

PLANATION STREAM PIRACY.

BY

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Introduction.

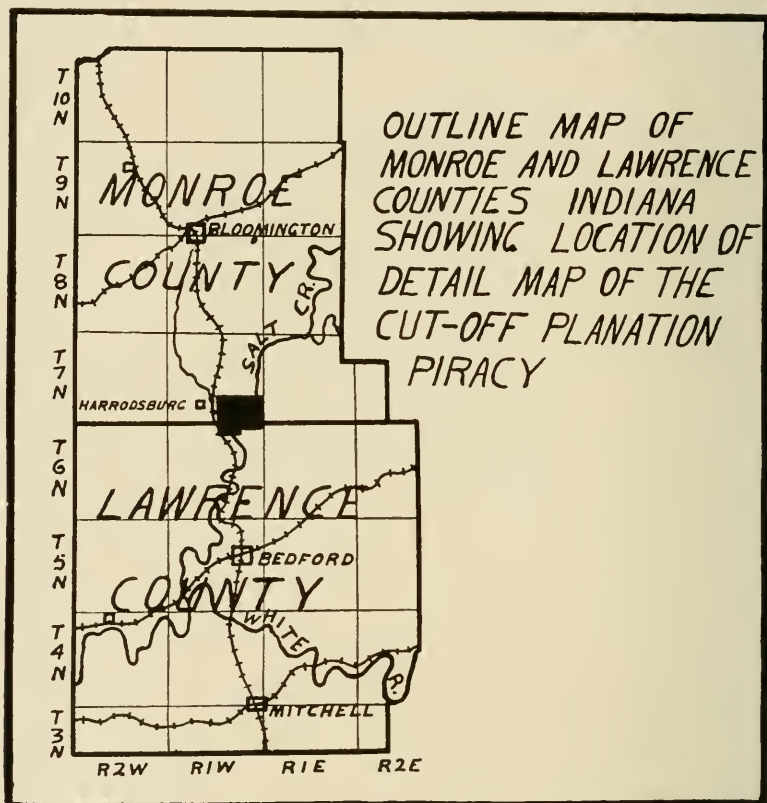
Definition of Stream Piracy.—Stream piracy is not an uncommon phase of stream adjustment during the development of the erosion cycle. Stream piracy consists of the diversion of a portion of a stream system usually by the encroachment of a portion of a more vigorous stream system. Thus the drainage area of the more vigorous stream is enlarged at the expense of the weaker stream. This encroachment and diversion take place slowly by stream adjustment during the development of the erosion cycle. Stream piracy has nothing in common with stream derangement. Streams are frequently thrown out of their normal courses by such processes as glaciation vulcanism, deposition of sand by the wind, etc., but such stream derangement is not considered as a phase of stream adjustment and does not come under the term stream piracy. Stream piracy and stream derangement are very different physiographic processes.

Types of Stream Piracy.—Broadly speaking there are three types of stream piracy which may accompany stream adjustment. The most common, perhaps, is the headward erosion type. A condition favoring the development of this type is the cuesta where vigorous streams flow down the steep scarp. Such streams are frequently able to etch their way by headward erosion through the frontal scarp of the cuesta and divert the head-waters of more sluggish streams upon the back-slope. Examples of the headward erosion type have been described by Gilbert, Davis, Darton, and others. Probably the most famous examples of the headward erosion type are Kaaterskill and Plaaterskill creeks on the frontal scarp of the Catskill Mountains. Here these streams have undercut the headwaters of Schoharie Creek on the back-slope of the cuesta. A notable case of this kind in southern Indiana has recently been described by the writer.¹ Muddy Fork of Silver Creek of Clark and Washington counties has taken some 35 square miles of the drainage basin of one of the forks of Blue River. In this case the pirate stream had its beginning on the steep slope of the Knobstone escarpment. This form of headward erosion piracy usually gives rise to a barbed drainage pattern. Another form of headward erosion piracy is common in such mountains as the Appalachians, where not doubt the trellis drainage patterns so prevalent have been brought about by stream adjustment in which headward erosion piracy has played the chief role. The case of the Shenandoah River and Beaverdam Creek near Snickers Gap in the Harpers Ferry locality as described by Willis is a classical example of this form of headward erosion stream piracy.

