true science, the spirit of modern science, is at war with war. The right spirit of science is that of patient inquiry; of longing for the truth, cost what it may in brain power, energy, money or self-denial; it is the spirit of cooperation as wide as the needs of man; of constructive effort through slow accretions by many laborers in many lands through many years. "The touch of science makes the whole world kin."

Chas. Baskerville.
University of North Carolina.

DEFLECTION OF THE MISSISSIPPI.

The theoretical effects of the earth's rotation in deflecting the courses of streams have been discussed by several investigators, among whom are Baines, von Baer, Bertrand, Buff and Gilbert. The deflecting force being persistent and the time during which it acts practically unlimited, the sufficiency of the cause has been repeatedly maintained. So far, however, the discussion has been almost purely theoretical, few actual measurements of relative bank-cutting having been made. This note attempts to present certain qualitative and quantitative data that may have some bearing on the subject. The work was done at Harvard University under direction of Professor W. M. Davis.

The Mississippi River Commission published in 1900 a set of maps which record surveys of two different dates—that of 1883 and that of 1896. The former survey is printed in black, the latter in red. Thus the changes which have occurred in an interval of thirteen years are clearly and accurately recorded and make measurements possible of the relative amounts of right and left cutting.

The part of the river course so surveyed and mapped lies between Rosedale (below Helena, Ark.) and Bayou Goula Bend (below Natchez, La.). It may be divided into two distinct sections. The first lies between Rosedale and Vicksburg and is in that part of the river's course which here swings diagonally across the flood-plain from the bluffs of the Arkansas upland on the west to the bluffs of the eastern upland in Mississippi. The second is between Vicksburg and Bayou Goula Bend, along the eastern side of the flood-plain, where it is rather sharply limited by the bluffs against which the river impinges at ten different places. The two sections are roughly of the same length, when measured along the general course of the stream.

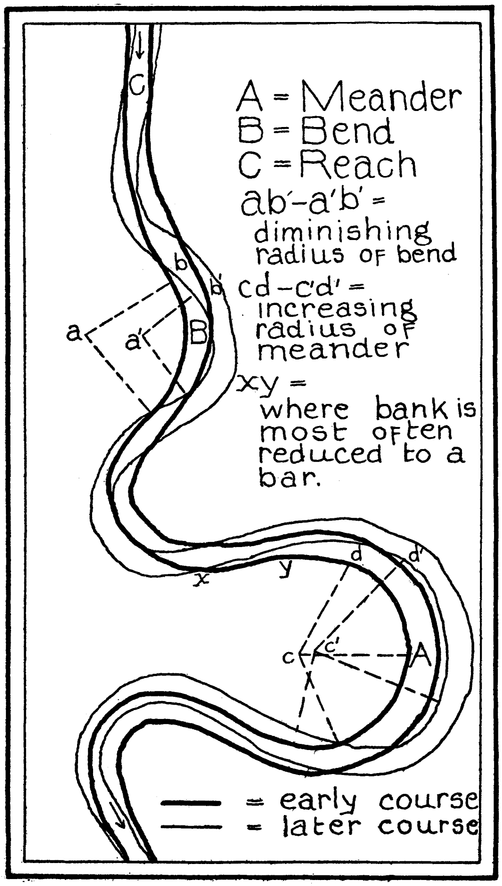

Fig. 1.

The lowermost part of the latter section—the part lying between Port Hudson and Bayou Goula Bend—has been in recent years so well defended by revetments that the course has here remained practically unchanged for thirteen years. It is above this point, in that part of the river's course which has not been so completely restrained artificially, that significant results must be looked for. Before presenting the results of my map studies, it is desirable to explain certain terms as illustrated in Fig. 1.

By 'bend' (Fig. 1, *B*) in a river channel is meant a curve whose lateral changes involve a decrease of radius; by 'meander' (Fig. 1, *A*) a curve whose lateral changes involve a steady increase of radius until a cut-off occurs or changes elsewhere in the channel induce a disturbance here. This distinction grew out of the difference in kinds and amounts of cutting at the two sets of curves. It is evident from an examination of the maps and the generalized conditions represented in Fig. 1 that as meanders develop, the relatively straight stretches in the river's course will be continuously shortened and there will be a corresponding increase in the length of that part of the course included within the meanders. As this change progresses the radius of curvature is reduced from infinity to a finite quantity, the reduction continuing until the neck is as small as any other part of the lobe. From this time on the same tendency which ultimately produces a cut-off between alternate meanders operates to the enlargement of the radius of curvature, not only throughout the meander between them, but at the place where a cut-off occurs as well. The oxbow lakes have for this reason a longer average radius of curvature than an equal number of present meanders. The reaches (Fig. 1, *C*) include those wavering parts of the river's course the further development of which can not be accurately foretold, although it can be shown that the reaches usually develop into bends and the bends grow into meanders. It is in the reaches that there is the greatest difficulty of navigation, islands and bars occurring irregularly, for, lacking a dominant tendency, the energies of the stream are not bent in a relatively permanent and definite direction which would result in a part of the channel being maintained at a somewhat constant depth, as is the case where in consequence of the development of bends and meanders, the threads of the stream pursue a less erratic course.

