Surficial Alluvium and Topography of the Overton Bottoms North Unit, Big Muddy National Fish and Wildlife Refuge in the Missouri River Valley and its Potential Influence on Environmental Management

By John Holbrook, Greg Kliem, Chima Nzewunwah, Zen Jobe, and Ron Goble

Chapter 2 of

Science to Support Adaptive Habitat Management: Overton Bottoms North Unit, Big Muddy National Fish and Wildlife Refuge, Missouri

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Contents

Figures

Tables

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Chapter 2
Surficial Alluvium and Topography of the Overton Bottoms North Unit, Big Muddy National Fish and Wildlife Refuge in the Missouri River Valley and its Potential Influence on Environmental Management

John Holbrook[1], Greg Kliem[1], Chima Nzewunwah[2], Zane Jobe[1], and Ron Goble[3]

Abstract

We mapped surficial sediments in the Overton Bottoms North Unit of the Big Muddy National Fish and Wildlife Refuge in Missouri using allostratigraphic techniques. This entailed identification of surficial features indicative of sedimentary allounits from remote-sensed data, then testing these predicted units by drilling for anticipated sediments. From the mapping we concluded that Overton Bottoms is characterized by numerous cross-cutting meander-loop allounits. Each meander-loop allounit contains a channel-fill unit and a point-bar unit, and most are dissected by numerous chute-channel-fill units.

Surficial mapping of flood-plain deposits in the Missouri River Valley provides insights into channel history, and has implications for management of environmental resources. The deposits of the Missouri River in the Overton Bottoms area record deposition from a low-sinuosity meandering system which was prone to development of numerous side-channel chutes. These side-channel chutes commonly enclosed islands, giving the channel an appearance similar to that recorded in late 19th century maps. Further, the distribution of channel-fill and point-bar units has a potentially strong effect on interaction of surface and ground water. Channel fills are characterized by up to 7 m (meters) of fine-grained low-permeability strata which can provide a substantial barrier to infiltration of surface water. The thinner and more permeable section of fine-grained deposits that tends to cap point-bar units is more conducive to communication of surface and ground waters. The areas above channel-fill units are thus better candidates for natural and engineered wetlands and are more likely to support standing water needed for wetland biota. The point-bar units will be more prone to rapid infiltration of surface waters, and will tend toward comparatively xeric species.

Introduction

The surficial alluvium of the Missouri River Valley in Overton Bottoms forms the foundation for the physical and the biological aspects of the flood-plain ecosystem. It determines the parent material within which soils form, determines the moisture retention and infiltration capacity of that soil, determines the local potential and rate of surface- and ground-water interaction, and provides the medium through which shallow ground water flows. Through these physical controls, surficial alluvium serves as an important control on habitat distributions.

The surficial alluvium is formed from the long-term channel and flood-plain processes of the Missouri River, and is thus a partial record of landforms generated and destroyed as the channel migrated across its valley. In this respect, the alluvium and the topography of the flood plain are closely related. Together, the alluvium and topography of the flood plain provide a record of recent river form and processes.

This study examines the surficial flood-plain stratigraphy of the Overton Bottoms North Unit of the Big Muddy National Fish and Wildlife Refuge (fig. 1) and evaluates its effects on biotic and physical processes at and just beneath the flood-plain surface. This chapter addresses three key questions: What is the distribution of surficial materials within the Overton Bottoms North Unit and what is its relationship to flood-plain topography? What channel processes controlled this distribution? What potential effects can surficial alluvium and topography impose upon present-day ecosystems and land management?

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The Missouri Valley and its Alluvium

The Bedrock Valley

In Kansas and Missouri, the Missouri River Valley is incised through a series of mixed carbonate and siliciclastic bedrock formations of late Paleozoic age. In the Overton Bottoms area, bedrock is dominantly Mississippian limestone. The bedrock valley floor is reported to reach maximum depths of 30–36.5 m beneath the flood-plain surface (Emmett and Jeffery, 1969).

The modern drainage of the Missouri River formed as continental ice sheets diverted north and east-flowing streams in Montana, the Dakotas, Kansas, Iowa and Missouri, allowing them to be captured by the south- and south-easterly flowing melt water system along the glacial ice front (Bluemle, 1972; Prather and others, 1998; Galloway, 2005). The present-day bedrock valley in the Overton Bottoms area is assumed to be at the position of an ice-front channel that drained the melt water from repeated southward-advancing Pleistocene ice sheets (Heim and Howe, 1963). Prior to the Pleistocene, a smaller channel with headwaters in western Missouri and eastern Kansas is thought to have passed eastward through this valley toward the modern St. Louis area (Heim and Howe, 1963). Detailed information on the early bedrock valley in the Overton Bottoms reach does not exist, but records of time and location of sediment input into the Gulf of Mexico suggest that the Missouri River likely coursed through this reach throughout Pleistocene time (Prather and others, 1998; Galloway, 2005).

The Alluvial Valley Fill

The surficial alluvium described over most of the Lower Missouri River Valley consists of medium-sand to clay-sized sediments of Holocene age, deposited over coarser sand and gravel deposits (Kelly and Blevins, 1995; Emmett and Jeffery, 1969). These coarser sand and gravel deposits are presumed to be accumulated outwash strata (Dahl, 1961), although no dates exist to confirm this through the Missouri segments of the river. Indirect evidence, however, supports this assertion. Sheets of Pleistocene wind-blown loess, presumed to have been derived from outwash deposits, flank the Missouri River