A second type of stream piracy may be called the subterranean type. This type is fairly common in limestone regions where subterranean drainage exists. A favorable condition is considerable relief of the limestone

¹"Some special Physiographic Features of the Knobstone Cuesta region of southern Indiana—An Example of Explanatory Physiography," Proceedings of the Indiana Academy of Science, 1919.

area. Subterranean piracy is dependent upon differential work of the surface streams in their downward cutting. Those stream basins or portions of stream basins which are relatively high above neighboring stream basins in limestone regions are subject to diversion by subterranean piracy. The most notable case yet described is that described by Beede in his paper on the "Cycle of Subterranean Drainage, as Illustrated in the Bloomington, Indiana, Quadrangle," published in the Proceedings of the Indiana Academy of Science, 1910. In this case several square miles of the upper por-



tion of Indian Creek drainage basin have been diverted by subterranean piracy into the more deeply entrenched streams on either side of the headwaters of Indian Creek.

The third type of stream piracy is the type with which the present paper deals. It is commonly found where a larger stream has reached the stage of maturity in an area of considerable relief. By the lateral planation of the mature main stream a nearly parallel minor stream may be literally cut into two streams, each entering the master stream independently. The upper part of the once continuous stream will enter the main stream at the place where the master stream invaded the valley of the minor stream. The lower part of the minor stream will be left in a valley far too large

for it. This form of stream piracy is less frequently seen in streams which are approximately equal in size. Where such cases occur it is probable that one stream does not cause the piracy by lateral planation more than the other, but they may be mutually responsible. In any case the stream which is deeper acquires the drainage of the other. Since this type of piracy takes place on account of lateral planation, usually by the major more mature stream, it is here proposed that this type of stream piracy be called planation piracy.

A Typical Case of Planation Stream Piracy.

Location and Geography.—The area which affords a typical example of planation stream piracy lies mainly in southern Monroe County, Indiana. A topographic map of the locality accompanies this paper. The area as mapped laps somewhat over into Lawrence County. Some seven square miles are included in the mapped area, the larger part of which lies in T. 7 N., R. 1 W. The portion of the area in Lawrence County lies in the next township to the south. A small portion of the mapped area is included in the extreme southeastern part of the Bloomington Quadrangle area. The case of piracy is about two and one-half miles east of Harrodsburg station and just south of the little village of Fairfax. The area is some twelve to fourteen miles south of Bloomington.

The area is cut by the intrenched valley of Salt Creek. The valley on approaching the area from the north makes an abrupt turn to the west and northwest, and then again turns to the south when within three-fourths of a mile of Harrodsburg station. It leaves the area trending in a southeasterly direction. These abrupt turns in the valley of Salt Creek have given rise to an upland mass of land partly surrounded by Salt Creek valley. The individual drainage of the upland is by rather minor streams, chief among which are Upper and Lower Cut-off creeks. These streams are not more than two miles in length. Clear Creek which heads near Bloomington enters Salt Creek near the southwest corner of the mapped area.

The area is rather sparsely settled and most of the steeper slopes are wooded. The gently rolling upland area and the broad valley of Salt Creek are under cultivation, but no part of the area is attractive from the standpoint of agriculture.

Topography and Relief.—The topography is shown specifically upon the accompanying topographic map which has been prepared to show the outstanding topographic features and their relationships. The area has a maximum relief of slightly over 250 feet, extending from the valley of Salt Creek which has an elevation of about 500 feet to the higher parts of the upland which reach an elevation of 750 feet or slightly more above sea level. Towards the east side this maximum relief of 250 feet is attained immediately between the valley and the upland. The chief topographic feature is the deeply cut, but flat-bottomed valley of Salt Creek. This valley ranges in width from about one-fourth of a mile to a mile. In places this valley is flanked by terraces which are from 10 to 40 feet in height above the present flood-plain. For the most part the upland rises abruptly from the valley floor with an ascent varying from 125 to 250 feet. The upland

is sharply trenched by minor stream development. The upland spaces between the minor stream valleys are rather gently rolling or flat, with some development of shallow sinkhole topography.

