Alluvial-River Response to Neotectonic Deformation in Louisiana and Mississippi

Abstract. *Repeat geodetic surveys show uplift of the Monroe and Wiggins anticlines in Louisiana and Mississippi. There are deformed Quaternary terraces, which indicate long-term deformation in the valleys of the alluvial rivers that cross these structures, and there are floodplain and channel convexities that provide evidence of modern deformation. In addition, the channels show significant variations of morphology (sinuosity, gradient, and depth) and behavior appropriate to reaches of increased and decreased valley slope. These alluvial rivers are adjusting to modern deformation and their adjustment confirms two geodetic leveling anomalies.*

Repeated geodetic surveys by the National Geodetic Survey reveal information about modern deformation (*1*) of the earth's surface, although one must exercise caution in interpreting these data because of possible random and systematic errors. This neotectonic deformation may be associated with earthquakes, or it may be aseismic. Rates of uplift approaching 10 mm/year have been measured in the Rio Grande Valley (*2*), and uplift rates of about 5 mm/year have been indicated by repeat surveys on the Monroe and Wiggins uplifts in Louisiana and Mississippi (Fig. 1 and 2). Although it is geologically rapid, an uplift of a few millimeters per year has not usually been considered as a factor causing alluvial-river instability or morphologic change (*3*), although slight changes of valley-floor slope are known to cause significant changes of channel pattern (*4, 5*). For example, upstream of an axis of uplift the channel gradient and valley-floor slope are reduced, whereas below the axis they are increased. Therefore, the geomorphic character of a river should reflect channel response to changed gradient due to uplift. A river can maintain its gradient with slowly increasing valley slope by an increase of sinuosity (ratio of channel length to valley length), but, if the change is more drastic, a meandering channel may braid with accompanying river metamorphosis and perhaps channel incision. In a reach of decreasing valley slope, sinuosity may decrease or the channel may braid, as a result of deposition, or multiple side channels may form an anastomosing pattern.

As an initial phase of a study of possible neotectonic influences on the lower Mississippi River (*6*), we studied the morphologic characteristics of rivers crossing the Monroe and Wiggins uplifts (Fig. 1). Repeat surveys of the National Geodetic Survey cross the southern part of the Monroe uplift and they cross the Wiggins uplift on a line between Jackson, Mississippi, and New Orleans (Fig. 2). Deformation of Tertiary strata indicates a Tertiary or Quaternary age for the structures (*7*). The repeat surveys demonstrate that both structures are active, and, in fact, the response of the alluvial rivers (*8*) that cross the uplifts provides convincing evidence of modern deformation.

The longitudinal profiles of Pleistocene and Holocene alluvial terraces (*9*), alluvial valley floors, and projected channel profiles (*10*) were plotted for streams crossing the uplifts (Fig. 3). The alluvial terraces show pronounced convexities that indicate uplift during Pleistocene and Holocene time. The modern valley floor and the projected channel profiles may also show convexities (Fig. 3b), which are evidence for modern uplift.

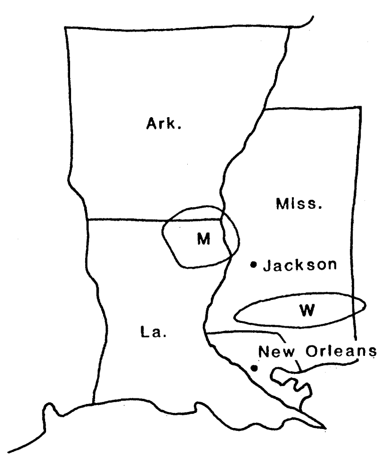

Fig. 1. Index map showing the general location of the Monroe (*M*) and Wiggins (*W*) uplifts.

Information on channel pattern (sinuosity) gradient, depth, and channel behavior were collected for five rivers crossing the Monroe uplift (Bayou Bartholomew, Boeuf River, Big Colewa Creek, Bayou Macon, and Deer Creek) and three rivers crossing the Wiggins uplift [Pearl River, Bogue Homo Creek, and Tallahala Creek (*11*)]. Big Colewa Creek provides a good example of the nature of channel response to uplift in this area (Fig. 4). Above the axis of the Monroe uplift, the reduction of valley slope and channel gradient has caused a reduction of sinuosity and an anastomosing pattern has developed; gradient and channel depth is less than that below the axis, and overbank flooding is frequent. Downstream of the axis, there is bank erosion and the channel is meandering. In a downstream direction, as the axis of the uplift is crossed, channel and valley slope, channel depth, and sinuosity increase. Big Colewa Creek has not yet incised through the axis of uplift to remove the convexity and to connect the upstream and downstream reaches, as a larger stream with higher discharge might do.

