U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

SCIENTIFIC INVESTIGATIONS MAP 2822
Version 1.0

SURFICIAL GEOLOGIC MAP OF THE SOUTHEAST MEMPHIS QUADRANGLE, SHELBY COUNTY, TENNESSEE

By
David W. Moore and Sharon F. Diehl
2004

Base from U.S. Geological Survey 1997
North American Datum of 1983 (NAD 83)
Projection and 1,000-meter grid: Transverse Mercator, zone 16
10,000-foot ticks: Tennessee Coordinate System of 1983

SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
SUPPLEMENTARY CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped by Moore and Diehl in 2000
Manuscript approved for publication March 9, 2004
Editing and digital cartography by Alessandro J. Donatich, Central Publications Group

This map was produced on request, directly from digital files, on an electronic plotter
For sale by U.S. Geological Survey Information Services
Box 25286, Federal Center, Denver, CO 80225
1-888-ASK-USGS
ArcInfo coverages and a PDF for this map are available at http://pubs.usgs.gov

SUMMARY

Loess (wind-deposited silt and clayey silt; Ql) is the predominant surficial deposit in the Memphis Southeast quadrangle. Loess covers the upland to depths of 4.5–12 m. In the floodplains of streams, alluvium (Qa) is 1–10 m thick; a few bog deposits (Qb) are present in the floodplain of Nonconnah Creek. No evidence of prehistoric liquefaction (sand boils or sand dikes) or slumping was observed in the quadrangle. Sparse, unconsolidated pebbly sand, 0.5–3 m thick, is present in narrow, linear point-bar and channel deposits of Nonconnah Creek.

DESCRIPTION OF MAP UNITS

Artificial fill (late Holocene)—Brown (7.5YR 5/4) silt to clayey silt. Locally, unit contains minor amounts of chert pebbles and sand where excavations locally cut the underlying gravel (“Lafayette Gravel;” QTg). Buildings or concrete and asphalt surfaces of roadbeds, airport runways, and other structures cover the artificial fill, which presumably is compacted to engineering specifications. Railroad ballast is pebble-size, angular, crushed crystalline igneous rock and limestone; thickness estimated to be about 1 m. At Memphis landfill site (1.6–3 km west of and 3 km southwest of Capleville, in southeastern part of quadrangle), unit consists of alternating layers of silt and refuse.

Shallow wells and casings penetrate the landfill, presumably to monitor fluid and gas content. Thickness of artificial fill is estimated to be 0.5–2 m under paved surfaces (not exposed), 1–5 m under access ramps to roadways, and 5–15 m in landfill

Bog deposit (Holocene)—Black (10YR 2/1) silt and clayey silt that contains wood (branches and small tree trunks) and abundant roots, 0.5–20 cm in diameter. Exposure in Tenmile Creek cutbank shows friable, carbonaceous silt and clayey silt in apparently lenticular beds. Contains fossil snails. Underlies 1–2 m of crossbedded, light-brown, fine, sandy alluvium (Qa) that forms a floodplain surface in Tenmile Creek in central part of quadrangle. Contours on topographic base map indicate that unit accumulated in one or more abandoned sinuous channels and on parts of surrounding floodplain of Nonconnah Creek. Thickness 0.5–2 m

Creek alluvium (Holocene and late Pleistocene)—White (10YR 8/1) and very pale brown (10YR 8/4) silt; laminated and very thin bedded; contains lenses of very fine grained, and fine- to medium-grained quartz and chert sand. Locally, silty deposit contains small amounts of admixed very fine sand. Upper meter or two is silty and probably reworked by wind and surface sheetwash. Unit is about 80 percent or more silt, washed from loess-mantled upland. Unit includes minor, local silty fan alluvium and probable local, buried bog deposits like unit Qb. Probable bog deposits are inferred from sinuous contour lines suggestive of former meandering channels on floodplain of Nonconnah Creek depicted on USGS 15-minute topographic maps dating to the early 1900's. In an excavation near the Mall of Memphis, Delcourt and others (1980) observed planar, interbedded clay, silt, and sand (location shown by a star symbol in east-central part of quadrangle, lat 35°04' N., long 89°54' W.). Location also yielded ankle, skull, teeth, and tusk fragments of the extinct American mastodon (Mammut americanum), fossil seeds, plants, wood, and beetle remains (Brister and others, 1981), which suggest a cool climate of the last continental glacial episode. Delcourt and others (1980) obtained several carbon-14 isotope dates of 23–17 ka on the fossil material.