Geologic Conditions and Physiographic Development of the Locality.— Since an understanding of the geology of a locality is frequently quite essential in the interpretation of the topographic forms present a brief sketch of the geology will be given here. The upland mass is composed chiefly of solidified Mississippian rocks of Keokuk and Warsaw age, covered over with a thin soil mantle except where the slopes are quite steep. Small deposits of late Tertiary gravel are present on the upland adjacent to Salt Creek valley. Salt Creek valley is partly filled with Pleistocene and recent alluvial material.

The rocks of Keokuk age are massive to thin bedded impure sandstones and sandy shales, all usually of a bluish color, consisting of the upper part of the so-called Knobstone group of rocks. These sandy shales and argillaceous, fine-grained sandstones are mainly exposed on the steep slopes of the area. More than 200 feet of the Knobstone rocks are exposed on the steep slopes on the eastern side of the area. Everywhere on top of the upland the clastic Knobstone rocks are covered with the thin to massive bedded Harrodsburg limestone of Warsaw age. The contact of this limestone with the underlying Knobstone is about 740 above sea level at the east side of the area, about 650 feet in the middle of the area, and about 580 feet in the hill east of the mouth of Clear Creek near the southwest corner of the area. With these figures in mind, reference to the topographic map will show that practically all of the tillable upland is on the Harrodsburg limestone. This limestone has a total thickness of about 90 feet, but only in one or two localities in the mapped area is the total thickness to be found. This limestone area is covered by a red soil in and on which are quantities of chert which has weathered from the limestone.

The dip of the Mississippian rocks may be computed from the figures given above on the contact of the Harrodsburg limestone and the Knobstone rocks. The dip is mainly west, or slightly south of west. The rate of dip is variable, being abnormally great in the eastern half of the area. There, the dip amounts to something like 80 feet to the mile, while in the western half of the area the dip has subsided to approximately the normal amount of 35 feet to the mile. The extraordinary dip at the eastern side of the area is probably because of proximity to a considerable structural disturbance a short distance east of the mapped area.

The region is a dissected plain. The topographic map shows distinctly the general level of the plain in the gently rolling to flat upland inter-stream spaces. This upland plain is about 760 feet above sea level at the eastern side of the area. It inclines to the west where it has an elevation of about 675 feet. This plain as preserved in the area is a portion of a more extensive one developed on the rather resistant Harrodsburg limestone which caps the upland area. The Harrodsburg limestone capping has protected the underlying easily eroded and weathered Knobstone rocks. Since this partly preserved plain inclines practically with the dip of the Harrodsburg limestone upon which it is developed, it may be regarded as a structural plain. It may also be called a structural peneplain, since it is

a plain developed on the structural level of the Harrodsburg limestone by fluvial agencies. It owes its preservation as a plain to the rather superior resistance of the limestone to mechanical denudation, and to the fact that its subterranean drainage in the limestone has temporarily greatly retarded its fluvial destruction. Where the streams have cut through the Harrodsburg limestone into the mechanically non-resistant Knobstone rocks they are flanked by very steep slopes, having angles of 20 to 50 degrees from the horizontal. This sharp stream trenching is quite characteristic of Knobstone topography.