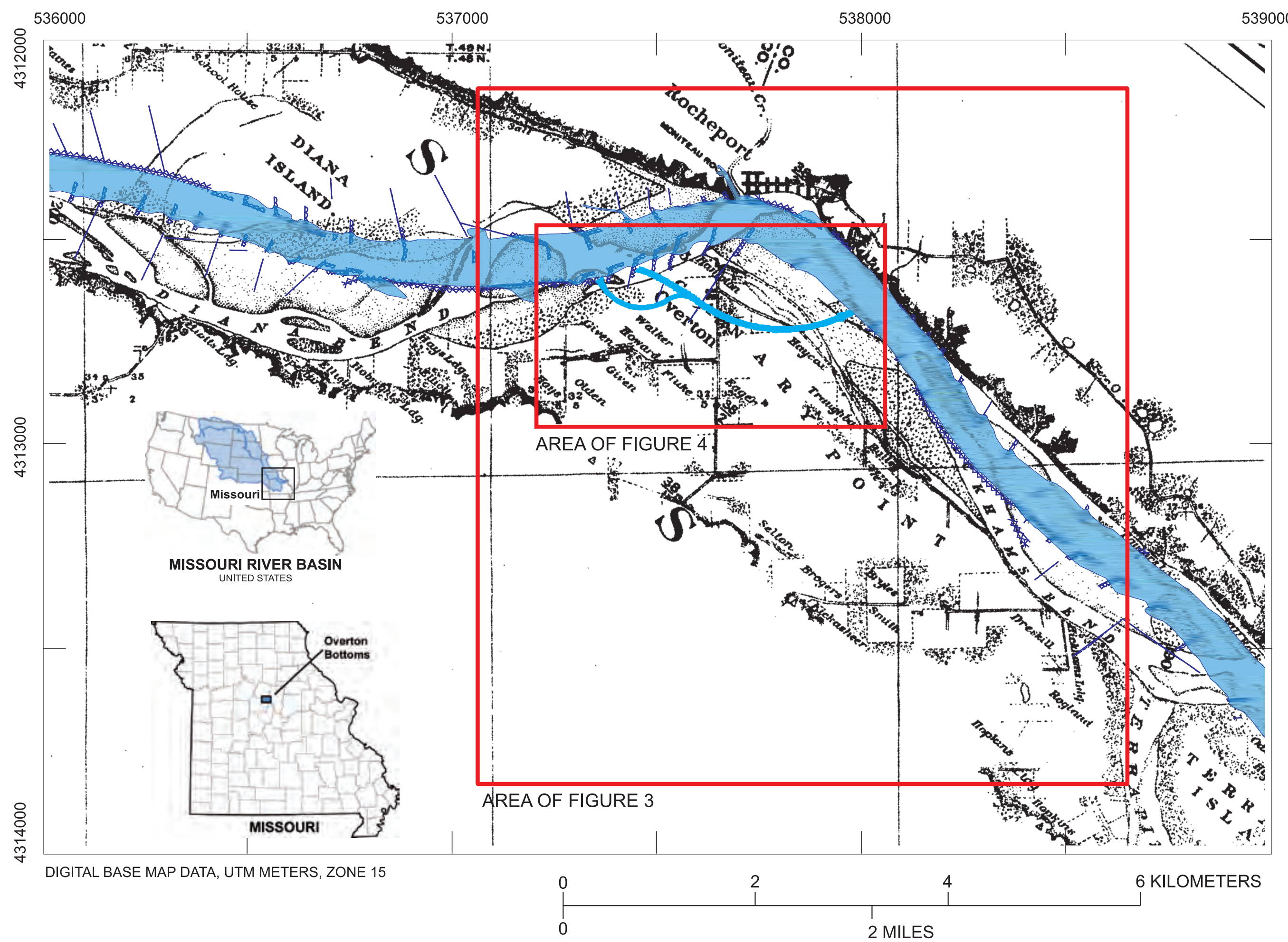

Figure 1. The modern Missouri River in the Overton Bottoms area is superimposed on an historic map of the pre-modification channel. (Modified after: Missouri River Commission, 1894)

Valley throughout Missouri, and are cited as indirect evidence that Pleistocene outwash once passed through the valley locally (Ruhe, 1983; Grimley, 2000; Forman and Pierson, 2002). Furthermore, the first confirmed channel deposits of Pleistocene age were recently mapped roughly 200 km (kilometers) upstream near the town of Carrollton, Missouri (Dolde and others, in press; Main and others, 2005). In addition, fine alluvium that is capped by Peoria Loess (Bretz, 1965) and carbon dated at approximately 25 ka (thousands of years before present; Nzewunwah, 2003) are recognized in the valley near Malta Bend, Missouri, and are presumed to record some form of Pleistocene slackwater deposition within the valley (Bretz, 1965; Nzewunwah, 2003). Together, these confirm that large Pleistocene rivers did pass down the valley and that their deposits have been preserved in places at the surface. This supports the assumption that Pleistocene outwash deposits exist beneath surficial Holocene sediments.

Holocene sediments dominate the surficial strata within the valley, indicating that river migration has been effective in eroding or covering most of the surficial Pleistocene deposits in most areas. The complete thickness of the Holocene section is unknown in most parts of the Missouri River Valley. The Holocene section, however, is at least 10 m thick, based on the maximum recorded depth of surficial channel fills (Amadi, 2004).

Surficial Holocene strata record a history of transition from a meandering river to what has traditionally been referred to as an island-braided river in a 50 km alluvial reach between Lexington, Missouri and Miami Station, Missouri, approximately 200 km upstream of Overton Bottoms (Nzewunwah, 2003; Amadi, 2004; Holbrook and others, 2005). Deposits between approximately 3.5 ka and at least 5.0 ka within this alluvial part of the valley were deposited within a single-channel high-sinuosity meandering river system (Holbrook and others, 2005). Starting somewhat abruptly at 3.5 ka, the river here began to take on a more island-rich form. By approximately 1.5 ka, the river had adapted the dominantly island-braided appearance known to be typical of the historic pre-modification channel (fig. 1). Variation of the channel patterns over time in narrow, bedrock-confined reaches like that at Overton Bottoms is unknown, and is the subject of current research.

Methods

We mapped surficial strata in the Overton Bottoms during two field seasons using allostratigraphic techniques. Allostratigraphy defines allounits (map units) based on recognition and delineation of their bounding discontinuities (for example, erosional contacts, or traceable soil horizons; NACSN, 1983; Jacobson and others, 2003). Examples of discontinuity-bound sedimentary bodies that may be mapped as allostratigraphic units include: ox-bow lake/channel fills, point-bar fills, natural levees, levee splays, buried alluvial deposits from a previous stage of river history, deposits underlying terraces, and a combination of such allounits.

The first step in the mapping procedure entails observation of topographic maps, aerial photographs, digital elevation models, satellite imagery, and existing soil maps for recognition of landforms characteristic of likely depositional units and landform affinities. Basic assumptions of depositional style derived from these observations are used in conjunction with established sedimentary architectural models to identify likely allostratigraphic mapping units within the valley alluvium. Construction of a series of "hypothesis maps" of allostratigraphic units follows based on the sedimentary models and landforms.

The architectural model used to define allounits in the Missouri River Valley bottom is based on Miall, 1996. Miall defines a series of seven discontinuity-bound allounits that make up the depositional elements of fluvial flood plains. These units are defined by their geometry and their fill, and include: channel fills, lateral-accretion elements, downstream macroforms, overbank fines, gravity flows, sandy bedforms, and laminated sand sheets. The most common features mappable at the 1:24,000 scale in the flood plain of a large meandering-to-braided system, such as the Missouri River, are channel fills, point-bar units that were deposited by lateral accretion, and overbank fine sediments. These units are illustrated and described in figure 2. Overbank fines were only distinguished from underlying deposits where they were consistently over 2 m thick or where splays were identified from the topography. In cases where overbank fine-sediment thickness was less than 2 m, fine sediments were not mapped separately, but were included with the underlying allounit. Adjacent channel-fill and point-bar allounits were commonly grouped into a single meander-loop allounit. A meander-loop allounit consists of the point-bar allounit combined with the channel fill of the outer bend of the point bar, and smaller channel fills which incise into the top of the point bar.

The next step in surficial mapping was to test landform-based hypotheses by sampling and describing sediments in drill holes. Allounits defined on hypothesis maps typically imply characteristic grain-size distributions and sedimentary origin. For instance, an arc-shaped swale is usually inferred to be an abandoned channel which is nearly filled. The fill is expected to have a fine-grain-size distribution dominated by silt- and clay-sized grains (fig. 2). If drilling confirms this prediction, the abandoned-channel-fill hypothesis is supported. If not, it is falsified and a new hypothesis is required. Continued hypothesis testing eventually results in a unique solution that is prepared as a final map of allounit distribution and grain-size characteristics.