This unit includes both alluvium in the modern channel and point bars of Nonconnah Creek, which is carried along the channel during modern high-discharge flows, and the late Pleistocene alluvium underlying the floodplain, from which it differs. The modern alluvium is 0.5–3 m thick and consists of roughly equal amounts of sand and subangular chert pebbles. The sand is chiefly medium grained, ranges from very fine to very coarse in grain size, and contains lenses of granules and pebbles. In contrast, the late Pleistocene and Holocene floodplain alluvium is mostly silt that contains local buried channels of sand and lenses of pebbly sand.

The natural meandering channels of many streams in the quadrangle have been straightened by dredging (Simon and Hupp, 1992), and some (for example, sections of Tenmile Creek and Black Bayou) are straight, concrete-lined ditches and conduits. In places, channel walls of Nonconnah Creek are nearly vertical, 2–3 m high, and are flanked by narrow piles of spoil (not mapped) in many places. Base of unit not exposed. Thickness 1–10 m

Terrace deposit (late Pleistocene)—Brown (7.5YR 5/4) mostly silt, clayey silt, and silty very fine to fine quartz sand. Unit is alluvium of Nonconnah Creek that is slightly older than unit Qa and that underlies a terrace, which is a small remnant of an older floodplain. Thin, silty sheetwash alluvium, perhaps admixed with thin loess, mantles unit. Deposit is compositionally similar to unit Qa. Extensively excavated by man. A terrace origin is inferred from its relatively level surface and general altitude, standing about 2 m higher than the floodplain of Nonconnah Creek (Qa) and lower than loess-covered (Ql) hilly upland south of the creek. Base of unit not exposed. Thickness estimated to be 1–2 m

Loess (late Pleistocene)—Brown (7.5YR 5/4) and light-brown (7.5YR 6/4) clayey silt. Calcareous, porous, and massive. Undisturbed uppermost 0.2–0.5 m of unit is oxidized, dark-brown (7.5YR 4/4) clayey silt, which is plastic when wet and hard when dry. This uppermost part locally contains vertical prismatic soil structures 3–5 cm wide and 20–30 cm long; this zone may represent a partial or entire B horizon of a relict soil. In many places, however, this soil has been removed or mixed with underlying material by earth-moving machinery. Parks and Lounsbury (1975) reported the following grain-size data for loess in the Memphis area: clay (<0.002 mm) 20–25 percent; silt (0.06–0.002 mm) 70–75 percent; sand (2.0–0.06 mm) <5 percent. Hwang and others (2000) reported clay 19 percent, silt 76.3 percent, and sand 4.7 percent. Bare slopes of loess erode readily to form small gullies spaced 0.5–1 m apart. Loess is cohesive and generally stands in 4- to 5-m-high vertical exposures, both manmade and natural. In much of quadrangle, the south half especially, unit has been excavated to various depths for construction projects, landfill sites, and active and abandoned gravel pits. Prior to this disturbance, loess uniformly mantled a stream-dissected upland surface formed on older alluvial sands, clayey sands, and pebbly sands of unit QTg.