The structural plain developed on the Harrodsburg limestone extends miles eastward from the area, and rises directly with the strata in that direction. But less and less of the interstream surface is level to the eastward; and finally the Harrodsburg limestone ceases to be present, though the plain itself has risen to an elevation of 900 to 1,000 feet above sea level. The divides in this high-level area are rather sharp, but have even crests of approximately the same elevation. This area furnishes a most excellent example of mature topography. This maturely dissected area which reaches elevations of 900 to 1,000 feet above sea level is probably representative of the earlier Tertiary fluvial peneplain, and may be correlated with the Highland Rim peneplain of Kentucky and Tennessee. The Highland Rim peneplain remnants represent the highest level attained in Indiana. In the region in question no part of the area reaches up to the Highland Rim level. Portions of the structural plain, however, probably represent a later more local peneplain of fluvial origin. This level has an elevation of 650 to 700 feet. The presence of old stream gravels at these elevations on the upland adjacent to the valley of Salt Creek is evidence of local peneplanation. These gravels were noticed near the higher places on the ridge in section 34, between Salt Creek and Lower Cut-off Creek. They are probably of latest Tertiary age, having been deposited as alluvial gravels previous to the uplift which is ordinarily believed to have ushered in the Pleistocene.

The Pleistocene uplift was responsible for the stream trenching of the area. This uplift allowed Salt Creek to intrench itself into the uplifted land mass 150 feet or more below the stream gravels of late Tertiary age. Stream trenching was considerably greater than the difference in the elevation of the present graded valley and the old gravels, since the present valley is partially filled with Pleistocene gravels, sands, and silts. It is filled some 50 to 80 feet below the present stream level. The upper part of the Pleistocene valley filling has been partly removed and reworked by the meandering stream over the over-broadened valley-flat. Terraces ranging in height from a few feet to over 40 feet above the present flood plain indicate that the Pleistocene filling of the intrenched valley has been partly removed. This Pleistocene valley material is composed largely of material derived from the rocks in which the valley is cut, but a portion of it is distinctly outwash material from the Illinois glacial lobe which came as far south as the headwaters of Salt Creek at the northern and northeastern limits of the triangular-shaped unglacial area in southern Indiana.

The Name of Cut-Off Piracy.—Upper and Lower Cut-off creeks are two small streams shown on the map accompanying this paper, and the names are applied to the streams for the first time, in this paper. These names

were suggested from the name, "The Cut-off", applied to a sag-like opening or col in the south half of section 35, which appears on Siebenthal's map of Monroe County published in 1895. In this paper the liberty is taken of making the term apply specifically to the sag, the expression "The Cut-off Col" being used. Since the col has resulted from a physiographic action in which a formerly continuous stream was divided into two sections, the term "Cut-off" has been applied to each section, the upper section or stream being named Upper Cut-off Creek and the lower section or stream being named Lower Cut-off Creek. The physiographic action which divided the parent stream into Upper and Lower Cut-off creeks was lateral planation or the side-wise swinging of Salt Creek in the process of widening its valley. This process took place in such a degree that Salt Creek actually invaded the territory of the parent Cut-off Creek and the upper part was diverted. Thus this case of planation piracy may well be called "Cut-off Piracy".

Evidence of Diversion of Upper Cut-off Creek.—That the valleys of Upper and Lower Cut-off creeks were once one continuous valley and the drainage of the present two stream systems was once a unit, is seen in the present courses of the streams and the existence of the low sag which separates them. Upper Cut-off Creek, arising in the southeastern quarter of section 36, flows west bearing slightly to the northward. In the southeast quarter of section 35 near Phillips School, it turns abruptly through a flat-bottomed opening and passes northward over the flat flood plain of Salt Creek to Salt Creek channel near Fairfax. (Figures 1 and 2.) Lower Cut-off Creek heads in a great sag, here called the Cut-off Col, one-fourth mile west of where Upper Cut-off Creek debouches upon the flood plain of Salt Creek. (Figures 3 and 4.) After extending west for three-fourths of a mile the valley of Lower Cut-off Creek turns southward and opens into Salt Creek valley. The upper part of Lower Cut-off Creek valley is directly in line with the valley of Upper Cut-off Creek. It may be said that Upper Cut-off Creek has no valley after making the abrupt turn northward through the opening at Phillips School, as it there debouches upon the



Fig. 1. View showing Upper Cut-off Creek where it turns abruptly northward through the narrow, flat-bottomed opening at Phillips School.



