STATEMAP
Pleasant Mound-SG

Surficial Geology of Pleasant Mound Quadrangle

Bond and Fayette Counties, Illinois

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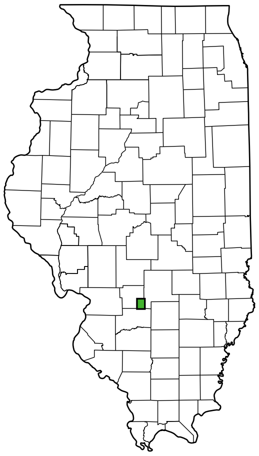
2018



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Introduction

The Pleasant Mound 7.5-minute quadrangle is located in the Kaskaskia River Basin and includes parts of Bond and Fayette counties, southwestern Illinois (Figs. M1, M2 [map sheet 2]). Surficial geology maps provide an important framework for land and groundwater use, resource evaluation, engineering and environmental hazards assessment, and geological or archeological studies. This study is part of a broader geologic mapping and research program undertaken by the Illinois State Geological Survey (ISGS) in southwestern Illinois (Grimley and Phillips 2006, 2011a,b). The Pleasant Mound Quadrangle is the third 1:24,000 quadrangle surficial geology mapping project in the middle Kaskaskia Basin region, following mapping of the Stolletown Quadrangle to the southwest (Grimley and Gemperline 2015) and the Keyesport Quadrangle to the south (Grimley and Walkowska 2017).

The Pleasant Mound Quadrangle is within an area that was entirely covered by glacial ice during the Illinois and pre-Illinois episodes (Figs. M1 and M2; Hansel and McKay 2010; Curry et al. 2011; Grimley and Phillips 2011a; Grimley et al. 2017). During a pre-Illinois Episode glaciation, ice likely advanced to southwestern Illinois from the Lake Michigan basin, the eastern Great Lakes region, or both (Willman and Frye 1970; Hartline 1981). After the ensuing Yarmouth interglacial episode, glacial ice once again advanced across the region during the Illinois Episode, originating from the Lake Michigan basin and reaching as far south as Carbondale, Illinois, and as far southwest as St. Louis, Missouri (Hansel and McKay 2010). The expansive Illinois Episode glacial ice lobe likely divided into multiple sublobes, including a sublobe in the Kaskaskia Basin (Figs. M1 and M2) and the Springfield Plain during its recession (Webb et al. 2012; Grimley et al. 2017). Various types of glacial hills, including ice-walled channels, kames, and morainal ridges, were formed within the Kaskaskia Basin during an overall recessional phase. This phase included times of glacial surging or streaming (Grimley and Phillips 2011a; Webb et al. 2012), perhaps affected by the subglacial substrate and hydrology, followed by stagnation and ablation (Leighton 1959; Jacobs and Lineback 1969). Based on findings from this mapping project (see Uplands section), we now envision that there may have been a late surge of the Springfield Sublobe, southeast into the Kaskaskia River Basin, that formed the curvilinear NW-SE trending subglacial lineations in the Pleasant Mound Quadrangle. This interpretation implies that ice marginal landforms of a portion of the Kaskaskia Sublobe were overridden (Fig. M2) and that the geomorphology is more complicated than previously thought by Grimley and Phillips (2011a). During the regional advance and retreat of the pre-Illinois and Illinois Episode glacial ice margins, proglacial outwash (from perhaps multiple sublobes) was deposited in parts of the Kaskaskia River Basin, including within a buried bedrock valley that underlies and closely follows the present valley (Grimley 2010; Phillips 2009; Grimley and Webb 2010). In response to periods of downcutting of the Mississippi River (Curry and Grimley 2006), the Kaskaskia River and its tributaries were incised during middle-late Pleistocene interglacials (Yarmouth and Sangamon Episodes) and during the early Holocene. Glacial ice did not reach the study area during the Wisconsin Episode (late Pleistocene); however, glacial meltwater streams from Illinois and the upper Midwest deposited outwash in the Mississippi River valley, which was the dominant source of the loess deposits (windblown silt) that blanket uplands in southwestern Illinois (McKay 1979; Grimley et al. 2001). The Kaskaskia River valley was likely a minor last-glacial meltwater stream for a relatively short time (from ~25,000 to 22,500 cal years B.P.); thus, it did not serve as a major Wisconsin Episode loess source (Grimley and Phillips 2011a).

In recent history, the construction of Carlyle Lake between 1958 and 1967 resulted in significant anthropogenic impacts. The lake's 445 feet above sea level (asl) normal pool level is shown on the map, although lake levels commonly fluctuate according to hydrologic conditions and U.S. Army Corps of Engineers planning. Areas below 462 feet asl may be subjected to controlled inundation, yet the highest level reached since 1967 has been 459.8 feet asl in 2002. Lake levels above 450 feet are not uncommon in recent years, with a crest of 454.4 feet asl in July 2015. Such high lake levels result in slackwater flooding in lower reaches of tributary valleys to the lake; thus, these areas seasonally alternate between fluvial and lacustrine regimes.

