the normal form. There are other specimens showing a similar variation and several are normal. The frontal aperture varies from subcircular to a mere slit.

The form of the spire varies from a fairly well-developed spiral cone with flaring base and acute apex to a form approximating a disk with very obtuse apex. The most disk-like form observed belongs to a shell less ventricose than the average and the spire is turned from the normal position. The number of whorls in the spires seems to vary slightly, though the material at hand does not admit of certain determination in this respect. Unfortunately the crural attachments of the spires are not shown in any of the specimens. However they must have been somewhat modified to accommodate the twisted position of the spires, unless, in the specimens examined, the spires which are abnormal had broken loose in the shell prior to fossilization, which I believe is improbable.

The above variations, except in the case cited, do not seem to accompany any particular form of shell. There is nothing visible in the specimens to show the cause of their abnormality.

It is dangerous to generalize much on the observations based on a single species. All that I suggest is that the foregoing seems to indicate that in those spire-bearing brachiopods, particularly the Athyridae, where the form of the shell does not govern the form and position of the spire, i. e., those which approach a spherical form, the spiralia may be subject to a considerable variation both as to the form of the spire and its position.

Topography and Geography of Bean Blossom Valley, Monroe County, Indiana.

V. F. Marsters.

In Monroe County, Indiana, and others lying to the southwest (Owen, Greene, Martin, Dubois, Pike and Gibson) occur a number of preglacial river valleys the present topography and content of which unmistakably suggest the existence of a temporary period of laking. Inasmuch as the attenuated edge of the Illinoian till plain passes diagonally through the above counties and crosses the mouths of many of the southern tributaries to the west branch of White River, which present evidence of arrested drainage near the limit of the till plain, it seems probable that the laking was consequently connected with the glaciation of the immediate region.

In Monograph XXXVIII, U. S. G. S., Mr. Frank Leverett has mapped and given a brief description of the probable preglacial drainage, the areal extent of the laking and the final adjustment of the postglacial drainage within the counties mentioned above. For the discovery of a few of the cases described, Leverett is indebted to Mr. C. E. Siebenthal, who furnished much of the data relative to the laked valleys found in Monroe and Owen counties. Mr. Siebenthal has also referred to this same topic in a paper published in the annual reports of the Indiana State Geological Survey. It is to one of these cases that I wish to devote the main part of the description and discussion presented in this paper.

Bean Blossom River takes its rise in the northern tier of townships in Brown County, flows a little south of west to Monroe County, reaching the northwest corner of Bloomington Township, where it turns rather sharply and continues in a due northwest course to the White River, into which it empties at a point about one mile below Gosport, Owen County. The topographic features of this rather picturesque valley, which are regarded as giving the key to its geographic history, are, briefly, these: First—The steepness of the valley sides and its persistence in close contact with the valley floor, together with its peculiar variations in direction. Second—The predominance of a broad flat floor, sometimes a mile or more in width, now occupied by a small meandering stream which for the greater part of its course insists upon keeping to the south or southwest side or edge of the valley floor. Third—The occurrence of both isolated and attached hummocks and ridges, the former usually located near the middle of the valley floor, the latter standing in rather close proximity to the valley slope. The rock content of these striking bits of relief is precisely the same as that which composes the upland on either side of the valley, namely, the subcarboniferous limestone and underlying sandstone locally known as the "knobstone." Fourth—The occurrence of a series of benches or so-called terraces rimming the valley slopes at various points and ranging in height above the valley floor from thirty to seventy feet. These consist of mixtures of sandy material and clay which have been derived from the rock formations as appear on the surface of the upland. Fifth—The development of V-shaped valleys just scarring the valley sloped to the present valley floor and not extending beneath it.

In attempting to unravel the geographic history of a river valley whose drainage has been subject to arrest by the invasion of an ice sheet, we find that the story of its life resolves itself into three fundamental parts.

First, what were the topographic characteristics of the valley before the laking stage; in other words, what was its preglacial history. Second, what happened to the valley during the laking stage, its glacial history. Third, what has happened since the disappearance of the lake, its postglacial history.

DESCRIPTION OF TOPOGRAPHIC FEATURES.

