

Geomorphology and Quaternary Geology Of the Lower Ohio River Valley: Mapping and Applications

By

William M. Andrews Jr., Steven L. Martin, Ronald C. Counts,
E. Glynn Beck, Brandon C. Nuttall, James M. Durbin,
Scott E. Waninger, John D. Lutz, and Kenneth E. Henn

Edited by M. L. Smath



Kentucky Society of Professional Geologists
And
American Institute of Professional Geologists – Kentucky Section

Guidebook for Joint Annual Fall Field Trip
October 5-7, 2006, Henderson, Ky.

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ACKNOWLEDGEMENTS

The Kentucky Society of Professional Geologists and the Kentucky Section of the American Institute for Professional Geologists would like to thank the Southeast Cement Association for their financial support toward the printing of the guide book.



The Kentucky Geological Survey Geologic Mapping Group would like to thank:

- U.S. Geological Survey STATEMAP component of the National Cooperative Geologic Mapping Program for funding;
- Wayne Newell, David Moore, Scott Lundstrom, and Shannon Mahan (U.S. Geological Survey) for geochronology analyses, field assistance, support, and encouragement;
- Personnel in the KGS Energy and Minerals, Geospatial Analysis, Water Resources, and Geologic Information Sections for assistance with KGS databases;
- The staff of the Illinois State Geological Survey for drilling, field assistance, and seismic reflection profiling;
- The staff of the Indiana Geological Survey for logging, field assistance, data sharing, and cooperation;
- The U.S. Geological Survey in Louisville, the Louisville District of the U.S. Army Corps of Engineers, the Owensboro City Engineer office, the Geotechnical Branch of the Kentucky Transportation Cabinet, and Daviess County Sand & Gravel for data contributions;
- Zhenming Wang (KGS Geohazards Section) and Dr. Ed Woolery and Bill Reid (UK Department of Earth and Environmental Sciences) for assistance with shear-wave refraction lines and processing;
- Dr. Harry Rowe (UK Department of Earth and Environmental Sciences), Bob Rathbone (UK Center for Applied Energy Research), and Alex Fogle (KGS/UK Department of Agriculture Economics) for assistance with particle-size analysis;
- The staff of the Kentucky Office of the U.S. Department of Agriculture Natural Resources Conservation Service for field assistance and support;
- ...and all the property owners for access.

The Kentucky Geological Survey Geologic Mapping Group includes:

- William M. Andrews, Jr., manager (2003 to present);
- Steven L. Martin, mapper (2003 to present);
- Ronald C. Counts, mapper (2003 to present);
- Michael L. Murphy, mapper (2005 to present);
- Mark F. Thompson, mapper (2005 to 2006);
- Matthew M. Crawford, mapper (2006 to present);
- Thomas N. Sparks, GIS specialist (2006 to present) and Digital Mapping Program co-leader (1996 to 2006);
- Scott E. Waninger, student employee (2005 to present);
- John D. Lutz, student employee (2006 to present).

The field trip leaders would like to thank:

Dr. James C. Cobb (Director, Kentucky Geological Survey); Richard Smath, Matt Crawford, Bethany Overfield, and Rick Sergeant (KGS); Dr. Michael May and Dr. Fred Siewers (WKU); Roy and Carolyn Adams (Daviess County Sand and Gravel); Morris and James Inc.; Mr. Joe Cox (Grand Eagle Coal); J & B Barbecue & Catering; Colby's Deli; the U.S. Army Corps of Engineers; and Angel Mounds State Historic Site.

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INTRODUCTION

Field Trip Goals

This field trip will review the results of recent mapping and student studies of unconsolidated sediments in Daviess and Henderson Counties in Kentucky and Spencer, Warrick, and Vanderburgh Counties in Indiana. Field trip leaders will present preliminary results of scientific investigations related to the mapping, and discuss applications and implications of the Quaternary geology of the area. Figure 1 shows the location of stops planned for this field trip.

Regional Overview

The field trip will be focused along the lower Ohio River Valley, and is in the Eastern Interior Plateaus physiographic province and Shawnee section of Fenneman (1938), which is locally subdivided into the Western Kentucky Coal Field in Kentucky (Burroughs, 1924; McFarlan, 1943) and the Wabash Lowland in Indiana (Malott, 1922). This area is characterized by low-relief bedrock uplands separated by broad alluvial valleys.

Although the area is south of the Pleistocene glacial limit (Fig. 2), the Ohio River served as a major outlet for glacial meltwater and entrained sediment during glacial stages. Heavy sedimentation in the main Ohio River Valley and along the mouths of tributaries led to impoundment and extensive deposition of slackwater sediment in the tributary valleys. The confluence of the Green River with the Ohio River is in eastern Henderson County (Fig. 1). Loess, primarily derived from the valley-bottom outwash and lacustrine deposits, mantles much of the uplands.

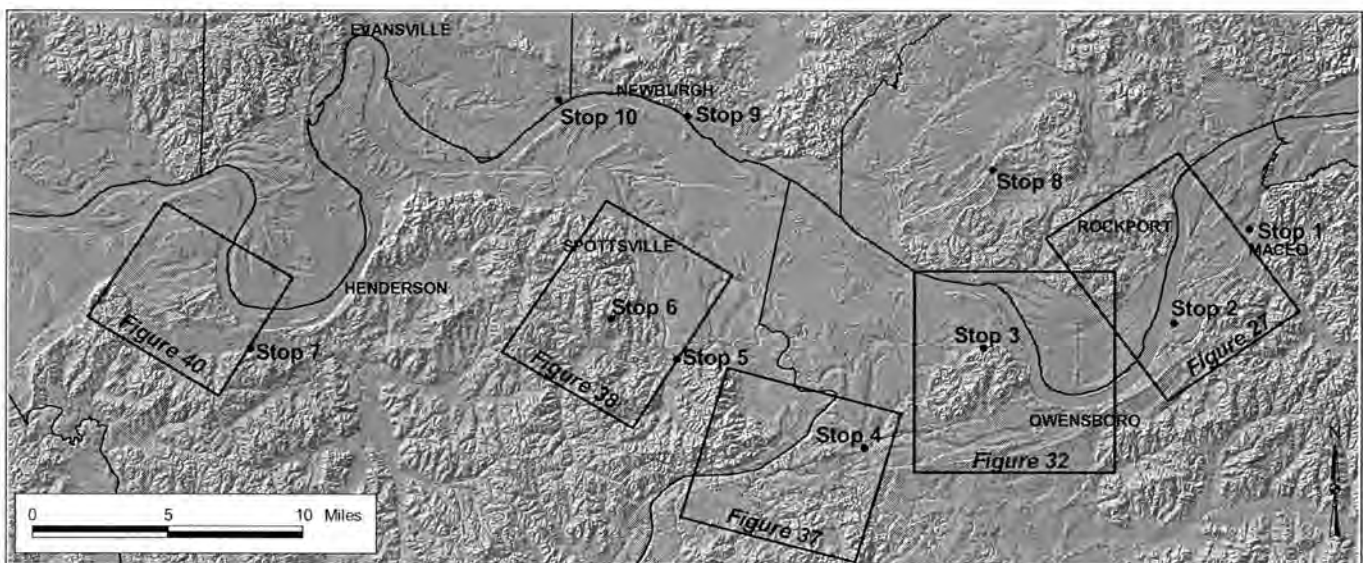


Figure 1. Shaded relief map of the field trip area, showing locations of planned field trip stops (black dots). Inset boxes show extent of indicated figures.

Figure 2. Location of field trip area (black dots) relative to Illinoian and Wisconsinan glacial limits. Alluvial valleys shown with gray shading.

The bedrock of the field trip area includes Middle Pennsylvanian sandstone, siltstone, shale, coal and limestone of the Carbondale Formation (Fig. 3). Greb and others (1992) described the geology and stratigraphy of the coal-bearing rocks in western Kentucky. The area is inside the eastern margin of the Eastern Interior (Illinois) Basin; bedrock strata dip gently to the west. The field trip area is just east of the Wabash Valley Seismic Zone and northeast of the New Madrid Seismic Zone.

Previous Studies

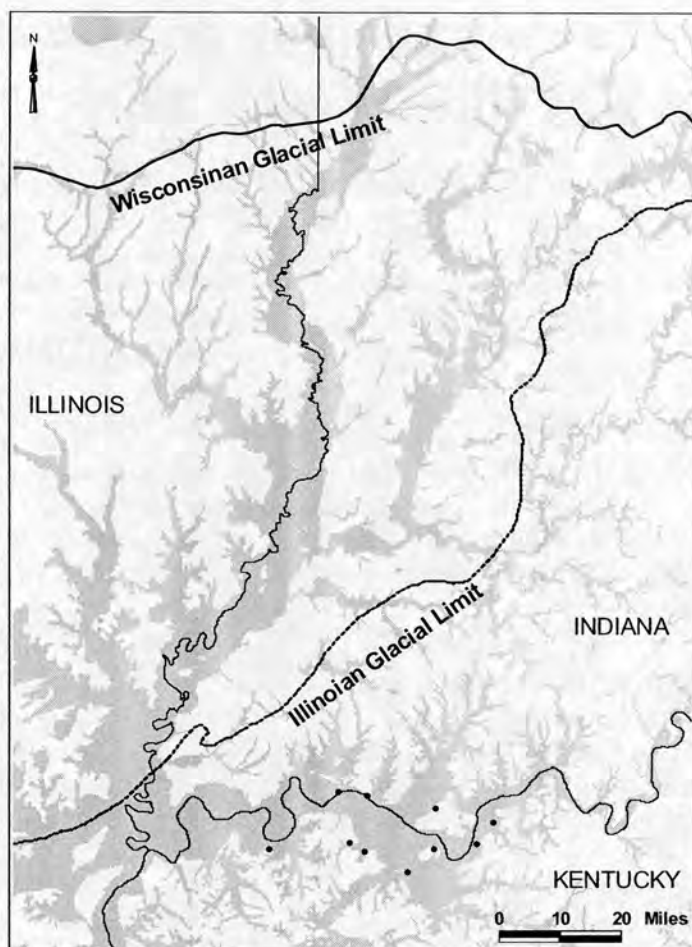
Theis (1928) mapped the geology, bedrock topography, and bedrock structures in Henderson County, Ky. He identified five strath terraces, undifferentiated Quaternary alluvium, alluvium of the recent floodplain, Wisconsinan alluvium, the Union Formation, and the “Lafayette” Formation. Theis provided hypotheses for the origins of the materials he mapped, identified potential and known economic resources, and examined engineering geology and water supply in Henderson County.

Leverett (1930) estimated the relative ages of Pleistocene glacial deposits by examining how much each deposit has been eroded, and inferred the durations of interglacial stades from these estimates. He placed the Wisconsinan glaciation from 85 to 10 ka, the Illinoian from 200 to 150 ka, and estimated Kansan and Nebraskan drift at 500 ka and 1000 ka, respectively.

Thornbury (1950) identified two lacustrine plains of Illinoian and Wisconsinan ages in southern Indiana. The Illinoian lakes developed as ice marginal lakes, and the system of Wisconsinan lakes formed when the mouths of tributary valleys were blocked by Wisconsinan outwash in the major sluiceways. Sand dunes and loess are associated with the lacustrine plains.

Wayne (1952) outlined the changes in Pleistocene drainage along the Ohio and Wabash valleys in Indiana. The Mahomet-Teays Valley system began entrenching 200 ft below its former course before becoming ponded by the Nebraskan ice lobe. As ponding continued, diversion of the drainage down the Wabash Valley began and the river began to incise the valley. The present drainages in central Indiana are the result of modifications caused by Tazewell and Cary glacial advances.

Walker (1957) described the deep channel of the Ohio River and the alluvium that fills the channel from West Virginia to the Mississippi River. The alluvial fill consists of sand and gravel and was deposited by meltwater as the Wisconsinan and Illinoian ice sheets melted. The sand and gravel deposits are overlain by finer-grained alluvium of clay, silt, and finer-grained sand.



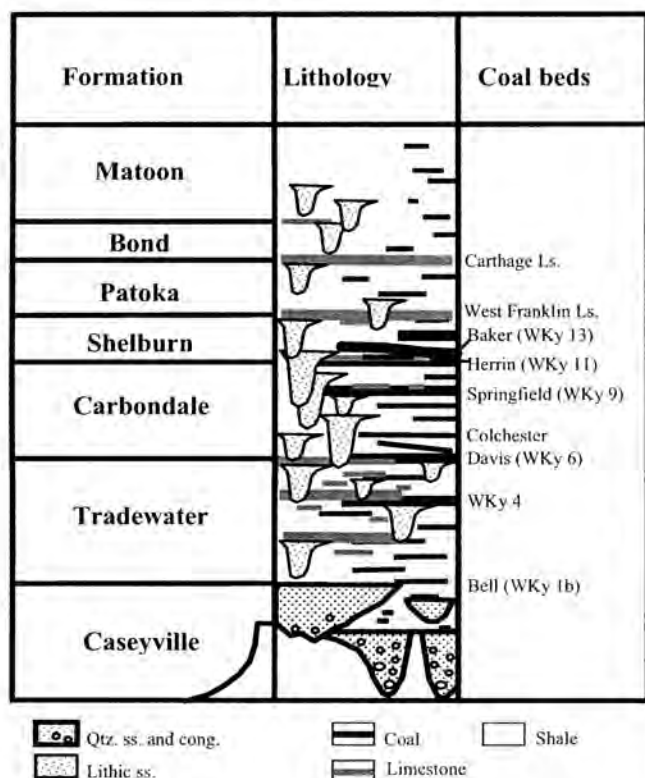


Figure 3. Stratigraphy of the Western Kentucky Coal Field, modified from Greb and others (1992).

Thornbury (1958) detailed the geomorphic chronology of the Wabash River from the Tertiary to the present. The Wabash served as a glacial sluiceway during the Kansan, Illinoian, and Wisconsinan glacial ages. He noted that the Wabash River Valley affords an excellent opportunity to examine multiple continental glaciations and delineate the glacial stratigraphy of the Pleistocene.

Ray (1963) analyzed samples of Peoria Loess to identify characteristic grain-size distributions and silt-clay ratios in zones of weathering. When compared to other grain-size analyses of loess, a uniform trend in parent material, origin, and post-depositional weathering is apparent. Silt-clay ratios are considered an important aid for regional correlations, understanding postdepositional history, and identifying local conditions at time of deposition. He noted that silt-clay ratios of the Peoria Loess differ greatly from those of the underlying leached Farmdale Loess.

Ray (1965) mapped the Quaternary geology of the Owensboro 15-minute quadrangle. He provided detailed descriptions of the Ohio River floodplain, two higher terraces, lacustrine deposits in tributaries, loess mantling the uplands, sand dunes, and Pliocene-Pleistocene upland gravel deposits. This work provided the geological foundation for the new KGS mapping program resumed in 2003.

Straw (1968) outlined the pertinent aspects of the geomorphic history, bedrock valley, and alluvial fill of the Ohio River Valley from Mauckport to Cannelton, Ind. The preglacial Ohio River in the study area comprised drainage from Otter Creek and the Salt River. The majority of the alluvial fill in the valley is Late Wisconsinan in age. The deep channel, cut in Paleozoic bedrock, is the result of several stages of incision.

Ruhe and Olson (1978) examined the loesses of southwestern Indiana in the thick loess belts bordering the Wabash and Ohio River Valleys. They fit the loesses into a stratigraphic framework with the Upper Mississippi River Basin and examined the paleosols and related soils that are associated with the loess layers. The Peoria Loess is the dominant Wisconsinan loess that mantles surrounding uplands.

Gray (1984) developed a depositional model of overbank silt deposits exposed in archeological excavations in the floodplain of the Ohio River. The linear ridges and swales that form the surface of the floodplain began as linear riverside sand and gravel bars, as indicated by cultural, stratigraphic, and morphologic context. The bars were followed by fine-grained overbank silt and fine sand deposits as prograding, elongate bars during high water. As the regime of the river changed, the ridged deposits were built up in successive subparallel sequences. The deposition of these overbank deposits appear to be from suspended load.

Fraser (1986) suggested that midchannel islands in the Ohio River are stable features that do not migrate laterally. The islands are identified as relict, late Pleistocene braid bars that impede modern river flow, not as depositional features of the modern flow regime. Over time, the islands become part of the floodplain as the river migrates laterally and the accretionary bank moves and infills around them.

Fraser and Fishbaugh (1986) examined the Ohio River Valley near Evansville, Ind., and distinguished the alluvium by grain size and stratigraphic position. They identified pre-Wisconsinan(?), Wisconsinan, and Holocene alluvium in the Ohio River Valley. Potential sand and gravel deposits are identified in the area as being only found in the valley-train sediments of Wisconsinan deposition.

Obermeier and others (1991) provided evidence for earthquake-induced liquefaction features in Holocene sediments in the Wabash Valley. The features are planar, sand-filled dikes injected upward through younger sediments when seismic shaking liquefied the sand. Using various relations, including the similarities with the 1811–1812 New Madrid earthquakes and their associated sand blows, the largest liquefaction events appear to have occurred between 7,500 and 1,500 years ago.

Wilkins and others (1991) used pollen from a lake core near Magnolia, Ky., to identify changes in vegetation, limnology, and climate since the last full-glacial interval. The late-glacial interval is marked by a transition from predominantly spruce, boreal forests to mesic deciduous woodland forests. After the Hypsithermal interval, grasses increased and there was a transition to a more open, barren environment in the area. These noticeable trends in ecological change indicate an overall warming climate.

From 1990 to 1996, the Indiana Geological Survey conducted surficial geologic mapping in the Evansville area to support seismic hazard assessment for the urban area. These maps are published as a series of open-file reports (Eggert and others, 1997a, b; Eggert and Woodfield, 1996) available through the Indiana Geological Survey.

Unthank (1997) used a two-dimensional sedimentological model to develop the estimated hydraulic properties, rate of recharge, and contributing areas of discharge for the alluvial aquifer near Owensboro, Ky.

Woodfield (1998) studied Pleistocene slackwater sediments in detail in the Little Pigeon Creek Basin and interpreted their depositional processes and sedimentary environments. She identified four megasequences and suggested that catastrophic flood deposits, from ice dam failures and morainal breaches in the Great Lakes region, are responsible for the fill in the Little Pigeon Creek Basin.

Grimley (2000) identified the relative contributions of sediments to Wisconsinan loess using magnetic susceptibility and silt and clay mineralogy. Variations in magnetic susceptibility and mineralogy represent changes in composition of outwash in valleys. These modifications indicate the fraction of glacial meltwater sediments that were derived from diverse parts of the Laurentide ice sheet.

Forman and Pierson (2002) determined the age of late Pleistocene loess deposits using infrared stimulated luminescence with single aliquot regeneration protocols. The analyses of the Peoria Loess and Roxana Silt yielded luminescence ages that coincide with corresponding carbon-14 ages. The combined luminescence and radiocarbon analysis indicate four distinct periods of loess deposition at 180–140 ka, 100–80 ka, 60–30 ka, and 25–12 ka.

Rutledge (2004) collected 7.5 km of high-resolution SH-wave seismic-reflection profiles through Quaternary sediments across the Mount Vernon Graben in southern Indiana. Forty-four imaged faults offset or deform soil horizons that are extensions of high-angle bedrock faults, confirming Quaternary displacement and reactivation of existing faults. Carbon-14 ages of displaced soil horizons suggest movement between approximately 26,000 and 42,000 ka.

Curry and Grimley (2006) cored and sampled fossiliferous lake sediment (Equality Formation) in the St. Louis Metro East area. The laminated silt and clay were deposited in response to aggradation of the Mississippi River Valley during the last glaciation. The samples were analyzed using X-ray diffraction and magnetic susceptibility, and terrestrial gastropods and wood fragments were dated by AMS radiocarbon. Analyses produced ages of 44,150 – 17,000 B.P. for the Equality Formation, where the oldest sediments are correlative with the Roxana Silt.

WESTERN KENTUCKY MAPPING

Kentucky Geological Survey Mapping Heritage

The Kentucky Geological Survey has a 170-year heritage of geologic mapping and research in western Kentucky. W.W. Mather (1838) reported the first detailed reconnaissance of Kentucky geology, and started his cross-Commonwealth journey by examining coal-mining operations near Henderson and along the lower reaches of the Green River. The First Kentucky Geological Survey (1854–60), directed by David Dale Owen, was operated from Owen's home and workshop in nearby New Harmony, Ind. (Fig. 4). The Sixth Kentucky Geological Survey (1920–32), directed by Willard Rouse Jillson, provided the first set of county-scale geologic maps, including one of Daviess County (Woodruff, 1928). During the Tenth Survey (1958–78), directed by Wallace W. Hagan, personnel of the U.S. Geological Survey completely mapped the geology of Kentucky at a scale of 1:24,000, working in close cooperation with the KGS. The effort of over 260 professionals produced 707 published geologic quadrangle maps at a total cost of \$20.9 million.



Figure 4. The home and workshop of David Dale Owen in New Harmony, Ind. Owen directed the First Kentucky Geological Survey (1854–1860) from here. Early collections of the Survey were kept in the Granary Building obscured by trees to the right. Standing on the porch is Dr. James C. Cobb, Director of the Twelfth Kentucky Geological Survey (1999–present).

Personnel of the Eleventh Kentucky Geological Survey (1978–99), directed by Don Haney, compiled extensive databases of water, coal, and petroleum information. The coal data were used in the National Coal Assessment and Coal Availability programs, again conducted cooperatively with the USGS, during the Eleventh and continuing into the Twelfth Survey (1999–present; directed by James C. Cobb). These projects focused on evaluating the remaining coal resources of the most economically significant coal beds in western Kentucky (Weisenfluh and others, 2001; Overfield and others, 2004).

The massive undertaking of digitizing all 707 published geologic quadrangle maps began in 1996 during the Eleventh Survey and also continued into the Twelfth Survey. Under the supervision of Warren Anderson and Tom Sparks, the initial digitization effort was completed in 2004. Publication of compiled 1:100,000-scale geologic maps is ongoing as of October 2006. The digital map data are becoming available via the KGS Web site. The digitized geologic map data were used to compile a series of county-scale generalized geologic maps for land-use planning (see Beck and others, 2004, for example).

KGS Quaternary Mapping Project

The original geologic mapping completed in the lower Ohio River valley focused primarily (but not exclusively) on energy and mineral production issues. The resulting maps provided very useful information on bedrock stratigraphy and the loess mantling the bedrock uplands, but for the most part did not differentiate the alluvial valley-fill sediments. Current societal needs and concerns in the field trip area include seismic hazard assessment, municipal and industrial water supplies, water quality and contaminant transport, and geotechnical and construction planning; all of these require detailed understanding of the unconsolidated materials in the area.

To address modern environmental and engineering needs, the Kentucky Geological Survey resumed geologic mapping in 2003. With funding from the USGS STATEMAP component of the National Cooperative Geologic Mapping Program, KGS personnel have been making 1:24,000-scale geologic maps of unlithified sediments, and building on the established foundation of previous geologic mapping in the area. The resulting maps improve on the quality and detail of mapped unconsolidated deposits. The mappers are distinguishing landforms using field work and examination of topographic data, and delineating associated unconsolidated geologic units based on lithologic characteristics. Stratigraphic and lithologic data are collected from profile exposures, new drilling (Fig. 5), and from existing databases of subsurface information on file at the Kentucky Geological Survey (derived from water wells, coal boreholes, and oil and gas wells) and the Kentucky Transportation Cabinet (derived from geotechnical drilling). Lithologic and other technical data are being connected to the resulting digital geologic maps, which allows for more rapid production of applied derivative maps.



Figure 5. KGS personnel extracting core during recent field work near Bluff City, Ky.

The goal of the current mapping project is to produce new Quaternary geologic maps that are more accessible to a wide range of technical (e.g., engineers, seismologists) and nontechnical (e.g., developers, land-use planners) audiences. The proximity to active seismic zones is the basis for an ongoing seismic hazard assessment in the greater Evansville area, which includes Henderson and Owensboro in Kentucky. Urban growth and development, as well as the extension of municipal water lines throughout rural areas in

Kentucky, require an expanding knowledge of the available aquifers and their hydraulic characteristics. Geotechnical, construction, and land-use planning all need accurate geologic information upon which to base project decisions, and the geologic information needs to be presented in terms familiar to the decision-maker. Continued environmental concern and regulation requires an accurate knowledge of groundwater flow characteristics related to contaminant transport and remediation. The new Quaternary geologic maps can also be used to support soil mapping and archaeological investigations. Ultimately, the new mapping will produce new ideas and a more thorough understanding of the late Pleistocene landscape evolution of lower Ohio River Valley.

Preliminary Mapping Results

The new Quaternary geologic mapping in the region has resulted in delineation of Pleistocene and Holocene landforms and associated sedimentary deposits that occur in the Ohio and Green River Valleys, along major tributaries to these rivers, and in the uplands in an area between Hawesville and Uniontown (Hancock, Daviess, Henderson, and Union Counties) in western Kentucky (Figs. 6–7). One of the early questions of the mapping project was whether landforms can be reliably used to predict the subsurface lithology of unconsolidated deposits. The mapping has found that this is generally possible, but local and significant exceptions occur, especially under the lacustrine/slackwater terrace in tributary valleys.

