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INTRENCHED AND INCISED MEANDERS OF SOME STREAMS ON THE NORTHERN SLOPE OF THE OZARK PLATEAU IN MISSOURI

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ABSTRACT

The streams of the northern Ozark area in central Missouri are well-known examples of intrenchment. The question arose years ago as to whether this intrenchment was due to downward cutting following rejuvenation by uplift or to downward-lateral cutting. Evidence is given to show that the Osage, Gasconade, and Meramec rivers intrenched themselves by downward cutting only as the area over which they were flowing was uplifted, probably in late Tertiary times. Hinkson Creek, a smaller stream, has cut downward and laterally in intrenching itself, being controlled in its downward-lateral cutting by the downward cutting of the Missouri River into which it empties.

INTRODUCTION

The streams flowing across the northern part of the Ozark Plateau have notably sinuous courses, which occupy valleys that are narrow and steep-sided, paralleling the streams closely. The valley bottoms of such major streams as the Osage and Gasconade lie from 100 to 300 feet below the upland surface. The tributaries also occupy narrow, steep-sided, V-shaped valleys, the larger ones having meandering courses and the smaller ones fairly straight courses.

The surface of the northern part of the old upland slopes from its highest points in Wright, Texas, and Dent counties in the central Ozarks to the northwest, north, and northeast. The course of the Missouri River lies across the northern flank of this upland, the northern margin of which is found a limited distance to the north of the Missouri River, crossing Boone, Callaway, and Montgomery counties.

During the early nineties the cause of the intrenchment of these streams was discussed by Professor W. M. Davis1 and Arthur

Winslow, then state geologist of Missouri. Professor Davis suggested that the streams had been meandering on a peneplain which had been uplifted, the meandering streams intrenching themselves as the land mass came up. Winslow, although not entirely disagreeing with Davis, suggested that the intrenched streams started as streams with minor sinuosities, and that as they cut downward they cut laterally also, thus increasing the sinuosities to their present size. The essentially horizontal character of the formations constituting the Ozark area favored, he thought, the downward and lateral movement.

Actually, both Davis and Winslow were describing intrenchment, but of two distinct types. The view of Davis is the accepted interpretation of intrenched meanders. They are due to downward cutting in a stream’s channel, through rejuvenation, which preserves the original meanders. Winslow’s view represents incised meanders, in which the stream has not only gone down but enlarged the meanders by cutting laterally. This important distinction has been very clearly and forcibly developed by Professor Davis in a later paper, but unfortunately for clearness in the use of the two terms the distinction has been lost sight of in recent textbooks and articles on streams. Inasmuch as nothing has been offered to replace the original meaning of “incised” it is strongly urged in this paper that the term “intrenched” be used only for streams that lower their channels vertically, and “incised” be used for those meanders which cut both vertically and laterally.

The derivation of the two words is in strict accord with the meanings given above, as intrench means to protect by means of a trench or wall and incise means to cut into.

It is the purpose of this paper to present the results of some years of study of the meanders of the streams in the northern Ozark area and to show that both types of meandering are present. Winslow was wrong, however, in assuming that the Osage and other streams were incised. Excellent examples of each type are found

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in this area and will be described. A small stream in Boone County, Missouri, illustrates an incised meander splendidly, and the Osage, Gasconade, and Meramec illustrate intrenched meanders.

GENERAL GEOLOGY OF THE AREA

The formations of the area range from Upper Cambrian to Pennsylvanian in age. The following columnar section shows these formations:

<table>
<thead>
<tr>
<th>Formation</th>
<th>Shale</th>
<th>Sandstone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvanian</td>
<td>Cherokee</td>
<td>Osage, Kinderhook</td>
</tr>
<tr>
<td>Mississippian</td>
<td></td>
<td>St. Peter</td>
</tr>
<tr>
<td>Ordovician</td>
<td></td>
<td>Jefferson City</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Roubidoux</td>
</tr>
<tr>
<td>Cambrian</td>
<td></td>
<td>Gasconade</td>
</tr>
</tbody>
</table>

The streams are working primarily on the Ordovician and Cambrian formations. These consist of dolomites and sandstones with minor beds of shale. Dolomite predominates over the other rocks, constituting 80–90 per cent. The dolomite contains a large amount of chert, which constitutes the major part of all the gravel and sand transported by the streams.