Valley Slopes. While the average slope of the valley side is somewhere between twenty-five and thirty degrees, it very rarely falls as low as fifteen and in many places attains a slope as high as forty degrees. The variation in the slope bears a direct relation to the minuteness of dissection, or the spacing of the streams crossing it. Observation bears out the conclusion that the closer the streams to each other, the more subdued the slope. For a number of stretches along the valley sides very few streams crossed them, and there the slope was invariably found to assume the steepest angle. Moreover, the trend of the slopes appear to have a peculiar and persistent variation in direction, considered with reference to the general direction of the valley. It is believed that these features afford certain criteria by which something of the early history of Bean Blossom may be determined.

Valley Floor. The greater part of the valley is remarkably smooth and flat. There is, however, some systematic variation from an absolute plain. If we should construct a cross-section of the relief of the valley, especially in the central or upper parts, we should find that its systematic departures from a plain are such as to suggest that such aggrading as occurred in the valley was governed to a very large degree, at least on the present surface, by fluviatile agencies and not to the promiscuous distribution of sediments over its bottom during a period of laking.

It should also be noted that the present river channel throughout a large part of its course persists in keeping to the south and west side of the valley floor. Only at a few points within the limits of Monroe County do we find that the present Bean Blossom succeeds in meandering across the entire width of the valley floor. In other words, this river is not appropriate to and does not fit the broad valley which it now occupies.

The monotonous plain of the valley is broken at various places within the limits of Monroe County by the projection of conical hills and elon-

gate ridges through its floor. In nearly all the cases examined in detail it was found that they were made up of the same rock as compose the uplands, sheeted over with a thin soil, and not of the same sort of incoherent mass of silts, clay, etc., constituting the valley floor.

The slopes vary between twenty and forty degrees and usually maintain a sharp angle with the valley floor as did the valley sides. They vary in size and shape from conical hills with almost circular bases one or two hundred feet in diameter, to ridges a half mile long, one to four hundred yards in width. Their tops fall a little short of the general level of the upland. They invariably lie either with their longer axis parallel to the trend of the valley or with their outer ends pointing diagonally across and down stream. In the latter case the trend of their slopes bears some linear arrangement and relation to the valley slope adjacent to it.

These elevations or "islands," when isolated, stand out well towards the middle of the valley; when, however, they happen to approach the valley slope, they are usually *attached* to the valley slope. Their nearness or remoteness to the valley slope determines the comparative elevation of the connecting part or extension of the valley slope to the outstanding bit of relief, or "island."

Terraces or Benches. Rimming the valley slopes are to be found a number of benches of variable widths, with surfaces sometimes as flat as a floor or with an exceedingly gentle decline valley-ward, with outer edges lobate in shape and descending with a marked angle to the level of the valley floor. These occur at various points within the limits of Monroe County, invariably situated on the north and east side of the valley, and varying in elevation from twenty feet in the lower part of the stream to seventy or more feet in the upper part of the valley near the east line of Monroe County. In all the cases examined they were found to be composed of mixtures of clay and sand undoubtedly derived from the disintegrated rock formations constituting the surface of the uplands. No glacial debris of any sort was found either on the surface or in any of the sections or cuts in the benches noted within the limits of Monroe County.

PREGLACIAL HISTORY OF BEAN BLOSSOM.

Inasmuch as the greater part of the clay and silt occupying the valley floor is precisely the same in kind as that covering the unglaciated uplands and valley slopes, it is evident that this filling simply represents the wash and soil-creep from the slopes and uplands on either side. Moreover, the rate of filling was so far in excess of the ability of the stream to carry off its load that the preglacial valley became clogged with the waste to such a degree that the stream now occupying the valley floor is for much of its course quite unable to spread its meanders over the entire width; only at the narrowest sections does Bean Blossom succeed in occupying the entire valley from slope to slope, as seen in sketch map No. 1.

Sketch Map No. 1. Section 9, Bean Blossom Township.

Inasmuch as the filling of Bean Blossom at its mouth and for some little distance up stream is covered over by a patchy film of glacial sand associated with boulders, composed partly of crystalline rocks, the underlying clays, silts, etc., antedate the glacial coating. Moreover, the occurrence of benches (to be associated with the glacial history) resting upon the valley filling also point to the same conclusion, that the present filling of the valley, less the benches and the glacial sands, etc., near the mouth of the valley, is preglacial.

The question then arises, what was the topographic expression of Bean Blossom before it was aggraded. There are a number of observations which throw some light on its early history, but much more data should be gathered over the adjacent area before a detailed analysis can be given.