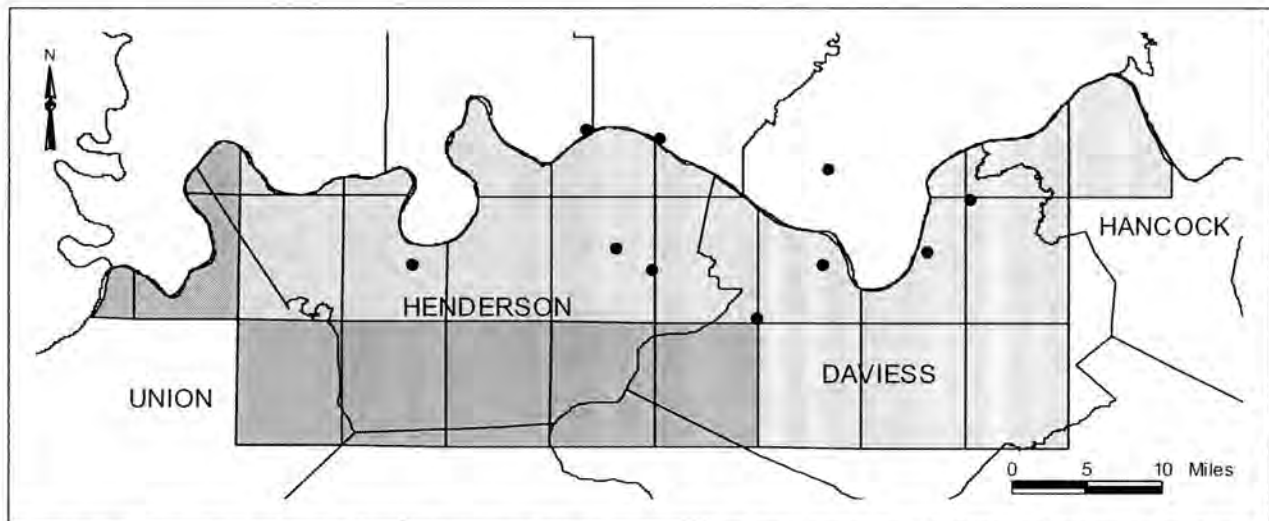


Figure 6. The extent of new Quaternary geologic mapping by the Kentucky Geological Survey in western Kentucky since 2003. Quadrangles in light gray have been mapped; quadrangles in dark gray are in progress. Black dots show the locations of planned field trip stops.

The new mapping is providing insights into the valley-fill stratigraphy and relative sequence of Quaternary geologic events in the Ohio River Valley. Data from new and published radiocarbon and luminescence analyses have provided a framework for a preliminary geochronologic framework of the Quaternary deposits described in the mapping area (Fig. 8). These data confirm that at least some of the deposits found in the project area predate the late Wisconsinan glacial stage. As more data become available and are integrated into the ongoing mapping effort, a more complete picture of the geomorphic history and valley-fill evolution of the Ohio River Valley should emerge.

Ohio River Valley

In the main Ohio River Valley, the current mapping effort has identified a series of Pleistocene high terraces, several intermediate terraces, and a Holocene floodplain. These different geomorphic features record the changing base level and flow regime of the Ohio River during the late Quaternary, as the discharge and sediment supply responded to glacial advance and retreat during the Pleistocene and the Ohio River switched from a braided to a meandering system during the Holocene. Preliminary analysis suggests that the intermediate terraces and floodplain represent cut-and-fill terraces inset into the older high terrace material, and thus result from a combination of erosional and depositional processes.

Wisconsinan high terrace

The high terraces are inferred to represent maximum valley filling by glacial outwash during the late Pleistocene Wisconsinan glacial stage. The high terraces are typically dissected, and are topographically below the lacustrine/slackwater terraces in tributary valleys and above the adjacent intermediate terraces in the main Ohio River Valley. The terrace surface is underlain by a thick accumulation (up to 180 ft) of fine to coarse sand and gravel with local lenses of silt and clay, interpreted to represent glacial outwash. Boulders up to 10 inches in

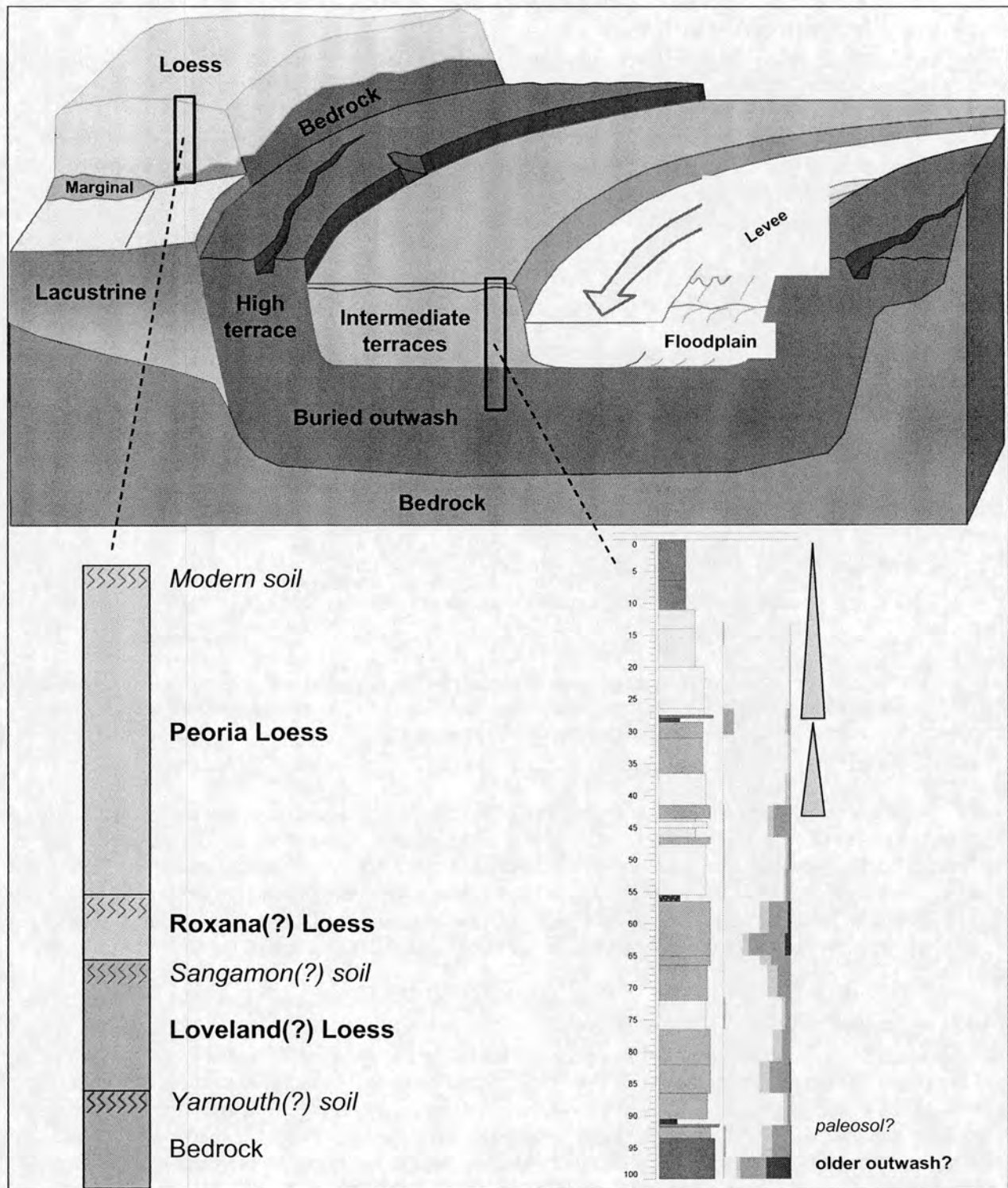


Figure 7. Generalized geologic model of unconsolidated deposits recognized in the Ohio River Valley by recent Kentucky Geological Survey geologic mapping. At the lower left is a summary of inferred loess stratigraphy recognized in upland exposures. At the lower right is an example subsurface log from an intermediate terrace near Owensboro; width of the log indicates relative grain size, and the column on the far right shows results of quantitative grain-size analysis of the log.

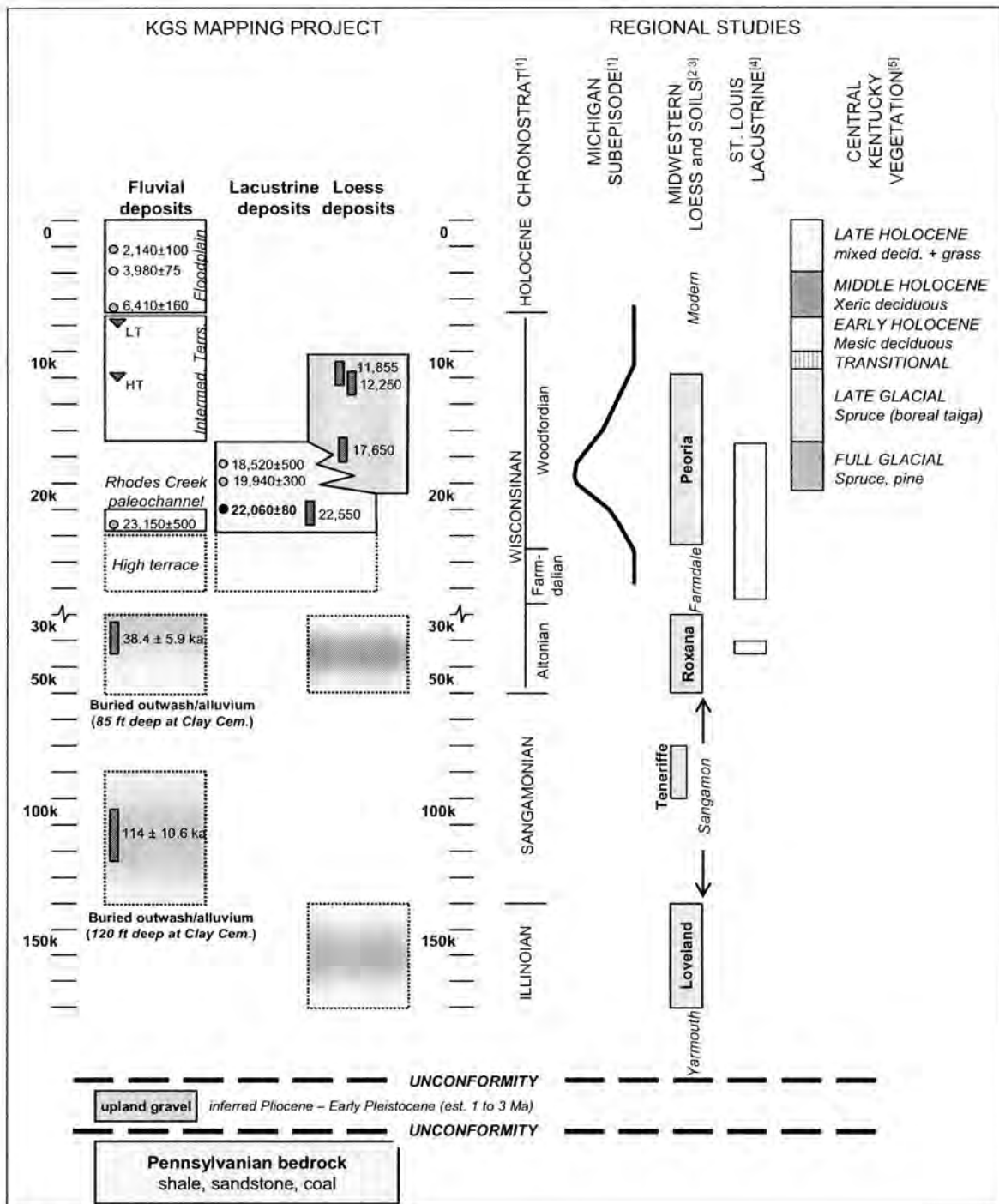


Figure 8. Preliminary geochronology of mapped deposits in the field trip area, compared with regional studies. Light gray circles indicate radiocarbon ages obtained from published literature (Ray, 1965; Fraser and Fishbaugh, 1986); dark gray circle indicates new radiocarbon age (W. Newell, 2005, U.S. Geological Survey, written communication); small dark boxes indicate new luminescence ages (S. Mahan, 2006, U.S. Geological Survey, written communication); triangles indicate minimum ages of terrace surfaces from archeological data (Fraser and Fishbaugh, 1986); LT – low terrace, HT – high terrace; dashed outlines indicate inferred/unconfirmed ages of units. References for regional geochronology: [1] Johnson and others, 1997; [2] Forman and Pierson (2002); [3] Grimley and others (2003); [4] Curry and Grimley (2006); [5] Wilkins and others (1991).

diameter were encountered near the bottom of Owensboro Municipal Utilities water wells drilled in 1957. The gravel lithologies from these wells include sandstone, siltstone, quartzite (metamorphic?), and igneous rocks, with minor quantities of coal and limestone (Fig. 9).

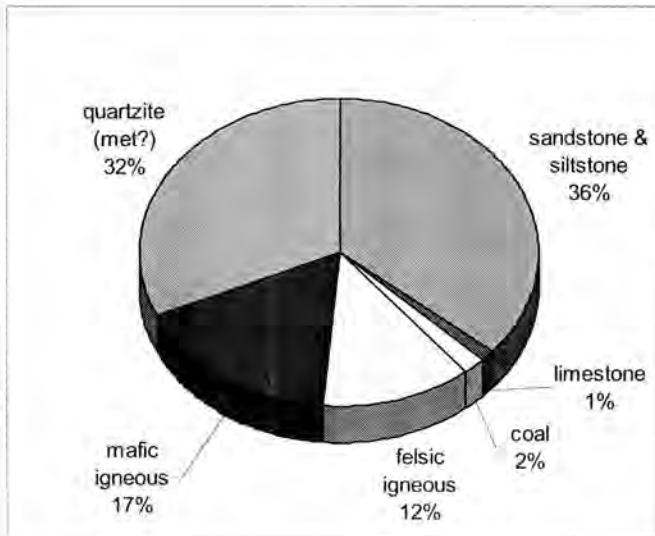


Figure 9. Lithologic proportions of gravel recovered from municipal water wells drilled in Owensboro.

Sparse geochronologic data and incision by a paleochannel with a tentative radiocarbon date of 23 ka suggest that the valley filling represented by the high terraces may have been completed relatively early in the Late Wisconsinan glacial stage, perhaps by as early as 22 ka. Additional detailed geochronologic research is needed to test this hypothesis. Fraser and Fishbaugh (1986) used archaeological material to provide an age of 10,000 to 12,000 years for the terrace surface. This provides a minimum age for the terrace, and probably reflects the cessation of loess accumulation on the terrace surface rather than deposition of the fluvial terrace material.

Illinoian(?) landforms and deposits

In the Mississippi Valley (and elsewhere upstream in the Ohio Valley), the maximum Illinoian fill is preserved topographically higher than Wisconsinan fill. Highly dissected Illinoian terrace surfaces are preserved in sheltered settings above less-dissected Wisconsinan terraces in the Ohio River Valley between Cincinnati and Louisville. This relationship has not yet been identified in the field trip area. The Illinoian material in the field trip area (1) could be buried, (2) could have been removed by post-Illinoian erosion, or (3) simply has not yet been recognized in the current mapping effort. Considering the drainage area of contributing glacial meltwater through this part of the valley during the Wisconsinan, preservation potential of older deposits and landforms in the main valley is assumed to be very low; only small remnants could be expected in topographically sheltered settings. If Illinoian landforms do exist in the project area, they are hypothesized to be very dissected and mantled by Wisconsinan loess, and thus be difficult to distinguish from adjacent uplands without detailed subsurface records.

Preliminary luminescence geochronology indicates buried pre-Wisconsinan outwash or alluvium in a core collected in the Wilson 7.5-minute quadrangle west of Henderson (38.4 ± 5.9 ka at 85 ft deep, 114 ± 10.6 ka at 125 ft deep; see Figure 8). Reconnaissance examination of modern cutbanks truncating older terraces along the lower Green River has identified gravel deposits with distinct color that suggest old soil; these may represent exposed remnants of Illinoian(?) outwash. These data are consistent with the hypothesized early filling of the valley by Wisconsinan outwash sediment; much of the valley's accommodation space may have been already occupied by pre-Wisconsinan deposits.

Intermediate terraces

A series of several intermediate terraces have been identified between the Pleistocene high terraces and the Holocene floodplain. These terraces are less dissected than the older high terraces, and flood more frequently. The surface patterns of these terraces, although subtle, suggest a braided pattern to the original fluvial depositional environments. The deposits underlying the intermediate terraces are lithologically indistinguishable from the high terraces, using water and petroleum drillers' logs available in KGS databases. These terraces may represent either (1) late glacial outwash from waning stages of Wisconsinan glaciation as ice retreated from the Ohio River basin, or (2) early Holocene post-glacial reworking immediately following retreat of the ice sheets from the basin. Detailed geochronology of these deposits correlated with detailed ice-sheet chronology will be necessary to resolve this question. The relatively low topographic relief of these terraces compared to the older high terraces

and the younger floodplain may represent either a short duration for dissection to develop or may result from late Holocene flood deposition. Fraser and Fishbaugh (1986) estimated an age of 6,000 to 8,000 years for intermediate terraces near Evansville, using archeological evidence. Stops 1 and 2 are situated on intermediate terraces northeast of Owensboro.

Ohio River floodplain

The Holocene floodplain of the Ohio River is characterized by a distinctive bar-and-swale topography, reflecting the meandering nature of the modern Ohio River. Deposits associated with the floodplain include sand, silt, and clay, and typically are finer grained than the older high and intermediate terraces. The surface of the floodplain includes sloughs and natural and artificial levees. In each meander bend of the Ohio River in this area, the floodplain slopes very gently downstream. Typically, natural levees are relatively well developed on the upstream side of the meander bend immediately adjacent to the river bank, and low-lying, swampy sloughs are developed on the lower and more landward sides of the meander bend. Sloughs consist of organic-rich, black and gray clayey silt and silty clay. Natural levee deposits consist of sand and silt, and are deposited as ridges, splays, or overwash deposits along the river bank. Artificial levees have been locally constructed along the lower, downstream margins of meander bends to protect agricultural fields from frequent small floods. Subtle terraces can be traced along the landward margins of the floodplain.

The floodplain is a dynamic system with active erosion along the upstream river bank of each meander bend, and active deposition along the downstream end of each bend and progradation of the natural levees downstream. Deposition during minor floods is typically low energy, with slackwater spilling onto the floodplain from the lower end of a meander bend. During larger, less frequent floods, the river flows over the upstream levees and results in complex patterns of local scouring and intervening deposition of sand and gravel bars across the floodplain. Gray (1984) examined the Ohio River floodplain near Louisville and proposed a sedimentological model of floodplain development for that region, which is likely similar to the field trip area. Along the inside of meander bends, coarse channel-deposit bars develop along the channel banks and prograde downstream. Channel bars are mantled by a veneer of fine-grained overbank deposition to complete floodplain construction.

Fraser and Fishbaugh (1986) used radiocarbon dating of wood recovered from boreholes to estimate a minimum age of the Ohio River floodplain at 6,400 years. Thus, by the mid-Holocene, the Ohio River had reached a relatively stable profile for the Holocene flow regime and switched from a braided to a meandering pattern.

Dams

The Ohio River is an engineered stream. A series of 20 locks and dams currently controls the flow of the Ohio River for navigation; numerous smaller structures have been removed. These dams produce local geomorphic responses of erosion and deposition in the immediate vicinity of each structure. Three dams are in the region near the field trip area: Cannelton Lock and Dam is upstream at river mile 721, Newburgh Lock and Dam (field trip stop 9) is at river mile 776, and J.T. Meyers Lock and Dam is near Uniontown, Ky., at river mile 846.

Green River Valley

The confluence of the Green River with the Ohio River is in the field trip area in eastern Henderson County. Below Curdsville, the Green River flows across and is incised into Pleistocene and Holocene Ohio River outwash and fluvial deposits. The Green River was periodically impounded by rapid aggradation of Ohio River sediment at the confluence during the late Pleistocene, and a slackwater lake developed in the Green River Valley. Silt and clay were deposited in the low-energy, slackwater environment. There is an extensive low-relief terrace in the Green River Valley as far upstream as the community of Morgantown in Butler County. The current mapping project has identified Holocene fluvial terraces inset into the lacustrine terrace. These terraces are more subtle than terraces in the Ohio River Valley. The Holocene floodplain of the Green River is underlain by sand, silt, and clay.

Tributary Valleys

Lacustrine/slackwater terraces and deposits

Tributary valleys commonly include lacustrine or slackwater deposits and modern alluvium. Lacustrine or slackwater deposits consist of clayey silt and silty clay overlying sand and minor gravel (Fig. 10). The basal sand and minor gravel represent deposition by the original tributary streams that carved the bedrock valleys. The overlying fine-grained deposits represent deposition in slackwater or lacustrine environments caused by impoundment of the tributary valleys by rapid deposition of glacial outwash at the valley mouth during glacial stages. These nonmarine incised valley fills are commonly at least 30 ft thick, and are locally more than 100 ft thick.

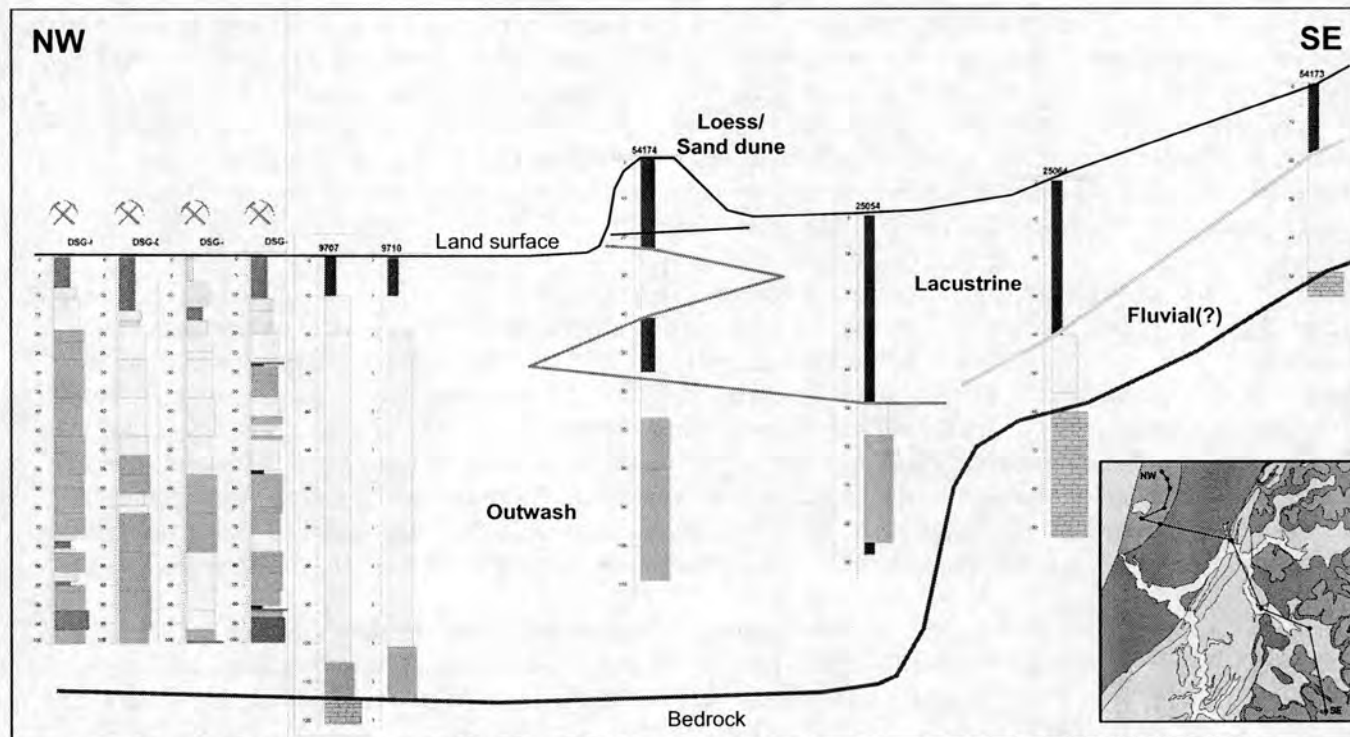


Figure 10. Profile of lacustrine deposit in Pup Creek Valley transitioning to Ohio River Valley outwash, northeast of Owensboro, near field trip stop 2. Note thin, coarse-grained deposit below fine-grained lacustrine fill in tributary valley, and buried hanging bedrock valley.

The associated landform is a very flat, dissected, low-relief terrace, which represents the final bottom of the paleo-lake, and is higher than the adjacent main-valley high terrace (Figs. 11–12). The land surface in the lower reaches of many of these tributary valleys is often subtly graded away from the Ohio River Valley, reflecting the significant contribution of the sediment to the slackwater deposits from the main Ohio River Valley. Stop 5 is situated on a lacustrine terrace in Bluff City.

The lake system responsible for these features has been hypothesized to be from an impounded Ohio River, caused by rapid sedimentation associated with jokulhlaups on the upper Wabash River (Woodfield, 2000) or a bedrock valley constriction near Caseyville, Ky. (Straw, 1968). This would require the lacustrine terraces to be at very similar elevations throughout the area of Ohio River impoundment. The surfaces of adjacent tributaries (lacustrine terraces) do not lie at identical elevations, however; lacustrine terrace elevations systematically decrease downstream (Figs. 11–12). This trend suggests that tributary valleys were incrementally filled as the free-flowing Ohio River locally aggraded and blocked the mouth of each tributary.

