MEANDERS IN TIDAL STREAMS: A REVIEW AND DISCUSSION

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MEANDERS IN TIDAL STREAMS: A REVIEW AND DISCUSSION*

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IN a recent bulletin of the Geological Society of America Mr. Marius R. Campbell presents an interesting discussion of the origin of meanders in tidal streams.

In the words of the author the main object of his paper is "to demonstrate the proposition that the action of running water at sea level is very different from what it is above that level." Attention is directed first to the well known fact that the lower Mississippi is remarkably free from meanders. As to the cause of the relatively straight course below Baton Rouge, described as occupying a position "at or below" sea level, the author regards the problem as highly complicated and involved; but he is inclined to believe that when the river reaches tide level it flows between banks of stagnant water instead of between banks of earthy material and hence fails to corrade effectively.

Turning to the San Jacinto River of Texas, the author cites the remarkably fine examples of crescentic meander "scars," or scarps cut in the valley walls bordering the drowned lower course of this stream, and recognizes that these scarps were cut by the normal current of the meandering stream when the land stood higher. A later subsidence partially drowned the valley and checked the tendency of the river to enlarge its meander curves. In similar manner the drowned lower course of the James River, also bordered by meander scarps, is cited as an example of a stream which practically ceased its meandering habit when submergence caused the river current to flow through the relatively stagnant waters of the embayment. Here the fact that meander scarps bordering the embayment are no longer being cut by the river current is supported by elaborate argument. It is concluded that in the lower San Jacinto and in the lower James, just as in the lower Mississippi, a stream flowing at tide level has no tendency to form meanders or to cut off meanders formed at some previous period under conditions different from those of the present. The arguments and conclusions are then used in interpreting the geomorphic history of the lower James River and of the lower Potomac River in the vicinity of Mount Vernon.

The reader will follow with interest, and probably without substantial dissent, the author's interpretation of the river histories last referred to; he will enjoy following the arguments with the aid of the excellent sketch maps, especially as the author has made this easy by indicating in parentheses numbers or letters which make possible quick identification of all critical points; and he will give to arguments and conclusions that careful consideration which anything from the pen of Mr. Campbell always commands. Yet he may lay down the paper with doubt both as to the method of argument employed and as to the validity of the chief conclusion reached.

Lower Mississippi Compared with San Jacinto and James

One prefers when possible to reason from things easily demonstrated to those more difficult to understand. The lower courses of the San Jacinto and James rivers

*Marius R. Campbell: Meaning of Meanders in Tidal Streams, *Bull. Geol. Soc. of America*, Vol. 38, 1927, pp. 537–556.

present no difficult physiographic problems in so far as concerns the partially drowned meander scarps and their significance. It has long been recognized that if a river valley like that shown in Figure 1 be partially submerged, the sea may come to rest against the crescentic meander scarps shown in Figure 2. The lower San Jacinto, the lower Seine, and other embayed streams have been cited as illustrations of valleys of former meandering rivers partially submerged by a change in the level of land or sea. When a river enters the relatively stagnant waters of a broadening estuary

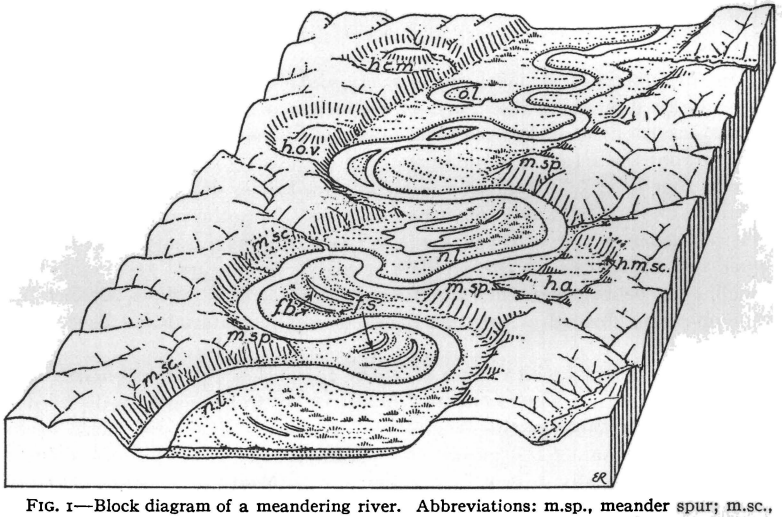

FIG. 1—Block diagram of a meandering river. Abbreviations: m.sp., meander spur; m.sc., meander scarp; f.b., flood-plain bars; f.s., flood-plain swales; n.l., natural levee; h.a., high-level amphitheatre; h.m.sc., high-level meander scarp; h.o.v., high-level oxbow valley; h.c.m., high-level cut-off meander spur; o.l., oxbow lake.

due to such submergence, its current, no longer confined to a narrow channel but free to take a more direct route to the sea, will abandon the outside of its meander curves and flow down a shorter and steeper slope. Such a current, bordered on either side by relatively stagnant water, ceases to corrade the estuarine shores.