The formations underlying the Ozark Plateau are nearly horizontal throughout the area. Actually they dip a few feet per mile to the northwest, north, and northeast in the respective parts of the area. This dip is so slight as to have no influence upon the streams of the area.

Minor faults occur, but neither the few faults nor the joints are prominent enough to have any influence on the position of the valleys, as was suggested by Winslow.¹

INCISED MEANDERS OF HINKSON CREEK, BOONE COUNTY, MISSOURI

Hinkson Creek, in Boone County, on the north side of the Missouri River (Fig. 1), but still on the northern flank of the Ozark Plateau, shows excellent incised meandering.

The Hinkson is about 25 miles long. It rises in the north central part of Boone County, flows slightly west of south for about

16 or 17 miles to a point near Columbia, then turns nearly west and
joins Roche Perche Creek, which flows southwest for about 3
miles to the flood plain of the Missouri River, then, turning abruptly
to the southeast, flows along the flood plain for 4 miles before
joining the Missouri. Both the Hinkson and Roche Perche
meander, more or less, but the portion of the Hinkson's course from
a point just east of Columbia to 2 miles southwest of Columbia has

![Figure 1: Physiographic provinces of Missouri and the streams discussed in this paper.](image)

well-developed incised meandering. This portion of the stream
is shown on the accompanying figure (Fig. 2). The valley is cut
in the Burlington limestone in this portion while that to the north-
est is cut in soft Pennsylvanian shales and limestones and is many
times wider than the portion cut in the Burlington.

The actual length of the stream in the area figured is nearly
twice the airline distance and includes several interesting drainage
changes. Before describing these changes it should be noted
that this area was covered by the ice during the glacial period and that the present valley of the Hinkson has been, in major part at least, developed since the retreat of the Kansan ice sheet. The area to the south of the river was not covered by the ice. This glaciated area was a nearly level surface which sloped mainly to the south in the north central and northwestern parts of Missouri, as is shown by the straight southward courses of the streams of northern Missouri (Fig. 1).

Fig. 2.—Incised meanders of Hinkson Creek, near Columbia, Boone County, Missouri.
The present valley of the Hinkson, then, is a measure of the erosive work of a small stream since the time of the Kansan ice sheet. It has developed a valley, which, when the respective volumes of the streams are considered, is on a par with that of the much larger Osage and Gasconade rivers.

Examining the course of the Hinkson, as shown in Figure 2, two relatively sharp meanders occur in the northeast quarter of Section 18, just below the old waterworks reservoir. Just to the west of the reservoir lies a small hill \( R \), surrounded by a shallow valley. Gordon’s Pond is the result of damming up a portion of this valley.

The Hinkson formerly occupied this valley, which may have been preglacial, but not necessarily so, as is shown by the equal development of similar meanders in limestone, a mile or so downstream. (The former course of the stream is shown by the heavy dotted line in Figure 2.) The hill \( R \) was formerly part of an upland spur projecting into the meander of the stream. The stream impinged against the north side of the spur, swung around its west end, and continued on to the southeast around hill \( S \). Eventually it cut through the spur \( R \), mainly from the upstream side, and isolated hill \( R \) by abandoning its former course. This is an example of “planation stream piracy” as described by Malott.\(^1\) It may have been aided in cutting through by an underground solution channel as has been found to be the case by J. Bridge\(^2\) for several Ozark streams.

The narrow opening through the spur, having rock bluffs on both sides, furnished an excellent site for a dam and was so used by the old Columbia waterworks company.

Hill \( S \), 60 feet high, is entirely surrounded by a shallow valley and was the former course of the Hinkson as noted above. Only part of the valley is occupied by an active stream at present. The steep slope (Fig. 2) at the northwest end, opposite the high bluff on the west side of the Hinkson, shows that this hill is also a cut-off portion of an upland spur. The stream, after cutting through the


\(^2\) Personal information.
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upland spur R and isolating hill R, impinged sharply against the side of upland spur S, then turned southeast and flowed around hill S and again cut into the upland spur on its lower side, soon cutting through and isolating hill S. The relationship of the bluffs on the present and former streams suggests that an underground channel aided in making this cut-off. It must have occurred soon after the first, if width of valley can be used as a measure of the time. Davis' has described the same type of cut-off on the Moselle near Berncastel, Germany.