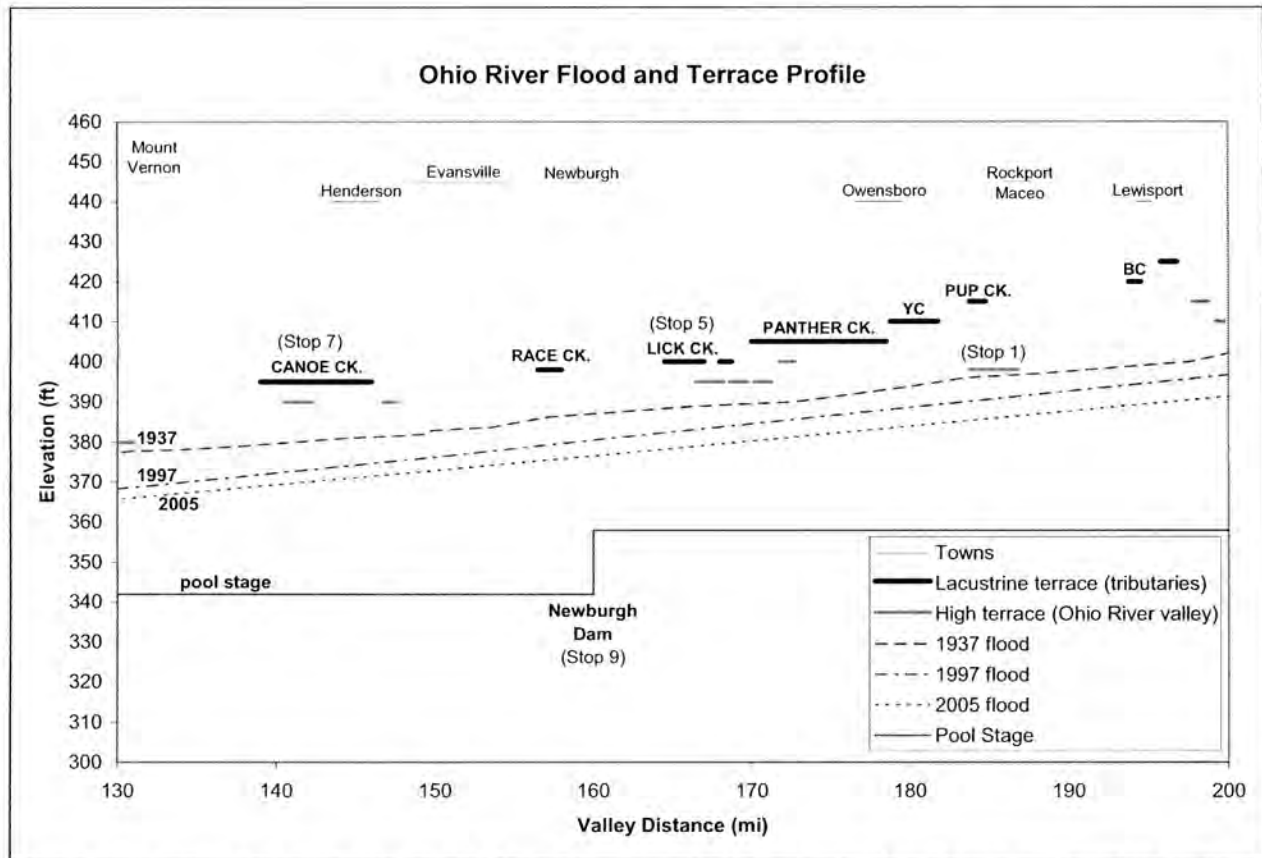


Figure 11. Longitudinal profile along the Ohio River, showing elevations of high terraces (gray), tributary-valley lacustrine terraces (bold black), flood profiles, and engineered pool stage. Note that the lacustrine terraces are roughly graded with the high terraces, and are 5 to 10 ft above the high terraces.

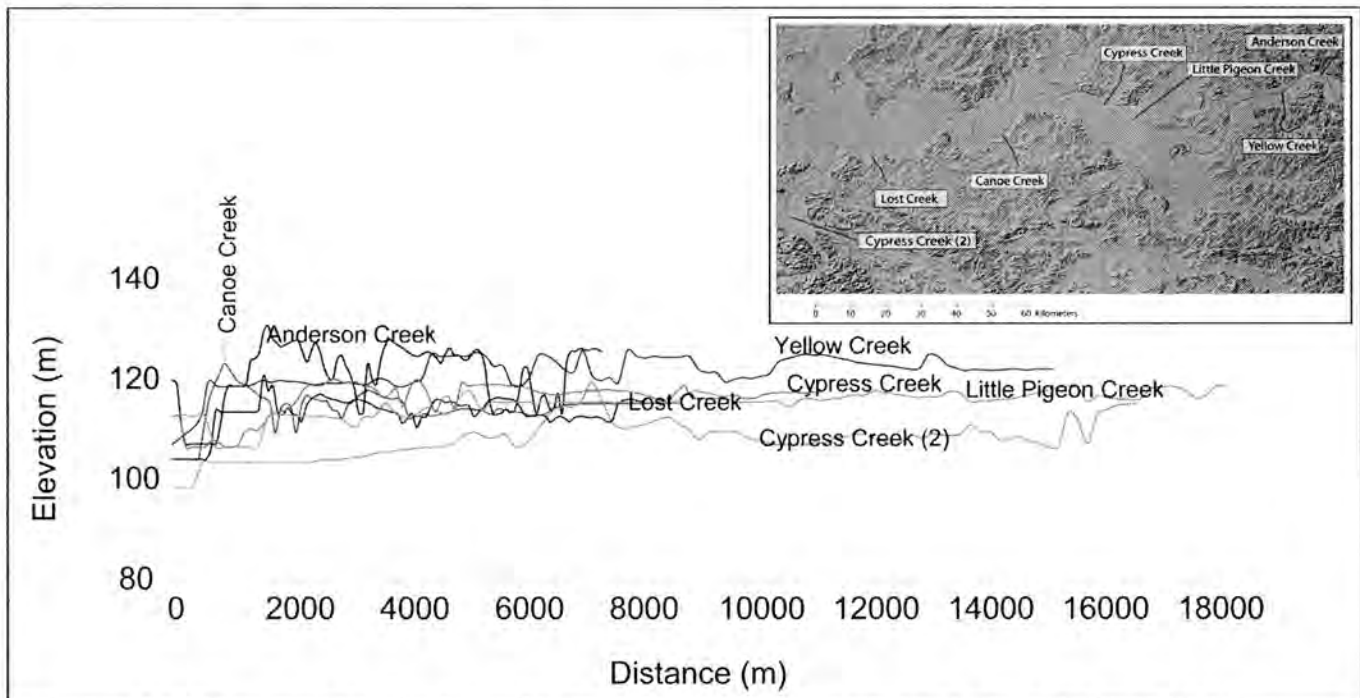


Figure 12. Longitudinal topographic profiles along selected valleys tributary to the Ohio River. Profile elevations extracted from USGS 10-meter National Elevation Dataset. Locations shown on inset map.

New data acquired during recent mapping for the KGS Statemap program, from the U.S. Geological Survey Seismic Hazard Mapping Program, and from collaborative work with the Indiana Geological Survey and the Illinois State Geological Survey support the hypothesis that tributaries were impounded as the Ohio River aggraded. On the basis of geomorphic evidence and assumptions discussed above, as well as a single radiocarbon date on wood near Evansville (22 ka at 14 ft deep with 55 ft of material underlying the sample), the valley fill deposits in tributary valleys might be dominantly pre-Wisconsinan in age.

Holocene alluvium

Holocene alluvium is found underlying the floodplains of the modern tributary streams. This alluvium consists of silty clay and sandy silt, with minor sand and sparse gravel. The lower reaches of the floodplains are typically inset into the adjacent slackwater/lacustrine terrace; the floodplains closer to the headwaters are typically graded to near the level of the adjacent older terrace.

Uplands

Bedrock

The uplands are underlain by sandstone, siltstone, shale, coal, and minor limestone of the Middle Pennsylvanian Carbondale Formation. Bedrock is only locally exposed in the project area, and is mostly known from coal borehole data and mine exposures. The bedrock is locally overlain by a distinctive brown-patina chert gravel, which is inferred to represent Pliocene-Pleistocene deposition by the preglacial Green or Ohio Rivers, or both. This deposit is poorly exposed and is recognized in a small number of coal boreholes and water wells, and from surface lags of the chert gravel. This deposit is comparable to the Luce Gravel of Ray (1965). Stop 6 will provide a view of bedrock in a coal mine south of Spottsville.

Bedrock topography. The thick alluvial valley fills in the study area obscure the topography of the bedrock surface in the valleys. As a part of the 1960–78 cooperative geologic mapping program, USGS mappers compiled bedrock topography maps for selected quadrangles in the field trip area. These maps were based on available water wells, petroleum wells, and coal boreholes. The interpolated contours inferred generally V-shaped bedrock valleys with floors gently sloping toward a central thalweg. Subsequent industry and research drilling does not support this inference. Valleys developed in comparable bedrock (e.g. eastern Kentucky) are typically more trapezoidal, with steep valley walls and relatively flat, benched floors. Local dense concentrations of subsurface data, and shear-wave refraction profiles collected by KGS-UK personnel in 2004 support a generally trapezoidal outline for bedrock valleys. Hanging bedrock valleys are preserved under the mouth of some tributary valleys.

Loess

Over much of the mapping area, bedrock is mantled by up to 60 ft of loess (Fig. 13). The loess consists of silt and fine sand and is typically massive, with only subtle stratification identifiable in good exposures. Loess deposits are thickest near the Ohio River and thin to the south and east; the Pleistocene outwash sediments of the Ohio River Valley are inferred to be the primary source of the windblown sediment. Thin loess deposits also cover older landforms in the main river valley. Detailed examination of loess exposures reveals at least three subtle, but distinct, horizons with slightly different colors and textures. These layers possibly correlate with the Peoria (25–12 ka), Roxana/Farmdale (60–30 ka), and Loveland (180–140 ka) Silts of the Mississippi and Wabash Valleys (Fig. 7). A highly weathered clay between a weathered loess and weathered bedrock may represent a pre-Loveland loess. Stop 3 examines a loess outcrop northwest of Owensboro.

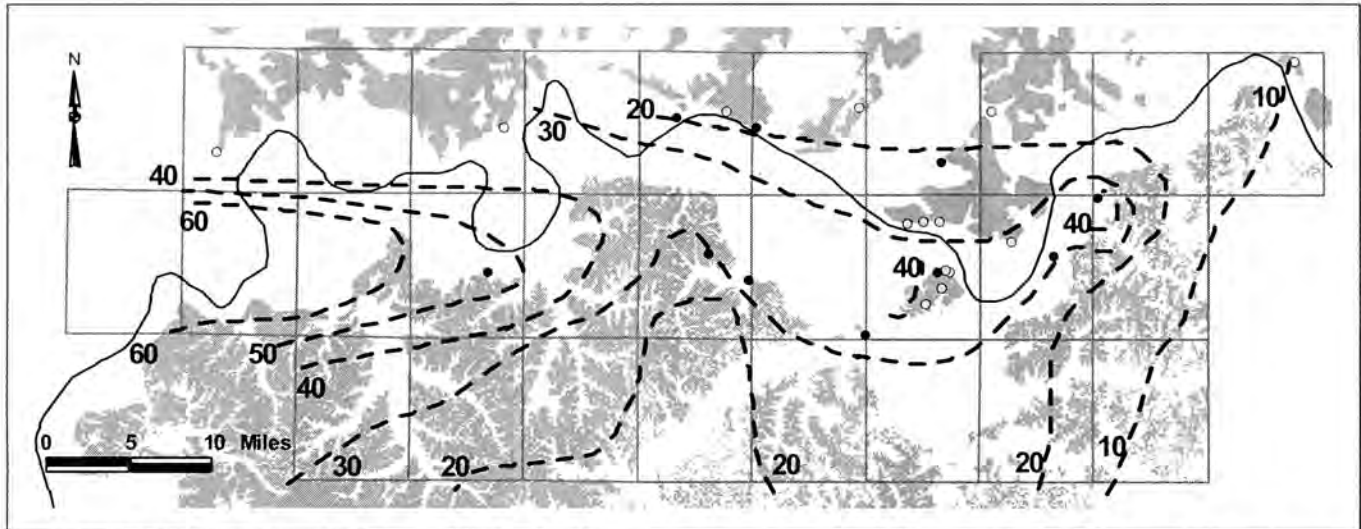


Figure 13. Generalized thickness (in feet) of loess mantling the uplands (gray shading) in the mapping area. Thickness derived from published geologic quadrangle maps, USDA soil maps, and published measured sections (gray dots)(Ray 1965; Ruhe and Olson, 1978). Black dots show locations of planned field trip stops.

Complex lacustrine margin

Along the lower margins of hillsides, the mapping project recognizes a complex zone of intermixed Pleistocene lacustrine sediment, loess, colluvium, and modern slopewash. This marginal unit consists of clayey silt, silt, and fine sand. This complex deposit grades into the adjacent loess deposits uphill and slackwater/lacustrine deposits downhill (Fig. 14). It may represent the shifting and ephemeral environments along the margins of the Pleistocene lakes, as lake levels rose and fell in response to changing discharge in the Ohio River Valley. The low benches along valley margins may represent wave-cut terraces. Stop 5 provides a view of the lacustrine margin landscape.

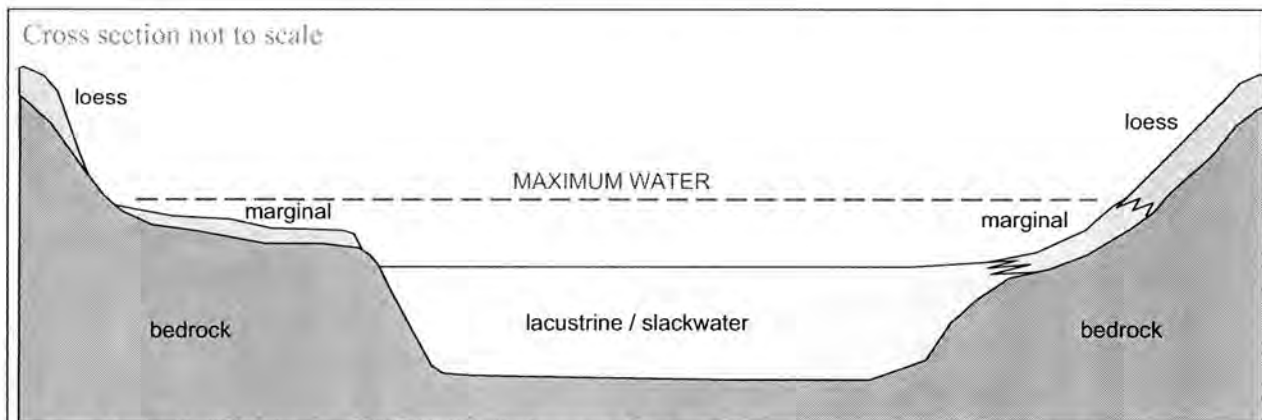


Figure 14. Generalized cross section showing spatial relationships between lacustrine terrace and adjacent marginal transition along valley sides. The inferred maximum Pleistocene inundation/impoundment of the valley is shown by dashed line.

Sand Dunes

Sand dune complexes are locally found along the western and southwestern margins of wider valleys. They locally overlie the high Ohio River terraces, the lacustrine/slackwater terraces, or bedrock/loess on upland margins. These long, linear ridges can be up to 20 ft high, over 1,000 ft wide, and as much as 9 mi long. Their subsurface extent is poorly known. They consist of very fine to fine sand, and are mantled by and interbedded with loess.

Green River Paleochannels

Inset into the fluvial and adjacent lacustrine terraces west and southwest of Owensboro are a series of meandering topographic lows (Fig. 15). These are hypothesized to represent late Quaternary paleochannels of the Green River, and likely range in age from 20 ka to recent. The younger paleovalleys are recently abandoned meanders of the Green River and are low, poorly drained, and swampy. The broad alluvial plain west of Owensboro preserves these younger paleovalleys in a complex mosaic of landforms representing the westward migration of the Green River from Katie Meadow Slough (12,000 years ago?) to the modern course of the Green River against the bedrock upland near Spottsville.

The Rhodes Creek paleovalley is the oldest identified in the area, and probably represents an abandoned northeast emcourse of the Green River that used to flow through what is now downtown Owensboro. The Beds at Hubert Court of Ray (1965) probably represent a thin fragment of this paleovalley exposed in the bank of the Ohio River on the east side of Owensboro. Ray described an 18-ft sequence of gray silty sand and sandy silt, and reported a radiocarbon date of $23,150 \pm 500$ b.p. from wood near the base of the section. Since this deposit is inset into the high terrace, it would suggest that deposition of the outwash underlying this terrace was complete very early in the late Wisconsin glacial stage. Stop 4 will discuss the Rhodes Creek and Katie Meadow Slough paleochannels.

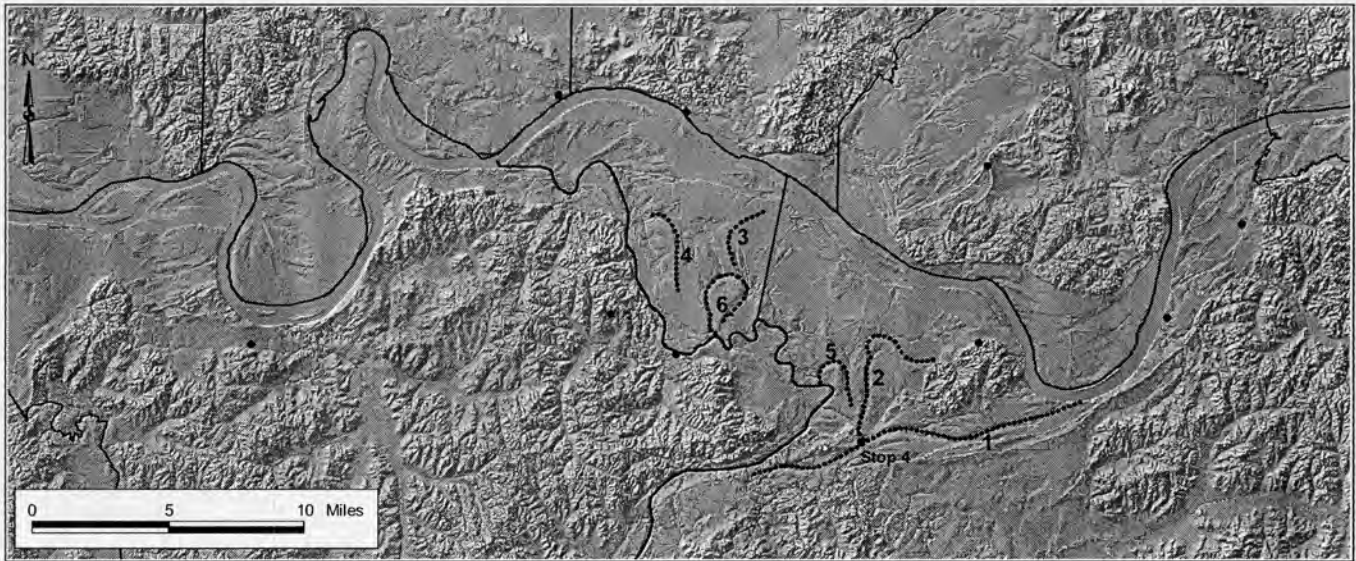


Figure 15. Location of Green River paleochannels identified during recent Quaternary geologic mapping. 1: Rhodes Creek paleochannel; 2: Katie Meadow Slough; 3: Keene-Williams paleochannel; 4: Black Slough paleochannel; 5: Hurricane Slough; 6: Richland Slough. Location of stop 4 shown near confluence of Katie Meadow Slough and Rhodes Creek paleochannel; unlabeled black dots are locations of other planned field trip stops.

Unresolved Questions Being Considered

- Is there evidence of paleoseismicity or neotectonic activity on the Kentucky side of the river, comparable to that found in southwestern Indiana? Why or why not?
- Is glacio-isostatic rebound expressed in this part of the Ohio River valley? Why or why not?
- Do the intermediate terraces represent late glacial or postglacial deposition?
- How much do individual floods contribute to overall floodplain deposition?
- Why isn't rooting or other bioturbation visible in loess exposures?

Applications, Implications, Economics, and the Landscape

A River Runs through It

The Ohio River is a major tributary of the Mississippi River and one of the main drainage systems of the United States, with a drainage area of approximately 100,000 mi² above Newburgh Dam. People have used the river for millennia as a transportation corridor, food source, water supply, and recreation area. Conversely, populations along the river have had to deal with the river as a barrier to north-south transportation, and frequent floods challenge communities to choose development sites carefully.

Water supply

The Ohio River aquifer serves as an important water supply for communities, industry, and farms throughout the valley. The thick accumulation of outwash sand and gravel act as a high transmissivity aquifer with constant recharge from the river. Communities and industry along the river derive their water supplies either directly from the river or from wells drilled into the outwash sand and gravel adjacent to the river. Locally, farmers are able to drive pipes as little as 30 ft into the ground to provide adequate supplies for crop irrigation. The results of the current mapping can provide improved understanding of the architecture of this critical water-supply resource. See Unthank (1996) for a discussion of water supply in relation to the lithologies of the Ohio River aquifer.

Floods

Flooding is a nearly annual occurrence along the Ohio River. Floods in the late winter or early spring commonly inundate low-lying areas in the floodplain (Fig. 16). Larger floods occur roughly every 10 to 20 years (1913, 1945, 1964, 1997; Fig. 17), and cover parts of the intermediate terraces (Fig. 18). The maximum flood of record in the valley was in 1937, flooding river towns throughout the valley. Only structures on the highest outwash terraces and the lacustrine terrace were spared flooding. Henderson was the only town of size from Ohio to Paducah that did not suffer significant flood damage, leading to the unofficial motto "By the Ohio River, but Never under It."



Figure 16. Along the floodplain margin near field trip stop 1 during (left) and after (right) the May 2005 flood. Corn planted in the field (12 to 18 in tall prior to flooding) was killed by roughly a week of submergence; the damaged corn crop was replaced by soybeans.

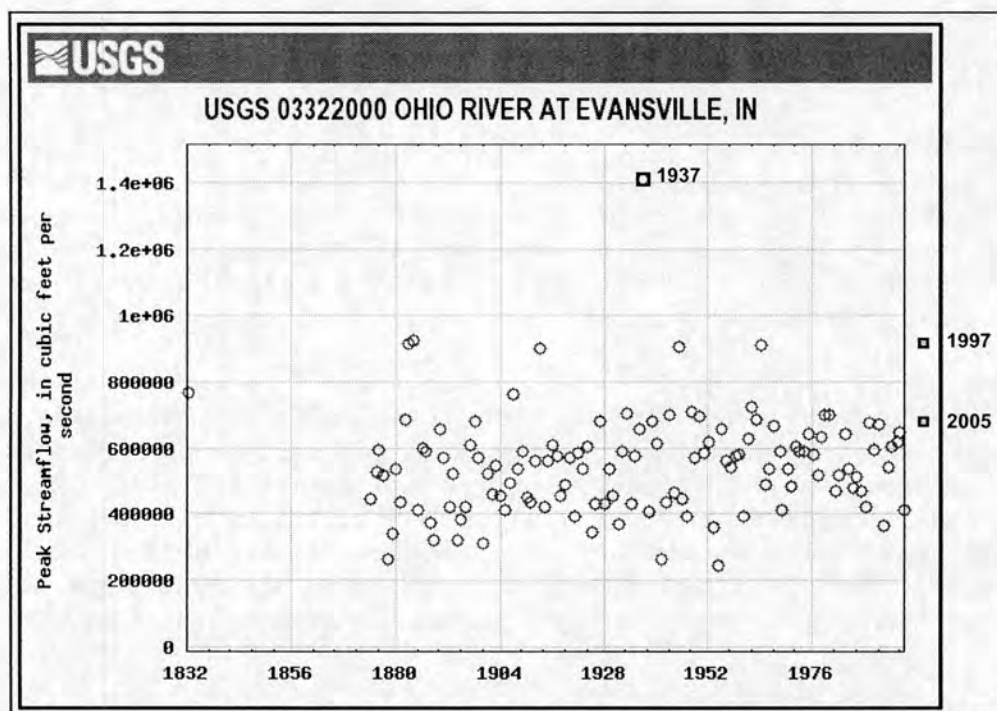


Figure 17. USGS stream gage data for Evansville showing peak annual flows from 1832 to 1996. Flood levels of 1997 and 2005 floods are shown in context. The 1937 flood is the maximum flood of record.