Modern uplift of the Wiggins structure is displayed by the resurveys (Fig. 2). Bogue Homo Creek is analogous to Big Colewa Creek, and it displays similar morphologic differences. Above the axis of uplift, the channel is anastomosing and the main channel is relatively straight. Immediately below the axis, the channel has incised below the former floodplain to form a low terrace and sinuosity is higher, but numerous cutoffs

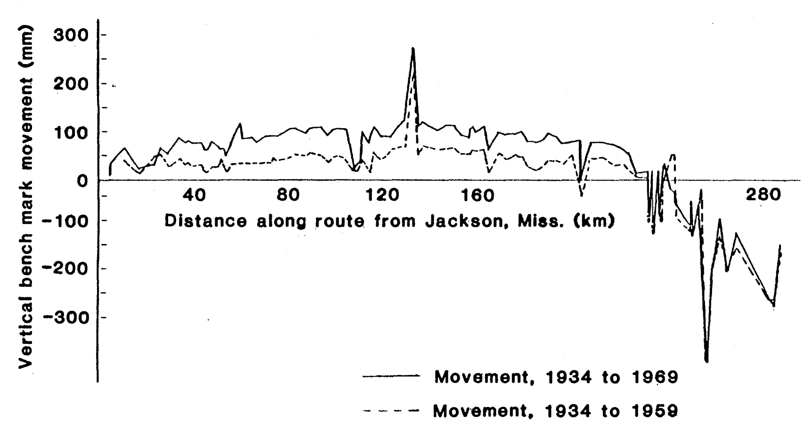

Fig. 2. Vertical bench mark movement along a National Geodetic Survey route between Jackson, Mississippi, and New Orleans, Louisiana (Fig. 1).

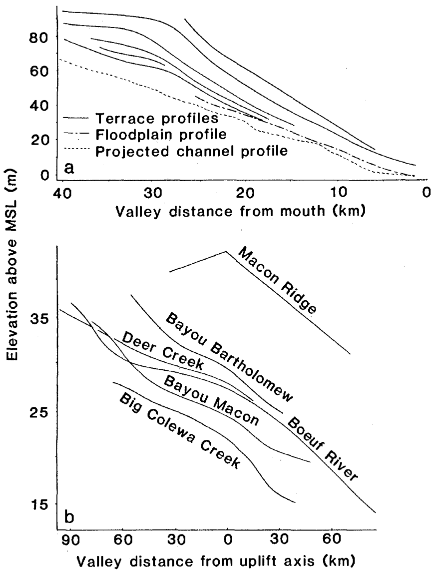

Fig. 3. (a) Longitudinal profiles of terraces, floodplain, and a projected channel profile of the Pearl River, a major river crossing the Wiggins uplift. (b) Longitudinal valley profiles of streams crossing the Monroe uplift. Macon Ridge, a remnant of a deformed Pleistocene Mississippi River terrace, is also shown; *MSL*, mean sea level.

have occurred and locally braided reaches have developed as a result of increased sediment loads resulting from incision (*12*).

A gaging station on Tallahala Creek provides evidence of channel incision at an average rate of 12 mm/year since 1940 (Fig. 5). This is three times the rate of uplift, but it is probable that the channel will adjust episodically to continuous uplift. This type of episodic river behavior has been documented by Schumm (*5*).

A factor that makes comparison of channel behavior difficult is the size or the energy of the channel. Small channels such as Big Colewa Creek and Bogue Homo Creek have been unable to keep pace and incise across the uplift axis. Streams of intermediate size such as Tallahala Creek have incised across the axis, but their long profile still shows a convexity. Large rivers such as the Pearl River (19,900 km^2) have been able to keep pace with the uplift and the projected long profile of this river is relatively straight, although terraces and the valley floor are deformed (Fig. 3a). Above the axis the Pearl River is not anastomosing, but it has developed a new floodplain below the axis of uplift and the former floodplain is now a low terrace.

Changes of channel morphology can frequently be attributed to man's activities and to the influx of water and sediment from tributaries. However, the patterns of channel change on the Monroe and Wiggins uplifts are demonstrably related to neotectonic deformation of the alluvial valley of streams crossing the uplifts.

This study reveals that, even in the "stable" central United States, alluvial rivers are presently adjusting to neotectonics, and this adjustment must be considered as an additional explanation for river instability. Furthermore, the geomorphic study provides independent support for the results of the National Geodetic Survey resurveys because river response to uplift conforms to that expected from field and experimental studies of river morphology (*3*).

The geomorphic approach discussed here should have application elsewhere, but, since other agents (hydrologic factors, sedimentologic factors, and man's activities) can produce similar river changes and since different types of channels (*13*) (braided and meandering) may have a different response, considerable care must be exercised before river channel change can be attributed to neotectonics alone.