Mapping during the first season focused on developing a general 1:24,000-scale map for the entire Rocheport 7.5' quadrangle (Nzewunwah and others, 2004; fig. 3). Aerial photographs were used with digital elevation models to assess areas consistent with allounit definitions. These map units were each tested by drilling using hand augers. Drilling samples were logged at 10 cm (centimeters) intervals and described for

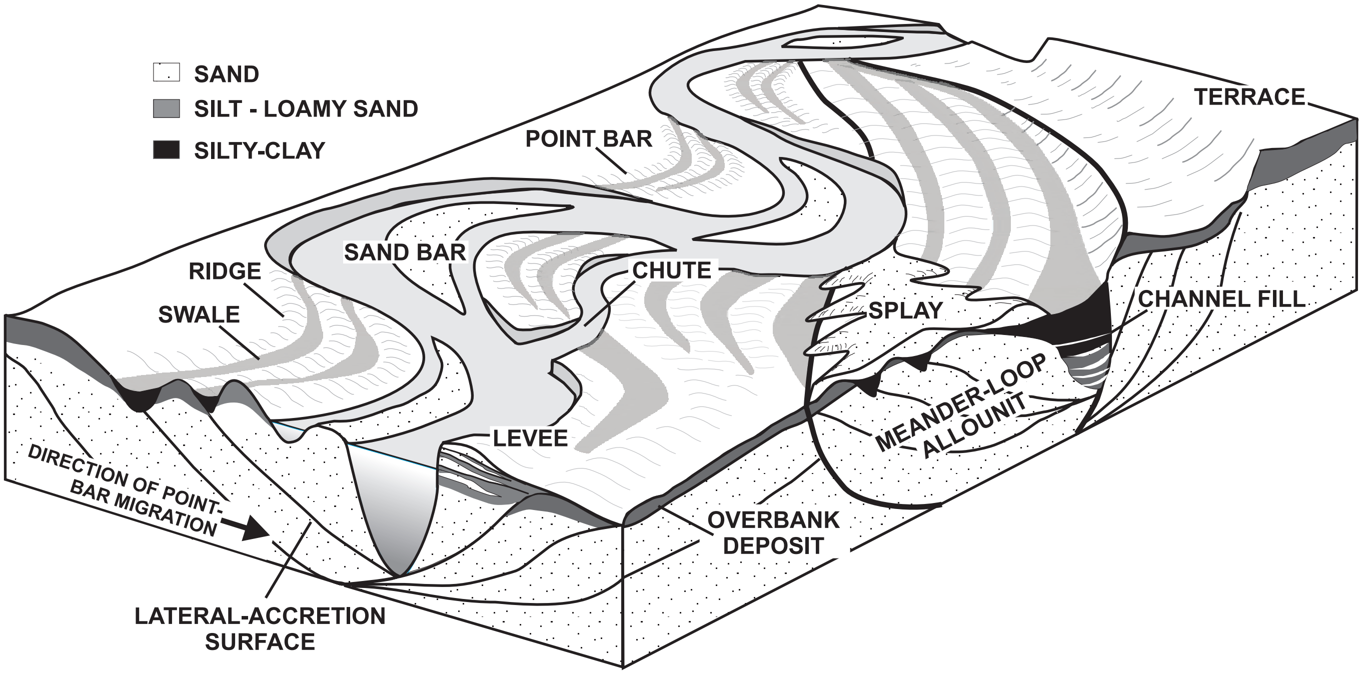

Figure 2. Architecture of the Lower Missouri River Valley bottom, after Miall (1996). Meander loops are formed by lateral migration of point bars and smaller lateral bars that are attached to the channel boundary on the inside of meander loops. Lateral migration occurs in stages, producing a series of lateral-accretion surfaces. Ridges and swales on point bars occur approximately parallel to the channel, and likely result from a combination of processes, including flow separation accompanying lateral migration during individual floods, preferential deposition in vegetation bands (McKenney and others, 1995), and erosion in overflow channels or chutes. Point bars tend to decrease in grain size upward from sand to fine gravel at the base to silt and clay at the top because shear stress of the flow decreases up the lateral accretion surface on which the bar grows. As banks are topped by floodwaters, the coarsest part of the suspended load is deposited along the channel margins forming natural levees, and the finer part of the suspended load is deposited more evenly across the point bars as clay-rich overbank mud veneers. Sand-rich parts of point bars are typically veneered by both silt-rich natural levee and clay-rich overbank deposits. Periodically, flood waters locally breach the natural levee (or engineered levees), and suspended load and bed load sediments will escape the channel and spread out onto the adjacent point bars to form a delta-type deposit known as a crevasse splay. Point bars are typically terminated on their outer bend against a channel-fill allounit, and are defined on their inner side by a sharp surface that truncates other deposits and marks a change in ridge-and-swale trend. Channel fills record sedimentation in channels that have been abandoned from the active flow by local meander-bend cut off, or shifting of the entire channel to a new location on the flood plain (avulsion). Channels will be cut off or avulse because a new location provides a steeper and more favorable course for channel flow. Flow is strongest in the abandoned channel during the early parts of the abandonment phase. Channel fills are thus generally floored with the coarse material typical of the bed load normally carried by the active river. If the channel is abandoned abruptly, and active flow does not return, the remainder of the channel will fill with clay and silt deposits in an ox-bow lake setting. If the channel is periodically reoccupied by the main channel, fill may be of any grain size carried by the river, and will alternate in grain size in direct proportion to flow strength during reoccupation. Channel fills are recognized as long arcuate-to-straight swales with widths equal to or less than the forming channel. Channels with dimensions substantially less than the full size of the modern Missouri River, as well as contemporary channel fills, are identified as chute channels. Apparent channels which follow ridge-and-swale topography, but are no wider than other swales, or include only silt and clay fill, are considered to be overbank-swale fills rather than channels.

grain size (as soil-textural class; Soil Survey Division Staff, 1993), color, oxide and salt content, and organic components. Field work during the second season was performed as a class project at the University of Texas at Arlington, and entailed construction of a detailed surficial geologic map and two cross sections depicting allounits through the central part of the Overton Bottoms North Unit area (figs. 4–6). Cross sections were constructed from 36 hand-auger drill holes, and were used as the basis for refining the surficial map of the prior year. The cross sections were oriented to provide information useful to coordinated ground-water and vegetation studies.

Four sand samples were collected during the second year for optically stimulated luminescence (OSL) dating (figs. 4–6). We collected each sample from fine sand layers in the upper part of point-bar allounits using a Missouri sampler, a device specifically designed for collecting OSL samples from drill holes within the Missouri River Valley. The Missouri sampler attaches to the bottom of the Dutch auger system, and employs a check-valve system to retain saturated sand samples within an attached opaque PVC pipe, which is driven into and then extracted from the sediment at the bottom of the auger hole.