If, then, we begin with the simple cases of the San Jacinto and James, the next step is to apply the principles easily demonstrated there to the more problematic lower Mississippi. But this step can be taken only if the physical conditions in the several cases are substantially identical. In the reviewer's opinion the physiography of the lower Mississippi has little in common with that of the two other streams. After all, the lower San Jacinto and lower James are rivers only in name; physiographically they are bays of the ocean, in whose expanded waters unconfined and much diffused river currents move where inertia and gravity lead them. What analogy have they with the lower Mississippi, a true river with its current rather closely confined by earthen banks?

RELATION OF RIVER LEVELS TO SEA LEVEL

If rivers meander extensively above a certain level, and not at all below that level, the limiting plane should be defined with precision. The author apparently uses the terms "sea level," "tide level," and "tidewater" as synonymous, although these terms are commonly applied to different things, which do not necessarily have the same level. That the difference in level is vital to the author's argument appears clearly in the next-to-the-last paragraph of the paper, where he excludes meandering

runways in tidal marshes as having little or no bearing on this subject, because any lateral cutting effected by the incoming and outgoing tides would be done "above actual sea level." We may assume that here the author has in mind the definite plane of mean sea level and believes (which the reviewer does not) that tidal currents do all their lateral cutting above that plane. Would the author regard sea water moving through these runways with the tides as not within the limits implied by such expressions as "tidewater" and "tide level"? One has an uneasy feeling

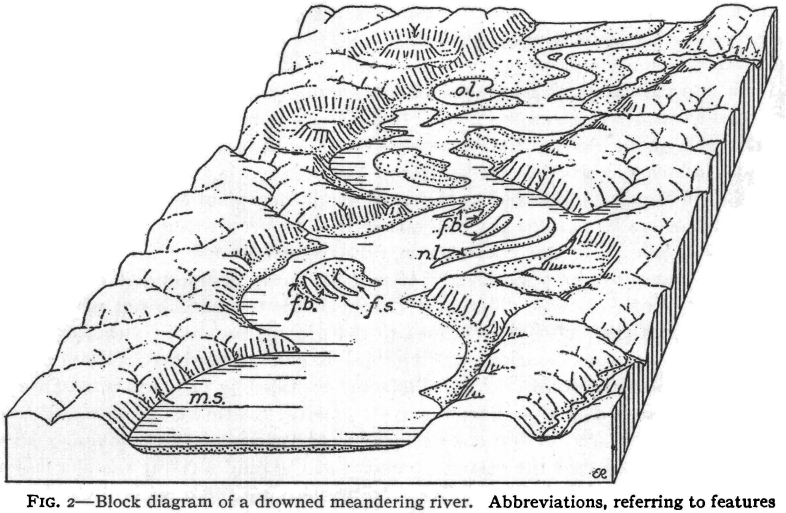

FIG. 2—Block diagram of a drowned meandering river. Abbreviations, referring to features partially drowned: m.s., meander scarp; f.b., flood-plain bars; f.s., flood-plain swales; n.l., natural levee; o.l., oxbow lake.

that perhaps meandering tidal creeks demonstrate the ability of streams, under proper conditions, to meander at tidewater or tide level (both above and below mean sea level) and hence that they may constitute a serious objection to the acceptance of Campbell's main conclusion.

If the reader feels that in the matter of meandering tidal runways the author has too summarily dismissed what appears to be an important phase of the problem, this feeling is apt to be reënforced by other parts of his text. James River is recognized as "a tidal stream from Richmond to Hampton Roads, but from the head of tide down nearly to City Point, at the mouth of Appomattox River, the stream behaves more or less as a normal river behaves, and the drowning is not sufficient to submerge the flood plain and carry the water far inland beyond the immediate banks." All this is true of the lower Mississippi; yet the tidal portion of the James here described has good meanders, whereas the lower Mississippi has not. Only low-water elevations are given for the Mississippi; yet it is admittedly during high water that the lateral corrasion of the stream is most effective. At such times the tidal portion of the river is above actual sea level more truly than are the waters of meandering tidal runways.

