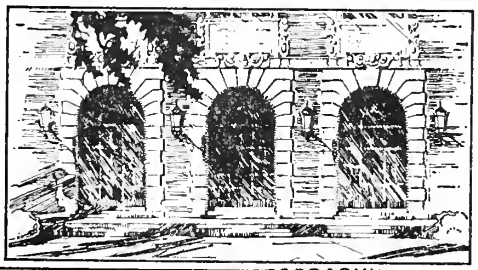

OCCASIONAL PUBLICATIONS OF THE DEPARTMENT OF GEOGRAPHY

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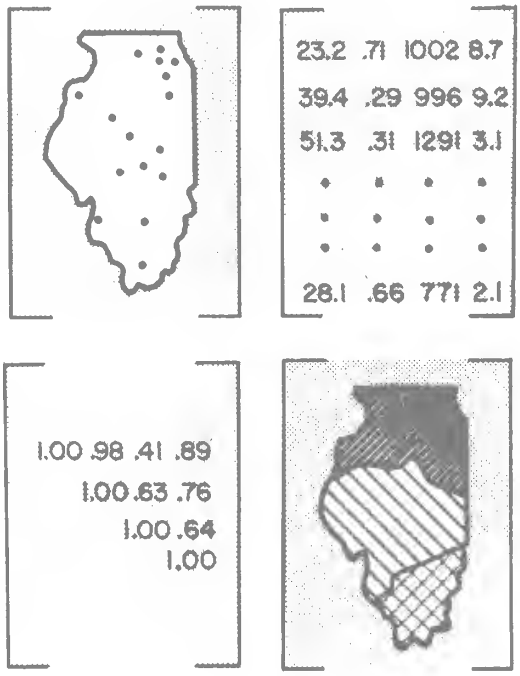
by

CHARLES S. ALEXANDER



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SOME OBSERVATIONS ON THE LATE PLEISTOCENE AND HOLOCENE HISTORY OF THE LOWER OHIO VALLEY*

Charles S. Alexander

ABSTRACT

The late Pleistocene and Holocene stream morphology of the lower Ohio Valley is the result of an interaction of deposition, erosion and deformation (arching) of late Wisconsinan valley train. The terraces and floodplains in the lower valley were field mapped and their elevations were plotted in longitudinal profiles. Trend lines were fitted to the elevation points. Analysis of the trend lines plus information from C-14 datings indicate that stream erosion resulting in the terrace form probably commenced about 14,000 years ago. Subsequent erosion and deposition plus crustal deformation resulted in two distinct zones of floodplain development along the lower Ohio Valley. Below Dekoven, Kentucky where deformation seems absent a single floodplain predominates. Above Dekoven, in the area of arching, there are two floodplains with an incipient development of a third. The coincidence of the arching and the additional floodplains suggests deformation is a major factor in their origin. Also related to the arching of the floodplains is a changing lateral extent of flooding along the lower Ohio with floods of similar magnitude.

INTRODUCTION

The late Pleistocene and Holocene stream morphology of the Ohio Valley downstream from Owensboro, Kentucky, has been described and mapped in several places but, except for Ray's brief synthesis, an overall interpretation of the morphology is lacking (Ray, 1963). Furthermore, though the valley fill has been studied, the floodplain below Owensboro has received relatively little attention (Ray, 1965; Walker, 1957; Harvey, 1956). The purpose of this paper is to analyze the fluvial morphology of the lower Ohio Valley in an attempt to determine the late Pleistocene and Holocene history of the valley.

*An oral version of this paper was read at the "Fifty Years of Berkeley Geography" special session of the Pacific Coast Division meetings at San Diego, California, June 14-15, 1973. Thanks are due to Professor Brigham Arnold for presenting the paper for me.