Fig. 2. View of the flat-bottomed opening through which Upper Cut-off Creek enters onto the wide flood plain of Salt Creek at Phillips School. Salt Creek flood plain is confluent with this flat-bottomed opening, and is beyond the projecting spurs of upland shown at either side of the view.

valley-flat of Salt Creek. The alignment of the valleys of the two streams, the presence of Cut-off Col between the valleys, the ending of the valley of Upper Cut-off Creek where the stream turns northward at Phillips School, the more sharply trenched condition of the upper valley, the undersized stream in the broad gently-sloping lower valley, and the great semi-circular bend of the steep south bluff of the entrenched valley of Salt Creek show clearly that a once continuous stream has been divided and the upper portion caused to empty into Salt Creek valley several miles farther upstream than where the drainage formerly entered. This condition undoubtedly resulted from the rather extraordinary widening of Salt Creek valley in the Phillips School locality by lateral planation.

Conditions Which Favored the Cut-off Piracy.—A number of conditions favored the Cut-off planation piracy. The parent Cut-off Creek flowed almost parallel with Salt Creek in its westward direction near Fairfax. This parallelism was not an extraordinary thing in this small stream, as the southward turn of Salt Creek valley allowed it to come into Salt Creek in a normal manner. (The southward turn of Lower Cut-off Creek is rather exceptional, as it causes the parallelism of the two streams to continue a greater distance than it otherwise would; but a discussion of this condition is not essential to the present problem.) Lateral planation is a normal action taking place in valleys which have reached the mature stage. But the conditions in the vicinity of Fairfax are rather favorable for an unusual amount of lateral planation. The valley here makes an abrupt bend somewhat greater than a right angle. Such a turn should normally cause the waters of the valley to impinge against the outside valley-wall, or in this case on the south bluff. It may be noticed that the valley is much

wider in the vicinity of Fairfax than it is for several miles either above or below this locality. No terraces flank the south side of the valley here, but on the inside of the great valley-bend more than the usual amount of terrace material is present. This abrupt turn of the valley certainly favored lateral planation on the outside of the great bend. The extraordinary concave bluff-line, with its farthest south extension near Phillips School, is a rather striking indication of the concentration of waters against the south side of the valley.

Another feature which enters into the problem is the fact that there has been much more water flowing in Salt Creek valley at times during the past than there is at present. Salt Creek is a small sluggish stream meandering in a valley rather too large for it. The Pleistocene valley-fill material and the flanking terraces are proof that the valley once was a sluice-way for the exit of glacial waters. No doubt during the melting seasons of the glacial ice near the headwaters of this valley, the valley was in a highly flooded condition, and the stream that occupied it was much larger than the present one. Lateral planation must have taken place on a much greater scale during this time than at present. The much larger Pleistocene stream must have brushed all outside turns of the meandering valley with considerable vigor. The great curve cut out in the south bluff south of Fairfax must have been made during this time, as the curve seems unusually large to have been made by the present rather feeble stream. The present position of the stream channel has no relation to this great curve. In one or two meanders in the flood-plain the present stream does come against the south bluff in the northern part of section 36, but this touching of the bluff in these two places has not yet destroyed the symmetry of the great curve in the wall-like bluff.

There is a strong probability that the parent Cut-off Creek received a small tributary from the northeast in the vicinity of the present site of Phillips School. The territory of this stream was invaded by the overwidened valley of Salt Creek. The sags, one near the center of section 35 and one in the N. W. quarter section 35, are indications that the upper portions of two small tributaries of Cut-off Creek became engulfed in the widened valley of Salt Creek. In the case, however, of the tributary which came in near the present site of Phillips School, the whole of the area of the tributary became a part of Salt Creek valley. When the great curve had advanced far enough to come into the valley of Cut-off Creek or approach it through the valley of the tributary, piracy of the upper part of the parent Cut-off was effected. It is believed that the piracy was effected during the Pleistocene period.