OSL samples were processed at the University of Nebraska Luminescence Geochronology facility. Sample preparation was carried out under amber-light conditions. Samples were wet sieved to extract the 90–150 μm (micrometer) fraction, and then treated with acid to remove carbonates. Quartz and feldspar grains were extracted by flotation and treated again with acid. Samples were then resieved and the <90 μm fraction discarded to remove residual feldspar grains. The remaining etched quartz grains were mounted on 1 cm

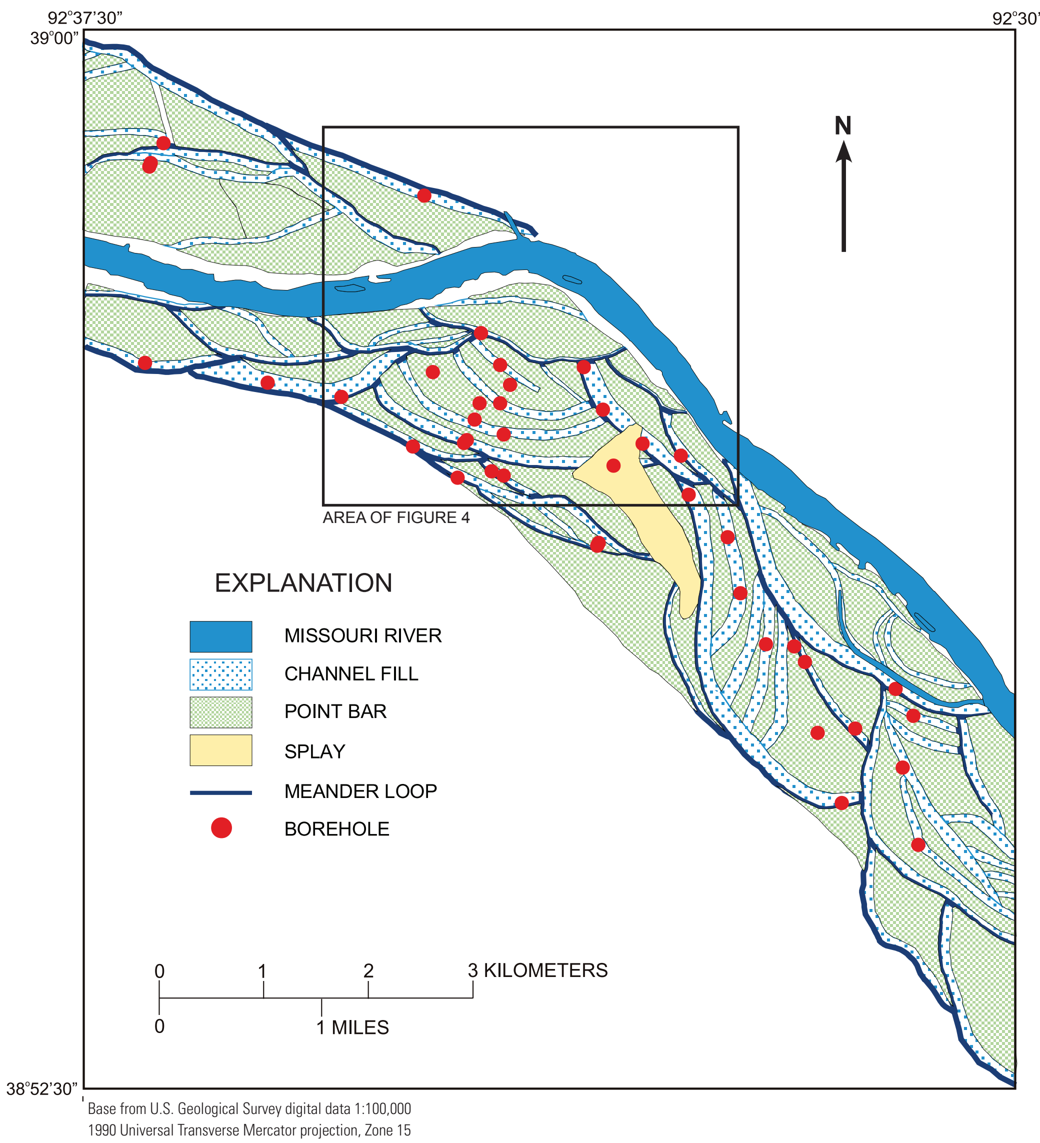

Figure 3. Surficial deposits in the Rocheport, Missouri 7.5' quadrangle. Blue linear features record channel-fill allounits, and green records point-bar allounits. Dark outlines define meander-loop allounits. (Nzewunwah and others, 2004)

aluminum disks for analysis. Chemical analyses were carried out by Chemex Labs, Inc., Sparks, NV, using a combination of Inductively Coupled Plasma Mass Spectrometry and Inductively Coupled Plasma Atomic Emission Spectrometry. Dose-rates were calculated using the method of Aitken (1998) and Adamiec and Aitken (1998). The cosmic contribution to the dose-rate was determined using the techniques of Prescott and Hutton (1994).

OSL analyses were carried out on a Riso Automated OSL Dating System Model TL/OSL-DA-15B/C,[1] equipped with blue and infrared diodes, using the Single Aliquot Regenerative Dose technique (Murray and Wintle, 2000). A preheat of 240ºC for 10 seconds was used, with a cutheat of 160ºC, based upon a preheat plateau test between 180 and 280ºC on calibration sample UNL988 (table 1). A dose-recovery test (Murray and Wintle, 2003) on another sample (UNL985) recovered 2.49±0.06 Gray (Gy, a measure of optical dose, or 1 J/kg, joules per kilogram) from an applied dose of 2.52 Gy. Thermal transfer for the same sample was 0.04±0.03 Gy. Examination of the growth curves for the samples showed the samples to be well below saturation. Optical ages were based upon a minimum of 20 aliquots. Individual aliquots were monitored for quality control and those deemed unacceptable were discarded from the data set prior to averaging.