Origin of the loess is tied to the midcontinental ice sheet. In late Pleistocene time (pre-late Wisconsinan and late Wisconsinan glacial time), when the Laurentide ice sheet covered land north of the present Ohio and Missouri Rivers, voluminous glacial valley-train deposits washed down the Mississippi River alluvial valley. From these unconsolidated sediments, prevailing winds picked up and carried silt mostly eastward, depositing it on uplands that include the Memphis area. Rodbell and others (1997) suggested that loess deposition was episodic in the region, based on recognition of soil-separated loess units, named the Loveland Loess, Roxana Silt, and Peoria Loess from oldest to youngest. Loess in this quadrangle is probably chiefly Peoria Loess. We mapped one undifferentiated unit. Thicknesses observed in excavations in quadrangle range from 4.5 to 5.5 m. Drillers' logs indicate thickness as much as 12 m

Gravel ("Lafayette Gravel" of Hilgard, 1892, early Pleistocene and Pliocene?)—Poorly exposed under loess (Ql) and alluvium (Qa). The following description is of the ferruginous, weathered upper 1–2 m of the unit observed in manmade excavations and stream cutbanks. Mottled, strong-brown (7.5YR 4/6), brown (7.5YR 5/4), and red (2.5YR 4/6), fine- to coarse-grained sand; chiefly chert and minor quartz pebbles and granules, subrounded to subangular. Some chert pebbles contain minute biogenic skeletal debris (spines?, spicules, foraminifers). Gravel layers are lenticular, occur at top of unit, and are interbedded with medium-grained, subangular to subrounded quartz sand, commonly in a red (2.5YR 5/8) sandy clay to clayey sand matrix that is 3–5 percent of rock by volume. Firm, moderately well cemented by clay minerals, hydrous iron oxide(?), manganese oxide(?), and silica. Locally present are abundant vertical, roughly cylindrical (2–20 cm in diameter), iron oxide-cemented sand structures (root casts?, burrows?). Locally, gravel is overlain by brownish-yellow (10YR 6/8) silt that contains root casts 1–2 mm in diameter and tens of centimeters long. Vesicles 0.5 mm in diameter are common. The lower exposed beds commonly are red (2.5YR 4/6), medium to coarse sand. In a 300-m-long, 4- to 7-m-deep, north-south excavation (south edge of quadrangle, about 250 m west of the former "Bella Vista Country Club," lat 35°00'10" N., long 89°55'40" W.), loess-buried, crossbedded pebble gravel is the uppermost bed and is present in two or three gently sloping, planar beds. Beds dip 1°–2° southward, stepping downward to the south, and have 1–2 m vertical separation, suggestive of terraces or alluvial surfaces.

Age of unit is uncertain, as is age relation between loess-buried gravel deposits in eastern part of quadrangle and those in Southwest Memphis quadrangle immediately west. Previous workers referred to similar topographically high, widespread graveliferous deposits in the Mississippi Valley region as Orange Sand, Lagrange, Upland Gravel, Lafayette Gravel, Citronelle, or the Upland Complex (Autin and others, 1991, p. 554). Unit QTg is exposed in gravel pits. Based on interpretations of drill-hole data (see Methods, also cross sections), thickness of unit varies from 5 to 21 m and overlies Tertiary bedrock. In exposures, uppermost gravelly beds are 1–1.5 m thick and are underlain by sand beds of unknown thickness; base covered

Bedrock (Tertiary)—Shown in cross sections only. Interbedded sand, silt, clay, and lignite; loosely consolidated. Probably Eocene Jackson Formation or upper part of Eocene Claiborne Group (Kingsbury and Parks, 1993)

Contact—Solid where relatively certain; dashed where less certain
Mastodon site—Lat 35°4' N., long 89°54' W. (Delcourt and others, 1980)
Drill-hole locality and identification number

INTRODUCTION

The purpose of the map is to help assess the susceptibility of surficial deposits and materials to liquefaction and landsliding during strong ground shaking (earthquakes). These susceptibilities are related to the characteristics of the deposits and materials and their topographic position (Youd, 1991; Hwang and others, 2000), which are described and depicted here. Other possible uses of the map include land-use planning, zoning, education, and locating aggregate resources. The Southeast Memphis quadrangle is one of several quadrangles that were mapped recently for these purposes (fig. 1).