Static Rejuvenation of Upper Cut-Off Creek Basin.—The virtual division of the parent Cut-off Creek into Upper and Lower Cut-off creeks allowed the drainage waters from about 260 acres to enter Salt Creek directly, instead of having to flow some two miles farther before entering Salt Creek valley. Upper Cut-off Creek at the time of its diversion must have been perched 90 to 95 feet above Salt Creek valley. This is specifically indicated by the elevation of the old abandoned portion of the parent stream valley which is now the divide between Upper and Lower Cut-off creeks. (Figure 3.) The valley of Salt Creek at the place of the entrance of Upper Cut-off Creek upon it is 515 feet above sea level. The abandoned

portion of the parent stream valley at the Cut-off Col is 595 feet above sea level. The col is thus 80 feet higher than the valley-flat of Salt Creek. But the col is at present some distance west of the place where the piracy was effected, and in that distance the parent stream had a fall of 10 to 15 feet. Thus, Upper Cut-off Creek at the time it was diverted was perched 90 to 95 feet above Salt Creek flood-plain. At the time of diversion the waters of Upper Cut-off Creek entered Salt Creek valley over a fall 90 to 95 feet high. This fall may have endured for some time, but the nature of the rock is such that the fall could not have persisted. The rocks are easily eroded and weathered, and there are few or no ledges of superior hardness. The correction of this peculiar gradient of the diverted stream has deeply entrenched the valley, having cut it some 90 to 95 feet deeper than the valley of the parent stream. Thus the Upper Cut-off Creek drainage basin furnishes an excellent example of a stream basin that has been statically rejuvenated.²

Migration of the Cut-Off Col.—At the time that the parent Cut-off stream was divided into two parts by the lateral planation of Salt Creek the divide between the two parts was probably immediately west of the place where the cut-off was effected. The rejuvenation of the upper stream basin was followed by its intrenchment far below the former fairly well graded valley-level. The tributary stream which comes in from the south near Phillips School was probably for a time a tributary to Lower Cut-off Creek. But the rejuvenation brought about by the piracy gave rise to a condition favorable for normal headward erosion piracy. Rainwash and gullying on the west brought about the capture of the somewhat sluggish stream from the south, thereby enlarging the basin of Upper Cut-off Creek. Headward erosion continued westward down the course of the parent stream, and the small ravines on either side were captured in succession. The divide has now migrated by this headward erosion process about one-fourth mile west of its original position at the time the planation piracy



Fig. 3. View directly across the "Cut-off Col" from the south. The small ravine at the left is the very head of Lower Cut-off Creek.

²C. A. Malott, Static Rejuvenation, Science, New Series, Vol. LII, No. 1338, Aug. 20, 1920.



Fig. 4. Oblique view across the "Cut-off Col" from the southwest. The deeply intrrenched reversed drainage of the invading portion of Upper Cut-off Creek is shown in the back-ground.

took place. Thus, this planation piracy started normal successive headward erosion piracy.³ This type of piracy is not yet complete in the area. Other small ravines to the west of the col will eventually be taken into the upper stream system. This successive piracy proceeding down the course of the old parent stream will continue until the gradients of the new reversed stream and Lower Cut-off Creek are in a balanced condition. Thus Cut-off Col may be expected to migrate west of its present position probably as much as a half-mile before the balanced condition is attained.

The whole basin of former Cut-off Creek had an area of some 1,040 acres. Immediately following the planation piracy this area was divided into an upper basin of approximately 260 acres in area and a lower basin of about 780 acres. On account of the headward erosion piracy following the planation piracy, Upper Cut-off Creek stream system now consists of a drainage basin of approximately 400 acres in area, while the lower stream basin has dwindled to approximately 640 acres in area. When the gradients of the present invading portion of the upper stream and the lower stream have reached a balanced condition, it is probable that the basins of the two stream systems will be approximately equal, as it appears that some 120 acres in area will be taken from the lower system by the invading part of the upper system.

Summary and Conclusion.