That the preglacial Bean Blossom valley *was very much* narrower than the present one, is attested to by the occurrences of various knobs and remnants of ridges protruding through the aggraded floor. Some of these are subcentrally located, suggesting that the prefilled valley must have been confined between the slopes of the half-covered ridges and the opposite valley slope, thus decreasing the average width of the pre-filled valley by nearly one-half its present cross-section within the limits of Bloomington and Bean Blossom Townships, Monroe County.

There are also certain features which suggest that Bean Blossom must have been at grade at a time antedating the completion of the filling of the preglacial valley.

At a number of points within the limits of Monroe County are to be found curved valley sides extending for a half mile or more, with steep slope, making an angle with the valley floor of thirty-five to forty degrees. Such regularly curved slopes and at such steep angles at once suggest a *meander-cut* slope.

Moreover, there is no evidence that these slopes have been cut by a meandering stream on the *present floor*. We must conclude, then, that they antedate the present surface of the valley floor, and if meander-cut in origin, as the topographic relief very strongly suggests, Bean Blossom must have been at grade before the present filling, at least completed, because a meandering habit is not begun until the stream has already finished its vertical cutting, or, in other words, has cut down the slope of its channel to such a gentle descent that it could not be lessened. Then it was that Bean Blossom must have begun its side cutting and carved the curved slopes, only remnants of which are now seen projecting above the level of the *present* valley floor.

Another set of facts also points toward the conclusion that the preglacial Bean Blossom had reached grade and become a mature stream long before the laking or the completion of preglacial filling of the valley.

A small tributary (Jack's Defeat) running northeast from Steinsville presents some features evidently of interest in connection with the geographical history of Bean Blossom. This stream, now rather diminutive, runs upon a flat floor, and hence at grade. The topography, however, of the valley slopes reveals incised meanders. The present slopes are steep and sharp cuspate points now project into the valley on either side. Such only could have been produced by a stream that had at some time reached grade after the incision of its meander. The crests of the meander-cut

slopes now stand some 80 to 100 feet above the valley floor. If this view be correct, it would seem altogether probable that the main stream, Bean Blossom, inasmuch as both flow over the same kind of rocks with the same structure and texture, had also passed through the same stages as did its tributary.

But so deeply has the valley been filled after grade was reached that such meander-cut slopes as were developed have been largely buried beneath the present filling. Either, then, Bean was early at grade and widened its valley by meandering, or after it came to grade was compelled to incise its meanders, nearly all of which have been subsequently buried beneath its present valley floor.

Moreover, so deeply has Bean Blossom been aggraded that many of the tributary valleys are also aggraded for some distance up stream. This wholesale filling would necessarily force the slopes to rapidly retreat at the junction of the tributary with the main stream, so that, as a result, the trend of the valley sides would assume a systematic angularity. The consequent narrowing and broadening is well exhibited in the lower ten miles of Bean Blossom.

LOST RIDGES AS EVIDENCE OF AGGRADING.

It is evident, should a valley be refilled, in part, with waste from the uplands, that any relief left between its valley slopes, as well as the dissected slopes included, would lose relief in proportion to the amount of filling brought into the valley. In such a case we should expect to find many successive stages of burial of the dissected slopes, according as they were near or remote from the center of the prefilled valley. Many of these stages are well shown in the lower portion of Bean Blossom.

In the middle of Bean Blossom valley occur a number of illustrations in which the inter-stream spaces of moderate relief have been so deeply buried that the uppermost portion of the same now stands above the valley floor, as isolated ridges or "islands," with very steep side slopes, extending to and beneath the present floor of the valley. These are locally spoken of as "lost ridges," a term quite appropriate to their geographical history. Such islands are shown in a number of sketch maps. In sketch map I a small subcircular knob (Section 5, Bean Blossom Township) stands in line with a point standing between White River on the left and Bean Blossom on the right. Its position suggests that it is the *buried* end of this point (see Plate No. 1).

About one mile up the valley is another elongate ridge about one-third of a mile in length, some three or four hundred yards in width and with an elevation of some eighty feet above the valley floor. This is found in section 9, Bean Blossom Township, and illustrated in sketch Map No. I, and by the photograph plate II. The same topographic feature is again duplicated in section 24, Bean Blossom Township. This illustration is locally known as Lost Ridge. This case is not so centrally located as the former one, but lies close to the east side of valley—but still separated from it by a hundred yards or more of flat floor. As in other cases, the trend of its slopes and that of the adjacent valley slope shows such an alignment as to strongly suggest attachment beneath the present valley floor. See sketch map No. II. Photograph plate III gives some idea of

Sketch Map No. II. Section 24, Bean Blossom Township.

steep slopes, presented by an end view of the Ridge. Other cases of the same thing might be enumerated, but the above are sufficient to show the type of relief consequent upon the more complete stages of burial of the spurs near the central part of the preglacial valley.

