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The Evolution of the Lower Missouri River: Preliminary Results of NMD Research at Lisbon Bottom

by

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ABSTRACT

The purpose of this investigation is to determine the relationship between the geomorphology of Lisbon Bottom and the spatial and temporal distribution of its wetlands. The project is focused specifically on the Quaternary geology of the river valley and the relationship between the valley's alluvial architecture and the hydrogeology of its wetlands. The Quaternary geology of the river valley has been determined through a field reconnaissance and visual inspection of topographic maps and digital elevation data. Data describing the morphology of the main channel and the physical properties of Lisbon Bottom have been collected. On the basis of these data, a preliminary model of the alluvial architecture of Lisbon Bottom has been developed, but it lacks subsurface verification owing to equipment failures and unseasonable high water. To date, the publications and presentations describing the project include a U.S. Geological Survey Open-File Report (OFR 01-176), two seminars hosted by the University of Missouri – Rolla, and an abstract that was submitted and accepted by the Geological Society of America for its annual fall meeting in November 2001.

PROJECT SUMMARY

Background

The Missouri River of the early 1800s was one of North America's most diverse and dynamic ecosystems, with abundant flood plain forests and wetlands, braided channels, chutes, sloughs, islands, sandbars, and backwaters (Laustrup and LeValley, 1998). These river and flood plain habitats were created and maintained by erosion and deposition, which continuously reshaped the channel and the flood plain (Schmudde, 1963; Funk and Robinson, 1974; Nicollet, 1993; Laustrup and LeValley, 1998). Seasonal variation in the river's flow recharged wetlands and backwater habitats in spring. It also exposed nesting habitat and provided slow and shallow aquatic habitat through late summer and fall. Since 1800, the Missouri River has been transformed into a navigation

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system regulated by reservoirs and flood control structures. These modifications have reduced seasonal flow variability and sediment load, and they have disconnected the river from backwater, off-channel, and flood plain habitats (Funk and Robinson, 1974; Interagency Floodplain Management Review Committee, 1994; Laustrup and LeValley, 1998).

Although the shape of the channel, the seasonality of flow, and the volume of sediment transported by the river have been changed significantly during the past 50 years, depositional processes are still at work in the valley that contribute to the alluvial architecture of the valley. The term "alluvial architecture" implies a predictable organization of sediment and sedimentary structures. Further, it suggests that a model can be constructed to describe or simulate the characteristics of the site. Such a model can then be used to illustrate the relationship between the geomorphology of Lisbon Bottom and the distribution of wetland habitat on its surface.

Purpose

The purpose of this investigation is to determine the relationship between the geomorphology of Lisbon Bottom and the spatial and temporal distribution of its wetlands. The results of this investigation will include a discussion of the evolution of the river, coupled with a general model of the architecture of the valley. This model will illustrate the interdependence of physical and biological processes, as well as the spatial and temporal relationship between ground and surface water along the lower Missouri River. The results of this investigation will aid in developing goals for habitat rehabilitation projects and will provide a scientific basis for future flood plain management practices along the lower Missouri River.

This project is focused on three specific questions regarding the Quaternary geology of the lower Missouri River Valley and the relationship between the geology of the valley and terrestrial habitat along the river:

(1) What is the Quaternary history of the lower Missouri River Valley?

(2) Can a general model of the lower Missouri River Valley alluvium be developed?

(3) What is the relationship between the valley's alluvial architecture and the hydrogeology of its wetlands?

Whether Pleistocene glaciers advanced into or south of the modern Missouri River Valley between Kansas City, Mo., and the confluence near St. Louis has not been satisfactorily resolved. There is evidence that ice did advance south of the modern Missouri River near present-day Kansas City, Mo. (Simms, 1975; Colgan, 1992; Kelly and Blevins, 1995). Tills mapped by Baker (1993) also suggest that ice advanced into the Missouri River Valley near present-day Miami, Mo. However, there appears to be little or no evidence that ice advanced into or south of the modern valley either between these sites or at any others along the river.

Determining the architecture of the river's alluvium and the relationship between that architecture and the hydrology of the valley's wetlands will provide a more complete understanding of the relationship between the geology of the river valley and the dynamics of its terrestrial habitats. This will lead to a more complete understanding of habitat disturbance, rehabilitation, and restoration along the lower Missouri River.