Two important points should be made at the onset of this discussion. First, the fluvial deposits of the lower Ohio River Valley are mainly related to glacial rather than interglacial events. This is the case because the Ohio and its north bank tributaries served as spillways for glacial meltwater. As a result the valleys were filled with valley train material during glacial stages and eroded during interglacials; however, this clear-cut dichotomy is subject to modification as will become evident later. Second, the bedrock valley of the lower Ohio is partially filled by a 140 to 185 foot thick deposit of outwash and alluvium of Wisconsinan and recent age (Ray, 1965; Walker, 1957; Wayne, 1952). Although there is agreement on the age of the fill, the time of erosion of the valley is open to question. Ray (1965, p.24) believes the deep channel was cut prior to the rearrangement of mid-western drainage by the Kansan glacier. Walker (1957) considers that erosion occurred as the result of uplift during late Kansan and early Yarmouthian Stages. But he also thinks that, as the result of glacially lowered sea level, the river removed most of the Illinoian valley train during the early Wisconsinan. In my opinion, the Ohio River may have cut its bedrock valley during the early phases of the Illinoian and Wisconsinan glacial stages when sea level was going down, but before the glaciers reached the headwaters of the Ohio and its tributaries. However, this problem remains unresolved.

VALLEY DESCRIPTION

In general, the configuration of the lower Ohio Valley is related to the changing nature of the areal geology along its course. As a consequence of these changes the lower valley can be divided into three distinct sections (Figure 1). Between Owensboro, and Dekoven, Kentucky,

