Illinois Geologic Quadrangle Map
IGQ Valmeyer-SG

Surficial Geology of Valmeyer Quadrangle

Monroe County, Illinois

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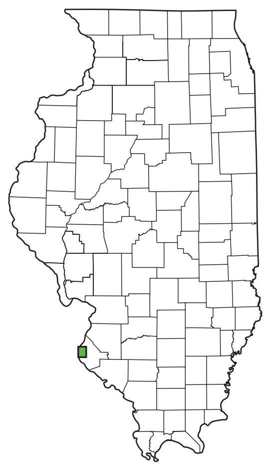

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Introduction

The surficial geology map of the Valmeyer Quadrangle, located in southwestern Illinois about 20 miles south of downtown St. Louis (fig. M1 on map sheet 2), provides an important framework for land and groundwater use, resource evaluation, engineering and environmental hazard assessment, and geological and archeological studies. The Valmeyer Quadrangle mapping project, in Monroe County, is part of a broader geologic mapping program undertaken by the Illinois State Geological Survey (ISGS) in the St. Louis Metro East region, which includes Madison (Grimley and Phillips 2006), St. Clair (Grimley and Phillips 2011b), and Monroe Counties in Illinois.

The Valmeyer Quadrangle straddles the maximum extent of Illinois Episode glacial ice, which advanced regionally from the northeast, originating from the Lake Michigan Basin (fig. M1; Willman and Frye 1970; Lineback 1979; Grimley and Phillips 2011a). Locally, however, glaciers probably advanced from an easterly or east-southeasterly direction (fig. M1; Grimley 2009). The limit of pre-Illinois Episode glacial ice, which advanced from the east or northeast, appears to have been several miles east of this quadrangle, although the boundary is not definitive and is based on isolated observations of till (Phillips 2000, 2010; Kolb 2009; Grimley and Phillips 2011a). Both the pre-Illinois and Illinois Episode glacial advances were impeded by the bedrock highlands in western Monroe County, which are underlain by Mississippian limestone in the Valmeyer and Waterloo-Dupo anticlinal belts. During the Wisconsin Episode (the last glaciation), glacial ice did not reach southern Illinois; however, meltwater streams from glaciers in the upper Mississippi River drainage basin deposited extensive outwash in the middle Mississippi Valley. This outwash was the source of the thick loess deposits (windblown silt) that blanket uplands in southwestern Illinois, including the highly dissected (>400-foot relief) bedrock-controlled uplands in the eastern portion of the Valmeyer Quadrangle. The western part of the quadrangle contains the broad and extensive Mississippi River valley, underlain by up to 120 feet of water-laid clay, silt, sand, and gravel, mainly from the Wisconsin Episode and postglacial times.

Methods

Surficial Map

The surficial geology map is based in part on soil parent material data (Higgins 1987), supplemented by data from reconnaissance outcrop studies, earlier outcrop studies in ISGS archived field notes, stratigraphic test holes obtained for this STATEMAP project, engineering borings from the Illinois Department of Transportation (IDOT) and U.S. Army Corps of Engineers, and water-well records. Map contacts were also adjusted according to the surface topography, geomorphology, and observed landform-sediment associations. The ISGS also constructed an electrical resistivity survey northeast of Moredock Lake as part of this project.

The locations of the various data used for the surficial geology map, cross sections, or developing landform-sediment associations are shown on the map, including outcrops and stratigraphic test holes, as well as engineering, water-well, oil and gas, and coal borings. All available data are shown except where several borings occur in a tightly spaced area, and only two or three representative borings are displayed for cartographic reasons. Also shown, as small black triangles, are the bedrock outcrop locations from mapping by Denny et al. (2009). The locations of many water-well borings were verified by plat books, permit maps, or field confirmations (for water wells only). Further information on all data shown, other than the archived field notes, is available from the ISGS Geological Records Unit. These data can be identified based on their labeled county number (5-digit portion of the 12-digit API number). Original archived field notes can be obtained from the ISGS library.

Cross Sections

The cross sections portray unconsolidated deposits as would be seen in a vertical slice through the earth down to bedrock (vertically exaggerated 10 times). The lines of cross sections are indicated on the surficial map. Data used for subsurface unit contacts (in approximate order of quality) are from studied outcrops, stratigraphic test holes, engineering boring records, water-well records, and oil- and gas-well records. Units less than 5 feet in maximum thickness are not shown on the cross sections. Dashed contacts are used to indicate where data are less reliable or are not present. The full extent of wells that penetrate deeply into bedrock is not shown. All subsurface data shown on the cross sections occur directly on the cross section line, although the geological context of nearby data was used in constructing the profiles.

Bedrock Topography and Drift Thickness Maps

Maps of bedrock topography (fig. M2 on map sheet 2) and drift (or unconsolidated sediment) thickness (fig. M3 on map sheet 2) are based on data from which a reliable bedrock elevation could be determined, guided by conceptual models of the geologic terrain. Various data within the quadrangle and a 0.6-mile buffer (not shown in fig. M2) were used for construction of the map. A total of 104 point data locations where bedrock was encoutered were used, including 10 outcrops, 9 stratigraphic tests, 17 engineering borings, 58 water-well borings, 1 coal boring, and 9 oil- and gas-test borings. An additional 251 bedrock outcrop locations (with approximate elevations) from mapping by Denny et al. (2009) were also used to guide the digitized contour lines in the model.