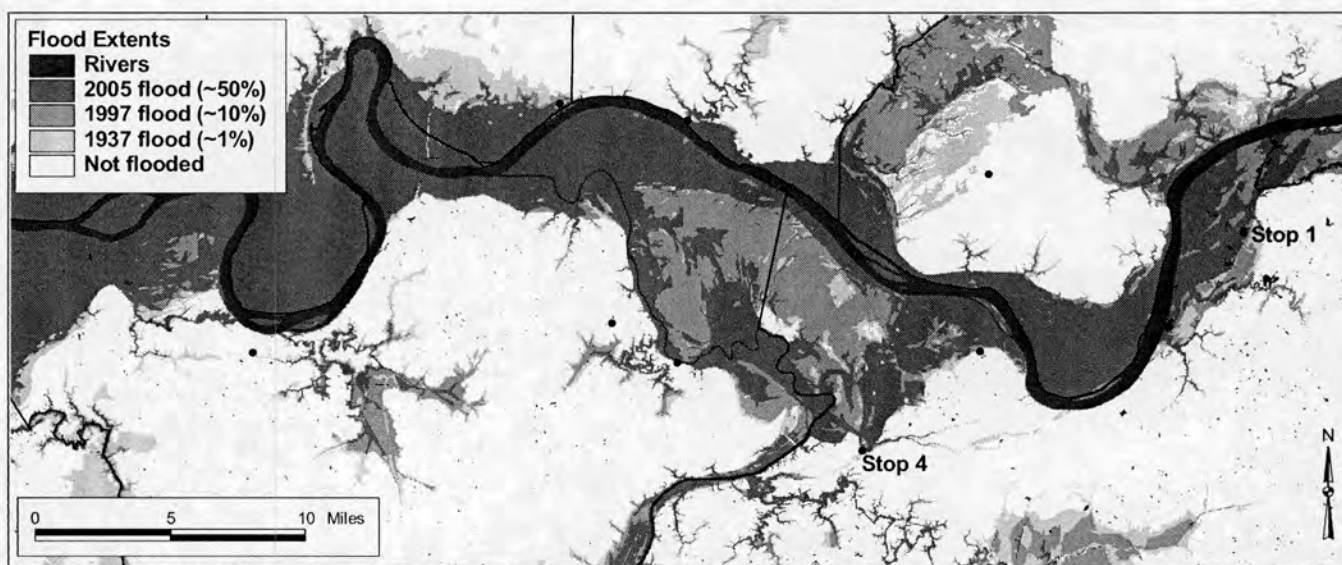


Figure 18. Estimated extent of selected floods that have occurred in the Ohio River Valley. Flood levels extrapolated from U.S. Army Corps of Engineers flood profiles and historical stream gage data available from the USGS and National Weather Service. Black dots are the locations of planned field trip stops.

The impact of flooding is reflected in the distribution of older homes and barns through the field trip area. Older homes and businesses are constructed on the lacustrine and high outwash terraces, and on the highest parts of intermediate terraces. Trailers and less expensively built homes are constructed on the intermediate terraces. Only barns are found on the high parts of the floodplain. The floodplain and low parts of the intermediate terraces are dominantly left to woodlands or used for row-crop agriculture. Most livestock husbandry is restricted to upland areas above the 10- to 20-year flood zone.

Ecology

The numerous sloughs, ponds, and other wetlands located along the Ohio and Green River floodplains attract a wide variety of native and migratory waterfowl and other wildlife. The lowest parts of the floodplain remain too wet through much or all of the year to support agriculture, and are left to natural woodland and wetland habitats. The USDA Natural Resources Conservation Service has an active Wetland Reserve Program that is returning selected low-lying agricultural fields in the region to wetland ecosystems.

Energy and Minerals

Coal and electric power generation

Coal has been produced from the area since at least 1820. The earliest coal was mined from as fuel for steamboats along the Ohio and Green rivers. Coal of the Illinois basin is generally high in sulfur and of moderate heating value, and is thus does not command the highest price on regional and national markets. Currently, most of the coal produced from the area is used as fuel in electric power plants. The plants take advantage of the cheap fuel, and the abundant water supply of the region to produce some of the lowest cost electricity in the nation. Stop 6 will visit a coal mine near Bluff City.

Petroleum

The petroleum industry in western Kentucky started in the 1850's. Sometime between 1850 and 1860, the Burbank and Holloway "deep" wells were drilled near Henderson (Orton, 1891, p. 194). In 1856, a distilling plant was constructed to produce kerosene from cannel coals being mined in the vicinity of Victoria Crossroads, Breckinridge County (Miller, 1919, p. 288). Drilling for natural gas began around 1858 with the discovery of the Old Rock Haven Field, Meade County (Eyl, 1922). The development of these resources was only somewhat interrupted by the Civil War. Between 1863 and 1865, drilling in Meade County resulted in the discovery of New Albany Shale gas. Twenty to 30 wells were drilled in the vicinity of Oil Hollow, a tributary to Doe Run Creek, in the pursuit of brine for the manufacture of salt. One of the first wells was the Moorman well, drilled in 1863 to a depth of 527 ft. This well encountered a strong flow of gas, which it produced until about 1872 (Orton, 1891, p. 171–172). The first known oil in western Kentucky was from two wells drilled about 1865, 2 mi north of Calhoun on the Beech Grove Road in what became known as the Long Falls Creek Pool, McLean County (Eyl, 1922; Bushong, 1970).

While oil production was the focus of drilling in other parts of Kentucky, the late 1800's saw natural gas development continue in western Kentucky. In 1889, Cloverport in Breckinridge County became the first city in Kentucky to "secure the inexpressible convenience of natural gas for fuel in quantities largely in excess of the demand" with the completion of a well drilled to 896 ft. The well was gauged at 2.5 million cubic feet of gas per day (MMcf/d) (Orton, 1891, p. 192). In 1890, the Kentucky Rock Gas Company completed 32 mi of 8-in. pipeline from the gas fields in the Brandenburg, Breckinridge County, area to Louisville at a cost of \$400,000. The gas was used primarily for domestic heating (Orton, 1891, p. 185–191).

The coming era of the dominance of oil production in western Kentucky was presaged in 1912 with the successful completion of the first commercial oil well in the area. The Western Kentucky Oil and Gas Company No. 1 A.A. Carter well was drilled to a depth of about 1,750 ft near Concord Church, northeast of Hartford in Ohio County. The well was completed in the Silurian/Devonian "Corniferous" lime below the New Albany Shale (Smith, 1968; Bushong, 1970). At the time of publication of his oil and gas map in 1922, W.C. Eyl showed no oil refineries in western Kentucky. The closest refineries were located in Allen, Warren, and Jefferson Counties, and these facilities processed mostly central and eastern Kentucky crude oils.

The oil production outlook quickly changed, however. In 1921, the Cole Jett well was drilled and started the Owensboro oil boom (Bushong, 1970). Oil was discovered in Hopkins County in 1922 (Jillson, 1930). In 1938, the Birk City Field, Henderson County, was discovered with the completion of the Hoosier Drilling No. 1 C.T. Blackwell well. That well was a gusher, initially flowing at a rate of 1,200 barrels of oil per day from the Mississippian McClosky, from a 2-ft zone between 1,872 ft to the total depth at 1,874 ft. This field initially produced so much oil that it caused a reduction in the wellhead price of crude oil statewide.

Production records indicate western Kentucky has produced about 445 million barrels of oil (57 percent of the statewide total) and 215 billion cubic feet of natural gas (4 percent of the statewide total). In 2005, the area produced 46 percent of the total 2.45 million barrels of oil and less than 1 percent of the 93 billion cubic feet of gas produced in the state that year. There are nearly 6,600 active oil wells (including waterflood wells) and 1,000 active gas wells. One of the largest gas storage fields in the continental United States is the Midland Field in Muhlenberg County, which has a storage capacity of more than 124 billion cubic feet of gas. The deepest well in Kentucky is the Exxon No. 1 Duncan well, Webster County, which reached a total depth of 15,200 ft in 1977. Most of the production is from Pennsylvanian sands and Mississippian carbonates and sands at depths generally from about 1,000 ft to 3,500 ft. Current exploration is focused on Mississippian carbonates (Aux Vaxes, O'Hara, and McClosky; more than 400 permits since 2000) and on New Albany Shale gas production (117 permits since 2000). Most of the New Albany Shale wells are being drilled in Breckinridge, Meade, and Hardin Counties near existing gathering, compression, and pipeline infrastructure.

Pump jacks are a common sight across much of the field trip area.

Non-energy minerals

Sand and gravel for use as aggregate are produced from quarries along the river valley, and dredged from the channel of the Ohio River. Stop 2 will visit a sand and gravel dredging operation near Owensboro. Clay and sand are produced from surface pits developed in residual materials in the bedrock uplands. Loess is excavated for construction fill from pits in the uplands. Stop 3 will visit an active borrow pit extracting loess for construction fill.

Earthquakes

The field trip area is proximal to the Wabash valley and New Madrid seismic zones (Fig. 19). Small earthquakes have been felt in the area relatively frequently. The significant thicknesses of unconsolidated sediment raise concerns about ground motion amplification of seismic waves and potential liquefaction. Regional seismic hazard assessment in the Evansville and Henderson area was an early justification for the current Quaternary mapping project. A better understanding of the architecture of valley-fill sediments, coupled with data on the geotechnical characteristics of these materials, can be used to better predict the local site behavior during a major seismic event.

Shear wave data recently collected by Kentucky Geological Survey and University of Kentucky seismologists provide a preliminary characterization of the unconsolidated sediments in the field trip area. Different sedimentary packages have different shear wave velocity characteristics. These differences are possibly significant for assessment of seismic ground motion amplification. The two-dimensional shear wave velocity structure from the refraction profiles was used to determine shear-wave velocities of general sedimentary deposits in the Ohio River Valley. Figure 20 summarizes the results of preliminary analysis of the data.

These results are compatible with the results of Higgins (1996) and Eggert and others (1993). Eggert and others (1993) measured shear wave velocity and determined soil period for unconsolidated deposits at 21 locations near Evansville, Ind. They determined an average shear-wave velocity of 244 m/s for fluvial sediments, including alluvium and outwash; lacustrine deposits averaged 214 m/s; a single measurement in loess was 161 m/s. Higgins (1996) measured shear-wave velocities at 26 sites near Henderson, Ky., and developed a preliminary seismic-hazard zonation map of the area. He determined average shear-wave velocities ranging from 151 to 370 m/s for the various unconsolidated deposits in the region. A goal of the KGS Quaternary mapping project is to integrate these published shear wave data with our mapping results to add geologic context to the seismic velocities.

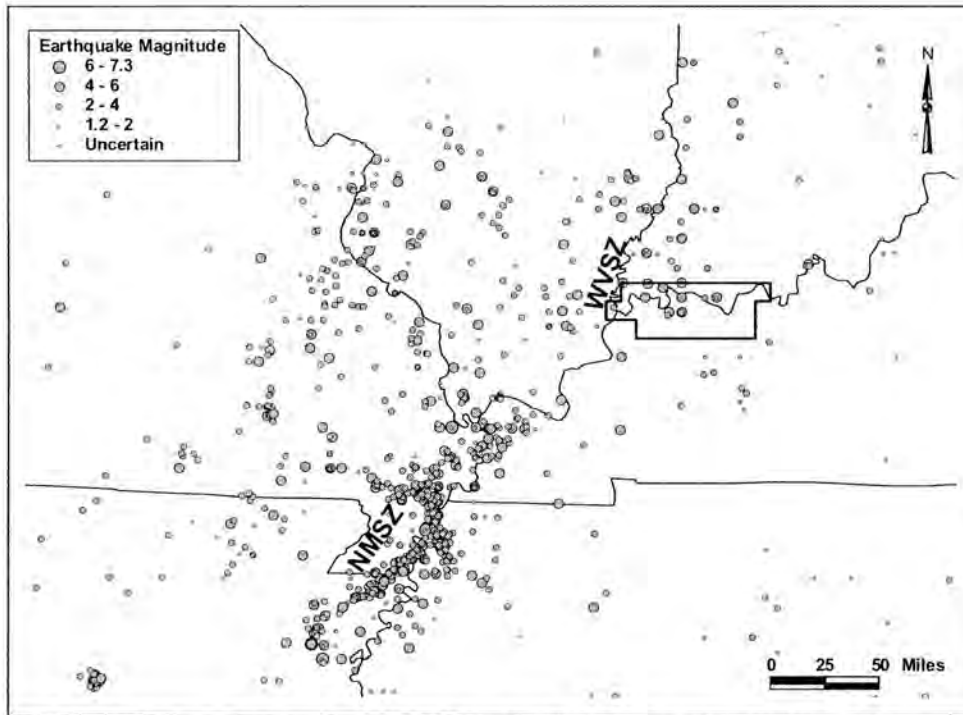
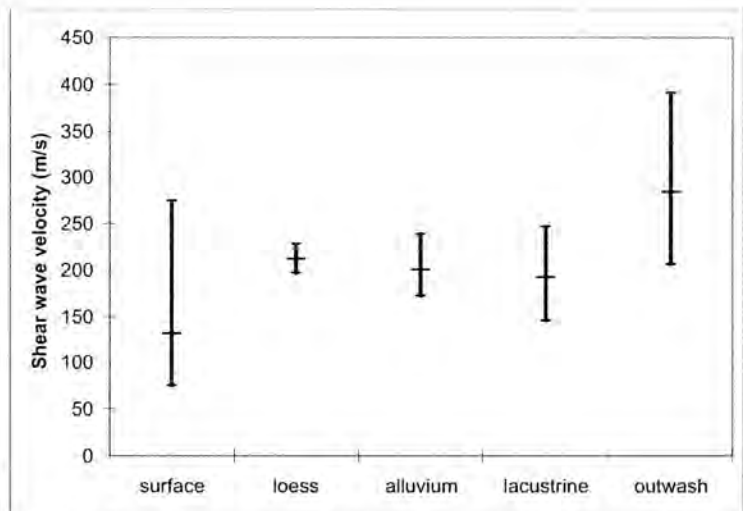


Figure 19. Locations of earthquakes in the central United States in relation to the field trip area, derived from USGS records for 1776 to 2006. NMSZ: New Madrid seismic zone; WVSZ: Wabash Valley seismic zone.

Figure 20. Range (vertical bar) and average (bold horizontal bar) of shear wave velocity for unconsolidated deposits measured at 15 sites in the field trip area.



Soils

The unconsolidated deposits of the field trip area are considered to be engineering soils. This contrasts with the concept of a pedogenic soil, which only includes the shallow near-surface soils affected by atmospheric weathering and shallow groundwater processes. Several stops on this field trip will discuss the geotechnical and hydrogeologic properties of unconsolidated sediments, and thus will use terminology for engineering soils. Stop 3 will examine pedogenic soil horizons developed in loess and related deposits.

Grain size distribution is one of the primary factors affecting the behavior of soils for geotechnical, hydrogeologic, and agricultural applications. The grain size distribution of unconsolidated sediments is dominantly controlled by the conditions under which the material was deposited. Low energy environments allow the deposition of fine-grained materials. High energy deposits limit deposition to only coarser grained materials. Eolian processes produce very well sorted (poorly graded) materials. Fluvial processes produce moderate sorting; colluvial processes produce poorly sorted deposits. Figure 21 illustrates the grain size distribution of selected unconsolidated deposits in the field trip area. Figure 22 is a ternary plot of grain size showing relative quantities of sand, silt and clay in the same deposits.

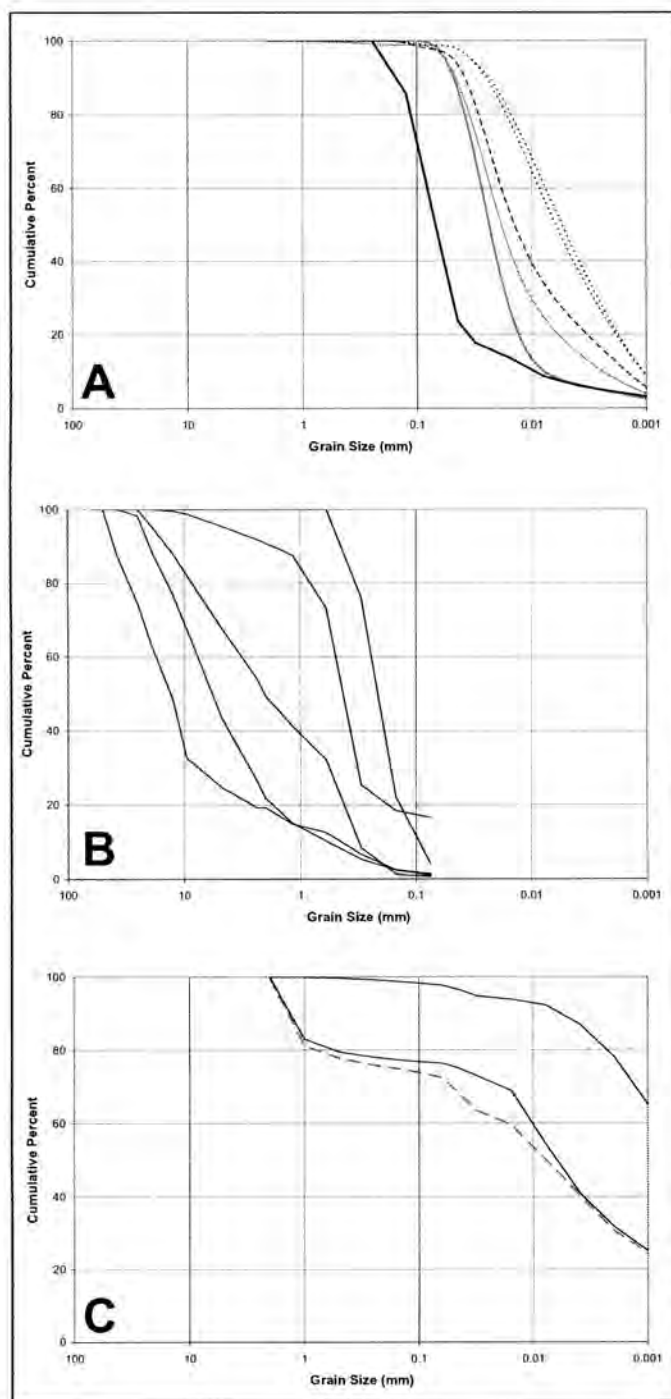


Figure 21 (left). Cumulative grain-size distribution curves for unconsolidated sedimentary deposits in the field trip area. Coarse grain sizes are to the left, fine grain sizes are to the right; steep slopes indicate well sorted (poorly graded) material.

A: Comparison between dune sand (bold black), Peoria loess (bold gray), Loveland loess (thin gray), shallow lacustrine (long dashed), and deeper lacustrine (short dashed) sediments; note the increase in clay content in the lacustrine samples.

B: Samples from various depths in an intermediate terrace.

C: Comparison between regolith samples (solid) and slopewash (gray dashed).

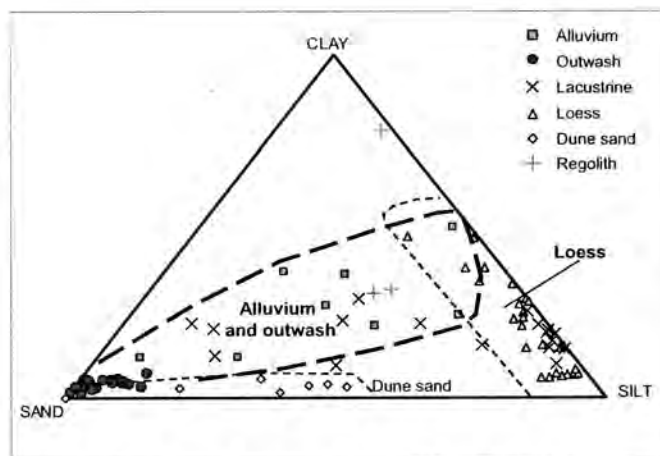


Figure 22 (above). Ternary diagram illustrating grain-size variation of unconsolidated deposits in the field trip area. Note the variation of "lacustrine" samples, reflecting complex depositional environments and significant fluvial influence. Data from KGS analyses, unpublished gradation analyses from industry, and Ray (1965).

Thixotropic soils are soils that are stable under normal conditions, but will behave like a fluid when agitated or shaken. The current mapping effort has discovered several occurrences of these geotechnically challenging soils in the field trip area. The silt soils that dominate the loess-mantled uplands are highly erodible. Soil piping and associated cover collapses are common hazards (Fig. 23) as ground water seeps through the silt and is commonly perched above fragipans. Great care must be taken during agricultural operations not to mobilize and lose this valuable resource.



Figure 23. Collapsed soil pipe in southern Henderson County. Gully is roughly 5 feet deep in foreground; mappers in the distance mark the lateral, depositional edges of a sediment fan of material eroded from the soil pipe.

Modification and engineering of the floodplains, such as the installation of artificial levees, shuts down the natural supply of sediment to low lying parts of the floodplain, and prevents the natural replenishment of soil nutrients by thin flood deposits.

Archeology

Humans probably have inhabited the Ohio River valley since the retreat of the Wisconsin ice sheet 12,000 years ago (Fig. 24). The ancient peoples likely used the rivers and streams of the area as transportation corridors, and took advantage of the diverse wildlife of the region for food. Lewis (1996) provides an overview of Kentucky

archeology, and Marquardt and Watson (1996) summarizes recent work on Green River archaeological sites.

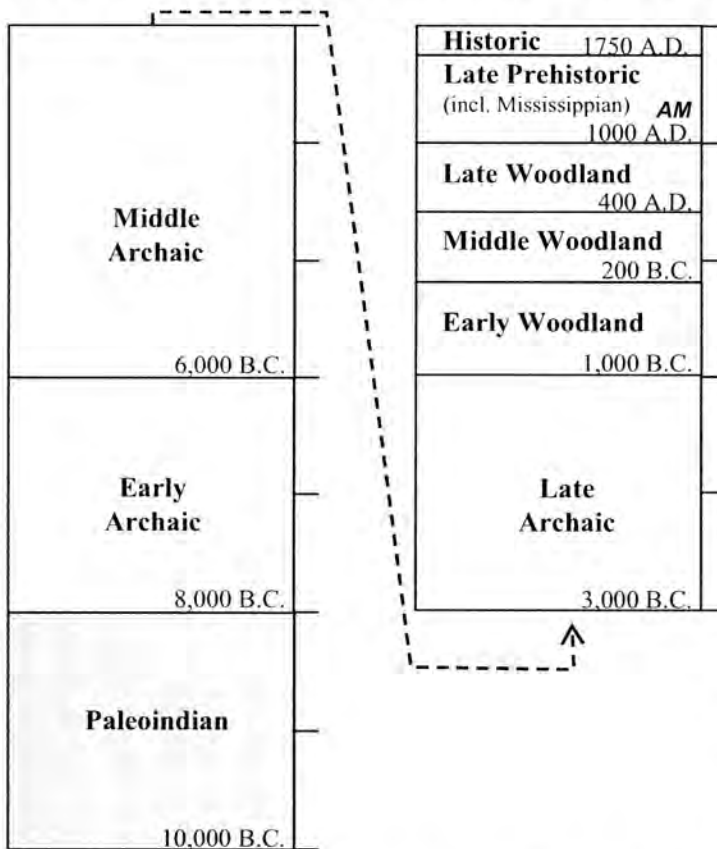


Figure 24. Generalized chronology of archeological periods represented in Kentucky; modified from Lewis (1996). AM: Approximate time period that the Angel Mounds site was occupied.

The Paleoindian period (10,000–8,000 B.C.) is the earliest in Kentucky archeology (Fig. 25). The Paleoindian people were Ice Age hunter gatherers who lived and traveled in small nomadic bands, and were the predecessors for later cultural groups living in the area. After glacial retreat, environmental conditions began to become more favorable for cultural expansion. The number and size of the hunter-gatherer bands began to increase. The Archaic Period (8,000–1,000 B.C.) represents a group of cultures that were still highly mobile, but culturally more complex. During the Archaic, numerous shell mounds were constructed along the Green River as groups moved along the river harvesting mussels and other local wildlife for food.

The Woodland Period (1,000 B.C.–1000 A.D.) records the technological advances as local groups made the transition from strictly hunter-gather to cultivator-hunter-gather. Larger villages developed, and archaeological sites became more complex as the development of agriculture supported larger populations. Pottery was

extensively developed and became more complex and decorative. The Slack Farm site in Union County represents a period of Early Woodland cultivation. The site was occupied for centuries because the rich Ohio Valley floodplain environment encouraged sedentary settlements. The Smith site and site 15He13 in Henderson County represent the Hopewell Middle Woodland cultures similar to Slack Farm. The Foster Site in Daviess County represents Late Woodland culture, which contains various domesticated crops indicating continued cultivation in the Ohio Valley floodplain.

The Late Prehistoric Period (900-1700 A.D.) is complex, with political and cultural variation in cultures. In the field trip area, the Late Prehistoric sites are considered to be part of the Mississippian culture. The Mississippian groups included ranked societies and chiefdoms with the organization of town sites. Agriculture began to become the staple for groups of the Mississippian Period. The Angel Mounds site in Vanderburgh and Warrick counties in Indiana represents a Middle Mississippian town site and chiefdom with a complex of earthen mounds (Stop 10; "AM" on Fig. 24). The town was likely an economic, cultural, political and religious hub, and represented an epicenter of growth with smaller establishments growing outward from the site. The area was occupied from at least A.D. 1100-1450. The town was abandoned for unknown reasons.

The local landscape was a significant factor affecting the various cultures that have occupied the region through time. The availability of resources such as water supply, chert for tools, and clay for pottery were key to the day-to-day functioning of living groups. Floodplain sites offered easy access to transportation, and rich floodplain soils supported crops. However, flooding of low lying floodplain sites was a hazard to the ancient peoples much as they are to modern society. Stafford and Creasman (1998) provide a geomorphic discussion of the distribution and preservation of archeological sites upstream in the Ohio River Valley.

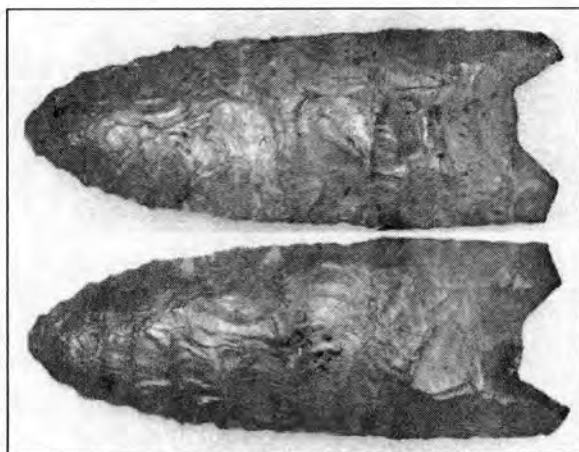


Figure 25. This Clovis spear point, found in Todd County, Ky., is one of the earliest Paleoindian lithic styles found in Kentucky. The artifact measures 2.75 inches long (shown approximately actual size).