[1] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

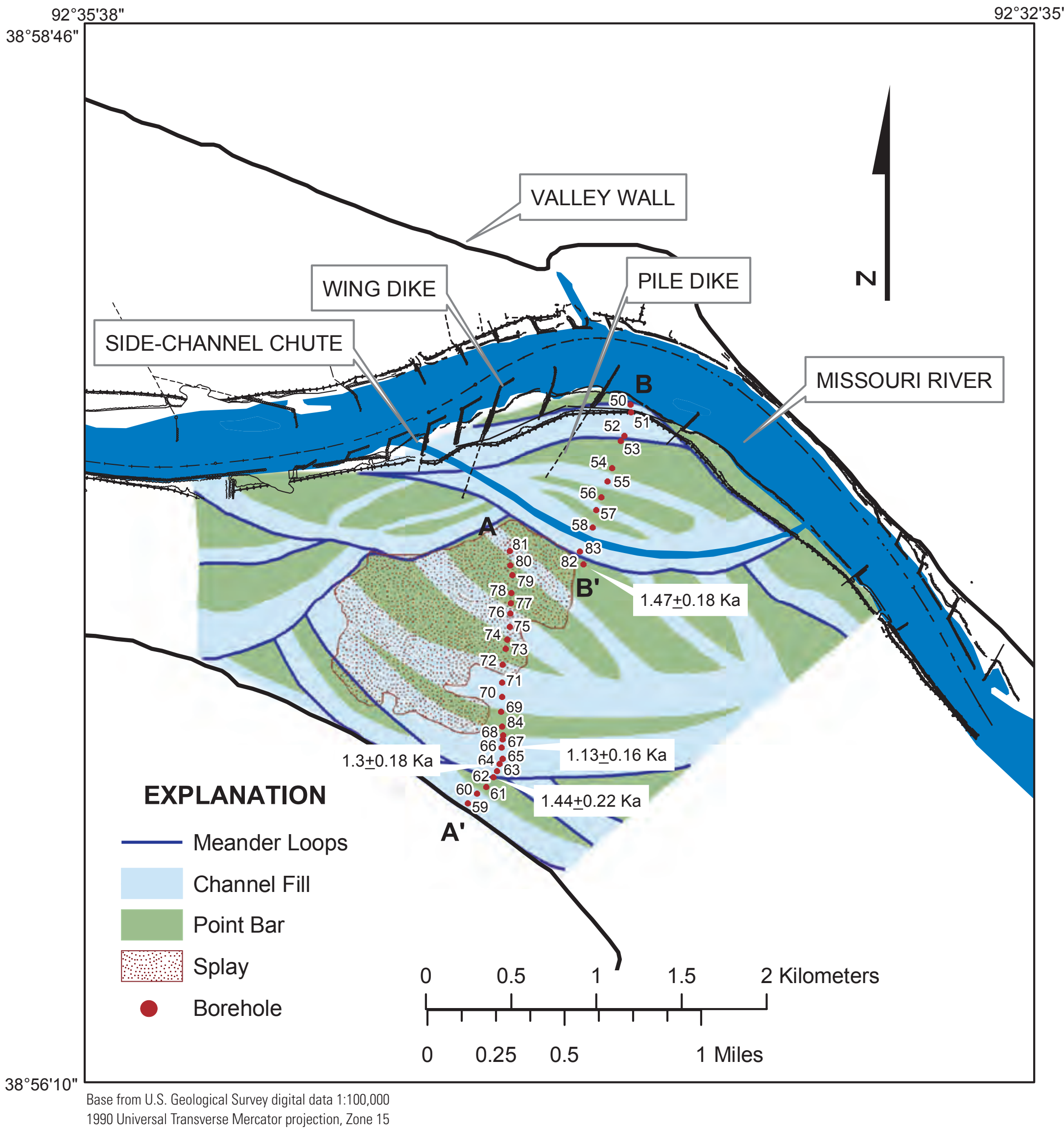

Figure 4. Overton Bottoms North Unit. Blue linear units are channel-fill allounits, and green units are point-bar allounits. Dark lines outline meander-loop allounits. Dots on the map are locations of boreholes used for this study. The location of cross sections A–A′ and B–B′ are indicated on the map by the equivalent trend of borehole locations.

Results

The generalized map (fig. 3) shows approximately 21 meander-loop allounits. Each meander loop is defined on the outside arc by a channel-fill allounit that wraps around a single point-bar allounit. The point-bar allounit typically has multiple smaller channel-fill allounits within it. These units represent fill in side-channel chutes or over-flow channels on point-bar swales. Channel-fill allounits within a point-bar allounit are typically oriented parallel to one another, but at angles to those in adjacent meander loops.

The detailed map and cross sections of Overton Bottoms North offer a higher-resolution view of the surficial stratigraphy of the area (figs. 4–6). The thickest channel-fill allounits within any meander loop are those defining the outer arc of the loop. These may be up to 7 m thick, but are usually less than 5 m. Channel fills crossing the point bar are generally thinner (< 4 m), and incise the underlying point-bar surface. Channel fills tend to comprise mixtures of fine-grained sediments, grading from loam to loamy sand at the base, to clay to silt loam in the upper parts. Most channel-fill allounits also include a definable stratigraphy with layers of contrasting and alternating grain sizes (figs. 5–7). In contrast to chute-channel fills, swale-fills are substantially thinner (< 1.5 m), and drape point bars without local incision. In many cases swale-fills grade laterally into clayey, overbank units that cap point bars.

Point-bar allounits are floored by well-sorted to slightly loamy cross-bedded fine sand (fig. 8). These units are thicker than our ability to auger and the total depth of the units is unknown. Point-bar allounits typically grade upward into loam and silt loam layers that are usually between 1–2 m thick. Silty layers are commonly capped abruptly by mud veneers composed of clay and silty clay, or layers with highly mixed textures. Thickness of these capping units is highly variable, but is typically less than 2 m, and is mostly less than 1 m. These units constitute overbank, fine deposits which were combined with point-bar allounits for mapping purposes, as they generally are of insufficient thickness and extent to warrant mapping as a separate allounits. A large splay deposit is grouped with overbank fines and is indicated by a stippled pattern on the map (fig. 4). The splay is well defined topographically and the sandy sediment associated with it is apparent in cores, however it has been mixed with finer sediment, apparently through deep plowing, and does not have clearly definable stratigraphic contacts with underlying sediments.

The detailed cross section A–A' (fig. 5) is on the south and west side of the recently excavated side-channel chute, and crosses two meander-loop allounits. The meander loop closest to the valley wall is dated at 1.4 $\pm$ 0.22 ka based on an OSL date from sand collected on the oldest preserved point-bar remnants beneath the truncating channel of a younger loop at 5 m depth in borehole 62 (table 1). The channel-fill allounit bounding this meander loop is up to 7 m thick (boreholes 59–60); it is composed mostly of loam and silt-loam sediment, with a 1 m thick unit at the base composed mostly of loam to sandy loam.

Moving toward the present-day channel, the next meander loop is bounded by a channel-fill allounit that is as much as 6 m thick (boreholes 62–67). This channel-fill allounit is dominantly loamy sediment, similar to the channel in boreholes 59–60, but it has a distinct clay unit between the loamy and sandy sediment (boreholes 62 and 63). This channel fill is separated on the surface from an adjacent and large chute-channel fill (boreholes 70–72) by a segment of point-bar allounit (boreholes 68, 84, and 69; fig. 5). The chute-channel fill is only 4 m thick; it is dominated by clay and silty clay sediment, and merges upstream and downstream with the larger channel fill penetrated by boreholes 62 and 63 (fig. 4). The point-bar allounit is crossed diagonally by two narrow chute channels (fig. 5) of no more than 4 m thickness each that are dominated by sandy-loam sediments. The youngest part of this meander loop is dated in boreholes 64 and 66 at 1.13 $\pm$ 0.16 ka and 1.3 $\pm$ 0.18 ka, respectively (fig. 5, table 1). The oldest part of this point bar is dated in borehole 82 within cross section B–B' at 1.47 $\pm$ 0.18 ka (fig. 6, table 1). The point-bar allounits in both meander loops are capped by < 2 m of fine-grained silt-loam-to-clay overbank sediment. These capping sediments are stratified and include a layer of clay to silty clay overlain by a layer of highly mixed strata with variable grain size. A topmost muddy unit above this mixed layer, which is not sufficiently thick to be distinguished on this cross section, overlies agriculturally disturbed soil horizons, and is probably overbank sediment from floods since 1993.

Table 1. Optically stimulated luminescence results from Overton Bottoms North Unit.