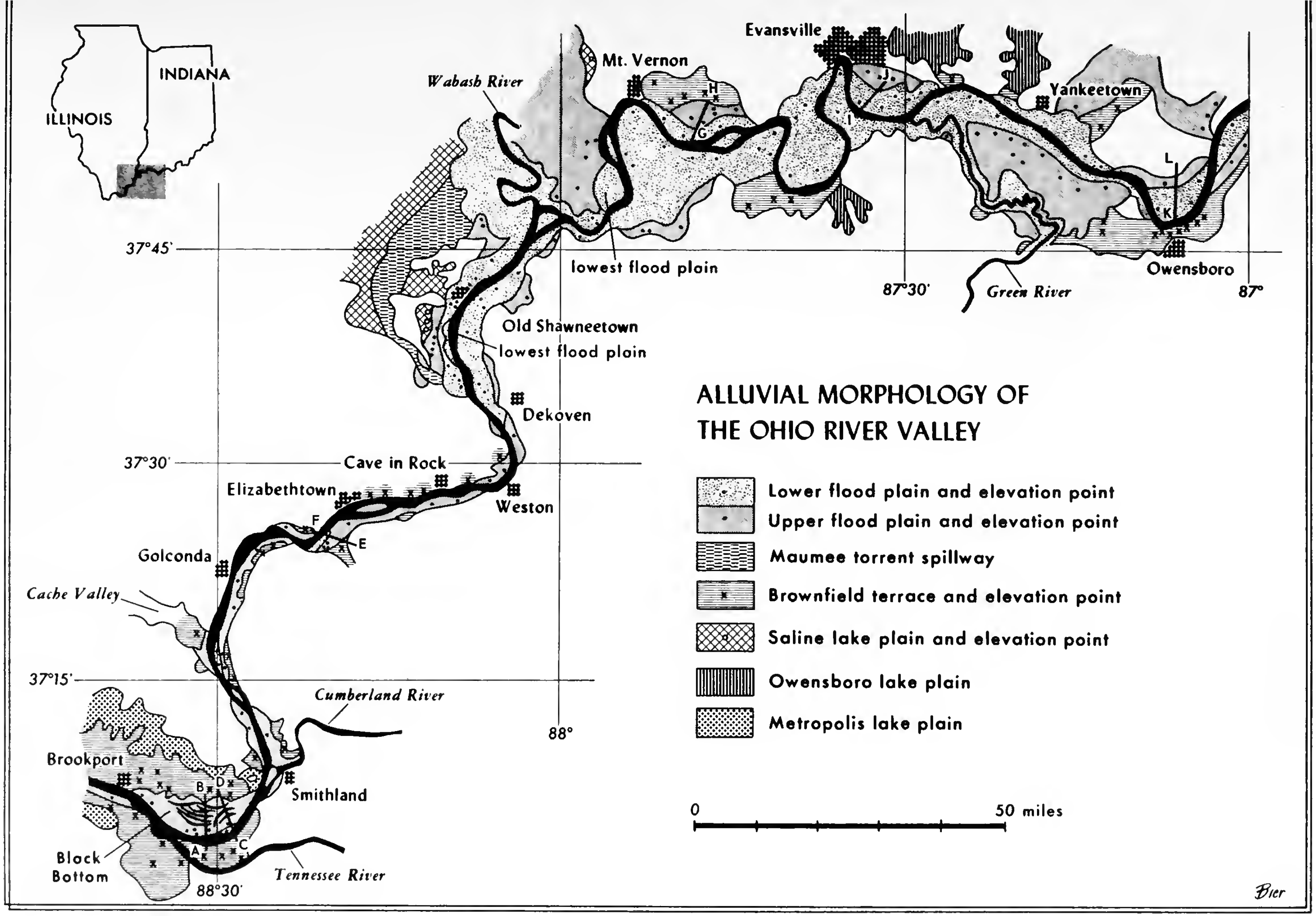

Figure 1

Map of the lower Ohio River Valley and its alluvial morphology. Notice the location of the floodplain cross sections between Brookport and Smithland, near Elizabethtown, east of Mt. Vernon and Evansville and north of Owensboro the valley formed in relatively soft Pennsylvanian rocks, and the valley floor is eight to ten miles wide (Willman, et.al., 1967). This section of the valley is characterized by broad meander loops, well developed upper and lower floodplains, an incipient lowest floodplain, one alluvial terrace (informally called the Brownfield), and adjacent (Owensboro) lake plains. Segments of the alluvial terrace are large and frequent between Owensboro and Mt. Vernon, Indiana. However no clear evidence for the terrace was found between Mt. Vernon and Dekoven. The terms upper, lower and lowest floodplains are used because all are flooded, though frequency of flooding is less for the upper, and all are areas of contemporary deposition.

Between Dekoven and Smithland, Kentucky, the river passes through a zone of relatively resistant Mississippian rocks (Willman, et.al., 1967). The valley is narrow and the floodplain is frequently less than two or three miles wide (Figure 1). In this section the upper floodplain virtually dominates the valley floor. Isolated fragments of what appears to be the lower floodplain occur at several localities. Two stream terraces are present but the upper is so badly eroded that its presence has been identified only to a limited extent and the remnants are too small to be shown on Figure 1. The lower or Brownfield Terrace has an intermittent occurrence and continues into the third section.

In this final section below Smithland, Kentucky, the valley widens again as it passes through soft Cretaceous and Tertiary rock (Willman, et.al., 1967). Here, the Metropolis lake plain, the Brownfield stream terrace, and the upper floodplain become prominent features in the valley landscape (Alexander and Eyton, 1973; Alexander and Prior, 1968). The lower floodplain occurs only at the southern tip of the meander loop immediately east of Brookport, Illinois (The Black Bottom).

METHODOLOGY

In order to correlate and analyze the Ohio River floodplains and terraces, they were mapped in the field using topographic maps (1:24,000) and air photographs. Between Brookport and Old Shawneetown, Illinois, field work was intensive, whereas between Old Shawneetown and Owensboro, Kentucky, mapping was based on field work, topographic maps and Ray's work in the vicinity of Owensboro (Ray, 1965). The resulting map was later checked at several locations along the valley with geologic quadrangle maps prepared by other investigators (Johnson, 1972a, 1972b; Amos, 1967, 1966, 1965; Amos and Wolfe, 1966).

The floodplains and terraces were plotted in longitudinal profile with elevations taken from 1:24,000 topographic maps (Figure 2). While most values came from benchmarks, and spot heights, a few were estimated at sites where closed contours cover small areas. All elevation sites were carefully selected so as to minimize errors resulting from human construction or natural erosion.