Local Color and Local Flavor (puns intended)

Owensboro was originally named “Yellow Banks” after the distinctive color of loess exposed along the Ohio River. Henderson was named for Richard Henderson, founder of the Transylvania Land Company and one of the earliest land speculators in what would become Kentucky.

Owensboro is the self-proclaimed Barbecue Capital of the World. During the late 1800's, sheep were the most common form of livestock raised in the region, and were commonly served to attendees at numerous political and religious meetings. The tradition lives on in many of the region's restaurants, which serve a distinctive style of western Kentucky BBQ and specialize in mutton. The annual Bar-B-Q festival in Owensboro attracts over 80,000 visitors each year.

The western Kentucky region has produced numerous musical legends. W.C. Handy married in Henderson, and lived there for a decade. The Everly Brothers hailed from Muhlenberg County to the south. Bluegrass legend Bill Monroe was born in Rosine, in Ohio County. Many communities in the area host bluegrass and other music festivals throughout the year.

Folks 'round here like to drive. Owensboro claims NASCAR drivers Darrell Waltrip, Michael Waltrip, Stuart Kirby, Jeremy Mayfield, David Green, Jeff Green and Mark Green and championship motorcycle racer Nicky Hayden as natives. The Little Sturgis Motorcycle Rally in Union County attracts motorcycle enthusiasts from all over North America to enjoy various events, concerts and dirt drag races. Proceeds from the rally are donated to charities and civic organizations.

Noted naturalist and bird-lover John James Audubon lived and studied for a while in Henderson. While living there, he experienced the 1811–1812 New Madrid earthquakes. John James Audubon State Park preserves the area where he lived (Fig. 26).

Actor Johnny Depp grew up in Owensboro. The twin church steeples featured in the opening credits of the sitcom *Roseanne* were filmed in Evansville.

In 1936, Owensboro was the site of the last public hanging in the United States.



A.



B.

Figure 26. A. The museum at John James Audubon State Park in Henderson; photo from Ann Wallace Shropshire Collection, University of Kentucky. B. Program cover for the 1972 Owensboro Regatta, which featured hydroplane races on the Ohio River.

FIELD TRIP STOP DESCRIPTIONS

Friday, October 6, 2006

Trip Headquarters

Each day, we will begin our trip from the Ramada Inn in Henderson, Ky. Because of its fortuitous site selection on high fluvial and lacustrine terraces, Henderson is the only riverfront town along the Ohio River that has never experienced significant flood damage. The community has adopted the unofficial motto, "By the Ohio River, but Never under It."

Stop 1: Ohio River Valley Alluvial Landforms along U.S. 231 and U.S. 60, Maceo, Ky.

Steven L. Martin and William M. Andrews Jr., Kentucky Geological Survey

Introduction

The primary objective of stop 1 is to show how the terraces and other landforms of the Ohio River Valley have been identified and represented on the KGS Quaternary geologic maps. At this stop we will also discuss land use with respect to flooding, geotechnical properties of Ohio River sediments, and the shear-wave architecture of the Ohio River Valley. New Quaternary geologic mapping in the surrounding area has been performed by Steven Martin and William Andrews.

Location

Stop 1 is located along U.S. 60 near the intersection with U.S. 231 in the northwestern corner of the Maceo 7.5-minute quadrangle in western Kentucky. This site is located on one of the intermediate terraces along the Ohio River Valley. From this vantage point you can identify different terrace scarps that have formed along the Ohio River.

Discussion

Landforms identified along this part of the Ohio River near Rockport, Ind., and Maceo, Ky., include a modern floodplain; at least two intermediate terraces and a high terrace developed on glacial outwash valley fill of the Ohio River; and lacustrine terraces developed in tributary valleys (Fig. 27). These terraces are delineated on the KGS Quaternary geologic maps by a contact drawn at the base of the terrace scarp. This contrasts, for example, with the model developed for the Duck River in Tennessee by Brackenridge (1982), who suggested that terrace materials onlap older landforms and the landforms have complex geomorphic histories.

The floodplain is the lowest terrace surface, and is found adjacent to the Ohio River. Intermediate terraces are identified by their elevation relative to the adjacent floodplain and high terraces. They have swale and scroll topography, but are typically lower relief than the floodplain or high terrace. The high terrace is the highest local terrace identified in an area of the valley. It is possible that not all high terraces mapped in the valley represent the level of maximum Wisconsinan valley fill (see Fig. 11). The high terraces are noticeably dissected compared to lower terrace surfaces.

The high terrace is underlain by sand and gravel, with a thin mantle of loess. This deposit is inferred to represent glacial outwash deposited during the Wisconsinan glacial stage. Data from elsewhere in the area strongly suggest that older deposits may be buried beneath the Wisconsinan fill. The intermediate terraces are inferred to be underlain by a 30- to 50-ft-thick deposit of outwash or locally reworked outwash, representing either late glacial or immediately postglacial deposition as the Ohio River adjusted to changing discharge and sediment loads. The lithology of the intermediate terraces is indistinguishable from the high terrace in most general well logs. The floodplain is underlain by 30 to 50 ft of alluvium derived from upstream in the Ohio River basin. This alluvium is distinctly finer grained than the older deposits.

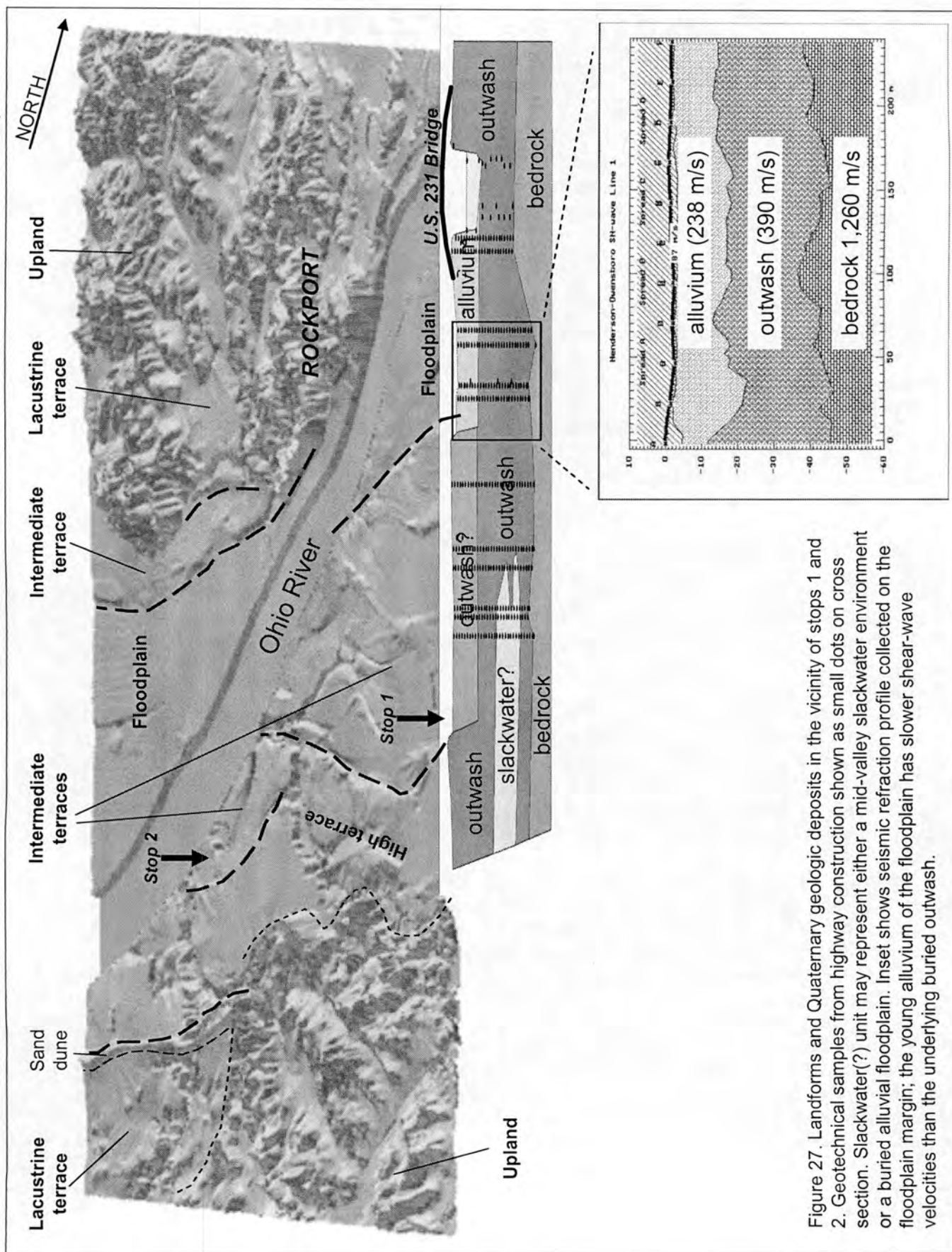


Figure 27. Landforms and Quaternary geologic deposits in the vicinity of stops 1 and 2. Geotechnical samples from highway construction shown as small dots on cross section. Slackwater(?) unit may represent either a mid-valley slackwater environment or a buried alluvial floodplain. Inset shows seismic refraction profile collected on the floodplain margin; the young alluvium of the floodplain has slower shear-wave velocities than the underlying buried outwash.

Ray (1965) identified the floodplain, high terrace, and one low terrace in this area. He assigned the high terrace to the Tazewell (full glacial) substage, and the low terrace to the Cary (late glacial) substage. The current KGS mapping recognizes multiple intermediate terraces. Ray provided detailed delineation of the swales and swells within these landforms; the current KGS mapping does not.

Floods are relatively common in this area. The relative frequency of flooding on the lower terraces makes construction of permanent structures undesirable (Fig. 28). The floodplain floods almost annually, and is mostly used for row crops or left as woodland; barns are only constructed on the levee and on the highest swells. The intermediate terraces flood every 2 to 20 years, and are also predominantly used for agriculture. They have more barns, especially along the crest of the terrace scarp adjacent to the floodplain. Locally, mobile homes and relatively inexpensive frame houses have been located on intermediate terraces. Historically, the high terraces have not flooded in this area. Older homes, most businesses, and major industry are most common on the high terrace. The towns of Lewisport, Maceo, and Owensboro were founded on high terraces. The maximum flood of record, in 1937, reached the edge of Maceo, visible across the highway from stop 1.

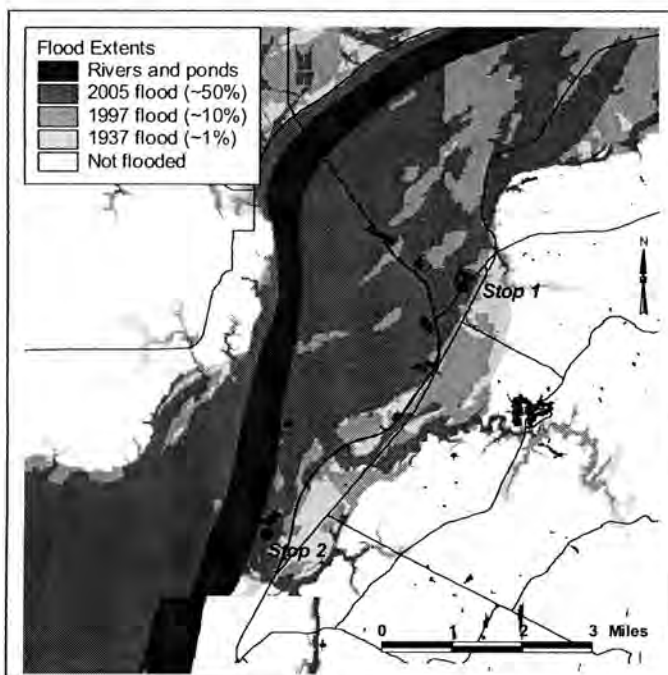


Figure 28. The extent of three major floods (1937, 1997, 2005) that have affected the area. Flood extents have been estimated from U.S. Army Corps of Engineers flood profiles and National Weather Service stream gage and flood records.

Geotechnical data collected during planning, and design of the new stretch of U.S. 231 and the Natcher Bridge (Fig. 29) provide an opportunity to complement the new mapping with an understanding of the geotechnical properties of the valley-fill sediments. Data from this project were provided to the KGS mapping project by the Geotechnical Branch of the Kentucky Transportation Cabinet. Selected data are summarized in Table 1.

Seismic refraction surveys conducted by KGS and UK reveal different shear-wave velocities in the Ohio River Valley sediments (Fig. 27, inset). These different velocities are interpreted to represent the modern

floodplain, glacial outwash valley fill, and the underlying bedrock. The shear-wave data provide a mapper a general understanding of the subsurface architecture of the Ohio River valley fill sediments. The shear-wave velocity data can be used to predict ground-motion amplification during a seismic event.



Figure 29. The U.S. 231 Natcher Bridge crosses the Ohio River near Rockport, Ind. The bridge opened to traffic in August 2002.

Material	N-values <i>min, avg, max</i> [# samples]	% Fines <i>min, avg, max</i> [# samples]	USCS (sorted by freq.) [# samples]	AASHTO (sorted by class) [# samples]
alluvium	3, 15.2 , 32 [37]	3, 37.9 , 99 [62]	CL [14] SM [8] SP-SM [7] CH[4] SP[4] SW-SM[3] ML[2] SM[1] SP[1] CL-ML[1]	A-1-b(1)[12] A-2-4(0)[7] A-3(1)[4] A-4(x)[4] A-6(x)[6] A-7-6(x)[7]
alluvium in intermediate terraces	2, 13.6 , 44 [55]	0, 17.5 , 95 [64]	SP-SM [15] CL [6] SM[2] CL-ML[1] ML[1]	A-1-b(x)[22] A-2(4)[2] A-2-4(0)[3] A-3(x)[7] A-4(x)[2] A-6(x)[5] A-7-6(x)[1]
outwash	2, 33.3 , 211 [224]	0, 13.7 , 89 [231]	SM [28] SP-SM [15] SW-SM [7] SP [6] SW-SP[3] CL[3] CL-ML[1] GP-GM[1] ML[1]	A-1-b(x)[35] A-2-4(0)[30] A-3(1)[5] A-4(x)[5]
lacustrine	2, 6.2 , 12 [17]	33.9, 78.7 , 99.5 [17]	ML [10] SM [3] CL[2] ML-CL[2]	A-2-4(0)[2] A-4(x)[15]
all samples	2, 26.7 , 211 [333]	0, 21.3 , 99.5 [374]		

Table 1. Summary of geotechnical data associated with Quaternary valley-fill deposits in the Rockport-Owensboro area. N-values (blow counts) are from standard penetration tests (SPT); %Fines equals clay + silt; Unified Soil Classification System (USCS) classifications are sorted by frequency of occurrence for each material; American Association of State Highway and Transportation Officials (AASHTO) soil classifications are sorted by class.

Stop 2: Daviess County Sand and Gravel, Owensboro, Ky.

Roy Adams, Daviess County Sand and Gravel

NOTE: This is an active sand and gravel production operation. Please wear a hard hat, stay with the group, and follow instructions from plant employees.

Introduction

This stop will provide an opportunity to visit an active sand and gravel production facility in the Ohio River Valley. The discussion below is from the company's Web site (www.dcsandgravel.com). New Quaternary geologic mapping in the surrounding area has been performed by William Andrews.

Location

Daviess County Sand and Gravel is located at river mile 751 on the Ohio River. The land entrance is northeast of Owensboro on U.S. 60/231. The dredge pond has been excavated into an intermediate terrace adjacent to the Ohio River (Fig. 30).

Discussion

In the 1950's, Daviess County Sand & Gravel began dredging from the Ohio River. Today, DCS&G produces over 200,000 tons of aggregate yearly, sold primarily to concrete plants, asphalt plants, golf courses, and construction contractors. They use a state of the art delignite system in the removal of deleterious material. This, along with the Eagle Autospec Classifying system in their sand plant, allows them to offer their customers state approved, quality aggregate. Daviess County Sand & Gravel is a Qualified Aggregate Producer for both the state of Kentucky and Indiana, and participates in INDOT's Certified Aggregate Producer Program (CAPP). We produce sand and gravel to meet state specifications, and distribute limestone produced at state approved quarries. All aggregates are tested at our yard according to state and federal regulations by a Certified Aggregate Technician.

DCS&G also offers river terminal services. They are permitted to load and offload a wide variety of products including limestone, sand, gravel, salt, potash, scrap metal, coal, petroleum coke, and woodchips.

Field Trip Notes:

The gravel produced by DCS&G includes pebbles and cobbles of limestone, sandstone, siltstone, coal, chert, quartz, quartzite, granite, and other igneous and metamorphic lithologies. The sand and gravel are produced by a dredge removing material from 80 or more feet below the terrace surface. Figure 31 shows an example subsurface log from the DCS&G property. If conditions permit, we will have an opportunity to examine a waste pile of some of the larger cobbles, which they do not process in their plant.

The borrow pit north and east of their dredge pit was excavated in the 1990's to provide fill for the construction of the new U.S. Highway 60 adjacent to the property.



Figure 30. Aerial view of the Daviess County Sand and Gravel property, showing the dredge pond excavated into the terrace (right center) and barge loadout facilities (lower right). Photo from DCSG Web site.

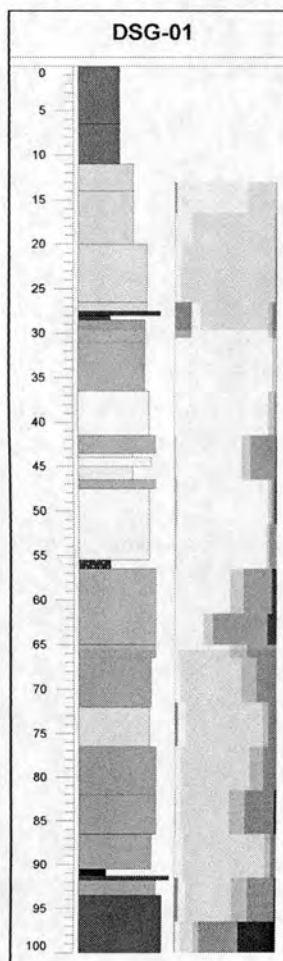


Figure 31. Subsurface log from Daviess County Sand & Gravel property. Width of column at right indicates grain size from geologist's description. Columns at left are from a gradation analysis performed at 5-foot intervals on the core.

Stop 3: Bon Harbor Hills Loess Section, Daviess County, Ky.

Ronald C. Counts, Kentucky Geological Survey

Introduction

The primary objective of Stop 3 is to examine the loess stratigraphy preserved in the Bon Harbor Hills in Daviess County, Ky. This site contains representative loess and associated paleosols for the Ohio River Valley, a late Pleistocene fluvial deposit, and bedrock. Ongoing research at this site has produced the first published dates for Peoria Loess in the Ohio River Valley, and additional dating, x-ray diffraction (XRD), grain-size analyses, and magnetic susceptibility studies are in progress or planned for the near future. Stop 3 is located at an active borrow pit that changes weekly, so the exposures are fresh; however, this means they can also be unstable. Please use caution and examine the vertical slope at the active face from a safe distance. New Quaternary geologic mapping in the surrounding area has been performed by William Andrews and Ron Counts.

Location

The Bon Harbor Hills lie less than 1 mi from the modern Ohio River in the northwestern corner of Daviess County, Ky. (Fig. 32). They are one of several isolated upland areas that stand prominently above the flat-lying alluvial lowland areas that surround them. During the 1937 flood, the largest ever recorded on the Ohio River, the southern side of the Bon Harbor Hills remained dry (Mansfield, 1938), but in the late Pleistocene they were an island that was surrounded by glacial outwash and meltwater.

Previous Studies

Unlike in the Mississippi River Valley and its tributaries, there have been few detailed studies of loess in the Ohio River Valley. Early workers hypothesized that the loess was of "aqueous" origins (see, for example, Lyell; 1847; Owen, 1859; Fuller and Clapp, 1903). Shaw (1915) was the first to correctly recognize that the loess in southwestern Indiana was primarily eolian, not aqueous as proposed by previous researchers. Since these early works, there have been only four detailed studies of loess in the Ohio River Valley. Johnson (1965) performed detailed stratigraphic analyses of the Peoria Loess in southwestern Indiana at 11 locations, only one of which was on the Ohio River. He identified 42 molluscan taxa, determined paleoecological environments, and used root-cast volume as a proxy for depositional rates. Ray (1963) examined grain-size distributions and silt-clay ratios of loess, and described many sections in and around the Bon Harbor Hills, identifying Peoria, Farmdale, and Loveland Loess (Ray, 1965). Olson (1977) analyzed loess sections on the Ohio and Wabash Rivers, comparing their clay mineralogy, paleosols, and grain-size distributions. Olson found that the Peoria and Farmdale Loesses had distinctly different clay mineral assemblages, yet the clay mineralogy of the Peoria and Loveland Loesses were similar. Most recently, Hayward (1992) and Hayward and Lowell (1993) used high-resolution magnetic susceptibility (MS) on Peoria Loess and found that changes in MS represented changes in loess accumulation rates, which they hypothesized were controlled by soil moisture.

Stratigraphy

Figure 33 is a stratigraphic column of deposits and soils exposed at this stop in September 2006.

Peoria Loess. The vertical face of the borrow pit is formed in the Peoria Loess, which is at least 44 ft thick (the base has not yet been observed). The modern soil is developed in the top of the Peoria Loess. The Peoria Loess is calcareous, and there is a lower horizon in the loess that has CaCO_3 concretions up to 2 ft long. Gastropods are present throughout the Peoria at this site, but it is uncertain if there are horizons where they are more abundant; the unstable exposure has prevented collection of a detailed measured section. Here the Peoria Loess has at least four dark bands, visible when the lighting is favorable, which are interpreted as weak A horizons (Figure 34). These alternating A-C horizons suggest sustained periods with little or no loess deposition. Dark bands have been observed in the Peoria Loess elsewhere in the Midwest (see, for example, Willman and Frye, 1970), as well as in other sections of the Bon Harbor Hills (Hayward, 1992). Luminescence dating near the top of the Peoria produced an age of approximately 12 ka (W. Newell, 2005, U.S. Geological Survey, written communication; and S. Mahan, 2006, U.S. Geological Survey, written communication), which suggests that the Ohio River was still transporting large sediment loads in braided channels at this time and had not yet switched to a meandering flow regime.

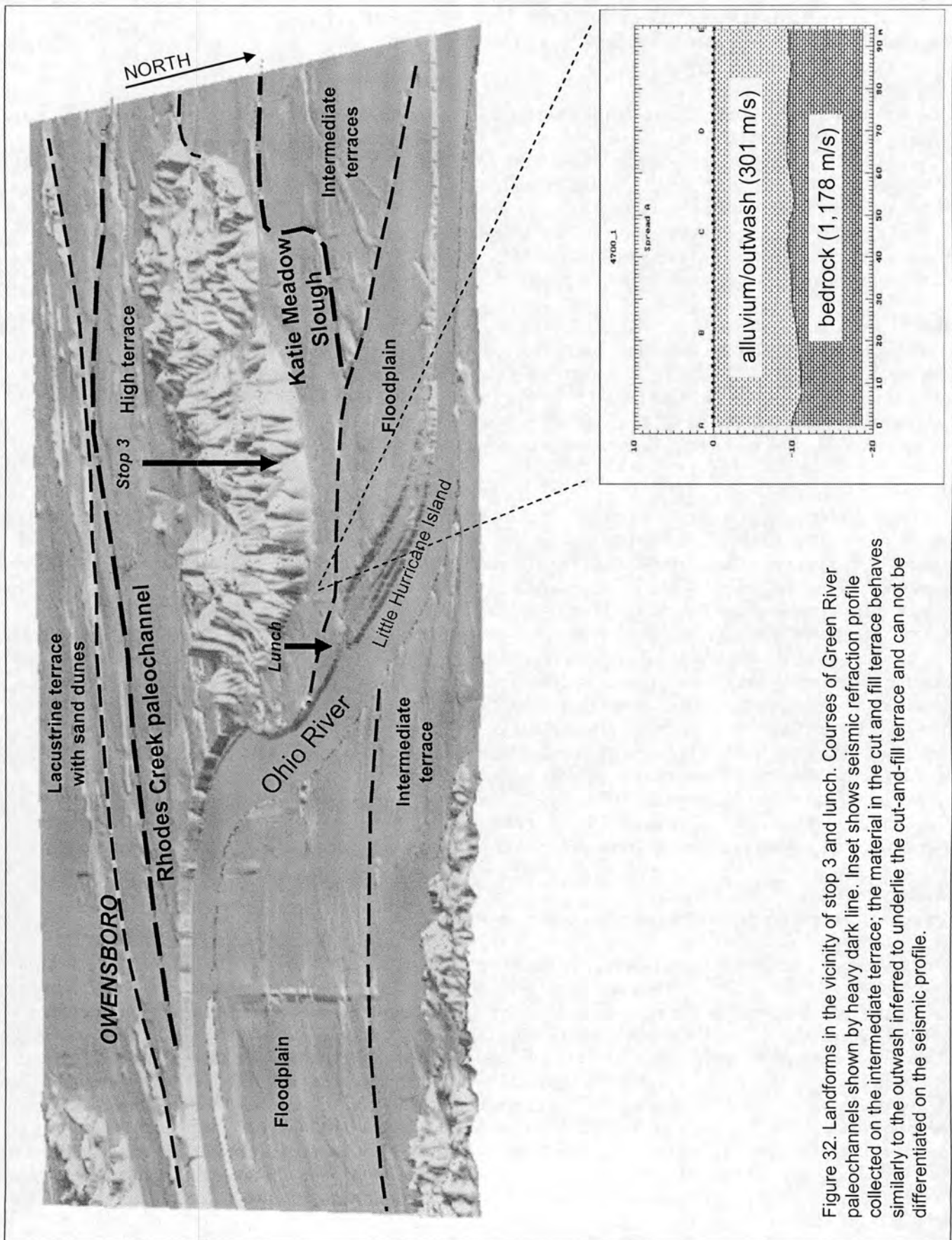


Figure 32. Landforms in the vicinity of stop 3 and lunch. Courses of Green River paleochannels shown by heavy dark line. Inset shows seismic refraction profile collected on the intermediate terrace; the material in the cut and fill terrace behaves similarly to the outwash inferred to underlie the cut-and-fill terrace and can not be differentiated on the seismic profile.