[m, meters; %, percent; ppm, parts per million; Gy, optical dose in grays; ka, thousands of years; s.d., standard deviation]

Univ. of Nebraska Lincoln lab number	Univ. of Texas Arlington field number	Burial depth (m)	H_2O* content (%)	K_2O content (%)	U content (ppm)	Th content (ppm)	Cosmic dose (Gy)	Dose rate (Gy/ka)	Equivalent dose (Gy)	Recuperation (%)	Age (ka $\pm$ 2 s.d.)
UNL985	MOV OB-62	5.0	20.1	1.70	1.1	4.7	0.11	1.72±0.09	2.47±0.11	8.6	1.44±0.11
UNL986	MOV OB-64	3.7	13.0	1.87	1.3	5.2	0.13	2.06±0.09	2.67±0.11	7.5	1.30±0.09
UNL987	MOV OB-66	3.5	7.3	1.99	1.2	4.7	0.14	2.23±0.09	2.59±0.10	7.0	1.13±0.08
UNL988	MOV OB-82	3.7	6.5	1.82	1.1	4.3	0.13	2.06±0.08	3.02±0.11	4.4	1.47±0.09

* In-place moisture content

Cross section B–B' crosses the excavated side-channel chute and continues north and east across the island that was formed by chute excavation (figs. 4, 6). The excavated side-channel chute roughly follows a 6–7 m thick channel-fill allounit that marks the outer boundary of a meander loop. This channel-fill unit (boreholes 58 and 83) has a complex layered fill of clay- and loam-dominated sediment, and is contiguous with two smaller branching chute channels (boreholes 55 and 57) that cross the island. Observations in the chute walls indicate that over most of its length, the side-channel chute was excavated through the channel-fill sediments into underlying fine-to-medium point-bar sand. The two smaller contiguous chute-channel units are approximately 3–4 m thick, respectively, and coarsen downward from loam to loamy sand. The unit in borehole 57 also has a prominent clay layer.

Another channel-fill allounit is prominent on the northwest margin of the island (boreholes 50 and 51). This channel-fill unit is visible in cross section at the western end of the wall of the excavated chute (fig. 7). In the boreholes, this channel is filled by loam, but in the chute cross section it is seen to contain large amounts of silt- and clay-size sediment, illustrating the amount of spatial variability that can be seen within channel-fill allounits.

Point-bar allounits on B–B' have slightly different stratigraphy than those on cross section A–A'. The clay-rich overbank and the splay stratum capping point bars in cross section A–A' are absent from B–B'. The meander loops in cross section B–B' also cross cut the meander loops in cross section A–A', and are therefore stratigraphically younger. Presence of pile dikes that were buried in these strata and exposed during 2003 chute excavation support the idea that deposition of the sediments shown in section B–B' was still in process during channel modification of the early 1900's.

Some additional relations are apparent from these cross sections. The depth to generally well-sorted and permeable sand is highly variable across cross sections A–A' and B–B'. Up to 7 m of fine-grained strata may be encountered in channel fills, but well-sorted sand is found generally about 2 m or less above point bars. Further, some relationship between topography and allounit is apparent. Cross section A–A' was constructed near the access road, where some topographic highs have been beveled by road construction activities. The

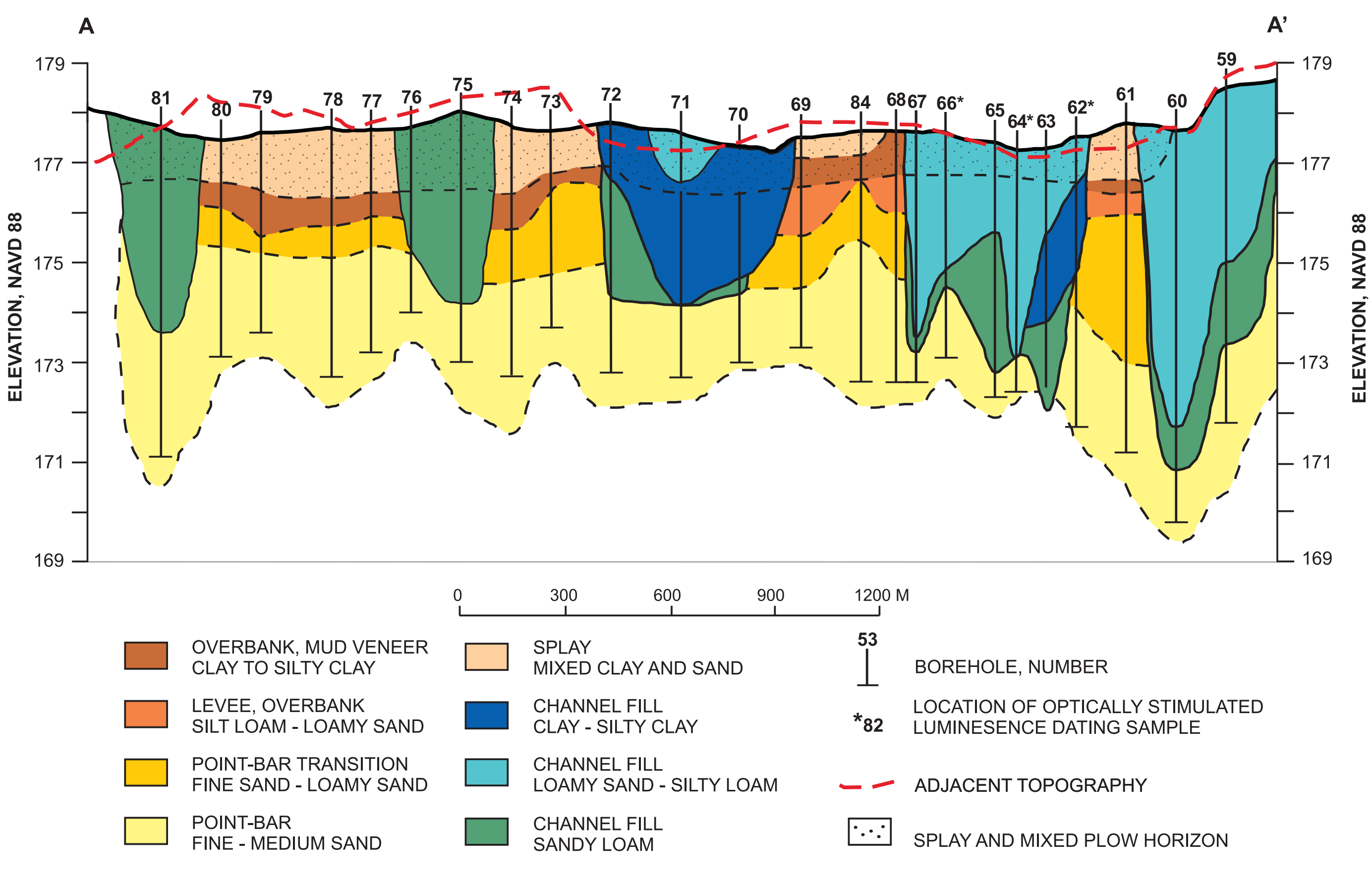

Figure 5. The cross section A–A' indicates channel-fill, point-bar, and meander-loop allounits mapped, and the grain-size and depositional environments which comprise these allounits. Mixed splay and underlying deposits are indicated with a stippled pattern that overlaps other unit designations. Splay deposits were not always clearly demarcated by contacts with underlying fine sediment, although particle size and topography indicated their presence. Sandy splay deposits from multiple deposition events were probably mixed with underlying sediments by agricultural plowing.

dotted profile on this cross section illustrates the trend of topography away from the road where the topography is more intact. This profile and the accompanying map illustrate a very subtle coincidence between channel-fill allounits and lower topography.

