Geologic Investigation of the Middle Mississippi River

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ABSTRACT: This report is concerned with mapping the Quaternary geology of an area comprising portions of approximately ten topographic quadrangles that cover an area of the Middle Mississippi River from St. Louis, MO, on the northern boundary of the study area, to Cape Girardeau, MO, on the southern boundary (Figure 1). The entire study area is within the U.S. Army Engineer District, St. Louis, extending from river mile 50 at Cape Girardeau to river mile 189 at St. Louis.

Physiographically, the floodplain of the Middle Mississippi River is flanked by steep sedimentary bedrock uplands. At its widest point, the floodplain is no more than 19 km (12 miles) across but typically averages approximately 8 km (5 miles) in width. Throughout the valley, the Mississippi River generally flows along the base of either valley wall. The largest metropolitan area in the study area is St. Louis, MO.

The purpose of this investigation has been to (a) determine the areal distribution and physical characteristics of the various alluvial deposits, (b) reconstruct the general geologic history of the area, (c) conduct subsurface stratigraphic correlation of various geologic environments of deposition as an aid in determining foundation and underseepage conditions, and (d) determine the depth and general nature of the Paleozoic deposits beneath the Holocene alluvium to the extent possible.

For approximately the past 30 years, the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, previously the Waterways Experiment Station, has been conducting a continuing geologic investigation of the major drainage basins within the Lower Mississippi Valley and the Deltaic Plain. This study on the Middle Mississippi River is a continuation of these previous studies along the Mississippi River in support of present and future civil works programs by Corps of Engineers District Offices. In all cases, including the present study, the basic data presentation has been a standard 1:62,500-scale topographic map supplemented with the surface geology and one or more detailed geologic cross sections. These geologic maps and cross sections are presented as scanned digital images in a jpeg format. Ten quadrangles comprising this report are shown on the index map in Figure 1. Each quadrangle is accompanied by a sheet containing one or more geologic cross sections which show the distribution of depositional environments on the floodplain of the Middle Mississippi River. The number of cross sections for each quadrangle was dependent on the availability of subsurface boring information.

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Preface

The following geologic study of the Middle Mississippi River was originally performed in 1985 by the U.S. Army Engineer Waterways Experiment Station, presently U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, Engineering Geology Branch (EGB), Geotechnical and Structures Laboratory (GSL), for the U.S. Army Corps of Engineers (USACE), Lower Mississippi Valley Division, U.S. Army Engineer District, St. Louis. Geologic mapping was originally performed by Mr. Eric G. Woerner, U.S. Army Engineer District, Vicksburg, Mr. Joseph B. Dunbar, ERDC, GSL, Geology and Geophysics Branch (GGB), and the late Dr. Lawson M. Smith, former Chief, EGB. Drafting of the maps and cross sections was performed by Mr. Bennie Washington, GSL, Geotechnical and Earthquake Engineering Branch (GEEB). This work was never finalized or published prior to this report. However, copies of the geologic maps and cross sections were submitted to the St. Louis District in 1985 in draft form for review, comments, and corrections.

Recent work in the Middle Mississippi River Valley by Ms. Eileen Glynn, GSL, GEEB, and Ms. Evelyn Villanueva, GSL, EGB, to support USACE Technologies and Operational Innovations for Urban Watershed Networks research led efforts to finalize this work and publish the engineering geology maps and cross sections in a digital format. Engineering geology maps were scanned by Ms. Glynn in 2002. Cross sections associated with each geologic map were scanned by Ms. Villanueva in 2002. Geologic maps and cross sections were then digitally formatted and edited by Mr. Dunbar. The original report to accompany the maps and cross sections was finalized by Mr. Dunbar and Ms. Villanueva. Engineering geologic maps and cross sections are presented as a series of scanned maps bearing the name of the 7-1/2-min quadrangle map located in the northwest corner of the 15-min map. The final report was written by Messrs. Woerner and Dunbar, Ms. Villanueva, and Dr. Smith.

The following study was completed under the general supervision of Dr. Lillian Wakeley, Chief, GGB; and Dr. David Pittman, Acting Director, GSL.

Commander and Executive Director of ERDC was COL John W. Morris III, EN. Dr. James R. Houston was Director.
1 Introduction

Geographic Setting

This report is concerned with mapping the Quaternary geology of an area comprising portions of approximately 10 topographic quadrangles that cover an area of the Middle Mississippi River from St. Louis, MO, on the northern boundary of the study area, to Cape Girardeau, MO, on the southern boundary (see index map, Figure 1). Figure 1 illustrates Plates 1 through 9. The plates are shown following the figures. The entire study area is within the U.S. Army Engineer District, St. Louis, extending from river mile 50 at Cape Girardeau to river mile 189 at St. Louis.

