLACIAL DRIFT.

A striking characteristic of the glacial deposits in southern Illinois, Indiana, and Ohio is that they are overlaid, to a greater or less extent, by a very fine deposit almost devoid of grit and wholly free from gravel. Near the Missouri and Mississippi Rivers this is of great extent, sometimes being as deep as 100 feet, and being of such texture that wells dug in it to that distance will stand for years without curbing. There seems to be no signs of stratification in this deposit, and its origin is a question hotly disputed, some writers, like Richtofen, Clarence King, and Pumpelly maintaining that it is the accumulation of dust which in the course of ages has been brought along by the wind.

But the more general opinion is that it is a water deposit, though upon that theory the absence of stratification and of the remains of shell-fish is difficult to explain. In southwestern Iowa Prof. J. E. Todd took

me to a fresh section fifteen or twenty miles back from the Missouri River and several hundred feet above it, where a blanket of loess about twenty feet in thickness rested unconformably on irregular deposits of till, while near the junction of the loess and the till a stratum, a foot or more in thickness, contained many fragments of carbonized or half-decayed wood.

In my recent investigations I have kept in mind these problems concerning loess, but I can not say that very much light is shed upon them by my observations. Their whole relation to the glacial deposits throughout the region I have more particularly investigated is to me very perplexing.

In the first place, there seems to be no material difference between the loess covering the hills in Perry County, Missouri, entirely outside the glaciated region, and that superimposed upon the glacial deposits of Randolph and Jackson Counties, upon the opposite side of the river, in Illinois. The deposits upon the high lands of Perry County would be ordinarily and reasonably reckoned residuary clays, resulting from the decomposition of the limestone rocks upon which the deposit rests. Yet a chemical analysis fails to reveal any essential difference between the deposit in that place and that which rests upon the surface everywhere in southern Illinois. A partial analysis of two specimens taken from a cut near Perryville, Perry County, Missouri, 10 miles back from the river, and about three hundred feet above it, where the loess is about ten feet deep, gives the following results:

	Per cent.
First specimen, 2 feet below the surface:	
CO_2	.061
CaO	.164
MgO	.264
Second specimen, 5 feet below the surface:	
CO_2	.087
CaO	.237
MgO	.201

The next three specimens are taken from a cut in Randolph County, Illinois, several miles east of Chester. The cut is about twenty-five feet deep, and for the first 10 feet is without much grit and perfectly free from gravel; but gradually it merges into a deposit having every characteristic of true till. Three specimens of soil were taken from this cut, of which the first was near the surface, the second 10 feet lower, and the third 23 feet lower still. The following are the determinations of the same elements sought for in the preceding specimens from Missouri:[1]

	Per cent.
First specimen, near the surface:	
CO_2	.184
CaO	.257
MgO	.203

[1] These determinations were made by Mr. W. C. Metcalf, who accompanied me in this portion of the field.

Second specimen, 10 feet below the surface:

CO_2	.101
CaO	.207
MgO	.128

Third specimen, 23 feet below the surface:

CO_2	.149
CaO	.347
MgO	.192

The uniformity of composition in these specimens is certainly remarkable, as is the small amount of carbonic dioxide in each, being in no case as much as one-quarter of 1 per cent. In several specimens, however, from other places in southern Illinois a marked increase in carbonic dioxide was found in the lower portions of the deposits. For example, near Phillipstown, White County, a specimen from the fine soil near the surface shows but 0.039 per cent, while that from the till underneath gives 5.792 per cent of CO_2. In another cut in the same town the specimen from three feet below the surface yields no CO_2, while that from 10 feet yielded 7.029 per cent. Again in Heralds Prairie township, in the same county, a specimen from three feet below the surface, which is entirely free from gravel, yields 0.018 per cent of CO_2, while one four feet lower in what is noted as true till yields 6.007 per cent of CO_2. Again, in a cut three miles south of New Harmony, Posey County, Indiana, near the extreme limit of glaciation, the upper specimen, from two feet below the surface, yields 0.229 per cent, while that from 10 feet lower yields 6.032 per cent of CO_2.