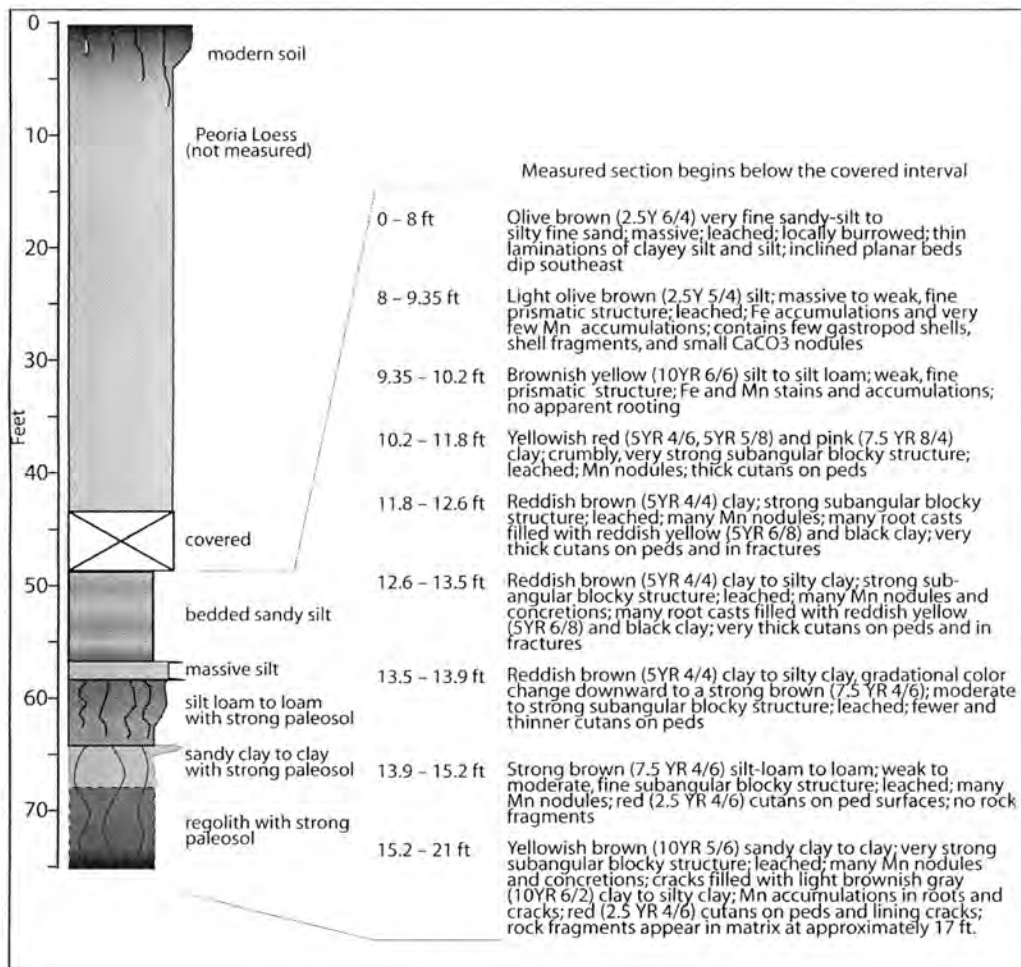


Figure 33. Measured section at stop 3.

Figure 34. Alternating light and dark bands in the Peoria Loess are interpreted as A-C horizons.





Figure 35. Thinly bedded lacustrine deposits underlying the Peoria Loess at stop 3.

Late Pleistocene fluvial/lacustrine deposit. A fine-grained deposit of fine sand and silt that is at least 12 ft thick underlies the Peoria Loess. This unit is composed of inclined, planar sand beds 10 to 20 cm thick interbedded with 1- to 2-cm-thick clayey silt beds (Fig. 35). Locally, there are traces of burrowing and rooting. Gastropods are abundant, though it is unclear if they were aquatic species or if they washed in from the upland. This unit is interpreted as a lacustrine bar or spit. Luminescence dating of sand and radiocarbon dating of the gastropods indicate this unit was deposited approximately 22 ka (Fig. 36).

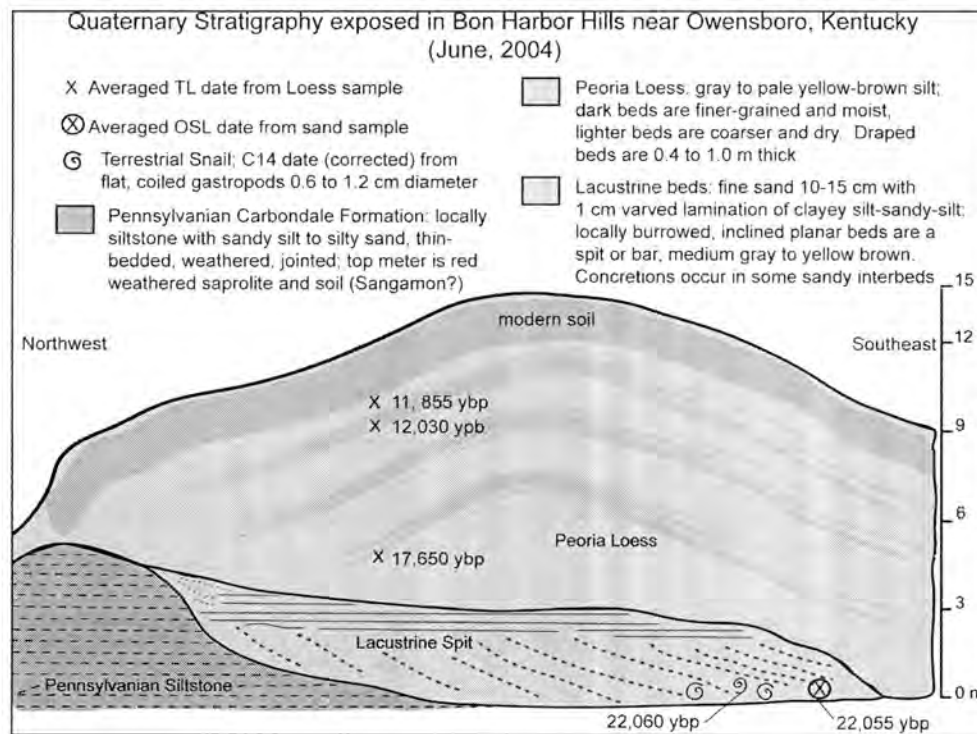
Massive silt (Roxana Loess?). A 1.35-ft-thick bed of silt underlies the laminated lacustrine beds. X-ray diffraction (XRD) samples have been collected to determine if this unit is correlative with the Roxanna Silt.

Sandy silt (Loveland Loess?) with a well-developed paleosol (Sangamon?). Beneath the massive silt a strong paleosol is developed in a sandy silt deposit. Near the base of the deposit, translocated clay decreases significantly, and a sample was collected for luminescence dating. This unit is likely the Sangamon Paleosol developed on Loveland Loess. Ray (1965) reported finding the Loveland Loess in nine locations in the Ohio River Valley.

Fine sandy clay to clay with a well-developed paleosol (Yarmouth?). The texture of the overlying sandy silt changes rather abruptly to a sandy clay or clay that is approximately 2 ft thick. This unit has been significantly altered by pedogenesis, and a very strong paleosol is developed through the sandy clay and into the underlying regolith. This unit could be extremely weathered bedrock that contains no rock fragments, or possibly the remnants of pre-Illinoian (pre-Loveland) loess.



Figure 36. Radiocarbon and luminescence ages for late Pleistocene deposits in the Bon Harbor Hills, KY (Newell and Mahan, writ. comms.). Photo at left shows context of diagram below.



Lunch at Little Hurricane Boat Ramp

At our lunch stop, field trip participants will have a scenic view of the Ohio River and the southeastern end of Little Hurricane Island (Fig. 32). Fraser (1986) examined the midchannel islands in this part of the Ohio River and concluded that they were not mobile, dynamic features. He interpreted them as relatively stable features anchored by locally resistant, submerged Pleistocene outwash bars that diverted Ohio River flow and protected the islands from erosion. The islands remain in one relative location as the river migrates past and around them.

The parking lot and adjacent woodland at Little Hurricane Park offer an easily accessible laboratory for examining local deposition along the channel margin during floods. Sediment deposition on the parking lot makes frequent maintenance and scraping of the paved boat ramp necessary. The ramp was briefly shut down in 2005 because of underwater erosion at the toe of the boat ramp. Several vehicles were nearly lost into the river as the wheels of boat trailers were lodged below the eroded end of the ramp.

Stop 4: Green River Paleochannels, Sorgho, Ky.

William M. Andrews Jr., Kentucky Geological Survey

Introduction

After maximum valley filling occurred, the Green River migrated widely across the area. At least six distinct paleochannels, paleovalleys, or large abandoned meanders are preserved across the alluvial plain between Owensboro and Spottsville (Fig. 15). This stop examines the landscape at the intersection of the two oldest paleochannels (Fig. 37). New Quaternary geologic mapping in the surrounding area has been performed by William Andrews, Ron Counts, Mark F. Thompson, and Matthew Crawford.

Location

Sorgho is located west of Owensboro at the intersection of Ky. 54 and Ky. 56. The buses will stop in the parking lot of Sorgho Baptist Church.

Discussion

This stop is at the intersection of at least two Pleistocene paleochannels of the Green River (Fig. 37). The Rhodes Creek paleochannel is the oldest and highest identified in this area. It trends east-northeast through the community of Sorgho, and is correlated in Owensboro with the Beds at Hubert Court of Ray (1965). The Beds at Hubert Court have been reinterpreted in the new KGS Quaternary mapping to represent a sliver of the Green River paleochannel preserved along the banks of the Ohio River. Ray (1965) reported a radiocarbon age of 23 ka on wood from Hubert Court. Katie Meadow Slough trends to the north away from Sorgho, and dissects Ohio River intermediate terraces, which are estimated to be 8,000 to 12,000 years old in this area. The location of Sorgho probably represents the point where drainage from the Rhodes Creek paleochannel was diverted into Katie Meadow Slough in the latest Pleistocene or earliest Holocene. The Green River subsequently abandoned the Katie Meadow Slough paleochannel and has migrated west across the alluvial plain to its present position adjacent to the upland near Spottsville and Bluff City.

The community of Sorgho is almost 2 mi from the Green River, and 6 mi from the Ohio River. The low-lying area north of town associated with Katie Meadow Slough floods frequently, but only in 1937 did floodwaters encroach into the community itself and block the highways through town. The parking lot at this stop would have been under a few feet of water during that flood. The Audubon Parkway passes east-west about a third of a mile north of town. The lowest area immediately adjacent to the parkway embankment was a borrow pit where fill material was excavated to elevate the highway above the flood zone.

Stop 5: Lacustrine/Slackwater Geomorphology and Geology at Bluff City, Ky.

Michael L. Murphy and William M. Andrews Jr., Kentucky Geological Survey

Introduction

This stop provides an overlook of the Green River and the landforms near the mouth of Lick Creek, a tributary of the Green River. Typical landforms associated with the lacustrine terrace are easily visible here. Recent subsurface investigations nearby are providing a better three-dimensional understanding of the lacustrine valley-fill sediments. Figure 38 provides an overview of the landforms in this area and the location of subsurface investigations conducted thus far. New Quaternary geologic mapping in the surrounding area has been performed by Michael Murphy and Mark F. Thompson.

Location

The stop is located in Bluff City, Ky. The buses will stop in the parking lot of a church at the corner of Bluff City Road and Spottsville-Bluff City Road.

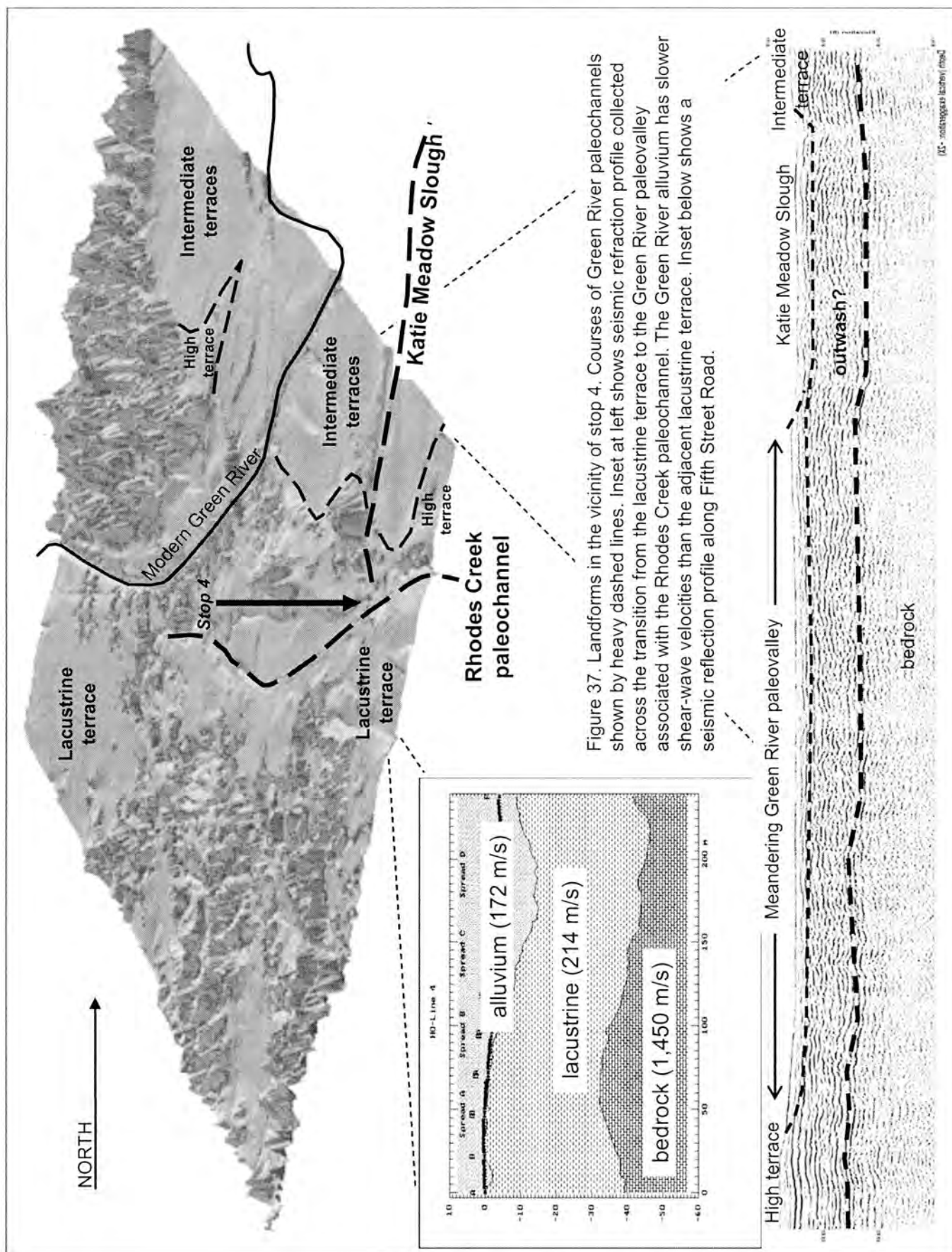


Figure 37. Landforms in the vicinity of stop 4. Courses of Green River paleochannels shown by heavy dashed lines. Inset at left shows seismic refraction profile collected across the transition from the lacustrine terrace to the Green River paleovalley associated with the Rhodes Creek paleochannel. The Green River alluvium has slower shear-wave velocities than the adjacent lacustrine terrace. Inset below shows a seismic reflection profile along Fifth Street Road.

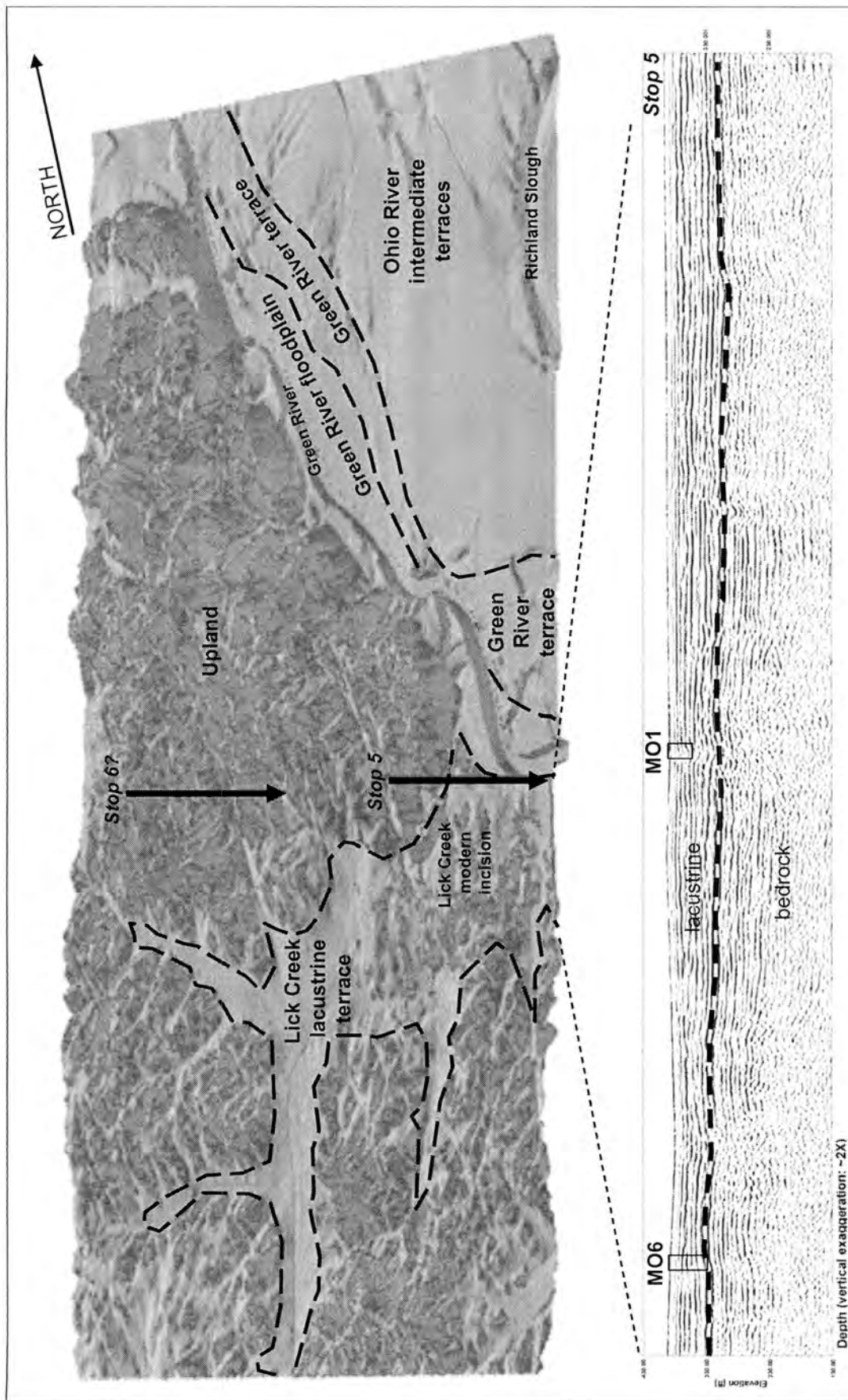


Figure 38. Landforms in the vicinity of stop 5; the location of the partially reclaimed surface mine which is one option for Stop 6 is shown. Inset shows a seismic reflection profile along Bluff City Road. Locations of two cores (MO1 and MO6) are shown on the profile; both cores recovered fine-grained lacustrine material.

Discussion

During the Pleistocene, the Ohio River carried meltwater and outwash past this location. Rapid aggradation of glacial outwash sediment at the valley mouth led to impoundment of the Lick Creek Valley and deposition of lacustrine/slackwater sediment up to 80 ft thick. The community of Bluff City is constructed on the crest of the lacustrine/slackwater terrace (Fig. 39). The terrace scarp is well developed and easily visible at this location. To the north is the Green River, with a narrow intermediate terrace preserved. Bedrock is exposed in the river bank below and east of the stop location. To the south, the land surface is reverse graded, with elevations gently decreasing away from the main river valley. To the southwest, the modern floodplain of Lick Creek is inset as much as 25 ft into the lacustrine terrace. Mass wasting of terrace material behind the church raises potential concern for the stability of the building's foundation.

Throughout the mapping area, a complex transition is recognized between the flat lacustrine terrace and the adjacent loess-mantled uplands (Fig. 14). This complex transition typically extends no more than 35 to 45 ft above the lacustrine terrace surface. The topography of this transition zone is typically more subdued and benched than the adjacent upland. Thorough analysis of this transition zone is incomplete, but in different areas a mosaic of loess, colluvium, slopewash, and lacustrine sediment have been recognized. Small debris fans originating in the topographically higher loess deposits or from collapsed soil pipes are relatively common. Bedrock depths are comparable to adjacent upland areas. This transition is hypothesized to represent areas that were periodically inundated as the Pleistocene lake levels fluctuated, responding to varying meltwater discharge in the main Ohio River Valley.

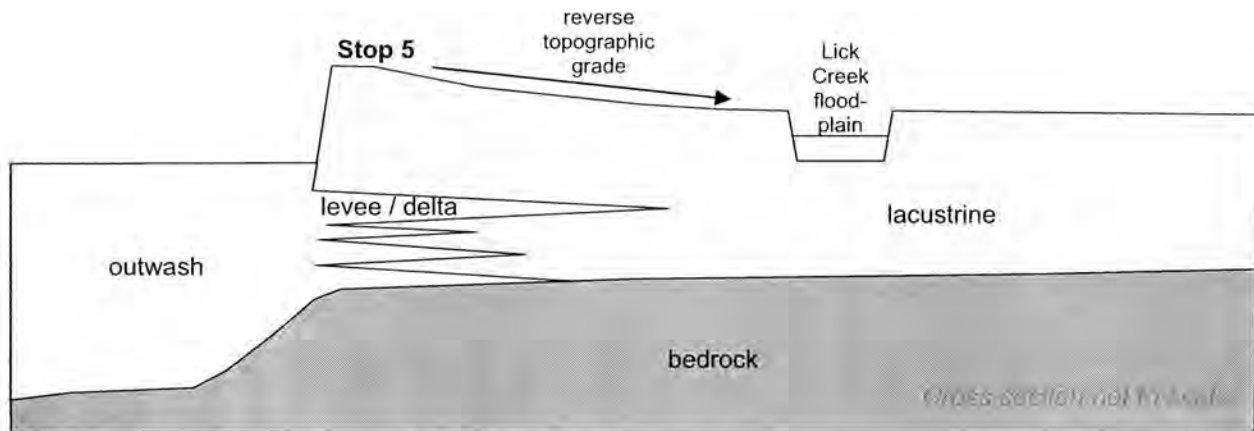


Figure 39. Cross section along Lick Creek Valley showing general relationships between Ohio River Valley outwash and lacustrine sediment in the valley.

Stop 6: Mining the Springfield Coal, Bluff City, KY

Michael L. Murphy and William M. Andrews Jr., Kentucky Geological Survey

The Springfield coal (W.Ky. 9) has been mined in the Bluff City area for several years, and active production continues from surface mines in the area. At the time of field trip planning, the viewing conditions of the active operations were unpredictable. We will visit either an overlook of an active surface mine operation or a partially reclaimed surface coal mine in the Bluff City area. Either of these will provide an operation to discuss bedrock geology and coal production in the field trip area.

Stop 7: Keach Farm, Henderson County, Ky.

Ronald C. Counts, E. Glynn Beck, and William M. Andrews Jr., Kentucky Geological Survey

Introduction

This stop will highlight some of the work that has been done by KGS on the Scott Keach farm. The ongoing groundwater project that began in 1996 has resulted in the accumulation of a large and diverse body of data from a variety of studies. These include drillers' logs from dozens of installed monitoring wells, hundreds of soil cores, electrical-resistivity profiles, aquifer tests, a cone penetrometer sounding, six gamma-ray logs, a seismic-refraction profile, a seismic-reflection profile, and detailed soil descriptions. New Quaternary geologic mapping in the surrounding area has been performed by Ron Counts.