Physiographically, the floodplain of the Middle Mississippi River is flanked by steep sedimentary bedrock uplands. At its widest point, the floodplain is no more than 19 km (12 miles) across, but it typically averages approximately 8 km (5 miles) in width. Throughout the valley, the Mississippi River generally flows along the base of either valley wall. The largest metropolitan area in the study area is St. Louis.

Purpose and Scope

The purpose of this investigation has been to (a) determine the areal distribution and physical characteristics of the various alluvial deposits, (b) reconstruct the general geologic history of the area, (c) conduct subsurface stratigraphic correlation of various geologic environments of deposition as an aid in determining foundation and underseepage conditions, and (d) determine the depth and general nature of the Paleozoic deposits beneath the Holocene alluvium to the extent possible.

For approximately the past 30 years, the U.S. Army Engineer Research Development Center (ERDC), Vicksburg, MS, formerly the Waterways Experiment Station (WES), has been conducting a continuing geologic investigation of the major drainage basins within the Lower Mississippi Valley and the Deltaic Plain. This study on the Middle Mississippi River is a continuation of these previous studies along the Mississippi River in support of present and future civil works programs by the U.S. Army Corps of Engineers (USACE) district offices. In all cases, including the present study, the basic data presentation has been a standard 1:62,500-scale topographic map supplemented with the surface geology and one
or more detailed geologic cross sections. These geologic maps and cross sections are presented as scanned digital images in a jpeg format. Ten quadrangles comprising this report are shown on the index map in Figure 1. Each quadrangle is accompanied by a sheet containing one or more geologic cross sections which show the distribution of depositional environments on the floodplain of the Middle Mississippi River. The number of cross sections for each quadrangle was dependent on the availability of subsurface boring information.
2 Methods

Mapping Procedure

The areal distribution of the Holocene environments of deposition was determined largely from NASA high altitude, color infrared aerial photography flown in September 1974 at a scale of approximately 1:64000. The mapping was supplemented with pertinent surface and subsurface data from geological publications, bulletins, and reports. In addition, boring data were obtained from the files of agencies such as the USAE District, St. Louis, the Illinois and Missouri Departments of Transportation, the Illinois Geological Survey, and several private engineering firms.

The more detailed subsurface information, generally the logs of borings drilled by the USACE, was used to construct cross sections through each of the various quadrangles and to define the surface elevation of the Paleozoic bedrock beneath the alluvium.

Data Presentation

The plates in this digital folio show the distribution of alluvial deposits in plan and in profile. The geologic mapping is presented on a 1:62500-scale topographic base map (plate designated as “a”), prepared from the most recent 7-1/2 topographic base maps, to ensure that the latest revisions would be included and were reduced to the desired mapping scale. Each base map is named according to the respective 7-1/2 topographic quadrangles which compromise each base map (Figure 1). Each depositional environment is identified by a unique color and/or pattern. Alluvial fans/colluvial aprons and natural levees are shown as a dashed and dotted overprint, respectively, in order that the underlying deposits are identified. The remaining four depositional environments are identified by a color pattern. The major swales in the point bar environment are also identified to show the trends of the meander and are mapped with a closed solid black line and a crossed pattern.

Included on the surface geologic map are elevations to the bedrock surface. Borings drilled to rock are shown with a small red dot and its accompanying elevation. A contour map was not constructed because the available data were insufficient in quantity and areal extent to accurately portray the bedrock surface.
Where boring information is sufficient, one or more cross sections have been prepared to accompany each geologic map. Each plate containing cross section(s) is designated as “b.” The principal source of data for the accompanying cross sections was obtained from the USACE, WES/ERDC, Technical Report No. 3-340, “Investigation of Underseepage Mississippi River Levees, Alton to Gale, IL” (USACE 1958).