The absence of any sharp line of demarkation between the loess and the till has also been both unexpected and puzzling. In oft-repeated instances the upper portion of a cut revealed several feet of loess entirely free from gravel, while, a few feet below, the till was unmistakable in its character and for two or three feet between, the character of the material was intermediate between that of loess and till. This occurred so often in both southern Illinois and Indiana that it may be set down as the prevailing characteristic. Over the southeastern part of Indiana there is a marked diminution in the amount of this superficial covering of loess. Still, it is nearly everywhere present. Over these counties there are extensive portions of the country occupying the summit of land, which is so level that drainage is extremely difficult. A few feet at the bottom appears to be compact till with granitic pebbles and scratched stones, while the surface and a few feet below is a light-colored loess.

Going still farther east, to Ohio, the phenomena are quite similar to those in the southeastern counties of Indiana (see above, p. 65 et seq.).

In Jackson County, Indiana, and farther west, near the sandstone knobs, the superficial deposit corresponding to the loess is a very fine sand, peculiarly favorable for the growing of melons. This would seem, evidently enough, to be a wind deposit. There is nothing corresponding to the loess in northern Ohio, so far as I know.

Considering the loess merely by itself, so far as it has come under my

observation, it would seem to be largely a residuary clay, and would most readily be accounted for by supposing a depression in the Mississippi Valley of several hundred feet after the continental glacier had attained its extreme limit, and then retreated to about the line marked by President Chamberlin as the limit of the ice during the second glacial epoch. Such an interglacial sea would have had poured into it the finer material washed down from the more northern regions, which would settle unconformably upon the older glacial deposits below. But the complete application of this theory of depression would involve so great changes in the more western and northern portions of the Mississippi Valley that it is doubtful to my mind whether it is tenable. Many of the phenomena of the loess may be accounted for, perhaps, by mere local causes. Temporary lakes may have been formed by slight orographic changes in different places. Over some of the extensive prairies of southern Illinois the direct wash from the melting ice to the north may have spread a film of fine material over the whole region to the south. Again, the winds may have had a considerable share in transporting this fine material before vegetation had advanced to cover the region from which the ice had recently retreated.

Professor Orton, anticipating Darwin's book on worms, many years ago suggested, in reference to the deposits in Highland, Brown, and Clermont Counties, Ohio, that the fine material had been brought to the surface through the agency of worms and other burrowing animals. President Chamberlin had also suggested this explanation for portions of the field. Such an explanation would seem the more reasonable over the regions mentioned in Ohio and southeastern Indiana, because of the comparative thinness of the deposit. The indefiniteness of the line of demarkation between the loess and the till over so wide a portion of the region would also favor the same view, except that frequently the depth of the loess is so great as to render such agencies insufficient. Still, perhaps the wind may in many instances have increased the depth.

GOLD NEAR THE GLACIAL MARGIN.

A few words should be said respecting the frequent discovery of gold near the glacial margin, since it is so often the cause of serious delusion. The whole region covered by my special investigations and lying west of the Blue Ridge in Pennsylvania, is covered with stratified deposits of the Upper Silurian, Devonian, and Carboniferous ages. So little disturbed are they that it would be hopeless to look for gold in them. The natural explanation, then, of finding gold anywhere in this region would be that it was a part of the glacial transportation from the granitic region to the north. I soon learned from experience that the gold diggings were sure to be located near the glacial margin, where it might be supposed that the till had been most weathered and washed, and which had, presumably, been skimmed from the disintegrated surface of the northern rocks on the first advance of the glacier over them. In this border

gold has been found frequently in quantities to repay a moderate expenditure in washing the gravel, but never in large quantities. I found such deposits in Brown County, Indiana (and indeed in all the southeastern counties of Indiana), in Brown, Clermont, Licking, and Knox Counties, Ohio, and in Lycoming County, Pennsylvania. In all cases these deposits are within the glacial boundary, and are near the glaciated margin.

The irregular and serrate character of the southern boundary of the glaciated region, along which these gold deposits are found, led Dr. Sutton[1] to speculate from false data as to the particular source of the gold. The relations of the gold deposits in Dearborn, Jennings, and Scott Counties, Indiana, to those in the northern part of Brown County, in the same State, are wholly accidental, arising from the irregularities in the glacial boundary. But, before that fact was discovered, it was natural to think them significant. Consequently an attempt was made by Dr. Sutton to locate the original gold accumulations to the far north by projecting the lines which were determined by the points in the southeastern counties and those in Brown County. I was more successful soon afterwards, when I had come to see the significance of the gold, in inferring from the reports of diggings what was the vicinity of the glacial margin in the localities named.