The City of Memphis is near the New Madrid Seismic Zone (NMSZ) and is within the upper Mississippi embayment, which is seismically active (Schweig and Van Arsdale, 1996) (fig. 2). Proximity to the NMSZ raises concerns that if earthquakes as strong as the 1811–1812 NMSZ earthquakes were to occur, life and infrastructure in Memphis would be at risk (Hamilton and Johnston, 1990). Compelling evidence of seismic risk includes the following: (1) probable earthquake-induced liquefaction features (sand dikes) exist inside the city limits of Memphis (Broughton and others, 2001), (2) severe damage in the area of present-day Memphis caused by an 1843 earthquake in the NMSZ, near Marked Tree, Ark. (Stover and Coffman, 1993), and (3) the characteristically slow attenuation of seismic energy in the midcontinental region heightens the risk of damage (Johnston and Kanter, 1990; Tuttle and Schweig, 1996).

The Southeast Memphis quadrangle is located on a loess-mantled upland of Holocene and late Pleistocene age. The loess (Ql), probably mostly the Peoria Loess (Leverett, 1898), covers alluvial sand and gravel of late Pliocene(?) to early Pleistocene age (QTg) that, in turn, overlies the uppermost, soft sandstone of the Clairborne Group of middle Eocene age (Tb). The Peoria Loess was widely deposited during the late Wisconsinan glaciation and during an aggradational phase of the Mississippi River, 25,000–14,000 years B.P. (Knox, 1996, p. 265), when winds deflated silty glacial outwash from the river valley. Subsequently, tributaries to the Mississippi River have eroded a dendritic network of drainageways in the Peoria Loess that covers the upland, and have deposited it as silty alluvium (Qa) and bog deposits (Qb) in their floodplains.

The main inaccuracies of the map are our generalized depiction of artificial fill (af) and manmade drainage, and our interpretations of stratigraphy using drill-hole data. These subjects are discussed in the “Methods” section.

METHODS

Mapping was based on field observations, analysis of color aerial photographs (scale 1:24,000, flown in 1997), topography, and drill-hole data. Grain sizes were estimated using a comparative chart that uses nomenclature of the modified Wentworth grade scale (American Geological Institute, 1982). Colors of materials were determined by comparison to Munsell Soil Color Charts (Munsell Color, 1973). Geologic ages of the surficial geologic deposits are based on relative and absolute dating techniques and the findings of previous workers (Hilgard, 1892; McKay, 1979; Delcourt and others, 1980; Brister and others, 1981; Saucier, 1987; Autin and others, 1991). Relative dating assumes that older deposits are higher above modern stream level and that the soils on

them are more fully developed than those on the lower, younger deposits. An absolute age is available from radiocarbon-dated fossil material in local stream alluvium (see Qa).
Parts of the quadrangle (in 2001) have been altered by construction. In these parts, the shape of the land surface differs from that depicted on the topographic base map (1997) and aerial photographs. The artificial fill (af), whose thickness is estimated in cross section, was mapped as a separate unit because it, like the natural geologic deposits, is subject to seismic shaking. We estimated that emplacement of unit af typically requires that the upper 1–3 m of surficial geologic material be removed, replaced or placed nearby, leveled, and compacted. We learned what goes into fill by watching it being emplaced at a warehouse foundation construction site (at the intersection of Getwell Road and Holmes Road, south-central edge of quadrangle) and at a highway access ramp construction site. At the warehouse site, a loess-covered hill (Ql) was leveled, and the backfilled loess was compacted using motorized sheep-foot compactors. We assume that artificial fill throughout the quadrangle, except gravelly railroad ballast, is composed of similarly compacted, silty material.

We constructed geologic cross sections to show the subsurface thickness of the units of interest. Depths to the boundaries between units were obtained from drill-hole data in the Shelby County Subsurface Database of the Ground Water Institute (GWI), University of Memphis (http://gwidc.memphis.edu/website/introduction). The depths were determined by hydrologists and geologists who interpreted drillers' logs and borehole electrical logs (Ank Webbers, formerly USGS, oral commun., 2000).

The locations of drill holes plotted on the map and cross sections in the quadrangle are subject to an unmeasured degree of error. Locations of some holes in the GWI database were determined in the field by previous workers using a global positioning system; others were located by previous workers using maps and addresses (Brian Waldron, University of Memphis, written commun., 2002). Most drill holes probably are plotted within a few tens of meters to a hundred meters of the actual drill site (Brian Waldron, written commun., 2002).