**Mapping Limitations**

The maps and cross sections in this folio should be considered as being of a reconnaissance nature only. The aerial photo interpretation was generally not field checked, and borings were not available for many locations to substantiate many of the more uncertain interpretations. In addition, the mapping technique allows for little quality control, i.e., features of doubtful origin and/or areal extent necessarily are portrayed in the same manner as are well defined ones of unequivocal origin. Also, it should be kept in mind that the accuracy of individual contacts is affected by the scale of the map, limitations in the source data, and progressive errors that may develop during the several stages of drafting and scanning. In no case, should accuracy in plan or profile of more than 152 m (500 ft) be expected for the position of a contact, contour, or other designation.
3 Geology

Geologic Setting

Incised into the Paleozoic sediments of the Middle Mississippi Valley region, the Mississippi River has served as the principal drainage route for the interior of the middle North American continent since approximately the Late Mesozoic, or almost the last 150 million years (Mann and Thomas 1968). The Mississippi River since this time has been transporting and depositing seaward the products of a continuing cycle of mountain building and erosion that has transpired within the interior of the North American continent. The product of this never ending cycle is a thickening clastic wedge of fluvial and fluvial-deltaic sediments, separated by thick sequences of marine deposits (primarily limestones). These deposits formed in vast seas that covered the interior continent for millions of years on numerous occasions. This massive wedge of clastic sediments collectively forms the present Mississippi embayment. This embayment begins at the southern boundary of the study area near the vicinity of Cairo, IL, and extends into the Gulf of Mexico. Maximum thickness of this ever growing sedimentary sequence occurs along the coast of Louisiana, with a thickness in excess of several miles (Fisk 1944).

The Paleozoic sediments in the study area, which underlie the alluvium and are exposed along the abrupt upland escarpment, range primarily in age from Ordovician through Mississippian (McCracken 1961 and Willman et al. 1967). These sediments consist largely of sandstones, shales, and limestones (Figure 2). Pleistocene glacial outwash and Holocene fluvial deposits lie unconformably on these Paleozoic sediments in a narrow entrenched valley. The average elevation of this downcut valley along its axis typically varies from 300 ft above mean sea level (msl) at St. Louis to about 67 m (220 ft) above msl at Cape Girardeau. The average floodplain elevation typically varies from approximately 122 m (400 ft) msl at St. Louis to approximately 101 m (330 ft) at Cape Girardeau. The alluvial fill generally extends a minimum of 30.5 m (100 ft) below ground surface along the axis of the valley, and progressively becomes shallower along either valley wall where the bedrock surface is exposed.

The upland elevations vary, ranging from less than 30.5 m (100 ft) above the floodplain to more than 61 m (200 ft). The surface expression of the upland geology is a function of the geologic processes that have been active in this region for millions of years. On the Missouri side of the river, the surface generally reflects the contours of the bedrock, which may be overlain by a thin veneer of glacial till;
while on the Illinois side, the surface has been strongly influenced by Pleistocene glaciation. On the Illinois side, the depth of unconsolidated materials over the bedrock surface is considerably more than the Missouri side, primarily because of the thick eolian loess deposits (Lineback 1979). Generally, the local relief disappears eastward from the bluff as the thickness of the easily erodible loessial silts diminishes. Also, diagnostic of the Illinois side is an upland surface dotted with numerous sinkholes and caverns due to the underlying soluble limestone bedrock.

**Middle Mississippi River Geology**

The oldest unconsolidated deposits filling the Middle Mississippi River Valley are generally Pleistocene glacial outwash deposits which consist of sand and gravel that primarily grade upward into silty sands (Figure 2). These sand rich substratum deposits were formed by numerous and shallow, swiftly flowing, braided streams which were carrying large volumes of coarse glacial debris following the retreat of the Pleistocene glaciers which covered much of North America. At St. Louis, these deposits have been differentiated into the Henry Formation (Smith and Smith 1984). For purposes of this study, the outwash deposits are undifferentiated because of the lack of detailed boring data. Outwash plain deposits are present at surface on the Cape Girardeau Quadrangle (Figure 3).

Overlying the outwash deposits and included with the wedge of substratum deposits are the basal or coarse-grained deposits associated with a meandering Mississippi River. The shift from a braided system to a meandering system on the Middle Mississippi River occurred sometime around 6,000 years before the present (Saucier 1974). Because of similarities in texture, sediment reworking, and depositional modes, it is difficult to differentiate between coarse-grained outwash plain deposits and substratum sands and gravels associated with a meandering fluvial system.

The present floodplain of the Middle Mississippi River represents deposition since the change occurred from a braided to a meandering system, the time interval roughly corresponding to the Holocene. Overlying the generally coarse-grained substratum deposits are a thin, discontinuous veneer of fine-grained deposits which forms the top stratum. Top stratum deposits are mainly composed of point bar and chutes and bars. Together, these two environments account for nearly 90 percent of the floodplain’s surface. A general discussion of each environment contained within the top stratum of the Middle Mississippi River Valley is presented in the next section of this report.