INTERGLACIAL MAN IN OHIO.

At the meeting of the Boston Society of Natural History for November 4, 1885, Prof. F. W. Putnam showed an implement chipped from a pebble of black flint, found by Dr. C. L. Metz in gravel 8 feet below the surface, in Madisonville, Ohio. This rude implement is about the same size and shape of one, made of the same material, found by Dr. C. C. Abbott in the Trenton, New Jersey, gravel, and is of special interest as the first one known to have been found in the glacial gravels of Ohio. The announcement of this discovery, coupled with a letter from Dr. Metz, saying that he had since found another such implement at Loveland, led me to visit the localities to see their relation to the glacial deposits of the region. The following are the results:

Madisonville is situated 11 miles northeast of Cincinnati, in the depression of a preglacial valley connecting the Little Miami River with Mill Creek, about 5 miles back from the Ohio. The Little Miami joins the Ohio some miles above Cincinnati, while Mill Creek joins it just below the city. The general height of the hills in that vicinity above the river is from 400 to 500 feet. But the hills just north of Cincinnati are separated from the general elevation further back by the depression referred to, in which Madisonville is situated.

The depression is from one to two miles wide and about five miles long from one stream to the other, and is occupied by a deposit of gravel,

[1] See abstract of paper on the gold-bearing drift of Indiana, Proc. Am. Assoc. Adv. Sci., 30th (Cincinnati) meeting, 1881, p. 177.

sand, and loam, clearly enough belonging to the glacial-terrace epoch. The surface of this is generally level, and is about two hundred feet above the low-water mark in the Ohio. On the east side, towards the Little Miami River, at Red Bank, the gravel is rather coarse, containing pebbles, ranging from one to three or four inches, interstratified with sand, and underlaid near the river level with fine clay. There is here a thin covering of loess, or fine loam. On going westward this loess deposit increases in thickness, being at Madisonville, one mile west, about eight feet thick. Further west it is much deeper, and seems to take the place of the gravel entirely. At several railroad cuttings, "till," with scratched stones, appears underneath all.

Thus it appears that this cross-valley connecting Mill Creek with the Little Miami back of Avondale, Walnut Hills, and the Observatory was once much deeper than now, and has been filled with the deposits made when immense glacial floods were pouring down these two streams from the north. The Little Miami was a very important line of glacial drainage, as is shown by the extensive gravel terraces all

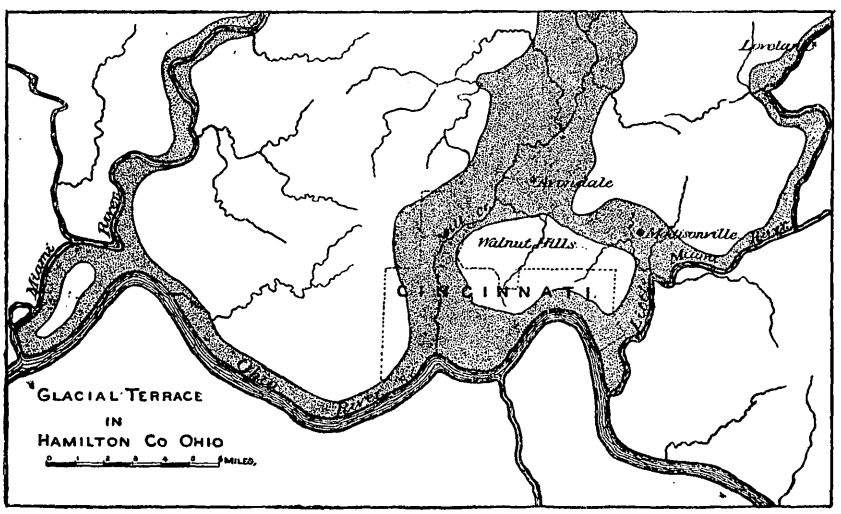


FIG. 10.—Map of Hamilton County, Ohio, showing situation of glacial terrace in which paleolith was formed.

along its course. The railroads resort to these terraces for ballast from long distances. The coarser material was naturally deposited near the direct line of drainage, where the current was strong. Naturally also back from the river towards Madisonville there is an increase of the fine deposit, or loess, which is particularly a still-water formation. There can thus be no doubt as to the true glacial character of the formation.