Trend lines representing the upper and lower floodplain and terrace surfaces were fitted to the elevation points by the least squares method (the lowest floodplain was omitted because of its limited extent). The linear, quadratic and cubic solutions were made. The quadratic solution provides slightly better fits for the terraces and lower floodplain. The terraces' surface has a very slight concave curvature whereas the lower floodplain shows a small convex curvature. The cubic solution yields the best fit for the upper floodplain and shows it to have a very slight concave curvature whereas the lower floodplain shows a small convex curvature. The cubic solution yields the best fit for the upper floodplain and shows it to have a very slight concave profile below Cave-in-Rock, Illinois, and a clearly visible convex profile above. The degree of curvature for the terrace and lower floodplain is so slight at the scale of the profile that it cannot be shown (Figure 2).

The advantages of fitting lines to the points by the least squares method are that the lines have an unbiased best fit to the points and the coefficient of correlation (r-value) shows the strength of the relationship between distance and elevation. Because of the high r-values of each line it may be assumed that its points belong to a set of closely related data--that they belong to distinct morphologic surfaces.

DISCUSSION

The terrace-floodplain profiles show several interesting aspects of the alluvial morphology in the lower Ohio Valley. (1) The convex curvature of the upper floodplain surface above Cave-in-Rock suggests the presence of mild crustal deformation. (2) The Metropolis lake plain appears to have no extension upriver. (3) The profiles demonstrate that the stream terrace remnants above Mt. Vernon and below Cave-in-Rock belong to a single feature--the Brownfield terrace. This result was anticipated by Ray (1965, 1963) in his studies of the Ohio Valley. (4) The major occurrence of the lower floodplain is almost entirely within the zone of arching and is probably related to it. Also related to the arching is the changing pattern of overbank flooding along the Ohio floodplain between Brookport and Owensboro.

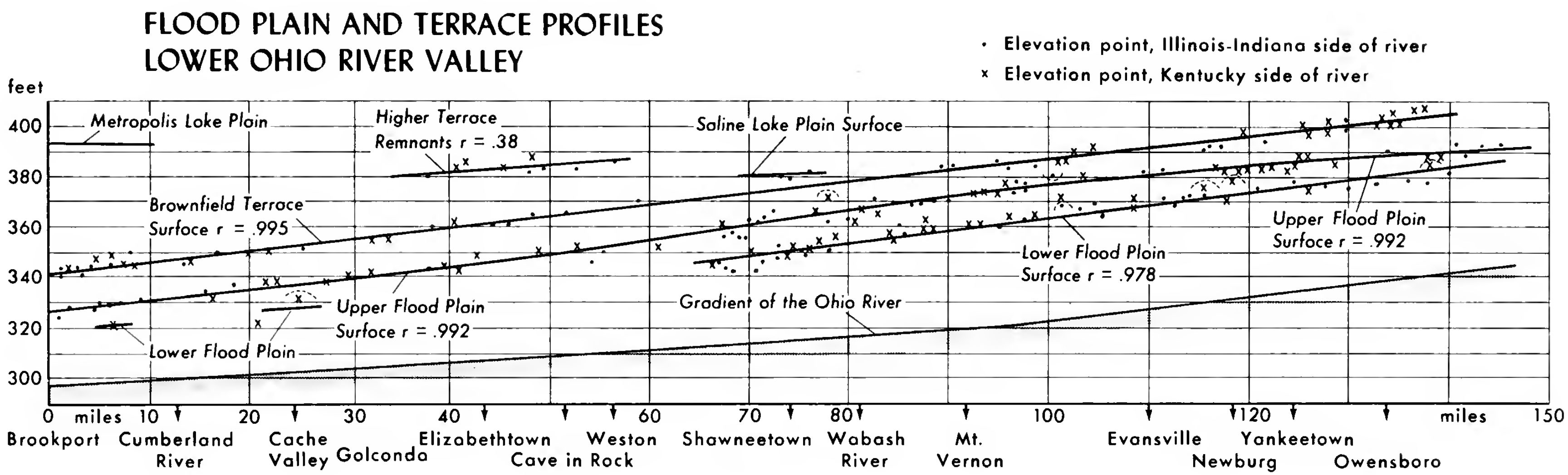

Figure 2

Longitudinal profiles of the Ohio River and its floodplains and terrace.