Depositional Model for Surficial Strata

The surficial alluvium maps and cross sections at Overton Bottoms North provide insight into a general depositional model for this part of the Lower Missouri River Valley. Meander loops record point-bar growth and lateral shift of the channel, and thereby provide fundamental insight into river mechanics. Compared to surficial geology of the Lower Mississippi River Valley (for example, Fisk, 1944), Missouri River meander loops have lower amplitudes, are less sinuous, and are dominated by channel fills with coarser sediment. Mississippi River meander loops more typically migrated until they reached a threshold amplitude, after which the channel would cut across the flood plain to leave an ox-bow lake that would fill with clayey sediment. In contrast, meander-loop geometry of the Missouri River indicates that old channels mostly were abandoned gradually as new channels were formed by subparallel chutes. This process permitted weakened flow to be maintained through old channels as flow was steadily lost to a newly forming chute. The fill of gradually abandoned channels is thus a mixture of grain sizes, reflecting the intermittent flows. Local thick clay deposits (e.g., borehole 62 and 63, cross section A–A') record intervals where a channel was temporarily blocked at the neck, and filling occurred in waters that remained still for extended periods. Channels dominantly filled by such "still water" conditions are rare and were only confirmed at two locations on the Rocheport quadrangle (fig. 3).

Dissection of point-bar allounits with numerous chute-channel-fill allounits (figs. 3, 4) indicate that a multi-channel river with many islands existed during most of the time represented by deposition of these sediments (1.47 ka). No substantial evidence for large in-channel bar formation typical of true braided rivers was found. Apparent islands record segments of previously developed point bars isolated between chute and

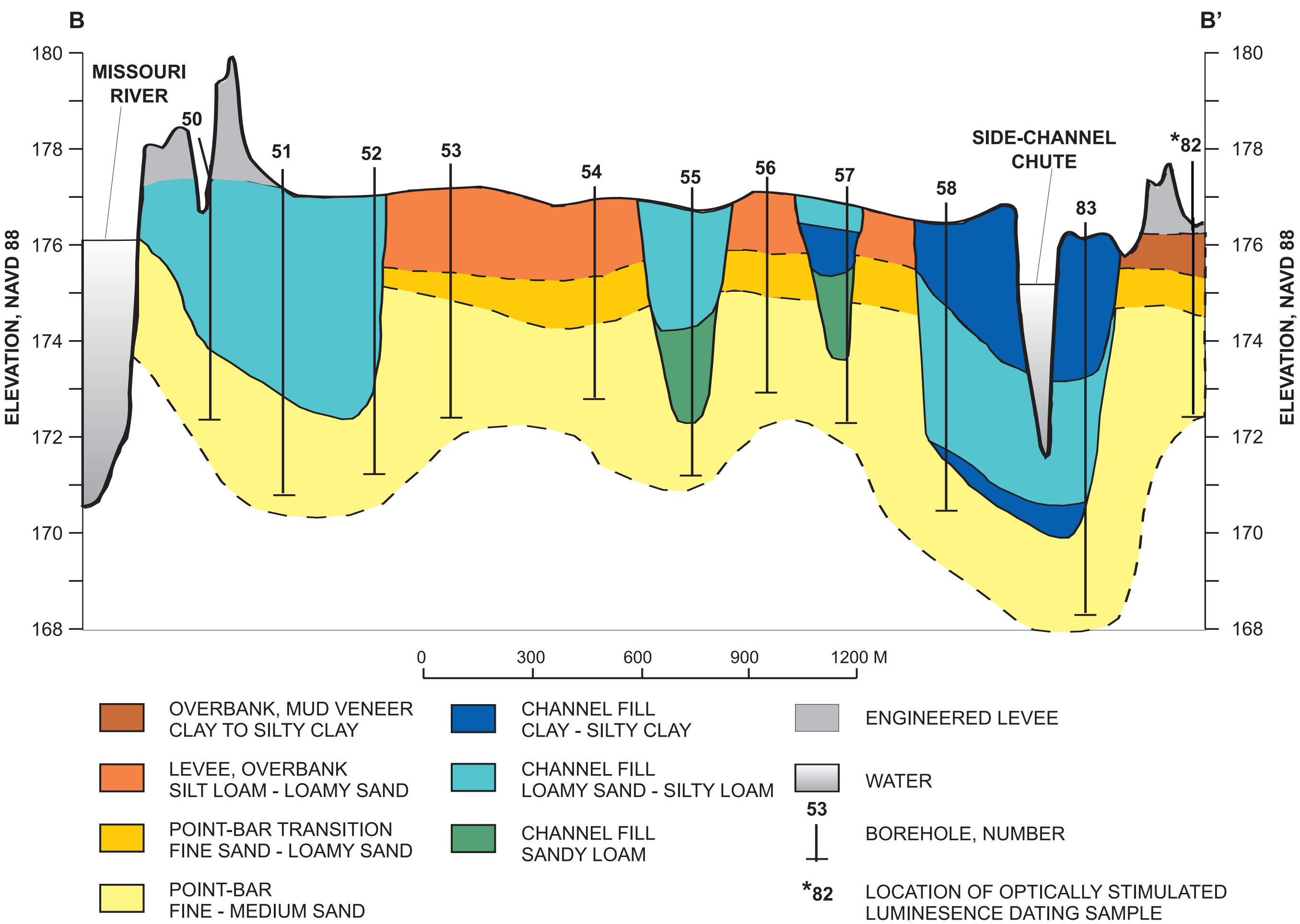

Figure 6. The cross section B–B′ indicates channel-fill, point-bar, and meander-loop allounits mapped, and the grain-size and depositional environments which comprise these allounits.

Figure 7. Cross section of a typical channel fill. This cross section was cut at the west end of the excavated chute channel and records the channel drilled in boreholes 50 and 51, cross section B–B′. Height of the bank is about 4 m.

main channels. The system in the Overton area would thus not be a true island-braided system, but would better be characterized as a meandering system with abundant islands developed by side-channel chute initiation. This multi-channel form persisted up to historical documentation in the 1800's (fig. 1). Flood-plain strata upstream near Carrollton, Missouri reveal a similar multi-channel form at that location that dates back to about 1.5 ka (Holbrook and others, 2005). However, older surficial alluvial deposits near Carrollton reveal varying dominance of a single-thread channel form prior to 1.5 ka. Whether the river near Overton Bottoms had a single-thread pattern prior to 1.5 ka as well cannot be resolved because previous alluvial deposits have been eroded.

Point-bar units at Overton Bottoms North fine upward from fine-to-medium, clean, cross-bedded sand to loamy fine sand, and are covered in most places by a thin veneer of clay to silty clay of variable thickness (typically < 1.5 m). The sandy part of the fining-upward succession records active bar growth on the inside channel bend during channel migration (fig. 8). The silty interval at the top of the point-bar deposits sits directly atop this point-bar succession and records levee and overbank deposition coeval with point-bar growth. The mud veneers which cover these deposits in cross section A–A' were deposited later during overbank flooding events. It appears that the younger, mostly historical-age strata in B–B' have not experienced the extent of overbank flooding recorded by the layer of mud veneer above silty levee deposits in A–A'. This likely reflects the younger age and shorter flood history of point-bar deposits in B–B'.

The stippled unit labeled as splay sand on top of A–A' conforms with topographic expression of a large splay form, and overlaps with areas of known sand-splay deposition that resulted from the 1993 flood. Cross section boreholes did not reveal distinct contacts of sand units on overbank fines, however. This observation suggests that episodically deposited splay sand has probably been mixed with underlying fine sediment in overbank and channel-fill deposits by deep agricultural plowing.