PRELIMINARY INTEPRETATIONS

The Southern Limits of Pleistocene Glaciation

A visual inspection of U.S. Geological Survey (USGS) 1:24,000-scale topographic maps and 7.5-minute digital elevation data covering the Missouri River Valley between Kansas City and Jefferson City, Mo., was completed. This inspection focused on identifying abandoned courses of the Missouri River south of the modern valley, as well as identifying remnant terraces along its tributaries. It is generally accepted that pre-Illinoian ice did advance south of the modern Missouri River near Kansas City (Simms, 1975; Colgan, 1992; Kelly and Blevins, 1995) and that ice advanced into the Missouri River Valley near present day Miami, Mo. (Baker, 1993). It is also generally accepted that glacial ice did not advance south of the modern river valley between Jefferson City, Mo., and the confluence with the Mississippi River near St. Louis (Anderson, 1979; Whitfield and others, 1993). It appears less certain that glacial ice advanced south of the modern river valley between Kansas City and Jefferson City.

If continental glaciers advanced south of the modern Missouri River, then physical evidence, such as glacial landforms, till deposits, or abandoned courses of an ice-dammed Missouri River, should still exist. Less direct evidence, such as remnant terraces indicating an ice-dammed river, may be identifiable along tributary streams. Such terraces occur near the modern confluence with the Mississippi River. There, terrace remnants along tributaries of the Missouri River in St. Louis County, Mo., are the result of ponding of the Missouri River caused by an ice dam across the Mississippi River at St. Louis (Goodfield, 1965). Similar terraces along tributary streams between Kansas City and Jefferson City should be identifiable through topographic map interpretation, digital terrain analysis, or field reconnaissance.

Whether ice advanced into or south of the modern Missouri River Valley at other sites is less certain. Several authors, beginning with Todd (1914), suggest that pre-Illinoian ice did advance south of the modern valley as far as 25 miles (Anderson, 1979; Dort, 1987; Aber, 1991; Whitfield and others, 1993; Aber, 1999). A glacial terminus south of the modern river valley between Kansas City and Jefferson City raises several questions:

(1) Had pre-Illinoian ice dammed the Missouri River, why are there no remnant diversion channels other than at Kansas City and Miami?

(2) Had pre-Illinoian ice dammed the Missouri River, why are there no remnant lake deposits as there are near St. Louis?

(3) Had pre-Illinoian ice advanced south of the modern Missouri River Valley and buried the preglacial valley, why did the river reoccupy, and presumably excavate, its former valley?

Field reconnaissance and map and digital terrain model analysis failed to identify abandoned valleys south of the modern valley. Although flow in the Missouri River during Pleistocene glacial maximums would have been low, because of upstream blockages, flow should have been sufficient to develop temporary bypass or spillway channels. Further, these investigations failed to identify other topographic features, such as stream valley reversals, which would be expected along tributary streams that presently flow north into the modern Missouri River between Kansas City and Jefferson City.

Similarly, field reconnaissance, and map and digital terrain model analysis failed to identify evidence of the development of an early Pleistocene lake occupying the modern valley between Kansas City and Jefferson City. Had the Missouri River been dammed by an advancing glacial front, a temporary lake would have formed and evidence, such as dissected terraces along tributary streams, would exist along the river as it does near St. Louis (Bretz, 1965; Goodfield, 1965).

Finally, it is difficult to explain why the river would excavate and reoccupy its preglacial valley following burial by pre-Illinoian ice. North of the modern Missouri River Valley, the entire pre-Pleistocene drainage system of North America was buried, and a new system superimposed. Along its entire length, the Missouri River delineates the southern and southwestern extent of Pleistocene glaciation. Short segments of the valley, such as areas close to the diversions near Kansas City or near Miami, were reoccupied following retreat of the ice sheet and increased postglacial flows. However, it seems unlikely that a postglacial Missouri River would have excavated its entire pre-Illinoian valley between these sites following retreat of the ice and more likely that it would have remained in and enlarged its relocated channel further south. Given the lack of topographic evidence, it is likely that the ice did not advance as far south as suggested by Anderson (1979).

It is possible that ice advanced only as far south as the modern valley and that supporting evidence, such as till or outwash deposits, was removed from the valley during high, postglacial flows. This scenario seems possible given the small till deposit exposed just north of the village of Lisbon. Its location is consistent with a southern terminus sufficient to enter the Missouri River Valley and divert the river's flow south into the North Fork of the Salt River. The deposit's proximity to the modern Missouri River makes it easy to imagine glacial outwash or postglacial floods capable of excavating a till-choked valley.