A problem was encountered in plotting drill holes in the cross sections. Elevations of the tops of drill holes obtained from the GWI database (derived from the National Elevation Dataset, NED, Gesch and others, 2002) did not agree well with elevations of the land surface at the drill sites as determined by the topographic map. To reduce these discrepancies, we assigned elevations from the topographic map to the tops of the drill holes. This required a re-projection of drill-hole locations (from state plane coordinates in the GWI database) to a Transverse Mercator projection and re-plotting of the new drill-hole locations on the Southeast Memphis 7.5-minute topographic quadrangle.

Summarizing the cross-section methodology, accuracy of vertical placement of the stratigraphic units depends mainly on three steps: (1) accurately locating drill holes; (2) correctly "picking" tops of units in the drill holes using electric logs; and (3) correctly plotting units on the cross sections.

ACKNOWLEDGMENTS

We thank Roy Van Arsdale, Department of Geological Sciences, University of Memphis, for sharing his geologic knowledge of the area. Joan Gomberg and Buddy Schweig, USGS and Center for Earthquake Research and Information (CERI), University of Memphis, gave collegial guidance, logistical support, and understanding of seismic risk. Ron Brister, Curator of Collections, Memphis Pink Palace Museum, assisted the senior author by providing radiocarbon dates, late Pleistocene climatic data, and a viewing of fossils that he and colleagues collected from the Mall of Memphis excavation site in 1980. Richard Dart, USGS, assisted with computer work. Brian Waldron, Ground Water Institute (GWI), University of Memphis, and Kathleen Tucker (CERI) helped us access drill-hole data in the GWI Shelby County Subsurface Database (http://gwint1.gwi.memphis.edu), which Howard Hwang, CERI, and Ank Webbers, USGS, compiled in part. Paco Van Sistine, USGS, re-projected GWI drill hole locations, enabling us to construct cross sections. Mary Berger, USGS, provided assistance with graphics. The U.S. Army Corps of Engineers, Memphis District, provided aerial photographs of the map area. Thanks to Tony Crone, USGS, and Derek Booth, University of Washington, for helpful reviews of the map and report.

REFERENCES CITED

American Geological Institute, 1982, Grain-size scales used by American geologists, modified Wentworth scale, in Data sheets (2nd ed.): Falls Church, American Geological Institute, sheet 17.1.

Autin, W.J., Burns, S.F., Miller, B.J., Saucier R.T., and Snead, J.I., 1991, Quaternary geology of the Lower Mississippi Valley, in Morrison, R.B., ed., Quaternary nonglacial geology; conterminous U.S.: Boulder, Colo., Geological Society of America, The Geology of North America, v. K-2, p. 547–582.

Brister, R.C., Armon, J.W., and Dye, D.H., 1981, American mastodon remains and late glacial conditions at Nonconnah Creek, Memphis, Tennessee: Memphis State University Anthropological Research Center Occasional Papers no. 10, 36 p.

Broughton, A.T., Van Arsdale, R.B., and Broughton, J.H., 2001, Liquefaction susceptibility mapping in the city of Memphis and Shelby County, Tennessee: Engineering Geology, v. 62, p. 207–222.

Delcourt, P.A., Delcourt, H.R., Brister, R.C., and Lackey, L.E., 1980, Quaternary vegetation history of the Mississippi Embayment: Quaternary Research, v. 13, p. 111–132.

Gesch, D., Oimoen, M., Greenlee, S., Nelson, C., Steuck, M., and Tyler, D., 2002, The National Elevation Dataset: Journal of the American Society for Photogrammetry and Remote Sensing, v. 68, no. 1, p. 5–10.

Gomberg, Joan, and Schweig, Eugene, 2002, Earthquake hazard in the heart of the homeland: U.S. Geological Survey Fact Sheet FS–131–02, 4 p.

Hamilton, R.M., and Johnston, A.C., 1990, Tecumseh's prophecy—Preparing for the next New Madrid earthquake: U.S. Geological Survey Circular 1066, 30 p.