Methods

Surficial Map

This surficial geology map is based in part on soil parent material data (Phillips and Goddard 1983; Hodges 1997), supplemented by data from outcrop studies and stratigraphic test holes obtained for this STATEMAP project, engineering borings from the Illinois Department of Transportation and Bond County Highway Department, and water-well records. Map contacts were also adjusted according to the surface topography, geomorphology, and observed landform–sediment associations.

Locations of subsurface data used for the surficial geology map, cross sections, or landform–sediment associations are shown on the map. All studied outcrops and stratigraphic test holes are shown on the surficial map, as are key engineering, coal, petroleum type, and higher quality water-well borings that were utilized for mapping or for developing the geologic framework. Some of the water-well and oil-gas type borings had sample sets in the ISGS collections that were examined to help verify unit contacts, unit descriptions, and confirm bedrock surface elevations. The locations of many water-well borings were verified by plat books, permit maps, address checking, field confirmations (for water wells only), or a combination of methods. Many other data in this quadrangle, particularly petroleum type borings, are not shown on the map because of poor descriptions of surficial materials or unconfirmed locations. Stratigraphic test core samples were described in detail and samples were analyzed for particle size, clay mineralogy, geochemistry (< 0.25 mm fraction), and magnetic susceptibility (< 2 mm fraction). Further information on all data shown, as well as other data, is available from the ISGS Geological Records Unit or from the ILWATER Internet map service (http://www.isgs.illinois.edu/ilwater). Geologic data records can be identified based on their location and the labeled county number (5-digit portion of the 12-digit API number).

Four electrical resistivity transects were aconducted to help with mapping surficial deposits (location of lines acquired for this project are indicated on map). A computer-controlled resistivity meter (ABEM Terrameter LS) was used and the survey line was moved in 100 m increments. A two-dimensional resistivity model, approximately 60 m deep, was calculated from the electrical data using a finite element inversion program. Topographic corrections (using LIDAR elevation data) were applied to the profiles.

Cross Sections

The cross sections portray unconsolidated deposits as would be seen in a vertical slice through the earth down to bedrock, and are vertically exaggerated 20 times. The lines of cross section are indicated on the surficial map and inset figures (Figs. M3 and M4). Data used for subsurface unit contacts (in approximate order of quality for use in this mapping project) are from studied outcrops, stratigraphic test holes, engineering boring records, water-well records, and oil- or gas-boring 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 totall depth of wells that extend into bedrock is not shown.

Bedrock Topography and Drift Thickness Maps

Maps of bedrock topography (Fig. M3) and drift thickness (Fig. M4) are based on data from which a reliable bedrock elevation could be determined (Fig. M3). Data within about a mile of the map boundary were also utilized (not shown). A total of 98 data locations were used in the map and in a 1.5 to 2.5 km buffer area (depending on data density), including one archived field note (outcrop), two stratigraphic test borings, 17 engineering borings, 35 water-well borings, one coal boring, 10 electrical resistivity profile estimations, and 32 oil and gas type borings. A bedrock surface was modeled from the 98 data points utilizing the "Topo to Raster" module in ArcMap 10.3 (ESRI), using a vertical standard error of 3 feet, and with "drainage enforcement," which attempts to make a hydrologically correct surface. The bedrock surface elevation in the Pleasant Mound Quadrangle ranges from about 385 to 490 feet above sea level (~105-feet relief). A drift thickness map (Fig. M4) was created by subtracting an elevation model (grid format) of the bedrock topographic surface from a land surface digital elevation model (DEM), using a 30-m cell size. Due to the processing, the resulting drift thickness map had some irregular, detailed, or small polygons, which were simplified to some extent in Figure M4. Drift thickness ranges from 0 (bedrock outcropping in northeastern part of quadrangle) to about 165 feet thick (esker ridge in southeast part of quadrangle).

Surficial Deposits

The surficial deposits are divided into four landform–sediment associations: (1) uplands/till plains underlain by mainly loess and till deposits (mainly northwestern areas); (2) glacial ridges and knolls containing either ice-contact sandy deposits, diamicton, or mixed lithology and all capped with loess; (3) broad, flat terraces with successions of glaciofluvial sediments (mainly in southeastern half of map) covered by loess; and (4) postglacial river valleys with alluvial sediments. Older concealed deposits (5), associated with a pre-Illinois Episode glaciation, are preserved in some areas as well. Areas of anthropogenically disturbed ground consist mainly of spoil piles associated with sand and gravel pits, areas of fill below roadways, and railway or levee embankments.