As a further test of partially aggraded valley, we should also expect to find as additional criteria, spurs of variable relief but attached to the valley slopes by narrow necks, still above the present level of the valley floor. Moreover, various stages of the tied-on knob or ridge ought to be in evidence if the present width of Bean Blossom is due to aggrading. Such additional stages are fairly well shown in contour sketch map No. I, where three small cases of attached knobs may be seen. A still better case is shown in the pen sketch, which occurs in section 32, Washington Township. A photograph of one, the south knob, is shown in Plate IV. Variation in the widths and elevation of the necks connecting the partially buried spur is well illustrated in the sketch.

In map No. III, section 4, Bloomington Township, is shown another illustration of special interest. This occurs at the rather abrupt turn of Bean Blossom Valley, on the northeast side, where the upland forms a point projecting into the valley. The point shows the same sort of topography (see Plate No. V) as noted in other cases—the rounded tops, increasingly steep slopes, descending to the valley floor, and the neck connecting it with the upland on the north. This case attains additional interest, as just to the west and opposite the gap or sag between the knob and the upland, is a bench varying in elevation above the valley floor from twenty to forty feet, and flanking the slopes of the projecting headland and spur. The geographical significance of the benches will be observed in another part of the paper.

Sketch Map No. III. Section 4, Bloomington Township.

In the center of the valley floor and just opposite (or to the south of) the last named spur, and also up stream for some two and one-half miles, still more evidence of valley filling is apparent. To the southeast of the point occurs a rather subdued ridge, somewhat irregular in relief, extending up stream for three-quarters of a mile, or thereabouts. A portion of this is shown in sketch map No. III. Bean Blossom flows close to its northern edge. On the south side of the elevation flows Muddy Fork Creek from the southeast, and reaches Bean Blossom some distance beyond its west end. So full has Bean Blossom, and its tributaries, as well, been filled with waste that the aggraded floor of both valleys have for some distance up the respective streams from their junction merged into *one* broad flat floor.

Plate I.

Plate III.

Plate IV.

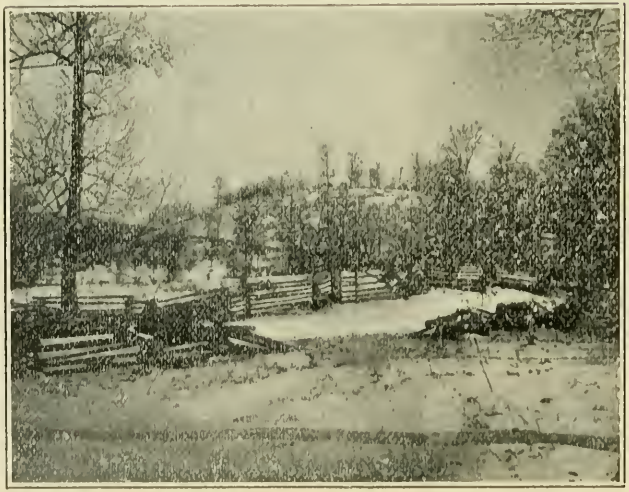

Plate V.

Plate VI.

There is still another case of the same thing in section 3, Bloomington Township, which touches the almost covered spur last mentioned on the east and extends to Dolan, east side of section 3. The little village of Dolan lies in the gap, or sag, between the knob and the spur of upland separating Bean from Muddy Fork. Had the valley floors of these respective streams been aggraded some twenty-five feet above their present level, the attached spur would have passed into the "island" type, as the floors of the two valleys would in that case have been confluent.

Additional illustrations might be appended, but the above series is sufficient to bring out the variations in topographic relief which furnish a key to this particular stage in the history of the valley.

In a word, then, we may say these various phases of topographic relief are not confined to a limited part of the valley within Monroe County, but are prominent features throughout its entire course. Moreover, they exist as inevitable consequences resulting from processes of aggrading and hence may be used as legitimate and trustworthy criteria by which to determine a part of the life history of the respective valley.