Implications of Surficial Mapping for Environmental Management

Previous studies have described the surficial alluvium of the Missouri River Valley simply as 6–9 m of fine "top stratum" overlying as much as 25 m of sandy and gravelly bottom stratum (Emmett and Jeffery 1969; Kelly and Blevins, 1995). Our study served to differentiate units within the surficial alluvium at a finer scale of resolution. The top stratum definition includes channel-fill allounits and the upper levee, overbank, and splay parts of point-bar allounits of this study. The lower sandy parts of our point-bar allounits are part of the underlying coarse "bottom stratum," much of which is assumed to be Pleistocene outwash. The coarse and permeable bottom stratum deposits form the alluvial aquifer deposit of the Missouri River Valley.

The thickness of the top stratum is highly variable, and determined by local presence of point-bar or channel-fill allounits. Point bars have much thinner top-stratum caps whereas channel-fill allounits can be as much as 9 m thick. Where the top stratum forms a sufficient permeability barrier, and the water table impinges on its base, these finer units have the potential to confine the water table.

Areas where this top-stratum is more permeable will be areas where the alluvial aquifer can be recharged directly from the flood-plain surface. Conversely, the ability of the top stratum to slow infiltration will determine the capacity of the flood plain to retain water on the surface. The capacity of the top stratum to inhibit infiltration is largely controlled by its thickness and texture, which is in turn controlled by allounit distribution.

Generally, channel-fill allounits will be better at retaining surface water than point-bar units. Channel fills are thick accumulations of mostly low-permeability deposits; they are thick enough that they are unlikely to develop secondary permeability from desiccation cracks or animal burrows that could connect to the underlying sand deposits. In addition channel fills tend to occur in topographic depressions and have internal bedding that is concave up, thereby increasing their ability to pond water (figs. 5–7).

In comparison, point-bar allounits comprise mostly permeable sand, and have thinner deposits of low-permeability top stratum. Some of these point-bar units are capped by relatively impermeable mud-rich overbank deposits, but others are capped only by silty levee deposits that may not impede infiltration. Thin overbank mud deposits capping point-bar deposits may be breached by desiccation cracks or bioturbation processes, however, and so may not always provide the infiltration barrier expected. Mud drapes can be expected to form on point-bar accretion surfaces during slower flows that follow major flooding events (figs. 2, 8). Such mud drapes, however, will tend to be of local occurrence and their concave down orientation may not provide an effective barrier to infiltration. Point-bar units therefore are areas of enhanced recharge to the alluvial aquifer, especially where the overlying top stratum is thin, and the water table is not at the surface. Such areas do not have high potential for engineered wetlands, and they present opportunities for enhanced contamination of the aquifer in the event of chemical spills.

Because of their topographic position and low permeability, channel-fill allounits have high potential for natural wetlands and would provide good opportunities for construction of engineered wetlands. Channel-fill units tend to occupy low areas on the flood plain inherited from their origin as channels. Thick sections of impermeable deposits within channel fills can slow infiltration sufficiently to support ponding of surface water.

Flood-plain biota can be highly affected by surficial geology and its influences on distributions of water and nutrients. Because sediments in Overton Bottoms are extremely young (<1.5 ka), the texture, pH, and nutrient content of the soil will be strongly determined by the distribution of sediment parent material. Distribution of plants with strong affinities for specific soil conditions may therefore be controlled by the distribution of allounits. Perhaps more important, allounit distribution can have a strong effect on biota distribution through the

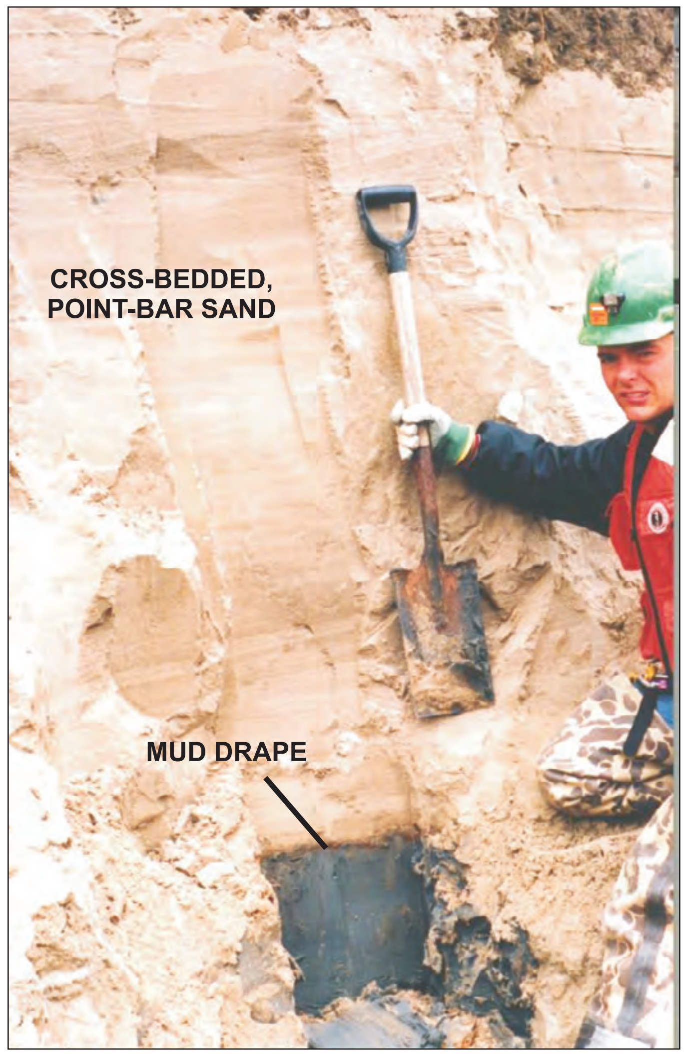

Figure 8. Point bar deposits exposed in excavated chute beneath strata of the channel fill drilled in boreholes 58 and 83, cross section B–B′. The section is of well sorted, planar cross-bedded sand, except for one thick clay drape in the lower part of the section. The location of the picture is approximately where cross section A–A′ would intersect the excavated chute, if A–A′ were extended toward the excavated chute.

effects on surficial water retention (for example, see Faust and others, this volume, chapter 5). Clearly, channel-fill allounits would be expected to retain water and enhance conditions for wetland plant species whereas point-bar allounits would be more conducive to comparatively xeric species. By extension, animals that depend on wetland habitats would also be expected to be associated with channel-fill units. The surficial geology thus strongly defines the mosaic of flood-plain habitat characteristics.

Understanding of surficial geology may also provide improved guidance for design of off-channel aquatic habitat rehabilitation projects. Channel-fill allounits indicate areas where the active river once flowed as a side-channel chute or main channel. As such, they can serve as natural design templates for new channel excavation. A three-dimensional view of channel-fill geometry would also be useful in design to either minimize or maximize ground-water connection. For example, the recently excavated side-channel chute at Overton Bottoms North Unit is excavated locally through the prior channel fill and into an underlying point-bar allounit, thereby potentially enhancing ground-water exchange between the chute and alluvial aquifer. Closer adherence to the thalweg of the old chute could have minimized connection with groundwater if this were desired. Excavation into the easily erodible sand, however, should also enhance widening and channel migration.

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