Hilgard, E.W., 1892, The age and origin of the Lafayette formation: American Journal of Science, v. 43, p. 389–402.

Hwang, H., Wang, L., and Yuan, Z., 2000, Comparison of liquefaction potential of loess in Lanzhou, China, and Memphis, USA: Soil Dynamics and Earthquake Engineering, v. 20, p. 389–395.

Johnston, A.C., and Kanter, L.R., 1990, Earthquakes in stable continental crust: Scientific American, v. 262, p. 68–75.

Kingsbury, J.A., and Parks, W.S., 1993, Hydrogeology of the principal aquifers and relation of faults to interaquifer leakage in the Memphis area, Tennessee: U.S. Geological Survey Water-Resources Investigations Report 93–4075, 5 pl., 18 p.

Knox, J.C., 1996, Late Quaternary Upper Mississippi River alluvial episodes and their significance to the Lower Mississippi River system, in Saucier, R.T., Smith, L.M., and Autin, W.J., eds., Geology in the Lower Mississippi Valley—Implications for engineering, the half century since Fisk, 1944, Vicksburg, Miss., December 5–8, 1994: Engineering Geology, v. 45, no. 1–4, p. 263–285.

Leverett, Frank, 1898, The Peorian soil and weathered zone (Toronto formation?): Journal of Geology, v. 6, p. 244–249.

McKay, E.D., III, 1979, Wisconsinan loess stratigraphy in Illinois, in Follmer, L.R., McKay, E.D., III, Lineback, J.A., and Gross, D.A., eds., Wisconsinan, Sangamonian, and Illinoian stratigraphy in central Illinois: Illinois State Geological Survey Guidebook 14, p. 95–108.

Munsell Color, 1973, Munsell soil color charts: Baltimore, Md., Kollmorgen Corporation, Macbeth Division.

Parks, W.S., and Lounsbury, R.W., 1975, Environmental geology of Memphis, Tennessee: Tennessee Division of Geology, Report of Investigations, v. 36, p. 35–63.

Rodbell, D.T., Forman, S.L., Pierson, James, and Lynn, W.C., 1997, Stratigraphy and chronology of Mississippi Valley loess in western Tennessee: Geological Society of American Bulletin, v. 109, p. 1134–1148.

Saucier, R.T., 1987, Geomorphological interpretation of late Quaternary terraces in western Tennessee and their regional tectonic implications: U.S. Geological Survey Professional Paper 1336–A, 19 p.

Schweig, E.S., and Van Arsdale, R.B., 1996, Neotectonics of the upper Mississippi embayment: Engineering Geology, v. 45, p. 185–203.

Simon, Andrew, and Hupp, C.R., 1992, Geomorphic and vegetative recovery processes along modified stream channels of west Tennessee: U.S. Geological Survey Open-File Report 91–502, 142 p.

Stover, C.W., and Coffman, J.L., 1993, Seismicity of the United States, 1568–1989 (revised): U.S. Geological Survey Professional Paper 1527, 418 p.

Tuttle, M.P., and Schweig, E.S., 1996, Recognizing and dating prehistoric liquefaction features—Lessons learned in the New Madrid seismic zone, central United States: Journal of Geophysical Research, v. 101, p. 6171–6178.

Youd, T.L., 1991, Mapping of earthquake-induced liquefaction for seismic zonation, in Borcherdt, R.D., and Shah, H.C., co-chairs, Proceedings of the Fourth International Conference on Seismic Zonation I: Stanford, Calif., International Conference on Seismic Zonation, v. 4, p. 111–147.

Figure 1. Locations of quadrangles for which the geology has been mapped recently as part of the National Earthquake Hazards Reduction Program of the USGS.

Figure 2. New Madrid and Wabash Valley seismic zones, showing earthquakes as circles. Red, earthquakes that occurred from 1976 to 2002 with magnitudes >2.5, located using modern instruments (University of Memphis). Green, earthquakes that occurred prior to 1974. Larger circle represents larger earthquake. Modified from Gomberg and Schweig (2002).