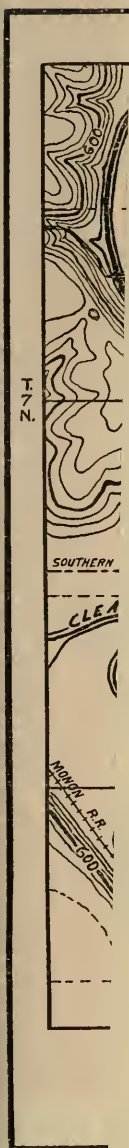
The subject matter of this paper is introduced by a definition of stream piracy and a classification of the types. The classification simply defines

³The writer has described a case of successive headward erosion stream piracy in detail in a paper entitled "Some Special Physiographic Features of the Knobstone Cuesta Region of Southern Indiana", *Proceedings of the Indiana Academy of Science*, 1919. The expression "successive headward erosion piracy" is rather bunglesome, but should be easily understandable.

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the fairly common types of stream piracy as phases of stream adjustment. The ideas presented are probably not new, but they are conveniently brought together and fairly clearly stated and differentiated. The three types of piracy briefly are the headward erosion type, the subterranean type, and the planation type. The main body of the paper deals with the details of the planation type of piracy. Following the method chosen by the writer as the most satisfactory method in presenting a physiographic subject, a complete view of the area is given before the details of the main subject are presented. The geographic position, the topographic condition, the pertinent geologic factors and the physiographic development of the area are presented in order before the details of the stream piracy are undertaken.

Planation piracy consists of the diversion of the upper portion of a stream by the invasion of its valley by the lateral planation of a neighboring stream. Usually the diverted stream is a minor stream and the pirate stream is much larger and is widening its valley by lateral planation. The case described is that of Cut-off Creek in southern Monroe County, Indiana, a short distance east of Harrodsburg. It is shown that the topographic condition of the area, the courses of the streams concerned, and the passage of glacial waters down the course of the master stream (though the area is distant from the glaciated portion of the state), were important factors favoring the development of the piracy. The principle of static rejuvenation is applied to the diverted and revived Upper Cut-off Creek. It is shown that the rejuvenation of the stream basin brought about by its diversion gave opportunity for further piracy to take place; but piracy of the headward erosion type. The upper, diverted part of the parent stream has grown at the expense of the lower part.

Planation stream piracy is rather common. An excellent example is shown on the Lockport, Kentucky, Quadrangle, where Kentucky River has invaded the drainage basin of Cedar-Sawdridge Creek and diverted that stream some three and one-half miles above its former entrance into the main stream. The lower portion of the divided valley is occupied by Pond Creek, a stream far too small for the size of the valley. Judging from the present gradient of Cedar-Sawdridge Creek, this stream at the time of its diversion was approximately 60 feet higher than Kentucky River at the place of diversion. The old valley at the divide between Pond Creek and the small reversed stream that is etching its way into the Pond Creek system is approximately 60 feet above the Kentucky River. A potential case of planation piracy is shown on the Buckhorn, Kentucky, Quadrangle, which in many respects resembles Cut-off Piracy. Mace Fork Creek, like Cut-off Creek is small. It will be divided into approximately equal parts, or rather far up stream. When the Kentucky River finishes cutting the narrow divide between Mace Creek valley and its own valley, the Upper part of Mace Creek will enter Kentucky River as a waterfall approximately 110 feet high, a fall similar to the fall of the newly diverted Upper Cut-off Creek. Salisbury, and Atwood is Professional Paper No. 60, U. S. Geol. Surv., call attention to Couler Valley North of Dubuque, Iowa, which is described as the former line of the discharge of Little Maquoketa River, which stream was diverted principally by the planation of the Mississippi River. Bowman⁴ has described a case in detail along the Huron

⁴Isaiah Bowman, "A Typical Case of Stream-Capture in Michigan", *Journal of Geology*, Vol. XI, pp. 326-334, 1904.

River in Michigan, and calls attention to a number of other cases that have been described. But in this paper this particular type of stream piracy is given the name *planation stream piracy*. The case of the Cut-off planation piracy is a clear one, as is shown by the accompanying topographic map. It has in it all the phases of any case of planation stream piracy. For these reasons the Cut-off planation piracy may well serve as the type case of planation stream piracy.