Crustal deformation

The curvature of the upper floodplain is gentle and continuous--there is no abrupt change in gradient between the concave curvature below Cave-in-Rock and the convex curvature above (Figure 2). Evidently, once the floodplain had developed, slight crustal warping changed its concave surface upstream from Cave-in-Rock into a gentle convex curve. To my knowlege no direct evidence for Holocene crustal deformation has been reported for the lower Ohio Valley. There is, however, considerable evidence for crustal instability. Numerous faults have been described along the lower Ohio and frequent earthquakes of slight to moderate intensity do occur. In light of these facts it seems reasonable to assume the arching of the upper floodplain is the result of local crustal movement(Heigold, 1968; Baxter, et.al., 1967; Baxter, et.al., 1965; Baxter, et.al., 1963; McGinnis, 1963; Butts, 1925).

The movement was slight and probably started after the Brownfield terrace sediments were deposited. Originally the terrace must have had a concave gradient appropriate for the hydraulic conditions associated with deposition of its sediment. Subsequent deformation would have cancelled the concave curvature resulting in the present nearly straight terrace profile. The almost imperceptible arching of the lower floodplain may be an indication that crustal movement is still occurring at an extremely slow pace.

The Metropolis Lake Plain

As the result of trend surface analysis, Alexander and Eyton (1973) believe the Metropolis terrace to be of lacustrine origin. The lack of loess deposits on the terrace older than the Peorian, and the moderate degree of stream dissection of the terrace surface suggest an Altonian age for the deposition of the lake sediments. They concluded that the lake may have been a slack water body impounded in the lower Ohio Valley by high flows of Altonian meltwater along the Mississippi River. The lack of related deposits up the Ohio Valley support their opinion that the lake plain is mainly a product of an event initiated outside the valley.

The Brownfield Terrace

Downstream from the junction of the Cumberland River, the Brownfield terrace has been interpreted as the result of lake deposition (Willman and Frye, 1970; Olive, 1966; Finch, Olive and Wolfe, 1964; Ray, 1963) or stream origin (Alexander and Eyton, 1973; Alexander and Prior, 1968). The material underlying the first 20 to 30 feet beneath the terrace surface, here and upriver, is silt or silty clay along with deposits of sand. Though the silt and silty clay occasionally occur in fine, horizontally bedded units, this is not diagnostic as to origin because fine, horizontal bedding is characteristic of both floodplain slack water and lake deposits. However, the high degree of fit of all elevation points to a line with a gradient slightly greater than that of the Ohio River strongly supports the theory of stream origin for the terrace.

The sediment underlying the Brownfield terrace accumulated rapidly--so rapidly in fact that it formed dams across the mouths of small tributary valleys. Sedimentation in the ensuing lakes resulted in several small lake plains (Owensboro lake plain) in southern Indiana and central northern Kentucky tributary to the terrace (Thornbery, 1950; Shaw, 1915). It is possible that the valley train sediment in the Brownfield terrace also formed the dam responsible for Lake Saline and the large Lake Saline plain in southeastern Illinois. A brief comment about the origin of the plain is in order because of its great importance to the interpretation of the history of the lower Ohio Valley.

The plain results from the time when Woodfordian outwash sediment clogged the valleys of the Ohio and Wabash Rivers forming a dam that backed up a shallow, semi-permanent lake of three to four thousand years duration. The lake surface was rising above the 360 foot level about 21,000 radiocarbon years ago and finally rose to an elevation of about 400 feet around 20,000 years ago. Eventually the rivers eroded through the fill and the lake slowly drained. Though this cannot be precisely dated it is thought to have occurred around 17,500 years ago (Frye, 1972).

The surface of the Brownfield terrace today is at least 20-30 feet too low to have formed the dam responsible for Lake Saline. However, Leverett (1929) reports that the surface of the Wisconsinan outwash frequently rises down river from the mouths of tributaries that carried outwash to the Ohio. Hence, it is entirely possible that the original surface of the Woodfordian outwash below the junction of the Wabash was higher. The higher terrace in the vicinity of Cave-in-Rock may represent eroded remnants of that surface. The sandy nature of the terrace deposits is compatible with the idea of outwash origin. During the time of lake drainage, erosion and deposition may have reworked the surface of the high outwash fill down to a level approximately similar to that of the present terrace.