Farther down the stream in Sec. 19, T. 48 N., R. 12 W., and Sec. 24, T. 48 N., R. 13 W., the Hinkson has developed five strong meanders in a distance of 1 mile. Each meander surrounds an upland spur, from 80 to 120 feet high, having a nearly vertical face on the upstream side and a gently sloping face on the downstream side, unless the meanders have cut in so close on that side as to steepen them (Fig. 3). The small isolated hill (Fig. 3) on the flood plain in Section 19, between the Hinkson and its tributary, the Grindstone, was formerly a part of the hill E and was isolated by the same method as hill R. There is also the possibility that this hill may have been the result of side cutting by the foregoing streams as is illustrated by the present development of "hill 720" (Fig. 3). The close approach of these two streams at the point D has nearly cut off this hill. Had this occurred, as it will in time, the Hinkson

would have acquired the headwaters of the Grindstone and would have perpetuated an interesting case of piracy through lateral planation.

The last prominent meander of the Hinkson as shown on Figure 2, in the east part of Section 24, has shortened itself and left a low hill on its flood plain at the point marked $x$. This hill was once a part of the prominent hill to the north (known locally as Lover's Leap). All of these small isolated hills consist of the same stratified Burlington limestone (Mississippian) as that forming the bluffs on the stream, thus furnishing further proof that they were originally parts of the surrounding upland.

There are remnants of several flood-plain terraces to be found all along the course of the stream. The interval between terraces ranges from 3 to 20 feet. The highest terrace, of which only small patches remain, is some 40 feet above the living flood plain of the Hinkson. The more recent downward movements have usually been 3–8 feet.

**HISTORY OF THE HINKSON’S DEVELOPMENT**

The ice sheet left this area essentially flat. Preglacial valleys existed, but were filled with glacial drift. One preglacial valley, about a mile and a half north of the area shown in Figure 2, contains about 100 feet of drift and had an east and west course. The Hinkson’s present valley cuts across this old preglacial valley.

Any stream flowing away from the front of the ice sheet would develop its valley by taking advantage of such irregularities as existed on the surface of the drift. The little topographic evidence available along the Hinkson indicates that it probably had a course marked by more or less irregularity. Downward cutting was controlled by the level of the Missouri River into which the Hinkson emptied. For a time after the retreat of the ice, the Missouri was evidently overloaded with débris from the melting ice and had aggraded its channel to a considerable height above its present level. The rock bottom of the Missouri may also have been at a higher level. That the water stood at a higher level than at present is shown by the occurrence of glacial bowlders along the Osage River and some of its larger tributaries at elevations ranging from 25 to 75 feet above the present river. Their position has been explained.
as due to ice floating up the streams which evidently contained much backwater from the melting ice. The bowlders at the lower levels may, of course, have been let down through erosion, but those at higher levels show that the water was either very deep in these streams or that their bottoms were at higher levels.

In view of the long period of time that has passed since the Kansan ice sheet was in this vicinity, 300,000 to 1,000,000 years ago, it would seem reasonable to conclude that the Missouri River had lowered its rock bottom to some extent. The river valley contains from 25 to 100 feet of valley fill at present. A conservative estimate of this lowering might be 25 feet, with 50 feet still within the range of probability. At any rate, the evidence all indicates that the Hinkson entered the Missouri River at a higher level during its early history.

Any lowering of the Missouri River level would be reflected in the lowering of the channels of its tributaries. During the early history of the Hinkson it would be cutting into the relatively soft glacial material, but would soon encounter, especially in its lower course, the underlying Burlington limestone. Throughout its history, the Hinkson has been retarded in its downward cutting by the slower downward cutting of the Missouri River, which forced the Hinkson to cut laterally as well as downward. Its cutting was facilitated by the nearly horizontal dip of the Burlington limestone, which permitted horizontal sapping at the foot of any cliffs developed, and an abundance of tools, derived from the drift in part, but largely from the Burlington limestone, which contains an abundance of chert that readily breaks up into sharply angular tools well suited for abrasion. Corrosion was also undoubtedly very effective in removing material.