A multistep process was used to create the maps. First, a bedrock surface (30-m cell size) was modeled utilizing the Topo to Raster program in ArcMap 10.0 (ESRI), with a vertical standard error of 3 feet. This program incorporated a combination of three information types: (1) the 104 data points coded with bedrock top elevations, (2) tens of digitized contour lines coded with bedrock top elevations (guided by bedrock outcrops and surface topographic expression), and (3) several digitized “streams” (ArcMap term) that forced the bedrock surface model to conform to a typical stream drainage pattern. The Topo to Raster modeling step underwent many iterations, with revision of point, contour, and stream inputs until the bedrock surface satisfactorily conformed to an envisioned geologic model. Next, any remaining areas with bedrock surface elevations higher than a LiDAR (light detection and ranging)-based land surface digital elevation model (DEM) were replaced with the value of the surface DEM by using a conditional statement in ArcMap 10.0. Finally, the bedrock topography surface DEM was subtracted from the land surface DEM to provide a calculated drift thickness map (30-m cell size) with all values ≥0. To cartographically finalize the resulting bedrock topography and drift thickness maps for the 1:80,000 inset maps (figs. M2 and M3), some small or irregular polygons were removed and some of the lines were smoothed or generalized with ArcGIS focal statistics.

Electrical Resistivity Profiles

Three electrical resistivity profiles were acquired in the eastern part of the Mississippi Valley. The measurements in this study used the dipole–dipole electrode configuration with a 5-m nominal electrode separation on 400-m-long lines extended at 100-m increments to create the resistivity pseudosections. The GPS locations were obtained every 100 m along the profiles, and topography was estimated from U.S. Geological Survey (USGS) 7.5-minute topographic maps. The finite difference algorithm of Loke and Barker (1996) was used to invert the pseudosections to resistivity models.

Surficial Deposits

The surficial deposits can be divided into three landform–sediment associations: (1) bedrock-controlled loess uplands, including some colluvial (gravity-deposited), glacial, or residual sediment; (2) tributary valleys and terraces, with postglacial alluvium and glaciolacustrine deposits; and (3) the Mississippi River valley floodplain, underlaid primarily by fluvial sediment from the last glacial to recent times.

Bedrock-Controlled Loess Uplands

Bedrock-controlled loess uplands constitute much of the eastern portion of the Valmeyer Quadrangle, about 29% of the mapped area. Areas with <5 feet of sediment cover (mainly loess or colluvium) are mapped as near-surface bedrock and include many areas of bedrock exposure. Bedrock outcrops along much of the Mississippi Valley bluffs and along many steeply incised streams have eroded through the relatively thin surficial deposits. The bedrock exposures consist predominantly of Mississippian limestone, with some cherty limestone and shale. The principal Mississippian units exposed, from youngest to oldest, are the St. Louis and Salem Limestones, the Warsaw Formation (shale and dolomite), the chert-rich Burlington-Keokuk Limestone, and the Fern Glen Formation (Norby 1987 Denny et al. 2009). Some exposure of Ordovician rock, including the Hannibal Shale, Maquoketa Formation (shale and limestone), and Kimmswick Limestone, are also known from lower Dennis Hollow and the ravines and hollows of Sec. 3, T3S, R11W (Norby 1987; Denny et al. 2009). Of structural importance, the Paleozoic bedrock in the uplands is folded in an asymmetrical anticline–syncline pair with axes that trend northwesterly. The southwestern flank of the Valmeyer Anticline dips as much as 15 to 25 degrees, but the northeastern flank dips much more gently (<5 degrees). Geomorphologically, the anticline–syncline structure controls the unusual bluff line shape that protrudes westward near the pre-1993 town of Valmeyer.

Some of the limestone in this area has been mined in the past century, resulting in some caverns having been used for extensive mushroom growing (Rheinertsen 1981). Mined-out areas have also been used for warehousing, some of which continues today with underground cold food storage and storage of National Archives records in a retrofitted limestone cave (fig. 1). Former quarries and underground storage areas are found in Sec. 3, T3S, R11W and mapped as disturbed ground.

Figure 1 Storage facility for National Archives records built into formerly mined-out areas in Sec. 3, T2S, R11W.