Some radiocarbon dates support the interpretation that the Brownfield terrace and Saline lake plain are contemporaneous. Two dates of woody material from terrace deposits in the vicinity of Owensboro indicate an age between 18,400 and 20,000 years (Ray, 1965). Mollusks from terrace deposits in the lower Tennessee Valley gave a date of 21,000 years (Oliver, 1966). Dates from the Cache Valley section of the Brownfield terrace are much younger. Three samples of wood and organic matter from the Cache Valley yielded dates of 14,000, 13,000 and 6,000 years (Alexander and Prior, 1968). The first two dates are from depths of 34 and 40 feet whereas the latter is from a depth of 32 feet. These younger dates are difficult to explain. Perhaps the 14,000 and 13,000 year old samples are the result of local scouring and redeposition of the Brownfield deposits during the passage of the Lake Maumee flood through the Cache Valley some 14,000 years ago. However, no physical evidence has been found to support this speculation. The 6,000 year old sample may have been contaminated during recovery by the commercial water well driller who made them available--this could also apply to the two older dates. Be that as it may, the minimum dates suggest the terrace deposits are younger than the lake plain whereas the older dates indicate contemporaneity. I favor the latter possibility with the reminder that the terrace form is substantially younger than the deposits underlying it.

The origin of the Brownfield terrace form probably commenced following the discharge of water from glacial Lake Maumee. This is indicated by several radiocarbon dates from alluvium in the Black Bottom, east of Brookport, which suggest the upper floodplain began to take on its present form a little over 10,000 years ago (Alexander and Nunnally, 1972; Alexander and Prior, 1971). The flood water flowed from the Wabash into the Ohio east and west of Shawneetown leaving shallow channels in the Saline lake plain (Frye, 1972). Traces of the former channel have subsequently been destroyed by stream erosion and deposition. Net incision of the valley fill by the flood water below Shawneetown was probably slight because in that section of the valley the transition between terrace and upper floodplain is usually gradual.

Once the Maumee flood ended, glacial events upriver virtually ceased to have much influence upon subsequent developments in the lower Ohio Valley. The river continued slowly eroding the valley fill and commenced to develop its present meander pattern. A variety of evidence indicates that the meander loops migrated to approximately their present position over a period of several thousands of years. However, within the last 1,000 years or so, the banks appear to have been in a state of dynamic equilibrium (Alexander and Nunnally, 1972).

The Floodplains

The rate of river incision, downstream from Cave-in-Rock, has been slow and apparently continuous. Cross-section profiles of the floodplains show that the crests of meander point ridges and natural levees can be fitted with straight lines that have a pronounced slope toward the river (Figures 2 and 3, Profiles AB, CD, EF). The erosion defining the Brownfield terrace evidently was not an abrupt event. As the river migrated laterally the flood water level necessary for the construction of meander point and natural levee deposits gradually and steadily lowered. The most obvious reason for this is a continuous, slight stream incision.

Upstream from Dekoven, stream erosion has been intermittent and produced the Brownfield terrace and the upper, lower and lowest floodplains (Figures 1 and 3; Profiles GH, IJ, KL). The coincidence of the lower and lowest plains with the zone of arching suggests that local