The downward-lateral movement widens the meander at its end and on the downstream side, thus undercutting the upstream side of the upland spur. As a result the entire meander belt is shifting downstream. This lateral-downward movement develops the slip-off slopes, shown in Figures 3, 4, and 5, and profile \( A \), Figure 6. Slip-off slopes are always an accompaniment of incised meanders. Figures 4 and 5 show the probable successive positions of the stream in developing its incised meanders. That these are incised meanders is shown by the valley walls not being equally
steep on both sides and by the long gentle slopes on the ends and
downstream slope of the upland spurs, which project into each
meander as they do in normal intrenchment. The development
of its incised meanders by the Hinkson has taken place without the
aid of upward movements of the land mass, but by the slow lowering
of its outlet. This type of incised meander would develop best
under the conditions of static rejuvenation as described by Malott.¹

Fig. 4.—Profile along a slip-off slope showing, a, b, c, and d, successive positions
of the Hinkson during its development.

Fig. 5.—Plan, showing the shifting of the meanders and the development of upland
spurs with the bluffs facing upstream and slip-off slopes facing downstream—the
direction of migration of the meanders. (1) Early course of the Hinkson. (2) Inter-
mediate course. (3) Present course.

Conclusion.—Hinkson Creek furnishes an excellent example of
“incised meanders,” caused by the downward-lateral cutting of
the stream as its outlet stream, the Missouri River, was lowered.
During this incising the Hinkson intrenched itself from 80 to 120
feet below the surrounding upland, and developed overlapping

upland spurs which have a steep bluff facing upstream, a long gentle slope on the back, and another leading down to the apex of the meander, the “slip-off slope,” formed as the stream slid down the back and end of the overlapping upland spur. The Hinkson

Fig. 6.—Profiles of the Hinkson Creek (A and B) and of the Osage River (C, D, E, F, and G).
illustrates the type of meandering stream suggested by Winslow,¹ and assumed by him as the probable method by which the Osage, Gasconade, and other streams of the Ozark Plateau developed their present courses. This, however, is not the origin of the intrenched meanders of these streams as will be shown below.

MEANDERS OF THE OSAGE RIVER AND ITS TRIBUTARIES

The Osage River is the largest southern tributary of the Missouri River in Missouri. Rising in east central Kansas, it follows an easterly course to central Missouri, then northeast to join the Missouri River a short distance east of Jefferson City.² The length of its course in Missouri is 331 miles. This study includes also 52 miles in Kansas, beginning at Osawatomie, Kansas, giving a total length of 383 miles. The river flows across Pennsylvanian rocks, mainly shales, with some sandstone and limestone, to the northeast corner of Vernon County, Missouri (Fig. 1), and from there to the Missouri it flows entirely on limestone and dolomite with occasional beds of sandstone and shale.

Throughout the entire distance of 383 miles, the stream has a meandering course. There is a marked difference in the character of the meanders between the upper and lower portions, however. From Osawatomie, Kansas, to the border line of the Ozark Plateau (Fig. 1) the river meanders widely on a broad flat flood plain (profile c, Fig. 6). From this point in western St. Clair County, the valley narrows rapidly until, within a few miles, the valley walls are close to the river and only a narrow flood plain, usually developed on one side of the river, exists. The river still retains its meandering course, the meanders becoming larger and larger and the bluffs on each side increasing in height until they attain a maximum of nearly 300 feet in the vicinity of Linn Creek, Camden County, at which point the Osage is the farthest up on the Ozark Plateau. From here to the Missouri River the bluffs gradually decrease until they are about 150 to 175 feet high. The accompanying


² See the following topographic sheets of the U.S. Geological Survey: Mound City and Olathe, Kansas; Butler, Clinton, Warsaw, Versailles, Tuscumbia, and Jefferson City, Missouri.
sketch (Fig. 7) drawn on the same scale, shows the comparative size of the meanders of the upper portion (near Rich Hill, Bates County, Missouri) and the lower portion (St. Thomas, Cole County, Missouri) (Fig. 1, A and B). The two sections of the river are about 270 miles apart.