A clayey, smectitic (expandable clay mineral), and sometimes cherty sediment or soil is commonly observed above bedrock and below the loess and till in upland areas, as was found in cores from stratigraphic tests for this study (nos. 23465 and 23466) and in several test borings for a geological evaluation of the post-1993 Valmeyer town location (Erdmann and Bauer 1993). This material, mainly from *in situ* bedrock weathering (residuum), but also containing admixed weathered loess and colluvium, is up to 30 feet thick in the Valmeyer Quadrangle. Such material has been mapped and informally classified as the Oak formation in other parts of southern Illinois near or beyond the glacial terminus (Esling et al. 1991; Grimley 1999). In the area of the new town of Valmeyer, >0.5-mm sand and pebbles were washed out from core and split-spoon samples of the Oak formation, revealing an upper zone with chert and silicified fragments, occasional fragments of quartzite or sandstone, and a few small (<4-mm), subangular to rounded quartz grains. A lower, more clayey zone is a more typical reddish brown residuum with angular chert fragments (classic terra rosa formed in limestone). Both the upper and lower zones of the Oak formation contain abundant iron and manganese concretions. The upper zone is interpreted to include some middle Pleistocene loess units (Curry et al. 2011), such as the Loveland Silt (Illinois Episode) and Crowley's Ridge Silt (pre-Illinois Episode), but these have been highly altered in paleosol profiles, pedogenically intermixed with the residuum, or both. Alternatively, the small, rounded quartz and occasional quartzite could be a remnant of a Pliocene or early Pleistocene high-level fluvial gravel, known as the Grover Gravel (Willman et al. 1975), or possibly a remnant of the Cretaceous Baylis Formation (Willman et al. 1975), which occurs at similar elevations of 750 to 850 feet above sea level (asl) in Adams and Pike Counties of western Illinois (Jacobson and Lasemi 2008). Last, it is also possible that the occasional quartz, sandstone, or quartzite fragments are remnants of thin, highly weathered till deposits. In any case, because of the uncertainty and relatively similar physical properties, all such highly weathered and clay-rich loess, diamicton (unrecognizable as till), residuum, and colluvium are included in the Oak formation for the purposes of this map and cross section. Of historical interest, the reddish clay of this unit was apparently used locally by native Americans for the production of ceramics (Koldehoff 2002).

Diamicton or weathered diamicton, interpreted as glacial till, is observed underneath the last glacial loess deposits in outcrop 23450 (cross section C–C′), underneath Cahokia alluvium in outcrop 23439 (Sec. 1, T3S, R11W), and in stratigraphic test holes 23465 and 23466. The till is interpreted to be Illinois Episode based on stratigraphic context, including the presence of Sangamon Geosol (last interglacial soil) alteration into the upper part of the unit. The unit is thus classified as the Glasford Formation (Willman and Frye 1970). It is mapped in the near surface in only one area, near Monroe City in the southeastern portion of the map. In the subsurface, the Glasford is up to 25 feet thick (boring 23465), where it is a silty clay to silty clay loam diamicton, is leached to weakly dolomitic, and has some inclusions of silt loam (probable Petersburg Silt). Occurrences of the Glasford Formation, in addition to observations of small glacial erratics along the creek valleys and hollows (Koldehoff 2002), were used to guide a revised Illinois Episode till border, as shown on the map. Neither the presence of till deposits nor any direct evidence of glaciation was found west of this line, so it has been concluded that the terminal ice margin of Illinois Episode glaciation was probably within this quadrangle, as has been documented previously (Lineback 1979). Although the glacial border is fairly similar to previous versions from a regional perspective, it has been modified somewhat to portray more influence by local topographic constraints, based on observations of thicker till deposits in lowlands and valley edges.

At some localities below the Glasford Formation and above the Oak formation, a silty unit is found that is lithostratigraphically classified as the Petersburg Silt (Willman and Frye 1970). This massive to faintly stratified unit was found to be 5.5 feet thick in core 23465 and one foot thick in core 23466 (not shown in the cross section). Its origin is interpreted as loess, redeposited loess, and possibly shallow lacustrine. Some of the silt appears to have washed periodically into the lowland of Bond Creek valley and was later overridden and buried by Illinois Episode ice. Conceivably, a small proglacial lake could have formed if the glacial ice blocked Bond Creek drainage from the north or northeast.

Wisconsin Episode loess deposits (windblown silt), the surficial material covering most of the uplands, are up to about 40 feet thick on upland crests along the Mississippi Valley bluffs, but thin (on uneroded uplands) southeastward to <20 feet thick. The loess thickness can vary considerably because of local erosion on the many steep slopes of sinkholes, hollows, and river valleys. The source of the loess was eolian deflation from outwash sediment in the broad Mississippi Valley. During the last glaciation, and in previous glaciations, fluvially sorted valley sediments were periodically windswept and the silt was carried in dust clouds eastward to vegetated upland areas, where it gradually settled across the landscape. Loess deposits are typically a silt loam where unweathered, but are altered to a heavy silt loam or silty clay loam in the modern soil solum (Higgins 1987). Stratigraphically, the loess consists of the Peoria Silt and the Roxana Silt (Hansel and Johnson 1996), which are yellowish brown to slightly pinkish brown, respectively. The Roxana Silt, the lower and older unit, is about one-half to three-fourths the thickness of the Peoria Silt, based on stratigraphic tests in this quadrangle. Both loess units are leached of carbonates to several feet depth, but can be weakly to moderately dolomitic where thick and can have secondary carbonates along fractures and root pores. Both the Peoria and Roxana Silts have fairly similar physical properties, being predominantly silt, with typically <10% sand and <20% clay when relatively unweathered (table 1). The Roxana Silt was deposited between about 55,000 and 28,000 ^{14}C years before present, whereas the Peoria Silt was deposited between about 25,000 and 12,000 ^{14}C years before present (McKay 1979; Grimley et al. 1998; Hansel and McKay 2010).