The following tables contain a detailed list of areas of lateral cutting expressed

TABLE I.

Classified Measurements of Areas Cut on the Right Side and on the Left Expressed in 250ths of a Sq. M. Sheets 13 to 17 Inclusive.

	Left.					Right.				
	Bank.	Bar.	Isl'd.	Bank-bar.	Sub-T.	Bank.	Bar.	Isl'd.	Bank-bar.	Sub-T.
Meanders	2626	432	578	39	3675	3054	473	0	30	3131
Bends	2349	398	126	248	3121	1774	411	131	10	2326
Reaches	492	165	0	107	764	235	441	120	40	1262
Totals	5467	995	704	394	7560	5063	1325	251	80	6719
Sheets 18 to 25 Inclusive.										
Meanders	1943	490	0	90	2523	2378	73	140	102	2693
Bends	1841	453	0	114	2498	2370	189	0	244	2803
Reaches	390	211	60	183	844	1795	70	0	417	2282
Totals	4174	1154	60	387	5865	6543	332	140	763	7778
Gr. Totals (13–25)	9641	2149	764	781	13425	11606	1657	391	843	14497

TABLE II.

LENGTH AND AVERAGE WIDTH OF AREAS CUT EXPRESSED IN 50THS OF A SQ. M.

SHEETS 13 TO 17 INCLUSIVE.

	Left.				Right.			
	Length.		Av. Width.		Length.		Av. Width.	
	Bank.	Bar.	Bank.	Bar.	Bank.	Bar.	Bank.	Bar.
Meanders	212	55	112	53	226	45	98	37
Bends	197	79	106	52	183	55	86	34
Reaches	62	31	41	22	97	63	34	52
Totals	471	165	259	127	506	163	218	123
SHEETS 18 TO 25 INCLUSIVE.								
Meanders	140	50	81	45	188	11	91	11
Bends	235	55	98	43	226	35	156	39
Reaches	104	26	37	25	155	16	83	7
Totals	479	131	216	113	569	62	330	57
Gr. Totals (13–25)	950	296	475	240	1075	225	548	180

in two-hundred-and-fiftieths of a square mile and classified with respect to reaches, bends and meanders in the two sections of the river.

The first column of Table I. gives the amount of bank cutting; the second column the amount of bar cutting. Island cutting is counted right or left, as the island lies on the right or left side of the line of deepest channel. The fourth column gives the amount of cutting involved in changing a bank to a bar. This measurement is necessarily somewhat indefinite. The sub-totals in column five allow easy comparison of cutting in meanders, bends and reaches. The totals, on the other hand, furnish means for rougher comparison, although it is thought that, undifferentiated as totals must always be, it is well to examine the different sets of data separately. By a careful system of checking, the percentage of error in the measurements was found to be but little more than one per cent. Bar-cutting in every case but one is less on the side on which there is the greater bank cutting. In the more finely subdivided records from which the sub-totals in this table were made up, this fact comes out even more strongly. In the bends there is a greater area of bar removed per length of area cut or per length and area of bank removed than is removed in the meanders.

It would seem that the most significant figure in the whole table is 3,054—representing the amount of bank cutting in meanders on the right side of the river. It exceeds the corresponding figure on the left side by more than 16 per cent. It is in this part of the channel that the diverting tendency due to rotation gives its greatest support to the maximum selective influence on velocities developed here under centrifugal force. Moreover, it is in this part of the river's course that the effect of wind-waves in concealing the deflective tendency is least, but a part of a right-handed meander running at right angles to the direction of the prevailing winds. In the bends and reaches (sheets 13–17) the left-handed cutting is in excess, as if the winds here overcame the effect of the earth's rotation.

Although the Mississippi wears its channel as much on one side as on the other, this fact does not contradict the theory of deflection. The direction of flow in the Mississippi is such that any tendency to excess of right-handed over left-handed cutting may be overcome in part, in whole, or may even be exceeded by the effect of the westerlies on the surface of the stream. If the river flowed north these two forces would combine to produce an effect that might be thought to be greatly in favor of the argument for deflection. In reality it would offer no better example than the Mississippi with its present direction of flow. In the former case the operation of the force would be less visible, but the proof of the existence of the force would be no less clear.