It is also possible that the ice advanced as small lobes, rather than as the continuous front suggested by most authors, and that those lobes only extended into the valley near Kansas City and Miami. Again, the location of the small till deposit exposed north of Lisbon can be used to argue the validity of this idea. Clearly, either scenario requires further and more focused study.

The Alluvial Architecture of Lisbon Bottom

From Glasgow, Mo., to the confluence near St. Louis, Mo., the meander bends of the lower Missouri River are confined by nearly vertical limestone and dolomite bluffs. In highly sinuous segments, such as the Lisbon Bottom reach, the river makes abrupt, high angle turns where the channel meets the valley wall. In an unregulated setting, deep scour holes can form where the channel meets the valley wall at high angles. Under these circumstances, the valley wall deflects the current, causing flow separation and the formation of a reverse-flow eddy on the upvalley side of the turn (Carey, 1969; Burge and Smith, 1999). This flow reversal can result in eddy accretion deposits, which form as the entire configuration of the channel migrates downstream. Burge and Smith (1999) note that eddy accretion deposits are one of the few remaining unstudied sedimentary deposits within confined meandering river systems.

Confined meander eddy accretion deposits have unique surface and subsurface characteristics that can be directly measured or indirectly observed. Carey (1969) identified several features that are characteristic of confined meander eddy accretion deposits:

(1) an abrupt, high-angle (90^0 to 100^0) bend in the channel owing to impingement on an erosion-resistant valley wall;

(2) a sharp point and sand bar on the inside of the bend;

(3) a powerful pressure eddy (reverse-flow) just upstream of the impingement;

(4) a suction eddy (normal-flow) on the point side of the channel just upstream of the impingement;

(5) concave topographic features upvalley of the pressure eddy; and

(6) slightly lower elevations than point bar, overbank, or levee deposits that remain low and swampy.

Carey (1969) also noted that small tributary streams that enter the valley turn and flow parallel to the valley wall along the depression formed by the eddy accretion scrolls and discharge into the eddy.

Data describing the morphology of the Missouri River, such as the sinuosity of the channel at Lisbon Bottom, the width of the channel, the width of the valley, and the angle between the main channel and the valley wall at bends near River Mile (RM) 213 and 217, were collected from digital aerial photographs and topographic maps. Table 1 summarizes several of these measurements.

Table 1. Summary of main channel and valley measurements

Characteristic	*Measurement*
Valley width	3060 meters
Channel width	370 meters
Valley : Channel	8 : 1
Sinuosity (RM 210 to RM 219)	3.3
Radius of Curvature near RM 217	800 meters
Channel width near RM 217	480 meters
Channel / Valley Wall angle near RM 217	105^0
Radius of Curvature near RM 213	740 meters
Channel width near RM 213	380 meters
Channel / Valley Wall angle near RM 213	97^0

The width of the channel and the width of the valley were measured along a line that would divide Lisbon Bottom into a northern and a southern half. The sinuosity of the Lisbon Bottom reach (Lisbon Bottom/Jamison Island "S" bend) was calculated by determining the ratio of the length of the channel around Lisbon Bottom and Jamison Island to the length of a straight line measured along the axis of the Missouri River Valley. A radius of curvature and the channel width were calculated for the northwest bend near RM 217 and the southeast bend near RM 213, using digital cartographic data and a geographic information system. The angle between the main channel and the valley wall was also measured at these two bends.

Channel profiles were collected at the apex of the northwest bend near RM 217, the apex of the southwest bend near RM 215, and the apex of the southeast bend near RM 213. The tops of rock revetments and channel control structures were exposed on the day that these profiles were collected, limiting the extent of the profiles to the engineered channel. Carey (1969) noted that the formation of eddy accretion deposits was dependent upon the channel forming an abrupt angle with the valley wall. The bend near RM 215 turns at an abrupt angle, but away from the valley wall. In addition to the bends near RM 213 and 217 (where the channel forms an abrupt angle with the valley wall), several profiles were collected at this bend to test the validity of this relationship.