The primary difference between the point bar and the chutes and bars depositional environments is a very thin or absent top stratum associated with chutes and bars. Top stratum, where present in the chutes and bars environment, generally has an ephemeral character which may be stripped away under a significant flood event. However, historic flood control measures along the Middle Mississippi River have confined the river flow to a relatively permanent channel and decreased the frequency of rapid channel evolution and migration.
4 Environments of Deposition

Point Bar

Method of deposition

Point bar deposits occur on the insides of river bends as a result of meandering of the river and extend to a depth equal to the deepest portion or thalweg of the parent river. Only the uppermost, fine-grained portion is included as part of the top stratum deposits and is identified in the accompanying geologic sections. In the point bar top stratum, there are two types of deposits: silty and sandy elongate bar deposits or “ridges” which are formed during high stages on the stream, and silty and clayey deposits in arcuate depressions or “swales” which are filled with fine-grained deposits during falling river stages. The ridges and swales form an alternating series, the configuration of which conforms to the curvature of the migrating channel and indicates the direction and extent of meandering.

Occurrence and characteristics

Point bar deposits are by far the predominant depositional environment on the floodplain of the Middle Mississippi River (Figure 4). These deposits were formed by continued lateral migration of the Mississippi River within its narrow steep-walled, bedrock valley.

Point bar top stratum deposits consist of tan to gray clayey silts, silts, and silty sands in the ridges; and soft, gray silty and sandy clays in the swales. The top stratum thickness of the point bar deposits varies from 1.5 to 7.6 m (5 to 25 ft). Both water and organic contents are relatively high in the swale deposits, while they are generally low in the ridge deposits.
Chutes and Bars

Method of deposition

The chutes and bars environment is formed in a similar manner to the point bar deposits, except that the surface frequently experiences inundation by floodwaters of relatively high velocity, which may cause considerable scour and deposition locally. As a result, chutes and bars typically have a less developed top stratum than the point bar. In addition, chutes and bars often contain a thin, temporary veneer of natural levee.

Occurrence and characteristics

Chutes and bars are the second major depositional environment characteristic of the Middle Mississippi River (Figure 5). The resulting deposit usually grades upward from sand and gravel at the base to a highly irregular top stratum of silty sand ridges and moderately deep silty clay and clay-filled chutes. The fine-grained filled chutes are laterally variable, extending from several hundred to several thousand meters (feet) in width, and may be of considerable thickness, but typically range from 6 to 9 m (20 to 30 ft). The chutes display water contents and soil consistency characteristics similar to those of abandoned channels while the sand ridges are similar to those of the point bar deposit.

Natural Levee

Method of deposition

Natural levees are low, wedge-shaped ridges that border one or both sides of a river’s channel. Natural levee deposits are formed when the river periodically overtops its banks and deposits its sediment onto the surrounding floodplain. The natural levees are highest and coarsest nearest the channel and decrease in grain size and height away from the main channel. Small-scaled drainage channels are often located along the back slope of the levee at right angles to the trunk channel and may develop into a major crevasse channel during a significant flood event. Abandoned crevasse channels are often filled with sediments that are distinctly coarser than the remainder of the natural levee.

Occurrence and characteristics

Significant natural levee development along the Middle Mississippi River is primarily restricted to the concave or cut banks of the major abandoned channels. Other areas of natural levee development include both the point bar and chutes and bars depositional environment. However, natural levee deposits overlying the chutes and bars environment are far less developed than other environments because of the dynamic nature of sedimentation rates characteristic of chutes and bars (Figure 6). In general, natural levee deposits associated with abandoned
channels and point bars range from 1.5 to 5 m (5 to 15 ft) in thickness while those associated with chutes and bars are usually less than 1.5 m (5 ft).

Typical natural levee deposits consist of stiff to very stiff, reddish to grayish-brown sandy silts, silts, and silty clays that exhibit moderate to high degrees of oxidation. Natural water contents of natural levee soils are generally low. Organic matter is seldom present except in the form of roots.