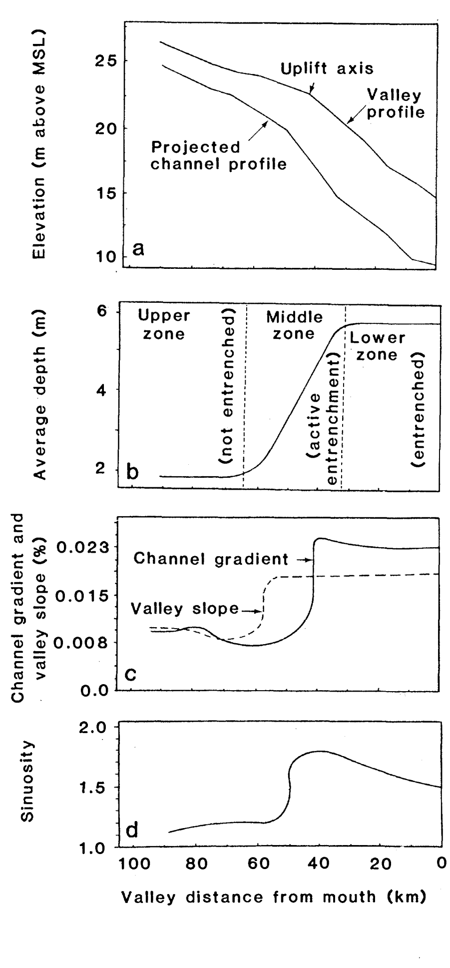

Fig. 4. Effect of uplift on Big Colewa Creek. (a) Valley and projected channel longitudinal profiles of Big Colewa Creek on the Monroe uplift. Note the increased gradient of both profiles and the increased depth of the channel below the axis of the uplift. (b) Change of the channel depth. Three reaches show different degrees of response to uplift. (c) Change of the channel gradient and the slope of the valley floor. (d) Change of sinuosity.

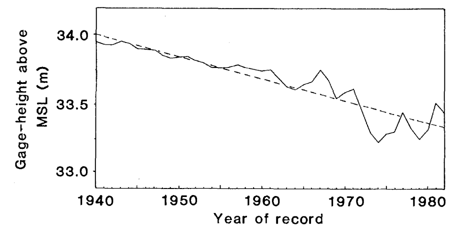

Fig. 5. Specific gage plot for the Tallahala River near Runnelstown, Mississippi. The water surface elevation was determined for a specific discharge of 78 cubic feet per second for each year of record. This discharge is the base flow and reflects a change of bed elevation; *MSL*, mean sea level.

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References and Notes

1. L. D. Brown and J. E. Oliver, *Rev. Geophys. Space Phys.* **14**, 13 (1976).
2. R. E. Reilinger and J. E. Oliver, *Geology* **4**, 583 (1976).
3. J. Adams, *ibid.* **8**, 442 (1980); D. P. Russ, *U.S. Geol. Surv. Prof. Pap. 1236* (1982), p. 95.
4. R. J. Russell, *Bull. Am. Assoc. Pet. Geol.* **23**, 1199 (1939); S. A. Schumm and H. R. Khan, *Geol. Soc. Am. Bull.* **83**, 1755 (1972).
5. S. A. Schumm, *The Fluvial System* (Wiley, New York, 1977).
6. A. W. Burnett, thesis, Colorado State University (1982); S. A. Schumm, C. C. Watson, A. W. Burnett, "Investigation of neotectonic activity within the Lower Mississippi Valley Division, Phase I" [Army Corps of Engineers, Lower Mississippi Valley Division (Vicksburg) Potamology Program, Report 2, (1982)].
7. K. K. Wang, *La. Geol. Surv. Geol. Bull.* **28**, 1 (1952); G. E. Murray, *Geology of the Atlantic and Gulf Coastal Plain* (Harper & Row, New York, 1961).
8. An alluvial river is not significantly affected by bedrock. It flows on a bed and between banks of sediment transported by fluvial processes (alluvium).
9. R. T. Saucier, *Arkansas Archaeol. Surv. Res. Ser. 6* (1970).
10. A projected channel profile is a plot of channel-bed elevation versus straight-line valley length. This kind of plot removes the effect of channel sinuosity on the long profile. Data on terrace and channel profiles were taken from U.S. Geological Survey topographic maps (7.5 minutes). The map work was supplemented by study of aerial photographs and field observations.
11. The locations of these channels are shown on the following national topographic maps (scale, 1:250,000): Hattiesburg, Miss.; Jackson, Miss.; Natchez, Miss.; Meridian, Miss.; and Shreveport, La.
12. Although man's activities have profoundly affected the channels of many areas in the southeastern United States, the uniform response of the channels and the lack of clear influence by man leads to the conclusion that the predominant influence is neotectonic.
13. S. A. Schumm, *Soc. Econ. Paleontol. Mineral. Spec. Publ. 31* (1981), p. 19.

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