GRADUAL CHANGE IN PHYSIOGRAPHY OF LOWER MISSISSIPPI

The change in the behavior of the lower Mississippi does not take place abruptly. Reference to the Mississippi River Commission's maps will show that, while north of Baton Rouge the river shows many meanders and cut-offs, below this point meanders are still pronounced, although evidences of cut-offs are rare or wholly

lacking. Near Donaldsonville the pronounced meanders gradually give place to a pattern characterized by simple bends rather than by true meanders. Not far below New Orleans the simple bends die out, and the remainder of the river's course is for the most part relatively straight or only faintly sinuous. Perhaps it would be most accurate, and likewise most significant, to say that the river changes somewhat gradually from a meandering to a non-meandering course, the three places named being arbitrary division points which serve to emphasize the extent of the progressive change. Any satisfactory theory to account for the non-meandering character of the lower Mississippi must take account of the facts that the change in the river's behavior is progressive and is effected above, not at or below, mean sea level, if due account be taken of the high-water stages. At Baton Rouge high water is approximately 40 feet, near Donaldsonville 30 feet, and a little below New Orleans 18 feet above mean sea level. Incidentally it may be noted that the river is tidal well above Baton Rouge during low-water stages, whereas at high water the tidal influence is scarcely perceptible at Donaldsonville.

If Baton Rouge be selected as the most significant point along the course of a river which alters its pattern gradually, then it is important to note that above and below this point there are contrasts in physical conditions which may be more significant than the one emphasized by Campbell—position of low water with respect to sea level. Some of these differences Campbell has touched on but without complete analysis of their possible relations to the present problem. Other differences may be worthy of consideration, sucn as those in river slope, in velocity of current, in direction and position of current as affected by tides, in proportion of salt water present, in average depth of channel and its possible relation to geologically recent coastal subsidence, and in the nature, height, and slope of the containing levees. Davis has suggested that the extreme tenacity of the mud forming the channel and banks of the Lower Mississippi may retard meandering there, while Powell earlier advanced the idea that near its mouth the silt borne by the river is too fine to serve as a corrading agency. It is possible also that the progressively more recent age of the lower and straighter portions of the river deserves more favorable consideration than Campbell has given this point, especially in view of the probability that sluggish rivers initially nearly straight require an immensely long time in which to develop their first meanders.

Need of Comparison with Other Streams

Concurrently with consideration of these elements of Mississippi physiography attention should be directed to other tidal rivers which reach the sea without passing through relatively stagnant water of a broadening estuary.[1] The examination should include streams like Maurice River in New Jersey, which meanders extensively where it traverses salt marshes; streams like the Combahee of South Carolina, which meanders through the salt marshes of its lower course and the fresh swamps farther up and in both places apparently with normal vigor, although tidal in both; streams like the Indus, where marked meanders and occasional oxbow lakes appear to exist in the lower, tidal portion, whereas the non-tidal portion immediately above (before the extensively braided section is reached) seems to have a relatively simple pattern, thus reversing the conditions found in the Mississippi case; and other variable types of meandering tidal streams. From such a study there might emerge a satisfactory explanation of the varying behavior of all such streams.

[1] While the present article was in galley proof an excellent study of this type appeared in the *Journal of Geology* for October–November, 1928, pp. 615–629, under the title "Meandering in Tidal Streams." The author, Dr. Donald C. Barton, shows that meandering with cut-offs occurs in the tidal Brazos River, Texas, and discusses a variety of conditions which may affect meandering both above and at sea level.

A Problem of Terminology

In conclusion it may be pertinent to refer briefly to a problem of terminology. Campbell proposes to apply the name "meander scar" "to any scar that marks the position of a former meander, whether it be on the upland or on the flood plain of the stream." This proposal will interest those who believe that the growth of geomorphology should be accompanied by increasing precision in the use of terms employed in the science. So far as the reviewer is aware, former positions of river meanders are seldom indicated in the topography of an upland surface, for the reason that this ancient element of the landscape has usually been too long exposed to the effacing action of weathering and erosion. Below the upland surface, more or less deeply incised in the land mass but still above the level of present flood plains, are frequently found traces of former meanders, including abandoned oxbow-shaped valleys, old cut-off meander spurs, and high-level amphitheaters open toward the valley lowland. On the present flood plain more recent meander paths are attested by oxbow lakes, crescentic marshy swales and ponds, crescent-shaped bars of sand, as well as by crescentic scarps cut in the valley wall. If the term "meander scar" is to be applied to all these features marking the positions of former meanders, then we must employ other terms to differentiate the various types of meander scars. The accompanying illustrations (Figs. 1 and 2) show a terminology, based for the most part on usages of earlier writers, which the reviewer has found serviceable.