GLACIAL HISTORY OF BEAN BLOSSOM.

That Bean Blossom and the adjoining uplands near its mouth have been occupied by an ice sheet is attested to by a series of observations. The occurrence of glacial boulders, gravel and fine sand near the mouth (section 9, Bean Blossom Township) and patches of sand with occasional boulders as far up stream as section 24, near Lost Ridge, warrant this conclusion. From section 24 Mr. C. E. Siebenthal has traced the edge of the till plain to the northeast, it being found to follow along the line of Indian Creek, and passing out of Monroe at Godsey into Morgan County, but returning again to Monroe some two miles east, where Hacker's Creek crosses the north line. From this point to the southeast the edge of the till is exceedingly difficult to trace. Patches of sand and gravel, however, occur in the head waters of some of the northern tributaries to Bean Blossom, in northeastern Monroe and Brown counties. Furthermore, glacial gravel and pebbles are known to occur within the limits of Bean Blossom itself, not far from the east line of Monroe; but whether this was ice or water-laid has not been determined. Enough facts, however, are at hand to show that the heads of northern tributaries of Bean must have

Plate II.

been invaded by the ice sheet, and at the same time the drainage was held up by the interference of the ice sheet at the mouth of Bean Blossom.

The evidence of the arrest of drainage at the time of ice invasion is found in the occurrence of a series of benches, inaptly termed terraces by some writers, rimming the eastern and northern slope of the valley at various points within the limit of Monroe County and are reported to occur with increased frequency in Brown.

In all the sections and cuts found in the benches, only clay and sandy materials appeared. No limestone and sandstone exposures, such as make up the valley slopes, were found in the benches; their contents are undoubtedly made up of the wash and soil-creep brought into the valley from the uplands, the clay portion being derived from the decomposed limestone and the sand constituency from the underlying knob stone.

The benches vary much both in form, areal extent and elevation above the valley floor. They are invariably attached to the slope, and exhibit in most instances a remarkably flat or sometimes gently sloping surface towards the outer edge. The outer rim is usually lobate in form, with narrow, young valleys extending towards the rock slopes, and sometimes, so far, as to traverse the entire width of the bench. The slope of the outer edge is usually steep and well defined. In some cases the tops of the benches are slightly undulating or rolling. Those, however, seldom attain the elevation of the flat-topped ones. In Marion and Washington Townships they may be traced continuously for three or more miles, and attain a width of something over half a mile. They also vary much in elevation above the valley floor, attaining a maximum height in Marion Township, sections 19 and 20, of seventy or more feet, and decreasing gradually down stream, until in section 32, Washington, they are found to be some twenty-five to thirty feet above the valley floor.

That these benches must have been deposited in water is attested to by various criteria. The flat tops, steep angle on the front, and stratification show that they are delta-like accumulations brought in during the arrest of the drainage and not terraces in technical sense, although they appear very much like the latter so far as form is concerned.

The various elevations attained in different parts of the valley may be due to different levels at which the laked valley stood during the laking period, or it may be accounted for in part, at least, to the larger contribution of residual materials from uplands to the upper part of the valley by the northern tributaries, than by similar streams emptying into Bean

Blossom nearer its mouth, so that only in the upper part were the benches built up to the highest level, while in the lower part the amount contributed was insufficient to bring them up to similar altitudes.

If the laked Bean Blossom stood at different levels during the laking stage, we should expect to find somewhere in the valley a lower lying bench corresponding in elevation to the successive lake levels and adjacent to the higher bench. Nothing of this sort was found. I am therefore inclined to attach more importance to the former interpretation, namely, that irregularity of height above the valley floor is largely due to the variation in amount of the residual material brought into the valley. The tributaries bringing the least amount of material constructed the smaller and lower benches.

Another interesting feature is associated with two of the largest northern tributaries to Bean Blossom, namely, Buck and Wolf creeks. Beside the portion of each creek, wriggling across the valley bottom, are rather long and narrow strips or delta-like accumulations similar in content to the benches already described, and extending from the valley slope to within a few yards of the Bean Blossom channel which hugs the south slope of its valley. The surface does not attain the characteristic flatness of the rimming benches, but is slightly irregular in relief and increasingly so towards the slope to which it is attached. This is especially true for the Buck Creek case, but not for the Wolf Creek. The increasing irregularity may be in part due to the nearly complete burial of a projecting spur, whose top is barely coated over with the delta deposits now spread almost across the entire width of Bean Blossom; but it must be said that no outcrops of limestone or sandstone, such as make the slopes of the valley, have been discovered within its limits. On the other hand, the irregularity of relief may have been produced by the piling up of the great load of silt within Bean Blossom by the tributary, but did not succeed in building it up to the lake level; in other words, it is an incomplete delta, or bar.