The Osage is a typically intrenched stream from Osceola (near the center of St. Clair County) to its mouth. The valley walls are steep on both sides and closely parallel the river. There are minor variations from uniform steepness on both sides, but a careful study of the river throughout its course shows that on the average the two sides are uniformly the same. Nearer the Missouri River this uniformity is lost because the river here is nearer grade. Its gradient is 6.96 inches per mile in this part of its course, and it is cutting laterally, thus steepening one side while erosion is rounding up the opposite slope.

Fig. 7.—Comparison of the meanders of the upper (near Rich Hill, Missouri) and lower (near St. Thomas, Missouri) courses of the Osage River.
The meanders near Linn Creek in Camden County, where the river is the farthest up on the Ozark Plateau, are striking evidence of intrenchment. The meanders are several miles in length, and inclose overlapping upland spurs which are continuous with the surrounding upland (elevation, 900 feet above sea-level). These spurs have an elevation of 850 and 900 feet. Both valley walls are steep at the sides and ends of the spurs (profiles D and E, Fig. 6). Profile D crosses the Osage River three times and shows very well the uniformity in the valley walls on each side. Profile E is taken along the crest of the upland spur in the large meander in Jasper Township in north Camden County. The noticeable feature here, and that which proves that the Osage is an intrenched stream, is the increase in elevation of the upland spur to nearly 900 feet at its end and the sharp and rapid plunge to the river bottom and rapid rise to the mean elevation on the opposite side of the river. If the Osage had intrenched itself by lateral cutting as well as downward it would have developed a slip-off slope along this spur such as the Hinkson has developed (Figs. 2–5 and profile A, Fig. 6). Profile E shows that the Osage has been cutting downward only and has thus intrenched itself below the upland. A glance at the contour maps and profiles of the Hinkson and the Osage shows at once that they represent two different methods of intrenchment.

If the Osage River did not develop slip-off slopes at the point where it has intrenched its valley the deepest, and where it had to do a maximum amount of cutting, then it certainly did not do so where its valley is shallower. In short, if the river had developed its present meanders from smaller original irregularities in its course by lateral migration accompanied with downward cutting, profiles such as those in D and E would have been impossible.

Profile G, Figure 6, is at Tuscumbia, Missouri, a point some 35–40 miles below Linn Creek. It should be noted that in this older portion of the stream, where the grade is less, the valley is U-shaped and that in profile F, Figure 6, within 15 miles of the Missouri River, the upland spur (right) has considerable slope toward the river. No doubt the damming of the waters in the Osage, and probable aggrading of its valley, had something to do with this shape. How high the water stood in this valley is not known, save
that glacial boulders have been found 75 feet above the present level of the Osage.

The tributaries of the Osage tell the same story as the parent-stream. The Grand River meanders widely on a flat flood plain in its upper course in west central Missouri, but, as soon as it reaches the uplifted area, its meanders are strongly intrenched (see Warsaw sheet). Cole Camp Creek (same sheet) shows a similar series of intrenched meanders that are splendidly developed. There is no flood plain, the valley walls are 150–200 feet high and cling closely to every curve of the stream. The Niangua River (Versailles sheet), flowing into the Osage from the south, shows some fine intrenched meanders. Big Gravois Creek (same sheet), entering from the north, shows intrenched meanders, and shows also how rejuvenation, working up the creek from the Osage, has reached the headwaters of the stream. Another excellent example is Big Tavern Creek on the Tuscumbia sheet.

The lower course of the Osage and its tributaries tells but one story, that of a drainage system which found itself superimposed on an area that was rising. It responded actively and as the area arose it intrenched itself, until today some portions of its channel are nearly 300 feet below the upland.