As to the implement, it is preserved in the Archæological Museum in Cambridge, Massachusetts, where any one can examine it and compare it with similar ones from other parts of the world, and is of the true paleolithic type. It is not smoothed, but simply a rudely chipped,

pointed weapon, about three inches long. Dr. Metz found it in 1885, while digging a cistern. In making the excavation for this he penetrated the loess eight feet before reaching the gravel, and there, near the surface of the gravel, this implement was found. There was no chance for it to have been covered by a slide, for the plain is extensive and level topped, and there had evidently been no previous disturbance of the gravel.

Subsequently, in the spring of 1887, Dr. Metz found another paleolith in an excavation in a similar deposit near Loveland, Ohio. Loveland is also on the Little Miami River, about twenty miles above Madisonville. The river makes something of an elbow at this point, opening to the west. This space is occupied by a gravel terrace about fifty feet above the stream. The terrace is composed in places of very coarse material, resembling very much that of Trenton, New Jersey, where Dr. Abbott has found similar implements. The excavation is about one-quarter of a mile west of the river, near the residence of Judge Johnson. The section shows much coarser material near the surface than at the bottom. The material is largely of the limestones of the region, with perhaps ten per cent. of granitic pebbles. The limestone pebbles are partially rounded, but are largely oblong, some of them being from one to three feet in length. These abound for the upper 20 feet of the section on the east side towards the river. One granitic bowlder was about two feet in diameter. On the west side of the cut, away from the river, mastodon bones were found, not long before, in a deposit of sand underlying the coarser gravel and pebbles. It was here, about thirty feet below the surface, that Dr. Metz found the paleolithic implement in question, which is an oblong stone about six inches long, four and one-half inches wide, chipped all around to an edge, and is, in the opinion of Dr. Metz and of Prof. H. W. Haynes, of Boston (a most competent judge), unquestionably of human manufacture. This, like the preceding implement, can be seen in company with Dr. Abbott's collection from Trenton, New Jersey, at Cambridge, Massachusetts.

Another similar discovery was made in 1886 at Medora, Jackson County, Indiana, by Mr. Hilborne T. Cresson, an experienced archæologist, of Philadelphia. Medora is upon the east fork of White River, near where it emerges from the glaciated region to enter the triangular unglaciated portion of southern Indiana, as shown upon our map. According to Mr. Cresson, a well-wrought paleolithic flint implement was found by him at this point in undisturbed gravel 11 feet below the surface, and about fifty feet above the flood-plain of the river, and in position such as to exclude its introduction, except in connection with the original deposit of the material. This implement is also in the Peabody Museum, Cambridge, Massachusetts.[1]

A fourth discovery was made on the 27th of October, 1889, by Mr. W. C. Mills, at New Comerstown, Tuscarawas County, Ohio. This is a

[1] See proceedings of the Boston Society of Natural History, vol. 24, p. 150 et seq.

fine specimen of the true paleolithic type four inches long, two inches wide, and an inch and a half in thickness, tapering to a point, and in every respect of true paleolithic type, such as has characterized the discoveries in northern France and southern England. The material is a black flint, such as occurs in nodules in the "Lower Mercer Limestone" of the near vicinity. The implement has the waxy, glossy appearance which indicates considerable age, and was found by Mr. Mills in a gravel-pit from which the railroad has, for a long time, been at work obtaining ballast. Upon receiving information of this discovery, I visited the locality, and found, as I had surmised from Mr. Mill's description, that the gravel-pit at New Comerstown belongs to the glacial terrace of the Tuscarawas River Valley which I have described in the body of my report. The trough of the river is here about a mile in width, and the summit of this terrace 35 feet above the flood-plain. Mr. Mills found the implement in undisturbed strata of this terrace, 15 feet below its surface.

By those familiar with the subject these paleoliths will at once be recognized as among the most important archæological discoveries yet made in America, ranking on a par with those of Dr. Abbott, of Trenton, New Jersey. They show that in the Mississippi Valley, as well as on the Atlantic coast, man was an inhabitant before the close of the glacial period.

GENERAL CONCLUSIONS.

On surveying the whole field of my investigations and limiting my conclusions mainly to what the facts there found would make necessary, the following would seem to have been the course of events:

From some center north of the great lakes snows accumulated until an ice flow to the south became necessary to dispose of the excess of the snow-fall over the annual melting power of the sun. This snow-fall was greater at some points than at others, so that there were separate subcenters for the outflow of the glacial ice. Thus, in part, is to be explained the serrate character of the southern margin of the glaciated region, the ice projecting farthest opposite the larger accumulation of snow. The lower level of the larger valleys had also some effect upon the distance of the southern flow. There would seem to be no conclusive evidence that isothermal lines had anyhing to do in determining the irregularity of the southern margin. But they may have had some influence.