The Wolf Creek case differs from the former only in having a moderately flat top, or at least the higher flats on it attain about the same level, thus suggesting that it was built up nearer to water level, and hence more even and uniform in relief. These differ from the rimming benches only in that they *extend across the valley floor*, while the former, being made by smaller streams close to each other, have built a series of small benches or deltas which have become confluent, and hence continuous *along the valley side*.

The pen sketch plate No. 1 gives some idea of the appearance of one of these benches (see pen sketch section 32, Washington Township). Plate VI shows beyond the trees a side view of one of the spur-like extensions of a bench occurring in section 4, Bloomington Township. (See contour map No. III, which also shows position of the partly buried headland.)

No. 1. Pen Sketch of Attached Spurs and Benches. Section 32, Washington Township.

Post-glacial History. Since the close of the laking stage Bean Blossom River has developed a meandering course on its broad floor. Only in the narrowest sections of the valley has it succeeded in spreading its meander belt across the entire floor. For the most part it keeps to the west or south side of the valley, and yet still assumes a meandering habit for considerable stretches. In other words, the stream does not fit the *present* dimensions of the broad valley, which accordingly must have been brought about by other conditions than that resulting from lateral cutting, by a mature stream. Cross sections of the valley at its broadest places reveal a slight curvature of surface in the center and occasional abandoned meandering channels. This slight variation from a plain surface suggests flood plain construction. Whether this constructive work antedates the glacial episode of Bean Blossom is not certain, but it would seem from the data at hand, that the present post-glacial Bean Blossom has not had time or the ability to do much constructive work since pleistocene time.

Young Valleys. Traversing the steepest slopes of Bean Blossom, are to be found numerous V-shaped valleys, with remarkably steep channels, ending their lower course at the point of intersection of the valley floor with the adjacent slope. In all cases small alluvial fans are built on the valley floor with their apex projecting but a few feet or yards at most beyond the mouths of the young valleys. In none of the observed cases was it found that the level of the valley floor would extend into the mouth of the young valley. It is therefore believed that the greater part of the cutting of these young valleys may date subsequent to the preglacial filling. The fact that alluvial fans and not deltas with steep outer edges and flat tops occur at their mouths, suggest that they have been constructed since the laking of the valley, and hence are regarded post-glacial.

Note. For a portion of the data used in the preparation of the contour maps, the author begs to acknowledge the assistance of Mr. E. R. Cumings and Mr. J. W. Beede, Instructors, Department of Geology, Indiana University, and Mr. J. W. Frazier, student, Indiana University.

Wabash River Terraces in Tippecanoe County, Indiana.

William A. McBeth.

General Description.—The Wabash Valley, in Tippecanoe County, Indiana, embraces an area of about eighty square miles. Its average width is about three miles. It is much wider below LaFayette than above, and it is less wide at that place than elsewhere within the county below the mouth of Tippecanoe River. The width of this valley above the city averages at least two miles, while below it is not less than four.

The valley comprises a broad, shallow trench, cut by a deeper and narrower trench, into the bottom of which is carved the river channel.

The general surface is about seven hundred feet above sea-level, and the bottom of the river channel is about two hundred feet below this. The inner valley or flood-plain tract averages about one mile in width and along this rise the terrace fronts from one hundred to one hundred and fifty feet above the stream. The inner valley is quite uniform in width throughout the county, but the terrace areas are much more conspicuous below LaFayette than above.

The outer valley is quite straight compared with the inner valley, which meanders from side to side, while the river crossing from side to side of this flood-plain meanders most.

The Terraces.—The terraces begin a few miles below Delphi, on the west side of the river, an island in the Deer Creek Prairie flood-plain comprising the farthest up-stream area so far observed.

The point between the Tippecanoe and the Wabash, where it rises above the flood-plain near the junction, is of this formation. Below the mouth of the Tippecanoe the terraces become conspicuous. On the west side of the stream the region called Pretty Prairie descends gently from the Grand Prairie and terminates in a bluff front which runs parallel with the Wabash at an average distance of a mile from it.