In areas of numerous sinkholes and steep slopes on the uplands, the loess deposits interfinger with and grade into colluvial deposits because of remobilization and resedimentation of the loess. Yet many sinkholed areas are mapped

Table 1 Physical and chemical properties of selected map units (typical ranges listed)

Unit	Geotechnical properties[1]			Particle size and composition[2]					
	w (%)	Q_u (tons/ft^2)	N	Sand (%)	Silt (%)	Clay (%)	Clay mineralogy	Carbonate content	MS
Cahokia Formation (tributary facies)	20–35 (2)	0.1–1.25 (2)	2–10 (2)		ND[3]		ND	None to low	50–85
Cahokia Formation (fan facies)	20–30 (1)	0.5–1.5 (1)	ND	5–10	75–80	15–20	50–65% expandables 25–35% illite	None	75–90
Cahokia Formation (clayey facies)	20–45 (3)	0.3–1.5 (13)	2–10 (13)		Generally >30% clay		High expandables	None to low	15–45
Cahokia Formation (sandy facies)	20–30 (3)	0. 25–1.25 (3)	5–30 (15)		Mainly very fine, fine, and medium sand		High expandables	None to moderate	15–35
Peyton Formation	ND	ND	ND		ND		ND	None (matrix) with calcareous fragments	ND
Equality Formation	~35 (1)	1–1.25 (1)	ND	0–10	45–65	25–55	High expandables	2–5%	15–30
Henry Formation	ND	ND	10–40 (15)		Mostly medium to very coarse sand		ND	None to low	ND
Peoria and Roxana Silts	20–30 (11)	0.75–3.0 (12)	5–15 (10)	0–10	80–85	10–20	50–70% expandables 15–35% illite	Leached to weakly dolomitic	50–80
Glasford Formation	20–25 (2)	1.0–3.0 (2)	ND	10–15	55–65	20–30	40–50% expandables 30–40% illite	Leached to 6%	10–30
Petersburg Silt	~20 (1)	1.5–2.5 (2)	ND	0–5	75–85	10–20	High expandables	Leached to 7%	75–80
Oak formation	20–45 (6)	1.0–3.5 (7)	5 to >50 (5)	0–10	15–55	35–85	High expandables	None (matrix) with calcareous fragments	20–25
Mississippian bedrock	ND	>4.5	>50		ND		ND	None to very high	ND

[1]Geotechnical properties are based on hundreds of measurements (total for all units) from about 30 engineering (bridge) borings and 8 stratigraphic test borings in the quadrangle. w, moisture content = mass of water/mass of solids (dry); Q_u, unconfined compressive strength; N, blows per foot (standard penetration test). The number in parentheses after geotechnical properties indicates the number of cores or borings used for data.

[2]Particle size and compositional data are based on a limited data set (~30 samples) from 4 stratigraphic borings. Sand = percentage >63 µm; silt = percentage 2–63 µm; clay = percentage <2 µm (proportions in the <2-mm fraction). Clay mineralogy = proportions of expandables, illite, and kaolinite/chlorite (in the <2-µm clay mineral fraction) using a Scintag X-ray diffractometer. Carbonate content was determined on the <74-µm fraction from 2 stratigraphic borings and 2 outcrops. MS, magnetic susceptibility ($\times 10^{-8}$ m^3/kg) from 4 stratigraphic borings and 3 outcrops.

[3]ND, no data available.

Figure 2 Creek flowing on bedrock in Dennis Hollow and exposing colluvial deposits (Peyton Formation) in the hillside (site 23434; Sec. 3, T3S, R11W).

as Peoria and Roxana Silts (loess) because this level of detail for colluvial mapping was too great to show on the 1:24,000-scale map and because the deposits are similar in character to the intact loess. Larger areas of pebbly silt deposits, interpreted as colluvium, are mapped as the Peyton Formation (Willman and Frye 1970; Hansel and Johnson 1996), generally in areas where it is more than 5 feet thick. Colluvial deposits in sloping areas are the most difficult units to map because of their irregular distribution and thickness. Therefore, many Peyton Formation contact lines are dashed to indicate a lack of precision. The matrix material in the Peyton Formation is generally a brown silt loam and has the soft consistency and appearance of loess deposits from which it is mainly derived. The Peyton Formation is also typically crudely stratified and contains up to 20% angular pebbles of local chert and limestone (fig. 2). The chert pebbles are commonly about 2 inches in size, whereas the limestone can be in slabs more than one foot in length where it has been locally moved downslope from nearby bedrock exposures. The mapped colluvial deposits have various origins, including creep, slumps, landslides, and rockfalls (Killey et al. 1985; Su et al. 1993).