MEANDERS OF THE GASCONADE RIVER

The Gasconade is the second largest tributary of the Missouri on the south. It rises in the west central part of the Ozark Plateau near the southern part of Wright County and flows northward down the slope of the Ozark Plateau and enters the Missouri about 30 miles below the Osage River. Although its meanders are not so large as those of the Osage, they are fully developed for the size of the stream. Its principal tributaries, Roubidoux, Big Piney, and Little Piney creeks, flow into it from the east and south and have similar meandering courses. Only a small portion of the Gasconade has been mapped topographically; hence the conclusive evidence that has been shown along the Osage cannot be given for this stream. The writer has seen the river in several places, and in all the evidence of intrenchment is plainly seen.
THE MERAMEC AND ITS TRIBUTARIES

The Meramec River rises at the crest of the watershed of the Ozark Plateau in Dent County, and flowing first north, then northeast, east, and southeast, enters the Mississippi River 20 miles south of St. Louis. It has a large tributary on the north, the Bourbeuse River, and one from the south, Big River. Both parent-stream and tributaries are noted for their meandering courses. A study of the topographic sheets which show these streams reveals abundant evidence of their being intrenched meanders. Figure 8 is a sketch of a portion of the Bourbeuse River on the Sullivan, Missouri, Quadrangle and shows the extreme meandering of this stream. The Meramec and its tributaries have been at grade longer than either the Osage or Gasconade, and, as a result, their meanders show more downstream migration, with consequent widening of their flood plains. The upland spurs closely entwined by the meanders leave no doubt that these streams owe their intrenchment to the same agent as that acting on the Osage and Gasconade.

CAUSE OF INTRENCHMENT

The intrenchment of the streams of the northern slope of the Ozark Plateau, the Osage, Gasconade, and Meramec, was caused by an uplift that followed peneplanation. The incision of Hinkson Creek to the north of the plateau was due to static rejuvenation, rather than uplift.

The Ozark Plateau was certainly peneplained during the Tertiary and possibly also during the latter part of the Mesozoic. The Ozark area was reduced to a plain above the general level of which rose only a few unreduced remnants of the original land surface. This peneplain truncates the various geologic formations of
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the Ozark area. The Missouri River was in existence during this time and received the drainage of the northern slope of the plateau as it does today. In late Tertiary times, probably late Pliocene in fact, although some authors think it may have been Middle Tertiary, the Ozark area was uplifted. This (late Pliocene) was a period of uplift over much of the United States and a movement of several hundred feet is believed to have occurred in the Mississippi Valley. The maximum movement involved the southern half of Missouri and the northern part of Arkansas, the axis following approximately the dotted line in Figure 1.

The Osage, Gasconade, and Meramec rivers flowed across this peneplain in meandering courses with wide valleys. As the area came up, these streams and the Missouri were rejuvenated and began cutting downward. The meanders they possessed at the time of uplift were preserved because the rate of uplift was about equal to the ability of the streams to cut downward. At present they have largely ceased to cut downward and are engaged in widening their flood plains by cutting into their valley walls. The lower courses already have flood plains a half to three-quarters of a mile wide. This conclusion as to the intrenchment of the Osage and other streams is in accord with that of Davis,¹ rather than that of Winslow.

The Osage shows how a stream may hold its own against uplift in its lower course, if the rate of upward movement does not exceed the cutting power of the stream. The upper course of the Osage, topographically, is old and the lower course, exclusive of the meanders, which are younger topographically, is in early maturity. Such an anomaly in streams indicates rejuvenation.

The Gasconade and Meramec lie entirely upon the Ozark Plateau; hence they show rejuvenation throughout their entire courses.

The Hinkson, lying as it does on the northward margin of the uplifted area and uninfluenced by the uplift, began incising its valley after the Kansan ice sheet had retreated from this area, and developed its incised meanders by static rejuvenation as the channel of the Missouri River, into which it empties, was lowered.

SUMMARY

The meanders of Hinkson Creek and of the Osage, Gasconade, and Meramec rivers have been described in detail in order to bring out the fact that the Hinkson began its incisement much later than the rivers to the south began to intrench themselves, and has developed its meanders through lateral and downward cutting, thus producing "incised meanders" with "slip-off slopes" on the upland spurs. This type of meander has been called an "incised meander" to distinguish it from the simple downward cutting of the intrenched rivers to the south. The incised meanders of the Hinkson are due to static rejuvenation (caused by the downward cutting of the parent-stream, the Missouri River), and the intrenchment of the Osage, Gasconade, and Meramec rivers is due to the uplift of the entire area across which the three streams had previously developed meandering courses on wide flood plains. This uplift is believed to have occurred in late Pliocene times. Since that time the Tertiary peneplain has been undergoing dissection, thus producing the restful and beautiful mature topography for which the Missouri Ozarks are justly famous.