Location

The Keach farm lies on a bedrock upland area that forms the southern Ohio River Valley wall in the Wilson 7.5-minute quadrangle. Figure 40 shows the landforms in the vicinity of the Keach farm.

Stratigraphy and Soils

The upland areas of the farm are composed of 25 to 40 ft of loess that overlies a relatively flat bedrock surface. There are no loess or bedrock outcrops on the farm, but soil chemistry analyses, grain size analyses, and descriptions of soil cores indicate that several paleosols are present in the loess (Fig. 41). No Pliocene-Pleistocene gravels were present in any of the cores or monitoring wells drilled at the Keach Farm.

The two dominant soils on the Keach farm are the Loring and Memphis series. Memphis soils are well drained and occur on the hilltops. Loring soils are poorly drained, often have fragic properties or contain a fragipan, and occur on hillsides. There are many seeps on the farm associated with fragipans in the Loring soils. These seeps are associated with perched water in the vadose zone and not with groundwater from the bedrock aquifer. The occurrence of fragipan soils may play a significant role in the development of topography. Many soil pipes are present on the Keach farm and are even apparent in aerial photographs (Fig. 42). These features form as slightly acidic rainwater infiltrates the soil and dissolves CaCO_3 in the Peoria Loess. Once the water reaches the fragipan it moves horizontally, forming a conduit that grows progressively larger. Eventually, the horizontal pipe collapses, forming a depression on the land surface that becomes the preferential flow path for runoff. The study of soil pipes in western Kentucky is a collaborative project that is currently in progress.

Groundwater

In 1995, a project was initiated in Henderson County to assess the impact of agricultural practices on upland bedrock aquifers. During the first phase of the project (1995 to 1998), a dairy holding/feeding lot, abandoned approximately 30 years ago, was discovered within 250 ft of the farmer's domestic water well, which contained nitrate-N concentrations between 35 and 55 mg/L $\text{NO}_3\text{-N}$. Initial research efforts ruled out present agricultural practices as the source of elevated nitrate-N in the domestic well.

Phase II of the project (1998 to 2000) entailed soil core collection, additional well installation, and isotope analyses to better define the source and movement of the elevated nitrate-N to the shallow bedrock aquifer, which is about 30 ft below land surface. Additional well installation, isotope analyses, and geostatistical modeling completed during the third phase of the project (2000 to 2001) better defined the areal extent of contamination within the shallow groundwater system and overlying soil. The most efficient and economical remediation plan for the abandoned feed lot was determined, and in phase IV (2001 to 2002), the feed lot was remediated by removing 518 yd^3 of organic-rich soil. The organic-rich soil was thinly spread on a nearby pasture. The excavated area was filled with native soil to original grade. Post-remediation groundwater sampling began in December 2001. During the 2002–03 and 2003–04 study years (phase V), post-remediation groundwater sampling and soil core collection was conducted to determine if nitrate-N concentrations were decreasing in the shallow flow system (soil column and bedrock aquifer). Since remediation, nitrate-N and chloride concentrations in groundwater beneath the feed lot has decreased dramatically to 82 mg/L and 191 mg/L, a reduction of 65 mg/L and 104 mg/L, respectively.

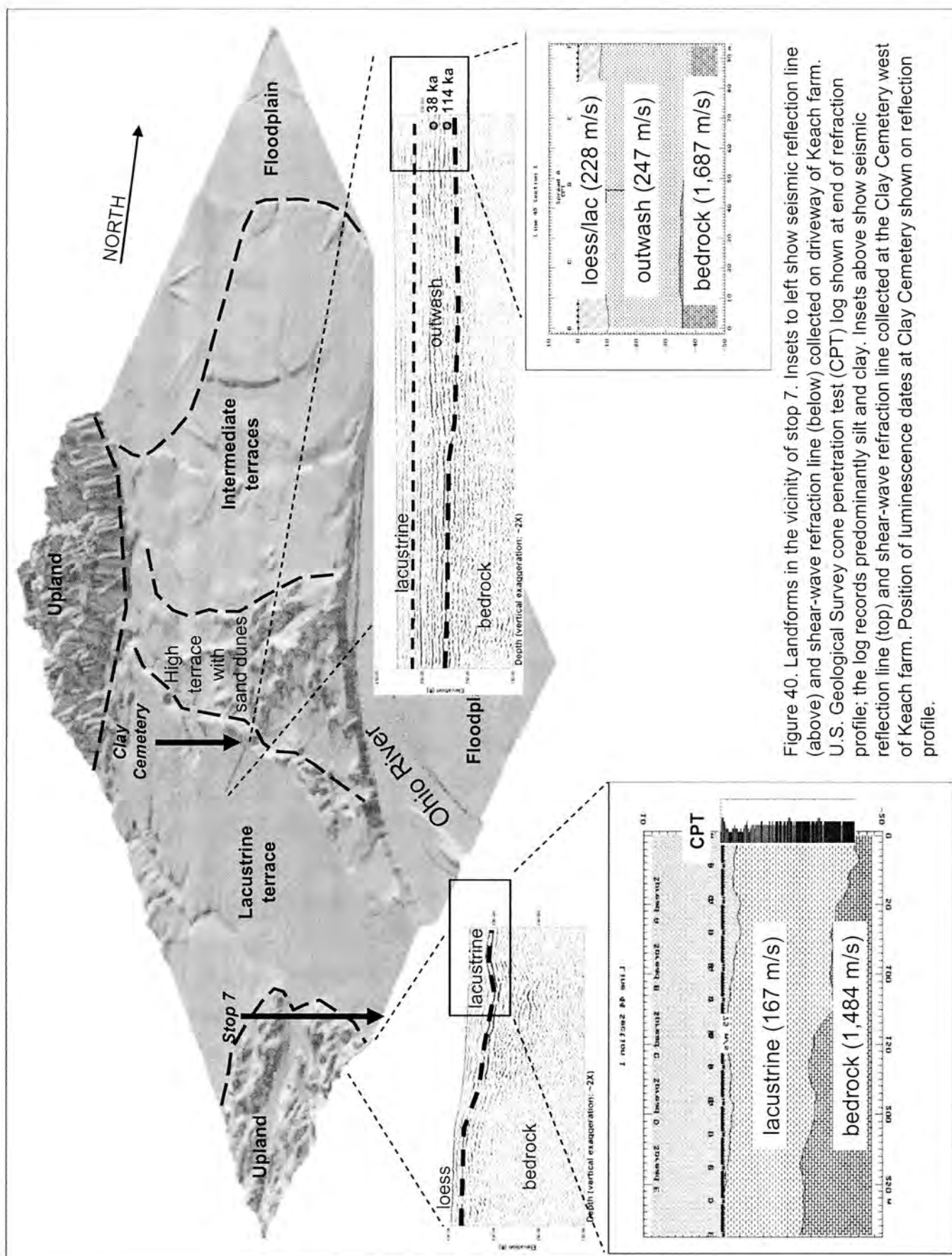


Figure 40. Landforms in the vicinity of stop 7. Insets to left show seismic reflection line (above) and shear-wave refraction line (below) collected on driveway of Keach farm. U.S. Geological Survey cone penetration test (CPT) log shown at end of refraction profile; the log records predominantly silt and clay. Insets above show seismic reflection line (top) and shear-wave refraction line collected at the Clay Cemetery west of Keach farm. Position of luminescence dates at Clay Cemetery shown on reflection profile.

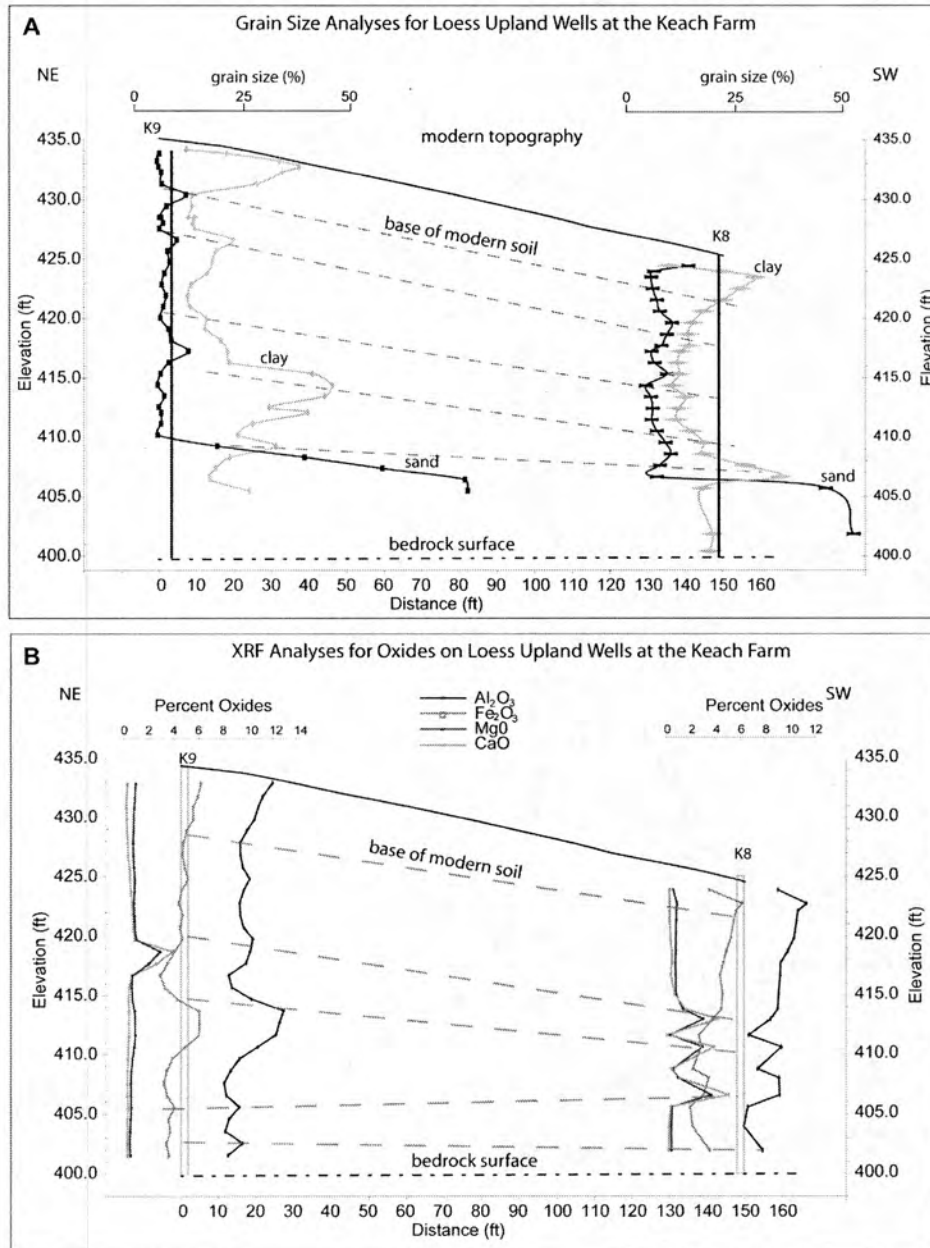


Figure 41. A. Grain-size analyses for monitoring wells on the Keach farm. Increases in clay content below the modern soil indicate paleosol development or possibly stratification of the parent material (loess). B. X-ray fluorescence (XRF) analyses of the same two wells. Aluminum and iron oxide peaks may correlate to paleosols. Similarities between the two graphs suggest that there are three or possibly four paleosols in the loess at the Keach farm.

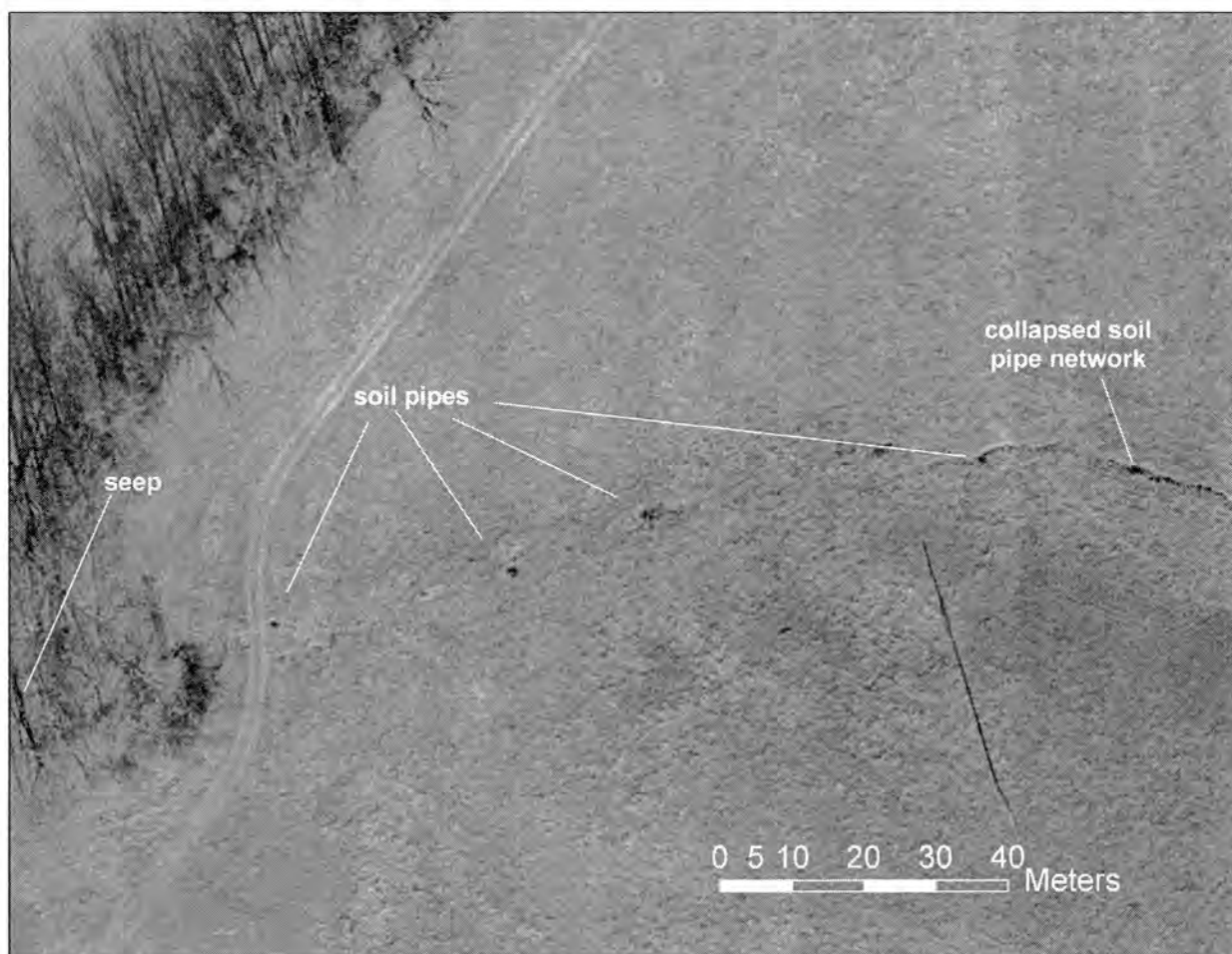


Figure 42. A soil pipe network on the Keach Farm.

Saturday, October 7, 2006

Stop 8: Sand Quarry in Paleodunes near Sand Ridge, Ind.

James M. Durbin and Scott E. Waninger, University of Southern Indiana

Introduction

This stop will examine a loess-capped sand dune west of Rockport in Spencer County, Ind. What makes this site interesting is the geomorphology of the area and how it fits in the larger framework of the region. The site lies along the eastern valley wall of a former channel of the Ohio River (Fig. 43). When the ancestral Ohio River carved this abandoned valley is not known, although topographic expression suggests the valley is a braid plain characteristic of Midwestern streams draining glacial environments during the last 20,000 years. Several linear silt-capped sand ridges, interpreted as loess-capped sand dunes (Ray 1965; Waninger and Durbin, 2005), run southwest–northeast, parallel to the eastern paleovalley wall. In some locations, the sand ridges have merged with each other and the valley wall. The sand dunes have been the subject of an ongoing investigation that ultimately seeks to constrain the age and origin of the linear features and correlate them to climatic conditions in the region.

The site occupies a position where two of the linear sand lines merge to become a single feature pinned against the valley wall. The quarry contains several distinctive strata, as discovered through examination of sediments exposed in the quarry highwall, sediment coring of the quarry floor, and examination of ground penetrating radar

lines that traverse the eastern valley floor up to the highwall (Fig. 44) and down the eastern face of the sand dunes (Fig. 45).

Location

This sand quarry is located in Spencer County, Ind. (UTM zone 16; 485,340 E; 4,195,150 N). The property is located east of Ind. 161 north of Sand Ridge, Ind. Public access is restricted to this working quarry, so seek permission before entering if you visit on your own time.



Figure 43. General location of study area in southwestern Indiana. Black box enlarged and shown to the right is a shaded relief map illustrating sinuous ridges. Location of the stop indicated by white box.

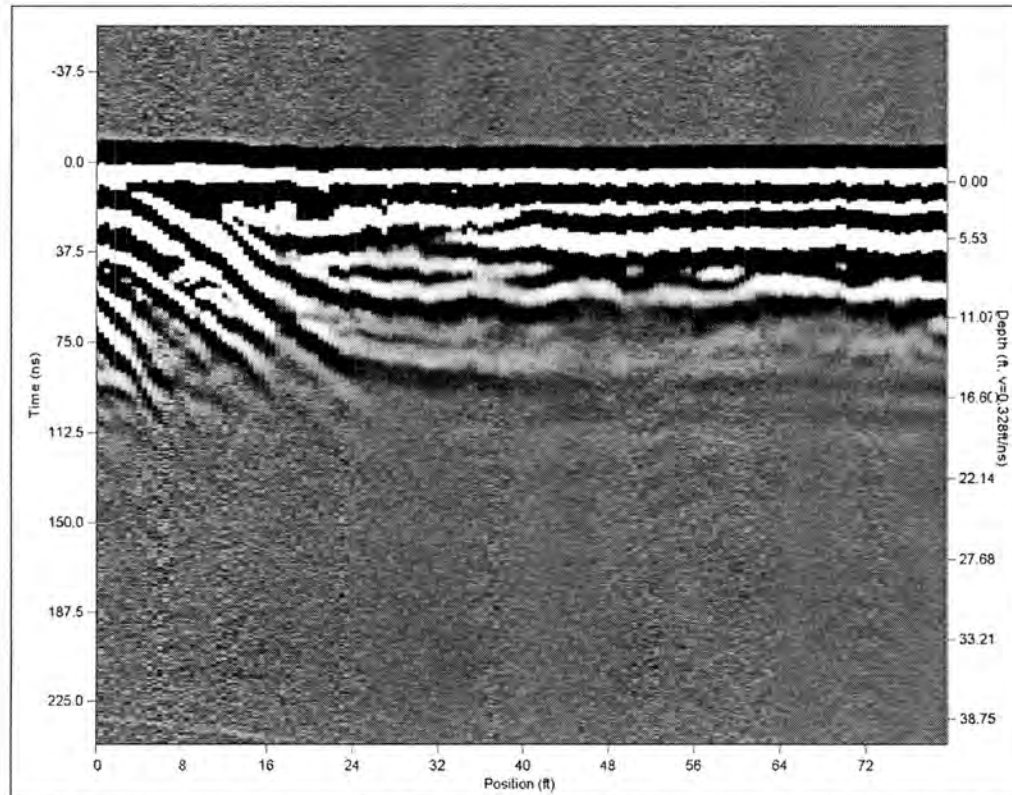


Figure 44. Ground penetrating radar profile running west-east from the crest of interpreted sand dunes into an old lake bed, known locally as Willow Pond.

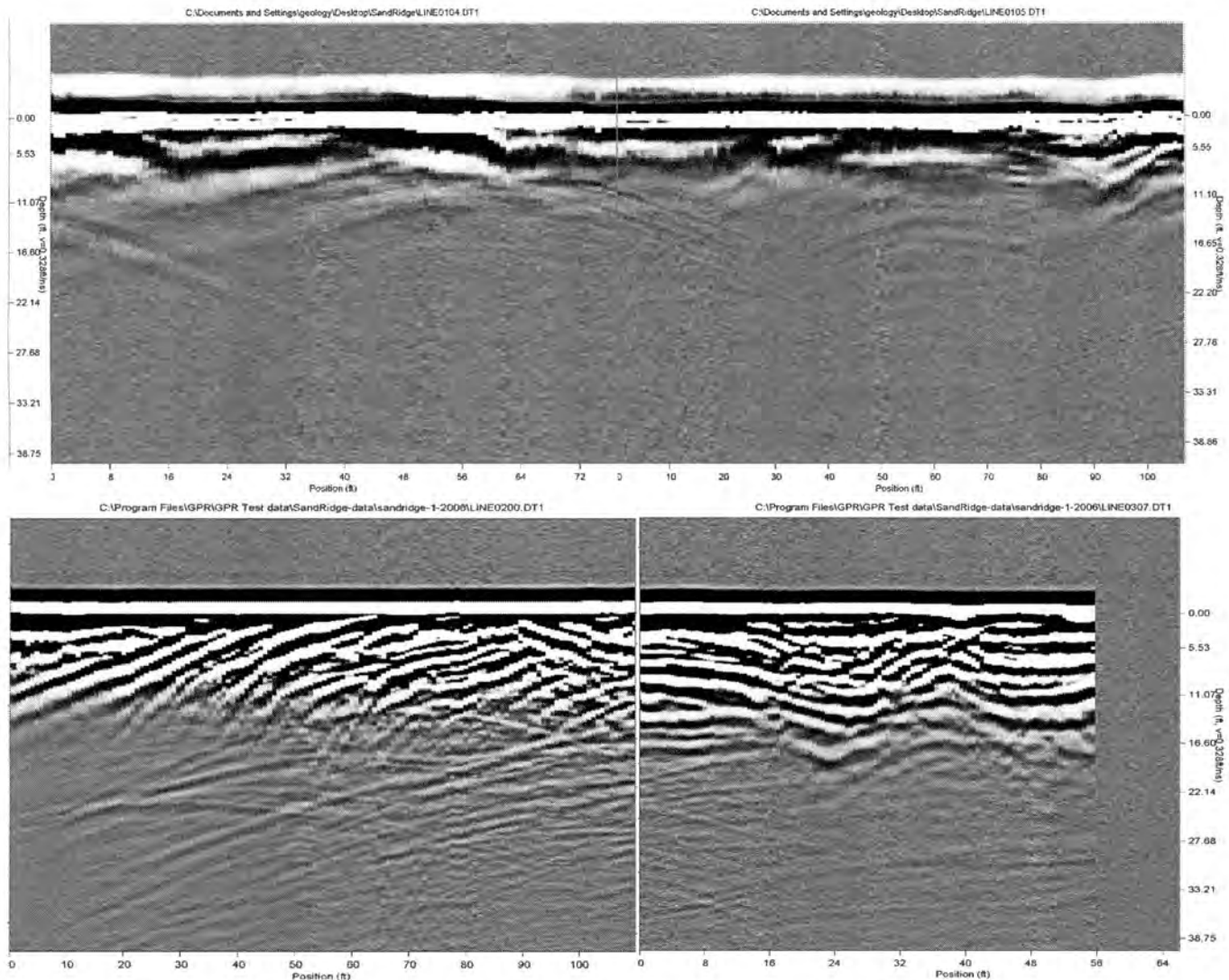


Figure 45. Ground penetrating radar profiles along the floor of the quarry running east–west, from the easternmost highwall to the entry gate of the quarry. Note the steeply dipping cross strata evident in the lowermost data set. Data overlap to form a continuous section.

Stratigraphy

The lowermost unit, unit 0, is not exposed in the sand quarry, as it underlies the floor of the quarry. Descriptions and sedimentary structure and architecture are limited, as most of the information on the unit is from sediment cores or ground penetrating radar. Sediments in unit 0 consist of thinly bedded (0.5–2 mm) lamina composed of gray silt, interpreted as having a lacustrine origin. The contact with unit 1 is at approximately –3.0 m, based on examination of sediment cores, making the total thickness of unit 0 about 6 m.

Unit 1 is a 4-m-thick, thinly bedded silt with intermittent fine sand beds. The sand is common throughout the unit, but becomes more abundant higher in the unit. Although the bedding is nearly horizontal in most locations, it dips slightly in others. Bioturbation has disrupted the bedding in some spots. Carbonate nodules occur throughout, although they are more abundant in the lowermost part of the unit. The upper contact with unit 2 is marked by a weakly developed paleosol of unknown age.

Unit 2 is an 8-m-thick fine sand that exhibits crossbedding with 1- to 2-cm-thick individual beds and intermittent silt lamina. In a few instances, the fine sand contains medium to coarse sand fractions. Crossbedding in this unit is

abundant, and apparent dip angles average about 30 degrees, dipping primarily east-southeast. Based on the crossbed angles and abundance of sand, this unit is interpreted as a dune. Thin beds of black, organic-rich crossbedded sediment occur at the base of this unit, and were sampled for radiocarbon dating. Although the date produced from unit 2 came back radiometrically older than 46,000 years (dead), the material does not appear to be related to Pennsylvanian coal seams that are commonly exposed in bedrock outcrops throughout the region (see Figs. 46–8). We are currently pursuing funding for optically stimulated luminescence or thermal luminescence dating to determine if the dunes are in fact older than 46,000 years or if the carbonaceous material dated was reworked noncoal organics from older fluvial deposits. The contact with unit 3 is distinct and somewhat wavy.