Tributary Valleys and Terraces

Upland stream valleys and hollows, along with isolated areas of Wisconsin Episode terraces, constitute about 3% of the mapped area in the Valmeyer Quadrangle. Postglacial (Holocene) stream deposits in the small valleys and hollows of the eastern part of the map are mapped as the tributary facies of the Cahokia Formation. Because of periodic flooding, this facies has relatively youthful, modern soil profiles that generally lack B horizons (Higgins 1984). The Cahokia Formation in the larger and wider tributary valleys, such as at Bond Creek and Monroe City Creek, is mainly silty (outcrops 23432, 23451, and 23468), with coarser silt in portions of the valleys adjacent to thick loess areas (outcrop 23449). Although mostly silt loam to silty clay loam, the basal couple feet can be rocky, containing various pebbles and slabs of the local carbonate rocks. Some parts of Bond Creek flow directly on local limestone bedrock (e.g., at outcrop 23433). In the steeper gradient, short tributaries along the Mississippi Valley bluffs, the alluvial deposits are also mainly silty but tend to have more rocky zones, including angular or slabby local bedrock (fig. 3). Limestone slabs in the alluvium, locally up to 1.5 feet long and about 2 inches thick, are well imbricated in exposures of the Cahokia Formation, as well as in modern creek beds. Examples of described localities with silty (loess-derived) alluvium interbedded with or underlaid by silty gravel, gravelly silt, or cobbly silt are in Trout Hollow (23430), Schaeffer Hollow (23437), and another nearby hollow (23436). The rocky or cobbly zones are typically 2 to 4 feet in thickness, consist of mostly chert and limestone, and likely represent former channel deposits. In contrast, the silty, loess-derived alluvium mainly represents overbank sedimentation during flood periods. Much of the alluvium is likely late Holocene in age, based on the minimal soil development. One radiocarbon age on wood or bark below several feet of silty Cahokia alluvium, in the small hollow in the vicinity of outcrop 23445 (Sec. 13, T2S, R11W), was determined to be 320 ± 70 (sample no. ISGS-6846) radiocarbon years old. This implies that a significant amount of deposition has occurred in the past few centuries since European settlement of the area. Although mostly consisting of locally derived pebbles and cobbles, the Cahokia tributary facies does include the rare erratic rock in some locations. In Bond Creek valley alluvium, a 3-inch cobble of quartzite

Figure 3 Silty and gravelly alluvium (Cahokia Formation tributary facies) in the creek hollow north of Potato Hill (site 23436; Sec. 15, T3S, R11W).

and a 5-inch cobble of granite were found at site 23433; two 2-inch granite erratics were found near site 23439; and a 5-inch granite cobble was found at site 23468. Small, rounded quartz pebbles were also found in the modern Bond Creek channel deposits. These, along with the observations of till, indicate that the Bond Creek drainage area was glaciated. A well-cemented reddish sandstone or quartzite cobble (4 inches long) was found in alluvium near the mouth of Monroe City Creek (site 23449) and was probably transported downstream following the deglaciation of the area about 2 miles to the east. One large gabbroic rock (several inches long) was found near the base of Hawkins Hollow (NW Sec. 36, T2S, R11W) during an archeological survey (Koldehoff 2002). However, erratic pebbles have not been reported or found as part of this mapping project in the small hollows in the western part of the uplands, such as in Dennis Hollow and Schaeffer Hollow. These areas are considered unglaciated. Erratic pebbles were also not found in Trout Hollow in Sec. 25, T2S, R11W or in the small hollow in Sec. 13, T2S, R11W, despite likely being glaciated, so it is conceivable that evidence for glaciation has been removed by erosion in this relatively rugged terrain. Therefore, the glacial limit proposed here is a best estimate.

Isolated remnants of terraces are found along the larger tributary valleys at surface elevations of typically 420 to 465 feet asl. These surfaces are interpreted as consisting of lake sediment related to the last glacial slack-water conditions. Maximum levels of deposition would have coincided with the peak of the Wisconsin Episode glaciation when Mississippi River sediment aggradation was at its maximum level, causing slack-water conditions up the tributary valleys. The terraces may be capped with a few feet of Peoria Silt that would contain the upper modern soil profile. Deposits in these terraces are mapped as Equality Formation and consist of massive to crudely bedded silt loam that is brown to tan and leached to weakly calcareous. The environment of deposition was primarily lacustrine, with sediments consisting mainly of redeposited loess that was washed into a lake or lowland area. The best exposure of Equality Formation was found in Sec. 19, T2S, R10W (county no. 23467), where about 25 feet of this unit was exposed along the east side of Bond Creek above a few feet of rocky bedrock colluvium. The exact age of the lake deposits is unknown but is suspected to be middle to late Wisconsin Episode according to radiocarbon ages in the region (Curry and Grimley 2006; Grimley and Webb 2010).