The ice as it moved onwards pushed on before it and incorporated into it much material that had been disintegrated by previous subaerial agencies, and also executed a large amount of mechanical erosion by its own force. This is evident both from the extensive fields still retaining the glacial grooves and scratches, and by the demonstrated mechanical character of much of the till. It is probable that the deposits near the margin are, more largely than those farther back, the product of preglacial disintegration. This would account for their

generally being more completely oxidized, and their consequent higher color. The rate of the advance of the glacier probably can not be directly determined by any facts accessible in this field.

Having advanced to its extreme southern limit, and the climate becoming ameliorated, the ice began slowly and irregularly to recede, occasionally readvancing to cover again ground from which it had temporarily withdrawn. In some instances, as where the buried forests are found, some scores or hundreds of years may have intervened between the retrocession and the advance over limited areas.

The formation of a terminal moraine at any point would depend upon two or three factors: First, upon how long the ice front remained stationary at a given point. Other things being equal, the longer the ice front remained at a point the greater would be the accumulation there. For some reason, the ice front would seem to have been longer stationary along the southern coast of New England than at marginal points farther west, perhaps because the waters of the ocean there met it and prevented it from attaining its natural southern limit. In the interior it would seem that the ice retreated rather steadily over most of the space occupied, so that the material which otherwise would have been heaped up in front as a terminal moraine is more uniformly spread over a wide margin, making up in breadth what it lacks in height.

During the time that the ice extended into Kentucky an ice dam was probably formed about 550 feet in height (that being the height of the barrier to the south), sufficient to set the water 300 feet over Pittsburgh. This long, crooked, narrow, slack-water lake is supposed to have continued long enough for considerable material to accumulate at various points above, where tributary streams, laden with sediment, joined the main body of water. The length of the continuance of this condition of things need not have been many hundred years.

The overlying loess in southern Illinois and Indiana, and the analogous formations over some of the counties of Ohio perhaps make it necessary to suppose a depression of that region soon after the beginning of the retreat of the ice from its extreme southern limit. This depression may also have extended to the Alleghanies, and so have had something to do in producing some of the effects attributed to the ice obstruction at Cincinnati.

In the more northern region, near the lakes, there are regions of stratified sand and gravel superimposed upon the till to a height of about 200 feet above Lake Erie, and at several lower levels towards the lake. These are evidently water deposits, and most likely bars formed a little outside the shore when the water stood at that height. The material of these ridges is largely local. From the extent of these ridges and the character of the surrounding country it would seem that the water did not remain long at the several levels indicated by these deposits. There are no animal remains in the lake ridges, but wood is often found underneath, and especially to the south of them on the side away from

the lake. The theory has been suggested, and seems altogether probable, that the barrier holding this body of water at such a high level was the unmelted ice of the glacier, which naturally remained longest to the north and east, across the valleys of the Mohawk and St. Lawrence.

Upon the question of the time which has elapsed since the withdrawal of the ice it is as yet too early to express any confident opinion. So far as the facts go, however, they point to a moderate estimate. The freshness of the wood that is found beneath the deposits of till, the small amount of erosion, both in the river valleys and in the gorges below the numerous waterfalls, together with the small extent to which the till has in general been oxidized, all would indicate a brief period of post-glacial time when compared with the enormous lapse of time during which the Ohio was wearing its long trough from a little above the Mississippi to the headwaters of the Alleghany and the Monongahela.

Through all this distance of not less than 1,200 miles the stream has worn a channel about a mile in width and several hundred feet in depth. The prosecution of investigations concerning post-glacial chronology will be of great historic interest if, as would appear from the discoveries of Dr. Abbott at Trenton, N. J., and those of Dr. Metz at Madisonville and Loveland, Ohio, Mr. Cresson at Mentone, Ind., and Mr. Mills at New Comerstown, Ohio, man was on the continent before the glacial ice had withdrawn from the headwaters of the Delaware and Little Miami rivers. The facts brought to light in the present report will greatly aid in such calculations. The subject merits more careful study than has heretofore been devoted to it.

INDEX.