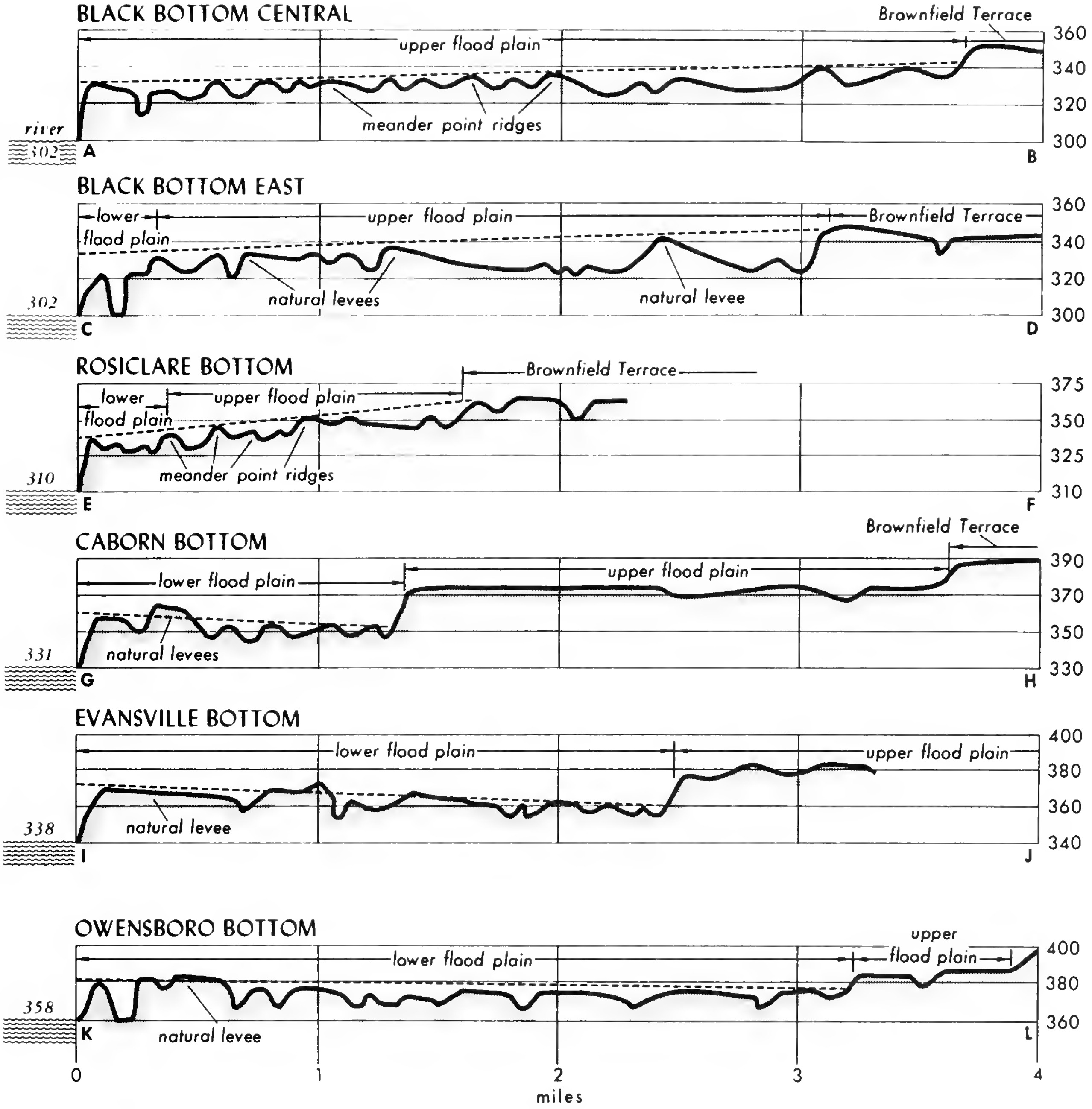

Figure 3

Transverse profiles of the floodplains in the lower Ohio Valley. Profiles AB, CD and EF, downstream from Dekoven show the floodplain with a pronounced slope towards the river. The floodplains above Dekoven (GH, IJ and KL) have a slope away from the river. The general trend of each floodplain surface is shown by a dashed line. See Figure 1 for location of profiles.

crustal warping was a major factor in their origin. The initial warping probably commenced while the first floodplain was being established. As the arching progressed the river cut down and began forming a new, lower floodplain. The slow migration of the meander loops, and the fact that the transverse slope of the lower bottom surface is away from the river, indicate that uplift was of short duration and then stopped or became extremely slow. Stable or near stable crustal conditions and channel aggradation permitted the migrating meander loops to deposit a sequence of meander point ridges, each of which had a slightly higher crest than its predecessor. The result is the ideal floodplain cross-section shown by the lower bottom, i.e., the highest land on the floodplain is adjacent to the river.