Mississippi River Valley

Near-surface deposits in the expansive Mississippi River valley (fig. 4) constitute about 68% of the mapped area and consist of interstratified very fine to fine sand, silt loam, silty clay loam, and silty clay in the upper 20 to 30 feet. The dominantly sandy alluvial deposits are mapped as Cahokia Formation sandy facies [c(s)], whereas the dominantly silty and clayey deposits are mapped as Cahokia Formation clayey facies [c(c)]. This division is made in the Mississippi Valley only. On the eastern edge of the valley, adjacent to the loess-covered bedrock bluffs, silty alluvial fan deposits are mapped [c(f)] that mainly consist of redeposited loess. Anthropogenically disturbed ground is found mainly in artificial levees along the Mississippi River floodplain and Fountain Creek drainageway, and in fill used to elevate the roadways and railways from the floodplain. In the subsurface, the Cahokia sand becomes better sorted and coarsens to a fine to medium sand below a depth of about 20 to 30 feet. At even greater depths, below about 330 to 340 feet elevation asl (see cross sections), the sand becomes medium to very coarse grained and a bit gravelly. This coarser unit is interpreted as glacial outwash from the Wisconsin Episode and is mapped as the Henry Formation. It also serves as an important high-yield aquifer for agricultural irrigation and local drinking water supply, among other uses. The thick sequence of alluvial deposits in the Mississippi River valley is underlain by Mississippian and Ordovician carbonates and shales (Denny et al. 2009).

The sandy Cahokia Formation deposits occur in near-surface channels and point bars of the Mississippi Valley, as well as in subsurface deposits up to 70 feet thick. Deposits of c(s) range from silty sand and very fine sand to loose, well-sorted, medium sand. The deposits are nearly always stratified and can be noncalcareous to weakly calcareous, with 5 to 7% of the grains reacting with weak hydrochloric acid. The

Figure 4 Looking from B Road, west of Moredock Lake, across the eastern portion of the broad Mississippi River floodplain. Exposures of Paleozoic bedrock can be seen in the distance along the bluff line.

sand is typically saturated below depths of 10 to 20 feet. The estimated age ranges from recent in modern point bars to possibly several thousand years old (mid to early Holocene) in the subsurface. Locally, some deposits of up to a few feet of sandy Cahokia Formation were likely sedimented during the levee breaches of the flood of 1993 (Chrzastowski et al. 1994). The clayey facies of the Cahokia Formation is interpreted mainly as overbank flood deposits, swale fills, and abandoned channel fills. The c(c) unit may be interstratified laterally with the Cahokia sandy facies, but in other cases, it is inset as a younger unit into c(s) deposits. The most prominent abandoned meander channel fill occurs in the Moredock Lake Meander, which is a large former meander about 0.5 miles wide and having a clayey filling about 10 to 60 feet thick (cross section A–A′). A west–east electrical resistivity profile (fig. 5) along Ziebold Road and Trout Road has shown that the clay filling is asymmetrical, with a thicker clay filling on the outside (southeastern) bend of the channel that would have been the former cutbank. Other former channel fills, with thick clay fillings, are found in the eastern part of the Mississippi Valley floodplain, such as on the east side of the pre-1993 town of Valmeyer (cross section B–B′).

The coarser-grained Henry Formation does not outcrop here, occurring at depths of 30 to 80 feet below the Cahokia Formation. The Cahokia-Henry Formation contact was based on a coarsening of sand and the presence of gravelly zones in numerous water-well borings and engineering boring records (from IDOT bridge borings and U.S. Army Corps of Engineers levee borings). The Henry Formation was observed only in sample sets from a few water supply borings (e.g., county nos. 22707 and 22708) on the east side of the Mississippi Valley, where the sand is medium to very coarse grained. The deposit also contains gravelly zones with pebbles of various types (quartz, chert, carbonate, granite, mafic igneous rocks) and various colors, typically <1 inch in diameter. The overall Henry Formation sand and gravel deposit is loose, saturated with groundwater, and generally subrounded to subangular. Groundwater in the Henry Formation is extensively used for agricultural irrigation and household water supply in the Mississippi Valley.

Economic Resources

Sand and Gravel

Potentially minable and usable deposits in the quadrangle may include sand with some gravel in the Henry Formation and to a lesser extent the Cahokia Formation sandy facies. The Henry Formation in the Mississippi River valley is relatively coarse grained (generally medium to coarse sand with some fine gravel), but is typically buried by about 40 to 60 feet of Cahokia Formation (clayey or sandy facies, or both) and occurs below the water table so that dredging would be necessary. The Cahokia sandy facies is generally less desirable for aggregate because it contains mainly fine- to very fine-grained sand and may be interstratified with silt and clay. Test boreholes or geophysical tests may be necessary for site-specific projects to determine the economic viability of resources.