Unit 3 is a 1.5-m-thick silt with minor amounts of clay and fine sand interpreted as loess. The unit is massive, with limited evidence of bedding. An incipient paleosol is evident at the upper boundary of this unit.

Unit 4 is a 1.3-m-thick silt, also interpreted as loess. It has some evidence of bedding, most notably sand with sand beds common in the lower part of the unit. The modern soil is developed within this unit, and as such any bedding that may have been present has been homogenized and obliterated in the uppermost part of the unit.

Discussion

The strata and sediments of morphologically distinct features exposed in a sand quarry in Spencer County, Ind., support earlier interpretations that the ridges along the eastern valley wall of Little Pigeon Creek (a part of the Ohio River Valley) are silt-capped sand dunes (Ray, 1965) and indicate multiple episodes of deposition (Waninger and Durbin, 2005). Changes in lithology, sediment, and bedding structures indicate five episodes of deposition within an overall transition from a lacustrine setting to a dry floodplain. Sharp contacts between the units with limited pedogenic influence indicate relatively short-lived unconformities. The development of incipient paleosols at the tops of units 1 and 3 indicates multiple, relatively short-lived depositional hiatuses where weathering rates outpaced deposition. An accelerator mass spectrometry radiocarbon date (Beta-217287) on organic material collected from the lower 20 cm of unit 2 was older than 46,000 years BP (Waninger and Durbin, 2006). Scanning electron microscope images of the dated material show no ancient fossil material (coal). Thus, the sample's age indicates an episode of eolian activity sometime before the onset of marine isotope stage 3 (approximately 50,000 years ago), or reworking of older material (pre-Wisconsinan) into discrete beds during the terminal Pleistocene.

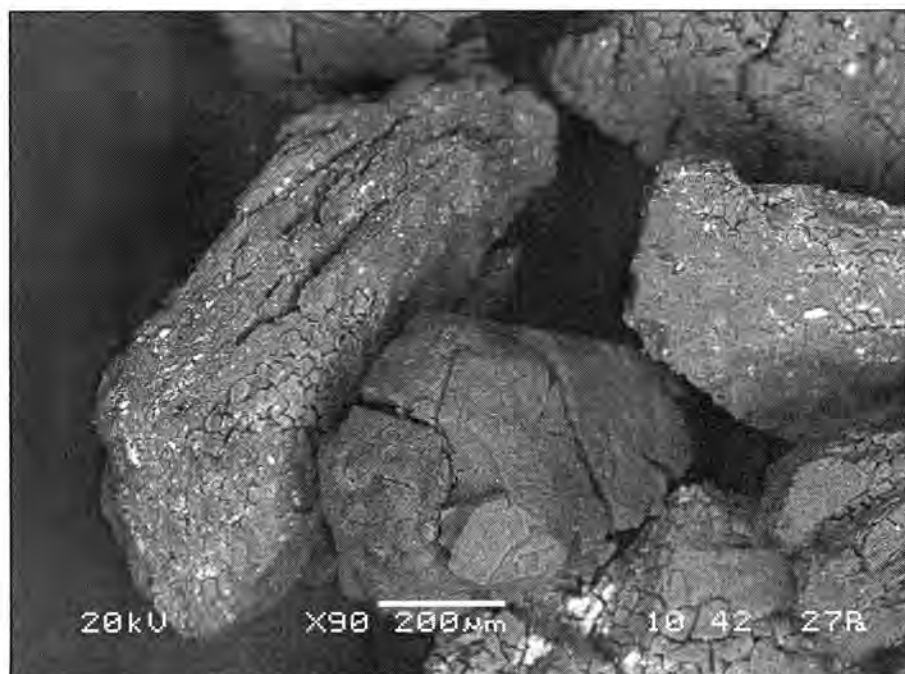


Figure 46. Photomicrograph from a scanning electron microscope showing carbonaceous material that produced the >46,000 BP date from unit 2.

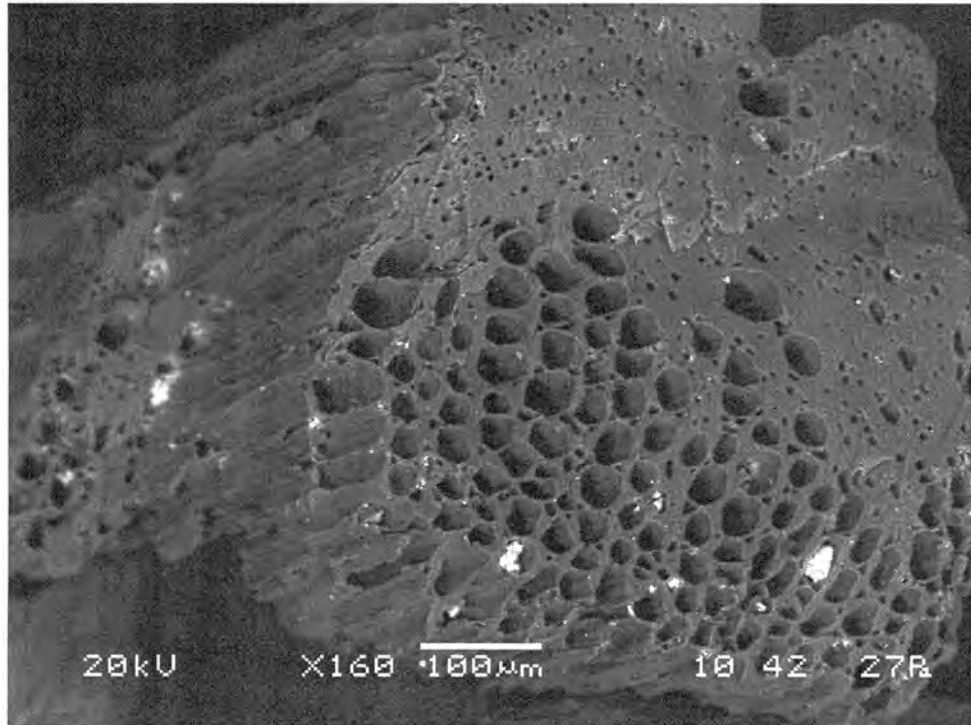


Figure 47. Plant structure from samples that were radiocarbon dated. Note the tubular structures on the right half of the photograph and the striated pattern along the left side of the grain.

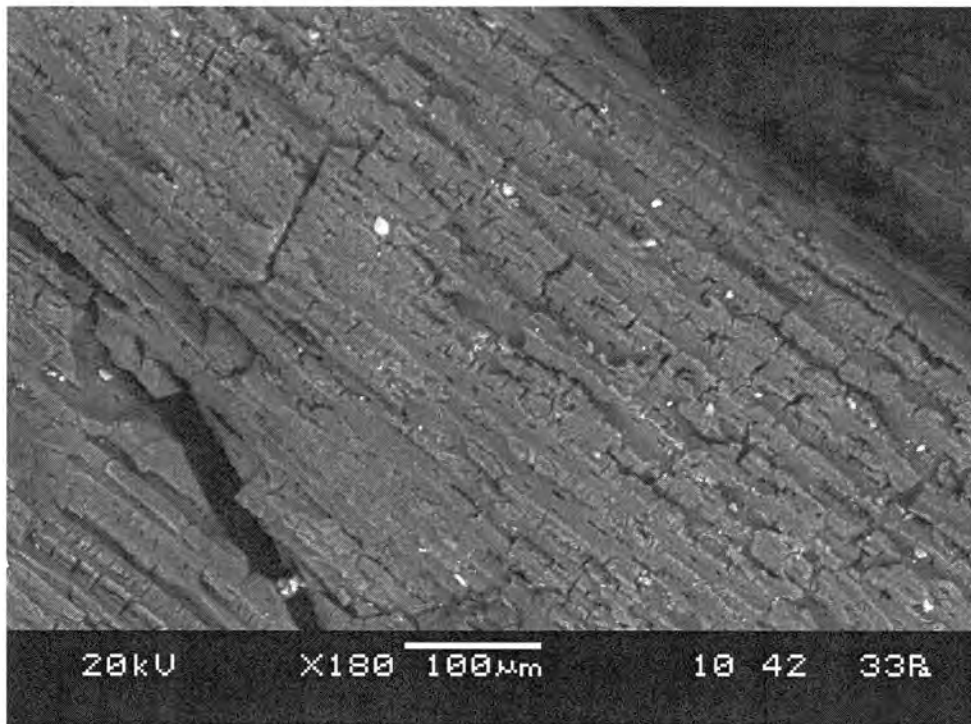


Figure 48. Photomicrograph taken perpendicular to the surface with striations shown in Figure 47. Based upon these pictures, we believe that the material was not coal, but may have been old carbon reworked from early Wisconsinan or Illinoian glaciofluvial sediments from Little Pigeon Creek valley, a former channel of the Ohio River.

Stop 9: Newburgh Lock and Dam

Kenneth E. Henn, U.S. Army Corps of Engineers

Project Location and Description

Newburgh Locks is located on mile 776.1 of the Ohio River, on the Indiana bank, approximately 2 mi upstream from the town of Newburgh, Ind. The project is one of eight navigational structures within the Louisville District and one of 20 structures on the Ohio River. It was constructed between April 1965 and November 1974 to replace the older and smaller Lock and Dam 46 located in Owensboro, Ky., and Lock and Dam 47.

Construction Authority

The Newburgh Locks and Dam Project was authorized as a replacement project for Lock and Dams 46 and 47 by the Secretary of the Army on April 24, 1962. This authorization was effected under authority of the Rivers and Harbors Act, approved March 3, 1909, Section 6, as amended. The project is a part of the overall replacement and enlargement of the Ohio River Navigational System. Construction initiated with the cofferdam for the lock, diversion of Cypress Creek approximately 0.8 mi upstream, lock construction, cofferdam construction for the dam, dam construction, and finally approach walls and fixed weirs.

Dam

The dam consists of a non-navigable, gated-crest structure that is 1,152.5 ft long and a fixed-weir navigable section that is 236 ft long, terminating within natural ground on the left bank, or Kentucky side, of the river. Nine tainter gates 110 ft wide by 32 ft high are supported by concrete piers. The fixed-weir section is composed of a 13-ft-high concrete crest structure over concrete-capped sheet pile cells. A concrete-capped sheet-pile cutoff wall extends from the end of the weir section farther into the bank. The gated section of the dam, including the upstream section of the locks, is topped with a prestressed concrete service bridge and includes a crane for positioning the upstream emergency bulkheads.

Locks

The two adjacent parallel lock chambers are located along the Indiana shore. The main lock chamber has clear dimensions of 110 ft by 1,200 ft and the auxiliary lock has clear dimensions of 110 ft by 600 ft. At normal upper and lower pools, the locks have a 16-ft lift height. Two sets of hydraulically operated steel miter gates are provided for each lock. Each lock has provisions immediately upstream of the upper miter gates for the placement of open-truss emergency bulkheads. Provisions for maintenance bulkheads exist immediately downstream of each set of miter gates. Sixteen aluminum truss maintenance bulkheads are available throughout the Louisville District. By use of bulkheads, each of the culvert valves, miter gates, and the entire lock chamber are designed for dewatering to facilitate maintenance. When the lock is closed because of high water, navigation may pass by the structure over the fixed weir between the gated section and the left bank.

Physiography

The Newburgh Lock and Dam is located in the Interior Low Plateaus Physiographic Province, further defined by A. F. Schneider of the Indiana Geological Survey as the Wabash Lowlands physiographic unit. Newburgh is located near the eastern boundary of the Western Kentucky Coal Field. The topography is gently rolling, wooded hills with wide, mature valleys, essentially the marginal foothills of the Crawford Uplands to the east. The area was not covered by any of the great Pleistocene glaciers that were diverted to both sides by the hilly Crawford and Norman Uplands areas of southern Indiana. The Kentucky side of the project lies in the low, flat aggraded floodplain of the Ohio River near the mouth of the Green River, which has its confluence with the Ohio at river mile 784.

The Newburgh Locks are located on the Indiana bank of the Ohio River at the mouth of Cypress Creek and just upstream from a bedrock high that controls the confluence of the Ohio and Cypress Creek. Both the Ohio and Cypress Creek are underfit streams with alluvial infills up to 80 ft thick. At the maximum erosion, Cypress Creek was about as deeply entrenched as the Ohio River. At present, its valley has been aggraded to an elevation of

about 370 ft, with a slow, sluggish stream meandering widely across the valley, and many oxbows and meander scars. The confluence of Cypress Creek was diverted about 0.8 mi upstream to allow construction of the locks.

Overburden

The Ohio River Valley in the vicinity of Newburgh Locks and Dam is filled with granular alluvial materials reworked from the Illinoian and Wisconsinan valley train deposits that filled the channel after their respective glacial recessions. Occasional boulders and cobbles are found scattered through the alluvium, particularly near the bedrock surface at the bottom of the river. These are probably erratic remnants of the reworked valley train materials. The massive Ohio River valley trains dammed the smaller tributaries to the Ohio, causing lacustrine deposits to be built up in the ponded areas. As the valley trains were worked down and leveled by the Ohio and the alluvial dams were cut through by the tributaries, a new alluvial cycle was started in the tributaries, but because most of the source material in the basins was lacustrine, the alluvial sediments they develop are finer grained and contain more silt and clay. This is the case at Newburgh Locks. Although the coarser valley train materials undoubtedly moved some distance up the original channel of Cypress Creek, causing the dams, the mouth of the creek at the time of construction had been crowded downstream against the prominent bedrock high that forms the lock foundation. The sediments making up the alluvium in and near the mouth of Cypress Creek are a combination of overbank silts and clays from the periodic flooding of the Ohio, and the upstream lacustrine deposits in the drainage basin, intermixed with some of the granular components from the reworked valley train. Consequently, the alluvium at the mouth of Cypress Creek is much less pervious than sediments in the surrounding area, as witnessed by the inability to get a producing water well under the service mound at the locks, even though excellent wells are producing large quantities of water within 2,000 ft.

The Ohio River channel and left bank floodplain are made up primarily of poorly graded sand and fine gravel from the glacial valley train deposits. These are overlain by 5 to 20 ft of silty fine sand, silt, and silty clay overbank deposits on the floodplains. When construction started, the low point in the river channel was at an elevation of 328 ft. Bedrock varies across the valley (exclusive of the bluffs) from an elevation of about 325 ft in the vicinity of the locks to 246 ft at the Kentucky bank, with the alluvial cover averaging 60 to 80 ft.

Overburden soils in the immediate area of the locks consist almost entirely of poorly graded (well sorted) sand and gravel (SP and GP in USCS classification). These sands and gravels were clean enough to be used for free-draining cell fill material in the cofferdam. Because the stream was aggrading in the recent past and since the Ohio River is essentially a lake behind Lock and Dam 47, the overbank silts and clays extend below the water surface. A distinct change from clay to sand was noted about 150 to 180 ft riverward from the Indiana shore. The clay was removed where cofferdam cells tied into the Indiana shore.

Bedrock Stratigraphy

The bedrock at Newburgh Locks and Dam is all Pennsylvanian in age from the Alleghenian Series coal measures. The entire locks structure is founded on strata of the upper part of the Petersburg Formation, part of the Carbondale Group. Since the deep-stage Ohio River eroded much of the underlying bedrock, the dam structure is founded on strata that is well into the Petersburg Formation, designated as shale No. 2. The Indiana bluff above the locks is made up of the lower part of the Dugger Formation of the same group. Fifteen to 20 ft of loess from the Pleistocene Atherton Formation caps the Indiana bluff. See Figure 49 for a generalized geologic section at the site.

Atherton Formation (Loess). The loess at the top of the Indiana bluff is not bedrock, but soil in the engineering sense. It consists of an extensive eolian deposit of fine sand, silt, and clay deposited during the early portion of the Wisconsinan glacial epoch and probably correlates with the prominent Peoria Loess of the Western Great Plains physiographic province.

Dugger Formation. The strata visible in the Indiana bluff from about 400 ft to about 320 ft are from the Pennsylvanian Dugger Formation. No coals of economic significance have been encountered in the Dugger Formation in the vicinity of Newburgh Locks. The Dugger Formation consists of interbedded, intermixed shales

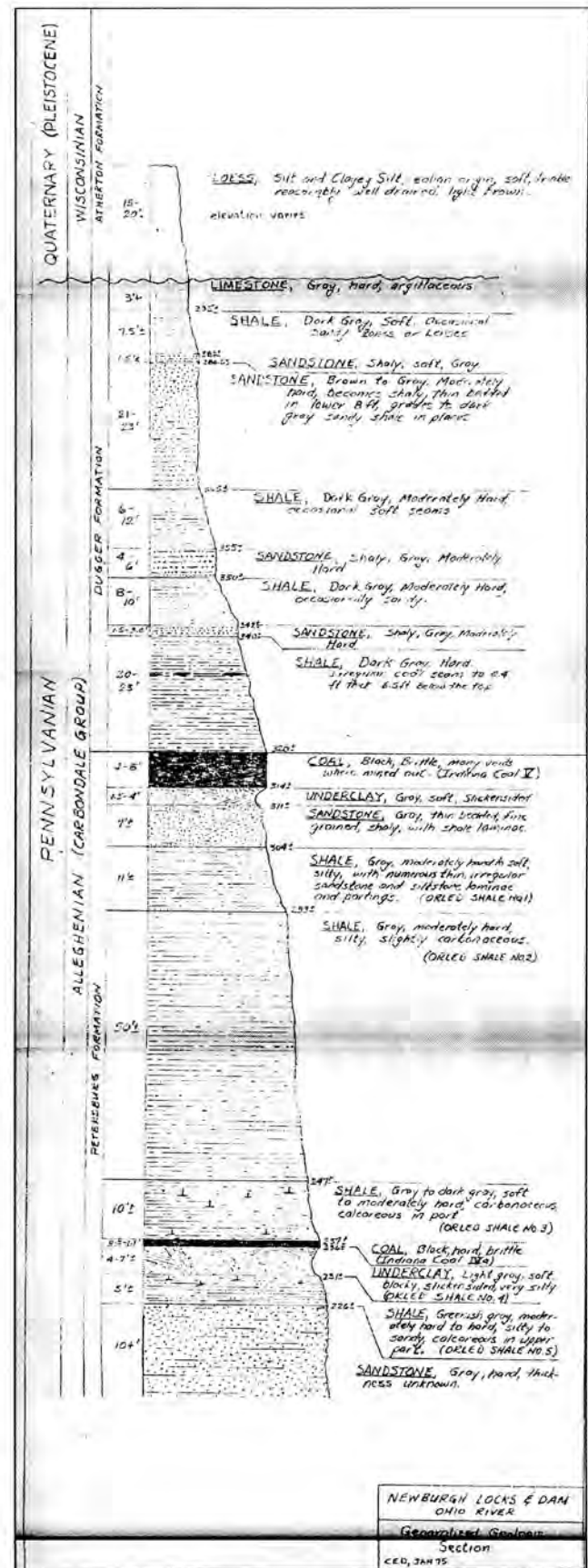
and sands with occasional thin limestones and carbonaceous seams that may represent significant coals in other areas. Typical of coal measures, the beds are laterally variable and locally discontinuous. Since the Dugger Formation was not considered for the locks foundation, very little boring data are available, and the available data are very limited in lateral extent. One boring, DC-105, indicated a 0.4-ft-thick coal bed 16 ft above the base of the formation. Since this was above any material considered for foundations and was not persistent in all borings, no attempt was made to identify it with the Indiana coal series.

Petersburg Formation. The entire locks structure is founded on strata of the Petersburg Formation. It is separated from the Dugger by a prominent coal bed 5 to 8 ft thick, known as Coal V or the Springfield Coal of the Indiana coal series. It has been mined extensively in the area, both underground and by surface mining. One boring in the bluff, DC-109, encountered a void where the coal should have been so it was assumed that the void was an old mine. This coal is underlain by an underclay 1.5 to 4.0 ft in thickness. The underclay, typical of the coal measures, was soft, highly slickensided, light gray, with carbonaceous fragments scattered throughout, and was generally a weak, troublesome material. It was never considered as a foundation material and caused some minor problems in excavation walls.

Figure 49. Stratigraphy for the area around Newburgh Dam.

Underlying the underclay was a shaly sandstone bed about 7 ft in thickness. This sandstone was used as the foundation for the land and middle walls of the locks, except the lower gate sill and the cross-over for the auxiliary lock. The sandstone contains some thin, discontinuous shale interbeds and is generally argillaceous throughout. The lower contact is gradational to shale, and selecting the break with the underlying material was difficult, as noted on the geologic profiles.

Beneath the sandstone is an 11-ft-thick transitional zone from sand to shale that has been designated shale I by ORLED-F. This zone, which acted as the foundation for the auxiliary lock lower gate sill and most of the river wall of the main lock, consists of sandy shale with many stringers and interbeds of siltstone and sandstone. This shale is generally harder and more resistant than the



underlying materials and together with the sandstone, acts as the caprock for the bedrock high that forms the foundation for the locks. At its base, shale 1 grades transitionally into shale 2, with a gradual decrease in sand content with depth and another stratigraphic problem determining where the contact should be.

Shale 2, underlying shale 1, is up to 50 ft thick and is described as moderately hard, silty, thin-bedded, slightly carbonaceous, gray to dark gray. Shale 2 was used for the foundation for parts of monoliths R-45 and M-14 and the crossover between them. It will be used for the foundation of dam piers in a future contract.

Although shale 2 is not exposed in the locks area, several borings penetrated strata below shale 2. These strata were of concern during construction of the dam. Below shale 2, approximately 10 ft of slightly calcareous and badly broken shale designated as shale 3 is present. This shale is massive but extremely soft and easily broken because of the lack of cementing agent. Underlying this is a black, much harder carbonaceous shale that constitutes shale 4. A relatively thin (0.5 to 1.1 ft) coal seam designated Coal IVa of the Indiana coal series, with an associated light gray underclay (fireclay) 4 to 7 ft thick, is found at the bottom of shale 4. The coal is argillaceous at its top, but grades to a pure carbon towards its bottom. The lower 0.2 ft of this coal is badly broken. The underclay is typically a troublesome material, with the upper foot being soft, plastic, and badly broken, transitioning to a harder and less plastic material in the lower 3 ft. Below this is about 5 ft of moderately hard to hard, silty to sandy, slightly calcareous shale, designated shale 5. Below shale 5 is a light gray, medium- to thick-bedded sandstone over 10 ft in thickness.

Structural Conditions

The Newburgh Locks lie on the low, southwestern flank of the Cincinnati Arch, at about the boundary of the Illinois or Western Kentucky Coal Field, to the west and southwest. Regional dips range up to 60 ft per mile toward the southwest; however, a small anticlinal fold near the site causes some local variation. In the locks area the bedding is essentially flat-lying, as well as can be determined in the irregular strata exposed. Joint patterns were not well defined in the sandstone. Jointing in the shales that were used for the river wall foundation was controlled by the configuration of the river valley. Most primary joints paralleled the bluff and were the expression of the tendency of the bluff to creep toward the channel. Poorly defined cross jointing at approximate right angles to the primary system was noted but overall, joints were not prominent in the foundation. No faulting was observed.

Weathering

Considerable residual soil and highly weathered rock are present on top of the bluff and along the valley side slopes. Some of the higher sandstones are particularly susceptible to weathering and oxidization because of their high permeability. None of these beds were used for foundation materials. Up to 24 ft of residual soil and weathered rock are on top of the Indiana bluff. In the immediate locks area, very little weathered rock is present because it has been carried away by the river scour, and since the river was aggraded, the bedrock surface lies below the groundwater level. Joints and fractures in Coal V allowed some groundwater movement and minor oxidation and precipitation of ferric oxides and sulfates on the fracture surfaces. The top of the underlying underclay locally shows minor streaks of oxidation and staining. In the foundations, after a thin veneer (generally less than 1 ft) of weathered material was removed, no other indications of weathering were present. Some slight staining and oxidation was present on joint surfaces in shale 1 under the river wall, but none penetrates to foundation depth. Leaching is not a problem because the foundation materials are well covered and below the groundwater level. No solution cavities or channels are present because there are no limestones in the area and there is a general absence of calcareous material throughout the stratigraphic section.

Stop 10: Angel Mounds State Historic Site, Evansville, Ind.

Introduction

The final field trip stop will visit the site of a Late Prehistoric (Mississippian cultural period) village along the banks of the Ohio River. The discussion below is summarized from the Angel Mounds Web site (www.angelmounds.org).

Location

Angel Mounds State Historic Site is located on Pollack Avenue southeast of Evansville, and is part of the Indiana Department of Natural Resources, Division of Indiana State Museums and Historic Sites. It is one of 16 state museums and historic sites in Indiana.

Discussion

For over 1,000 years, southwestern Indiana was home to many Native Americans. Today, Angel Mounds State Historic Site is nationally recognized as one of the best preserved prehistoric Native American sites in the United States. From 1,100 to 1,450 A.D., a town on this site was home to people of the Middle Mississippian culture, who engaged in hunting and farming on the rich bottom lands of the Ohio River. Several thousand people lived in this town protected by a stockade made of wattle and daub. Because Angel Mounds was a chiefdom (the home of the chief), it was the regional center of a large community that grew outward from it for many miles.

This settlement was the largest known town of its time in Indiana, but the Mississippian people eventually deserted it. No one today knows why. Fortunately, preservation and archaeological efforts at Angel Mounds State Historic Site offer a glimpse into this highly developed culture of the distant past. For 60 years, this living museum has told the story of one pre-contact Native American culture on the Ohio River.

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