Segments of the lowest floodplain were identified at two places only. One is a sizable bud-shaped segment south of Mt. Vernon (Figure 2). The second, south of Shawneetown, has a bow-shaped outline and is relatively small. At these localities the segment surfaces are set off from the lower floodplain by reasonably well defined scarplets about six feet high. The lowest bottom may occur elsewhere but could not be identified because its bounding scarplet is obscured by complexes of meander point ridges. Though the lowest floodplain appears to have a limited extent, what can be identified is of sufficient size to make it doubtful that the feature is the result of some localized, random event of river activity. The lowest floodplain probably represents a recent, slight renewal of arching or a slight increase in rate of movement.

Because of the arching of the upper bottom, the extent of overbank flooding varies from place to place along the Ohio River. The vertical separation between the upper and lower bottoms varies from about eight to ten feet at the Black Bottom to a maximum of 12 to 15 feet between Mt. Vernon and Evansville. Above Evansville the upper bottom starts to bend gently towards the lower causing their surfaces to converge. The two surfaces may indeed merge a short distance upstream from Owensboro (Figure 2).

Because of these differences in vertical separation, a flood of a given crest height will clearly result in different degrees of overbank flooding as the flood wave moves downstream.* However, flood magnitude is indicated by discharge not by crest height. Due to complex reasons that need not be discussed here, floods of comparable discharge may have different crest heights. Consequently, it is risky to discuss flood probability in terms of crest heights. Nevertheless, flood height is a convenient way to determine the extent of floodplain cover by floods of a given frequency.

Table 1 below was prepared by using the method described by Speer and Gamble (1965) for calculating flood probability along the Ohio River. Also involved in the calculations were certain assumptions about normal pool river depth and interpolations in the flood records to convert discharge to flood crest height. The table shows the probability of flooding for each of the floodplains at several localities along the river. The results shown in the table should not be regarded as accurate predictions. Rather, they indicate the relative difference in flood magnitude required to cover the several bottoms at different places along the river.

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* Hypothetical flood wave that maintains a uniform crest as it passes downstream.

Table 1

Relative Flooding Probability on the Lower Ohio Valley Bottoms

	Lowest Bottom	Lower Bottom	Upper Bottom
Black Bottom	Not Present	Mean annual flood	1 in 15 to 20 years
Shawneetown	Mean annual flood	1 in 15 years	1 in 20 years
Evansville	Not Present	1 in 20 years	greater than 1 in 50 years
Owensboro	Not Present	Mean annual flood	1 in 15 years

Clearly, the extent of flooding at any given locality on the lower Ohio River is not simply a function of flood magnitude but is also influenced by the degree of deformation of the floodplains.

The final event in the valley has been an increase in the rate of floodplain sedimentation. Radiocarbon dates of organic matter from the upper floodplain east of Brookport indicate that a period of increasing rate of sedimentation began some 1,500 years ago. This is especially true of the swales. A reasonable explanation for this increase is that it reflects an increasing extent of cultivation in the Ohio drainage basin during the last one to two thousand years (Alexander and Prior, 1971).

CONCLUSION

The late Pleistocene and Holocene stream morphology of the lower Ohio Valley results from crustal warping and the deposition and subsequent erosion of late Wisconsinan valley train. The sediment in the valley's one major terrace dates from the Woodfordian sub-stage. Stream erosion, resulting in terrace form, probably did not start until the onset of the Maumee flood some 14,000 years ago. Subsequent interplay of crustal warping and stream erosion and deposition produced two distinct areas of floodplain form. Below Dekoven, Kentucky, a single floodplain predominates and its surface slopes gently towards the river. Above Dekoven, as the result of local warping, three distinct floodplains developed--the upper which is continuous throughout the valley, the lower, with a surface sloping away from the river, that is mainly confined to the zone of deformation and the lowest that occurs near the western end of the deformation. Because of the floodplain arching the lateral extent of flooding along the lower Ohio River is a function of both flood magnitude and floodplain morphology. The last event along the river has been an increase in the rate of sedimentation during the last 1,500 years or so, probably as the result of increasing agricultural activity upriver.

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