Groundwater

Groundwater is extensively used for household, public, and industrial water supplies in southwestern Illinois. Surface water resources, such as the Mississippi River, are also used. Saturated sand and gravel in the Henry Formation and sand in the Cahokia Formation constitute the predominant aquifer material in the Valmeyer Quadrangle. Known sand or gravel material, or both, is stippled in the cross sections. Aquifer

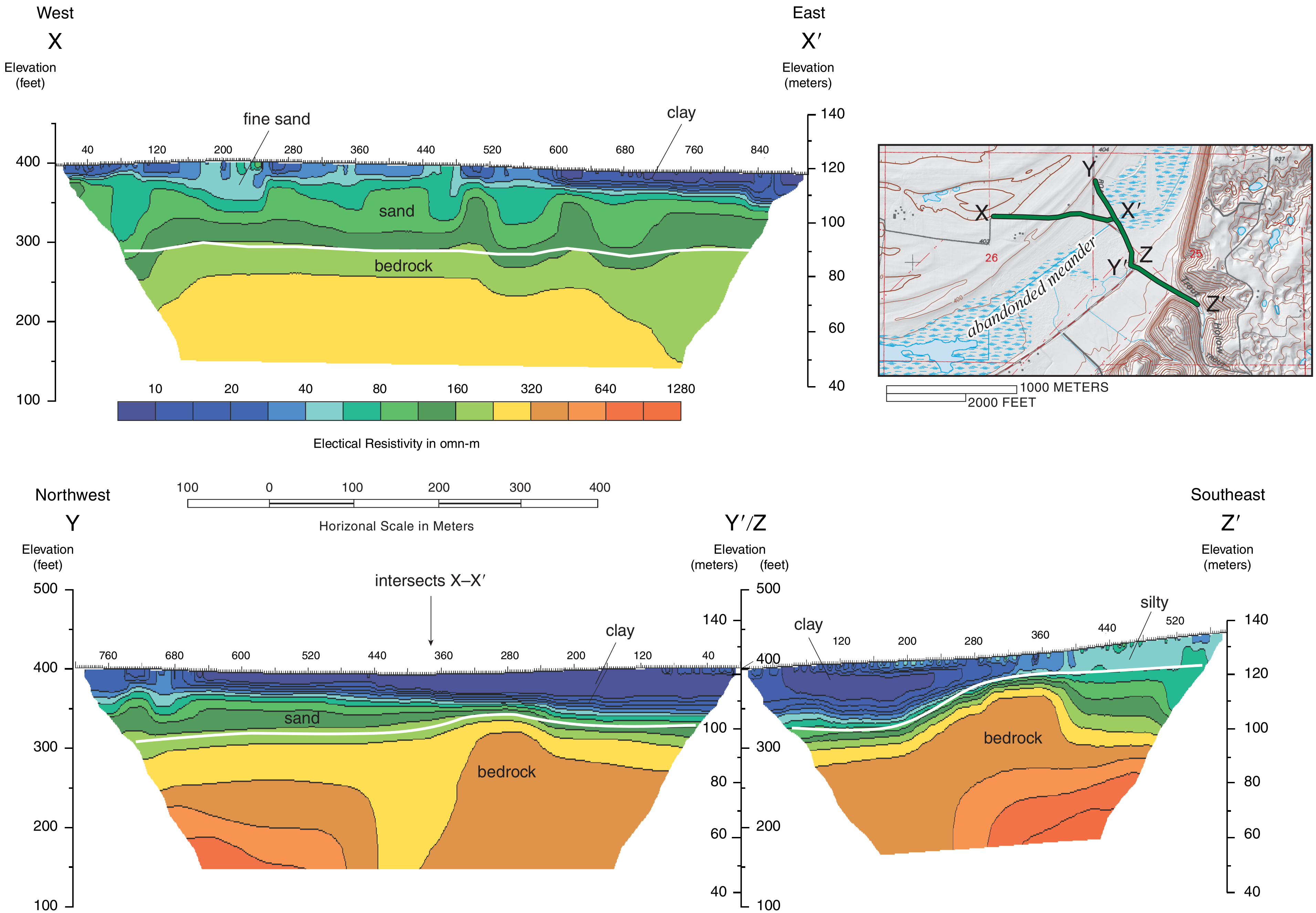

Figure 5 Three electrical resistivity profiles across an abandonded meander of the Mississippi River in Secs. 25 and 26 in T2S, R11W, Monroe County. Lower resistivities are found in fine-grained deposits (clayey). Higher resistivities are found in coarse-grained (sandy) deposits or local bedrock (mainly limestone). Horizontal scale is in meters; vertical scale is shown in meters and feet.

material in the Henry Formation in the Mississippi River valley is fairly extensive and is regionally used for household and village water supplies, including the new town of Valmeyer. Henry Formation sand and gravel and Cahokia Formation sand in the Mississippi River floodplain compose the most significant Quaternary aquifer of this quadrangle (see cross sections). Yields from this aquifer are high; however, the potential for contamination is also high because of the relatively thin and discontinuous covering of silt and clay (0–50 feet).

In upland areas, sand and gravel lenses within the thin local till or alluvium are rare, unsaturated, or unsuitable for more than a low-yield water supply. The silty loess deposits are also mostly unsaturated because of high relief and deep water tables. Thus, bedrock aquifers here, such as the groundwater in fractured or cavernous Mississippian limestones, are used almost exclusively for water supply in upland areas, although this groundwater is vulnerable to contamination (see below).