Abandoned Channel

Method of deposition

Abandoned channels are partially or entirely filled segments of river channels formed when the river shortens its course for a more hydraulically efficient channel. They are usually characterized by open water or oxbow lakes soon after formation. Subsequently, they may become completely filled and occasionally obscured by various meander belt deposits. The abandoned segment may represent an entire loop formed by the stream cutting directly across a narrow neck of two converging arms of a loop (a neck cutoff), or it may represent a portion of a loop formed when a river occupies a large point bar swale during flood stage and abandons the outer portion of the loop (a chute cutoff). If the abandoned channel is considered to have rapidly infilled, it is mapped as chutes and bars.

Occurrence and characteristics

Abandoned channels are fairly numerous along the Middle Mississippi River’s floodplain (Figure 6). Abandoned channels are typically from 5 to 11 km (3 to 7 miles) in length, but may extend to a maximum of 18 km (11 miles) in length as in the St. Louis area. Abandoned channels are generally several thousand feet in width and usually extend to depths of 6 to 9 m (20 to 30 ft). Channels are usually deeper along the bendways.

The upper portions of the arms of the loops of neck cutoffs are normally filled with a short wedge of silty sand or fine to medium sand. The remainder or middle portions of the loops are filled with soft, gray or blue-gray clays with high water contents that are characteristic of abandoned channels. Generally, neck cutoffs contain a larger percentage of fine-grained fill than chute cutoffs. The fine-grained portion of the abandoned channel deposit along the Middle Mississippi River ranges from 3 to 6 m (10 to 20 ft).
Backswamp

Method of deposition

Backswamp deposits consist of fine-grained sediments deposited in broad, low lying, shallow basins during periods of flooding. The sediment carrying floodwater is ponded between the natural levee ridges of the main channel and older, abandoned meander belt deposits, or between natural levee ridges and the upland valley wall or upland remnants within the Middle Mississippi River Valley. Backswamp areas typically have a very low relief and a distinctive, complicated drainage pattern in which the channels alternately serve as tributaries and distributaries at different times of the annual flood cycle.

Occurrence and characteristics

Backswamp deposits are confined to a very small portion of the floodplain of the Middle Mississippi River (Figure 7). The deposits are situated at St. Louis, along the eastern valley wall, and in the vicinity of East Fountain Bluff, in the southern third of the study area.

The few boring logs available from the backswamp environment of the Middle Mississippi River’s floodplain indicate that they range in thickness from 5 to 9 m (15 to 30 ft) and consist almost entirely of clays. Soft to firm, gray to dark-gray clays and silty clays are the typical backswamp deposits. Occasional thin lenses and lamina of silt and sand may be present. Water contents are usually high but less than those of channel and swale fillings. Organic matter is common and is in the form of disseminated particles, peat layers, and occasional stumps.

Alluvial Fans and Colluvial Aprons

Method of deposition

At the base of the upland bluffs, fan-shaped deposits of coarse-grained sediments are formed by tributary streams exiting the uplands onto the Mississippi River’s floodplain. Included with alluvial fans are colluvial aprons which are slope wash deposits off the valley bluffs. Alluvial fans radiate outward onto the floodplain and have a variable shape, ranging from circular or elliptical in shape, to more linear in shape with a narrow width in comparison to its overall length. The more linear deposits reflect the greater sediment contribution from slope wash as compared to that from tributary streams or reflect the coalescing growth of numerous fans.

Occurrence and characteristics

Alluvial fans and colluvial aprons are a relatively minor deposit as compared to other depositional environments which occur in the Middle Mississippi Valley.
(Figure 8). Well developed fans and aprons are numerous along the eastern valley wall and at Fountain Bluff. In general, these deposits are predominantly composed of sandy silts with lenses of sand and silty clays. Soils from this environment are well drained (low water contents) and are moderately to highly oxidized.
References


U.S. Army Corps of Engineers. (1958). “Investigation of underseepage Mississippi River Levees, Alton to Gale, IL,” Technical Memorandum No. 3-430, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Figure 1. Index map for the distribution of alluvial deposits as illustrated in Plates 1 through 9.
Figure 2. Time scale for geologic formations exposed in the Middle Mississippi River area.
Figure 3.  Example of outwash deposits (Plate 9a)

Figure 4.  Point bar deposits in the Raddle area (Plate 5a)
Figure 5. Chutes and bars in the Altenburg area (Plate 5a)

Figure 6. An abandoned channel and natural levee deposits at Wolf Lake (Plate 7a)
Figure 7. Backswamp deposits in the Gorham area (Plate 7a)

Figure 8. An alluvial fan in the Prairie Du Rocher area (Plate 4a)
Plate 8b
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