Data describing the morphology of the channel were collected using a precision echosounder, an acoustic Doppler current profiler, and a bed material classifier onboard the USGS R/V Slim Funk. The short length, shallow draft vessel was designed to maneuver and collect data in most conditions along the lower Missouri River. All data collected aboard the R/V Slim Funk were georeferenced with a 12-channel differential global positioning system (DGPS) to submeter accuracy. Differential corrections were provided by an AG Trimble 132 satellite-based system.

Bathymetric data were collected using a 208 kHz Innerspace 449 echosounder equipped with an 8^0 transducer mounted in the center of the boat hull directly below the DGPS antenna. The echosounder was calibrated by patch test to account for boat draft, blanking distance, and environmental conditions that could affect the speed of sound in water. Boat pitch and heave were not compensated because they are believed to be minor under typical working conditions (Jacobson and Laustrup, 2000). The precision of the echosounder data is 3 cm. Patch test results indicate that under favorable bottom conditions the depth accuracy is approximately 7 cm.

Flow velocity data were collected with a Workhorse Rio Grande model 600 kHz Acoustic Doppler Current Profiler (ADCP), manufactured by RDI, Inc. These data were also georeferenced with DGPS data, but were collected using a separate laptop computer. The ADCP was calibrated to collect three-dimensional water velocity data in 25-cm-deep bins from the surface to the bottom. A single column of bins, called an ensemble, was collected nominally every 2.5 seconds. This resulted in an ensemble spacing that varied from approximately 2.5 to 10 m at typical boat speeds. During data collection, boat speeds were maintained below 3 knots, which resulted in a maximum ensemble spacing of approximately 3.8 m. The ADCP was internally calibrated for measured water temperature and compensated automatically for pitch and roll.

U.S. Army Corps of Engineers navigation charts were used to locate additional abrupt, high-angle bends along the lower Missouri River (similar to those near RM 213 and 217) that were not protected by rock revetments and channel control structures in order to collect channel profiles and velocity measurements at unaltered sites. Although several other bends like those near RM 213 and 217 exist, each has been modified with engineered structures.

Subsurface geophysical data will be collected using ground-penetrating radar (GPR). Several GPR surveys were planned to occur during the spring of 2001. However, equipment failures, an unseasonably wet spring, and high water during the summer of 2001 have delayed this effort. GPR surveys are scheduled for late September 2001. GPR data will be collected over potential eddy accretion deposits along the southeastern margin of Lisbon Bottom and across the facies change between eddy accretion and point bar deposits along the eastern side of the bottom.

Data describing the morphology of the Missouri River and characteristics of the surface of Lisbon Bottom suggest eddy accretions along the eastern margin of Lisbon Bottom. Geophysical data describing the subsurface may provide additional evidence of the deposits.

Presentations and Publications

A literature review was completed and published as a USGS Open-File Report (OFR 01-176). The objectives of the project and preliminary results were presented at two seminars hosted by the University of Missouri – Rolla, and an abstract was submitted and accepted by the Geological Society of America for their annual fall meeting in November 2001. The title of the abstract is “The Geology of the Lower Missouri River at Lisbon Bottom – Stratigraphy, Geomorphology, and the Rehabilitation of Flood-Plain Habitats.”

PRELIMINARY CONCLUSIONS

(1) Field reconnaissance and the analysis and interpretation of topographic maps, digital elevation data, and aerial photographs suggests that pre-Illinoian glaciers did not advance south of the modern lower Missouri River Valley except as isolated lobes near present day Kansas City and Miami, Mo.

(2) Field reconnaissance and the analysis and interpretation of the morphology of the main channel of the Missouri River at Lisbon Bottom and physical characteristics of Lisbon Bottom suggest that eddy accretion deposits may be present along the east valley wall of the bottom. Such deposits affect the geohydrology of the site and require the reinterpretation of the results of previous geohydrologic site investigations at Lisbon Bottom.

(3) Subsurface geophysical data are necessary to complete a model of the alluvial architecture of Lisbon Bottom. Geophysical surveys had been planned, but were not conducted owing to equipment failures and unseasonably high water. Surveys are scheduled for late September 2001.

(4) The publications and presentations that have been completed during the first year of the project include a USGS Open-File Report (OFR 01-176), an abstract for the annual fall meeting of the Geological Society of America, and two seminars sponsored by the Geology and Geophysics Department at the University of Missouri - Rolla. The final phase of the project will be the preparation of various abstracts, oral presentations, papers, and a case study for the NMD trends and status document.

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