The best examples of deflection in these latitudes must, therefore, be sought among streams flowing neither north nor south, but in the line of the winds—east or west. The deflective tendency will, of course, be as strong under the latter conditions as under the former, while the effect of the westerlies will be distributed over right-handed and left-handed curves alike. When a larger number of measurements of cutting on such streams have been made and the wind effect and deflective tendency

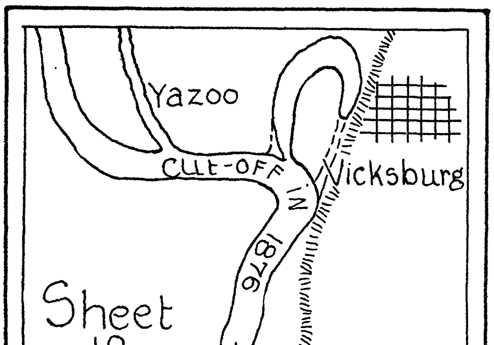

FIG. 2. The Cut-off at Vicksburg.

evaluated, it may be seen that the Mississippi offers as good proof of such tendency as any river we can find. The resolution of forces in such a manner as to produce a negative effect is no less interesting than the resolution of those same forces in producing a positive effect. A volcanic cone gradually and continuously building in mid-ocean at a rate which just counteracts the attack of the sea does not impress the geographer less than the loftier cones of similar origin more favored by position and climatic conditions.

Attention is called to the fact that between Rosedale and Vicksburg there are four cut-offs on the right and an equal number on the left side. Between Vicksburg and Bayou Goula Bend there are five on the right side and but one on the left, and that at Vicksburg, the dividing point between the two sections. This cut-off, as shown in Fig. 2, seems to have been possible only because of the direct way in which the river swings toward the bluffs from its previously free course on the open

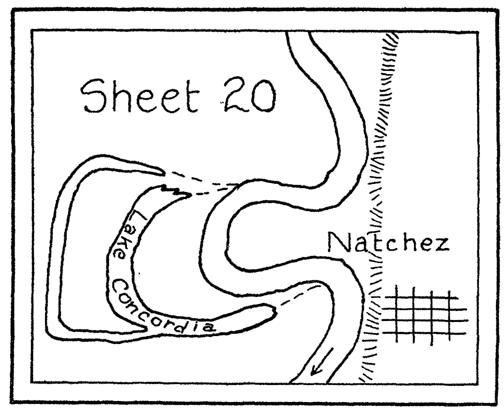

FIG. 3. The Meander and Cut-offs at Natchez showing effects of Restraints exercised by Bluffs on the Right Side of the River.

flood-plain. A bend having developed up-valley from the general course of the stream it was reasonably certain that the river, with the bluffs holding in the current on the left side, should at last pinch off the lobe and produce a cut-off; while farther down stream, where the general course of the river is close to the bluffs, cut-offs are just as certain to occur on the right side.

This restraining influence of the bluffs is brought out in the table. Below Vicksburg the right-handed cutting is notably in excess. Here the number of cut-offs is likewise in excess on the right side of the stream. A typical case of restraint may be seen at Natchez (Fig. 3), where the development of the left-handed curve is hindered while that on the right is free. As a result of these conditions and the down-valley migration of the meanders the river has twice cut through the neck of the lobe and is now increasing the radius of its present curve preparatory to a third cut-off. In stretches which have nothing but free flood-plain on both sides, a right-handed curve could not develop without an accompanying left-handed curve—a fact which can be more readily appreciated when it is remembered that, except for the down-valley movement of the meander as a whole, the center of the growing curve on the open flood-plain is relatively fixed, and the extension and development of sympathetic curves in adjacent parts of the channel are necessary attendants of the growth of the meander.

The foregoing serves to show that on the Mississippi, cut-offs as well as relative bank cutting should be counted as right or left not over the course as a whole but in sections which depend for their individuality, in part at least, upon conditions external to the river and not directly related to deflective tendency.

In conjunction with Professor M. S. W. Jefferson, of the Michigan State Normal College, the writer has undertaken measurements of this kind in Michigan along the River Rouge between its headwaters and Detroit. The river flows to the east through a plain of glacial and lacustrine origin which, on account of its level nature, offers advantages not possessed by the Mississippi. The latter stream, by cutting into a bluff, on one side, and into flood-plain deposits, on the other, does not enable one to use the maps previously mentioned in determining the absolute amount of work accomplished on the two sides of the stream. The areal expression of such cutting is no basis for the determination of the actual amount performed. The river may be doing even more work on the bluffs along its eastern bank than it accomplishes on the western bank. The River Rouge has incised itself in a level plain and in the process of deepening and widening its valley swings against bluffs of the *same* height on opposite sides of the valley.

During the summer of 1903 and in connection with hydrographic work for the U. S. Geological Survey I had the opportunity to examine most of the streams on Long Island with respect to the visible effects of deflection, and although many of the valleys on the south side of the island have a noticeably unsymmetrical development, one bank being steeper than the other, an actual count of the valleys from Montauk Point to Far Rockaway shows such a small majority of valleys asymmetrically developed and with the right bank steeper than the left, that in this case the argument based on deflective tendency does not appear well-grounded. The cuesta-like arrangement of the slopes on the island and the consequent great disparity of stream lengths, velocity and persistence throughout the year, precludes fruitful comparison of valleys on the northern and southern sides of the island as showing in how far the difference in composition of wind force and deflective tendency affects the fashioning of the valley slopes.

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SCIENTIFIC BOOKS.

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