Environmental Hazards

Flooding

Severe flooding occurs periodically in the Mississippi Valley region in the Valmeyer Quadrangle. The most prominent and dramatic recent occurrence was during the flood of 1993, when the Mississippi River was about 40 feet above its normal pool level. In the Valmeyer Quadrangle, four levee breaches occurred (August 1, 1993) along the Fountain Creek artificial levees northwest of Moredock Lake, where the levees likely intersected a former river channel (Chrzastowski et al. 1994). The levee breaches occurred when water surged from another levee breach of the Mississippi River in the Columbia Levee District that flowed south and was compounded with floodwater backing up Fountain Creek from the Mississippi River. After overtopping and breaching the levees, the water continued to surge southward through the Harrisonville Drainage and Levee District, which is located in the broad Mississippi Valley floodplain. The southward slope of the floodplain and topographically low area south of Moredock Lake channeled the water toward the original town of Valmeyer, severely damaging the town (Chrzastowski et al. 1994) as well as many structures in rural areas of the floodplain (fig. 6). The devastation was so great that the town of Valmeyer was relocated to the top of the upland bluffs within the next year (Erdmann and Bauer; 1993) in Secs. 1 and 2, T3S, R11W and Secs. 35 and 36, T2S, R11W. The levee structures along Fountain Creek have since been rebuilt, but the original pre-1993 town of Valmeyer has only a few remaining structures today.

Karst (Sinkhole and Cavern Development)

Karst topography, including sinkhole development (Panno and Luman 2012), is evident at the surface in many areas of the quadrangle where limestone bedrock is within about 25 feet of land surface. The areas most susceptible to sinkhole

Figure 6 (a) Flooded area of the Mississippi River valley near Valmeyer, Illinois. Photo taken by Joel Dexter on October 12, 1993, after the peak flood. (b) House in the Valmeyer Quadrangle displaced near a levee breach. During the 1993 flood, this house was pushed off its foundation and transported until it was stopped by a tree. Photo taken by Joel Dexter in December 1993.

and underground cavern development include those with thin loess and residuum overlying pure limestone, such as the Salem and St. Louis Limestones (Panno et al. 1997; Panno and Weibel 1998; Denny et al. 2009; Panno and Luman 2012). The sinkhole distribution patterns commonly follow joint sets in the bedrock. Karstic regions pose a hazard to building structures because of the danger of sinkhole collapse and widening. Furthermore, the bedrock aquifers underlying karstic regions are highly susceptible to contamination because groundwater recharge flows quickly into cavernous bedrock and is not filtered through soil, clay, or slowly permeable bedrock (Panno et al. 1997; Panno and Weibel 1998).

Groundwater Contamination

Surface contaminants pose a potential threat to groundwater supplies in near-surface aquifers that are not overlaid by a protective confining (clay-rich and unfractured) deposit such as till or lake sediment (Berg 2001). As mentioned, the limestone bedrock aquifers underlying karstic regions are highly susceptible to contamination (Panno et al. 1997). Groundwater in near-surface sand and gravel units (e.g., Cahokia Formation sandy facies) is also vulnerable to agricultural, surface mining, or industrial contaminants. The potential for groundwater contamination depends on the thickness, connectivity, and character of fine-grained alluvium, loess, or till deposits that overlie an aquifer. Because of lateral and vertical groundwater flow, the position of a site in the overall groundwater flow system needs to be considered. Aquifer material in the Henry Formation (outwash facies) of the Mississippi Valley is moderately protected in some areas by 20 to 30 feet of fine-grained alluvium (Cahokia Formation), but in other areas, it is laterally in contact with overlying sandy material that provides a connection to any surface contaminants.

Mass Wasting

Areas with various types of mass wasting (including creep, slumping, rockfalls, and landslides; Killey et al. 1985) are common on the high-relief uplands of the Valmeyer Quadrangle. Several landslides and rockfalls along the steep, 200- to 400-foot-high Mississippi Valley bluffs have formerly been identified and classified as definite, probable, or possible within the Valmeyer Quadrangle by using remote sensing methods (Su et al. 1993). Some mass wasting is possibly related to paleoseismic events. On the Valmeyer surficial map, some areas of rockfalls and landslides are included within near-surface bedrock polygons because the colluvial deposits are intermingled with nearly all areas of bedrock outcroppings along the bluff line and are thus difficult to differentiate. Landslides and toppling rocks have been significant hazards in the past, causing disruptions along the bluffside roadways.

Seismic Hazards

Near-surface fine sand in the Henry and Cahokia Formations is potentially liquefiable where materials are saturated (below the water table) and are subjected to strong ground shaking. Tuttle (2005) identified paleoliquefaction features, such as ancient sand blows, at several localities in the southwest Illinois region. These features likely formed during past earthquake activity in the New Madrid Seismic Zone or from other seismic activity in southern Illinois or southeastern Missouri. Seismic shaking hazards are also an important issue, especially in areas with loose sand, disturbed ground (fill), and soft clay (Bauer 1999). Areas with near-surface Cahokia Formation sand and clay, fill material, or Equality Formation are the most susceptible to seismic shaking because they are relatively soft and unconsolidated and have low density. These conditions amplify earthquake ground motions.

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