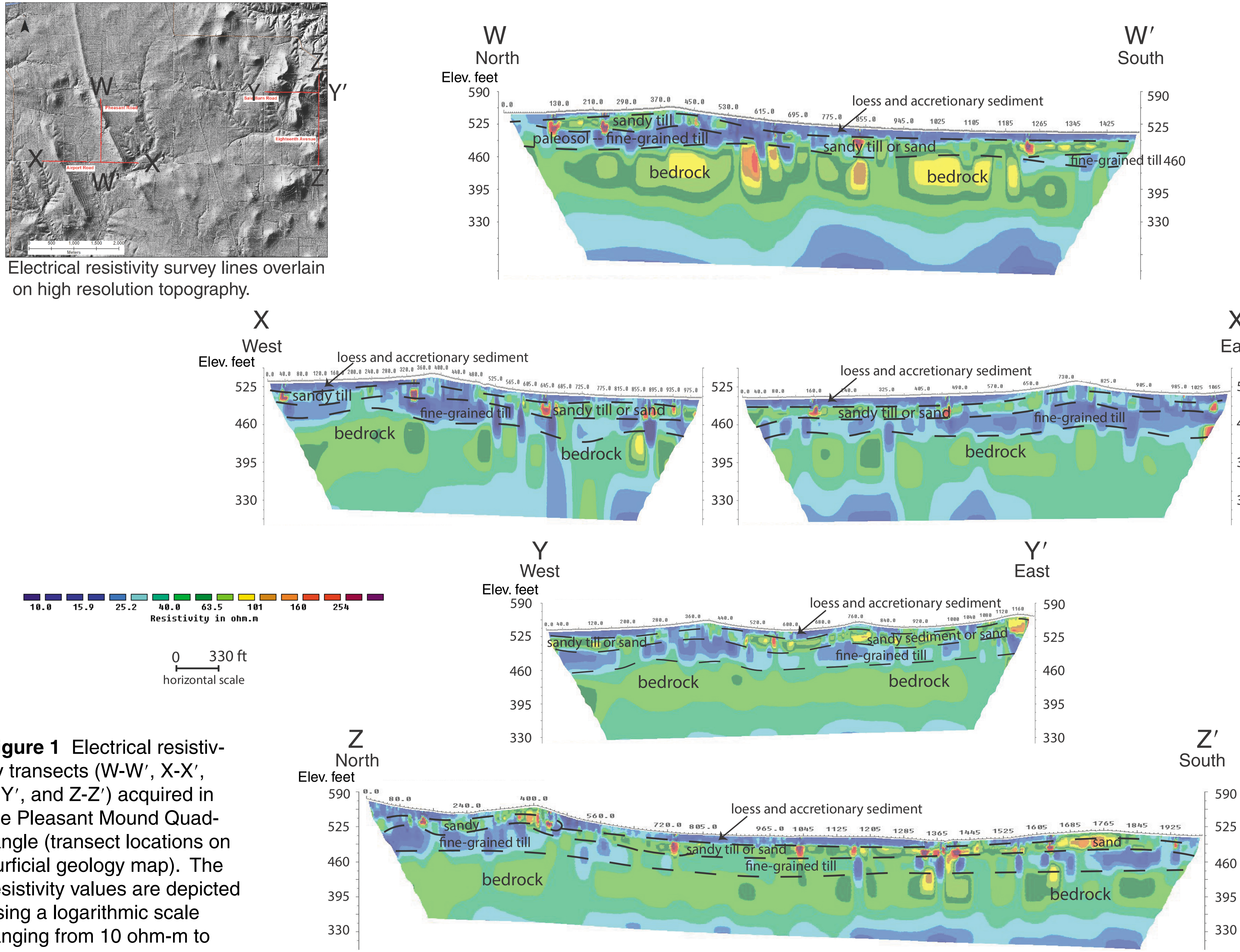
(1) Uplands—till plain and subglacial lineations

Flat to gently rolling uplands, underlain by mainly loess, paleosol, and till deposits are found mainly in the northwestern half of the quadrangle (~35% of map area). Because of a more than 5-foot-thick loess cover, many such areas are mapped as Peoria and Roxana Silts, but the loess is directly underlain by typically weathered accretionary deposits (Berry Clay Member) and glacial till (Glasford Formation) as shown in the cross sections (map sheet 2). Older pre-Illinois Episode glacial units are found below the Glasford Formation in some areas (see Concealed Deposits Section). Pre-Illinois Episode deposits, present in the subsurface in the northwestern portion of the quadrangle, are mostly absent in the eastern portion of the quadrangle (see cross sections) probably because of enhanced fluvial or glacial erosion during the Illinois Episode in the Kaskaskia Bedrock Valley. Pennsylvanian bedrock units in the area (the Bond and Shelbourne-Patoka Formations) regionally dip gently eastward toward the center of the Illinois Basin (Kolata et al. 2005). Thus, the generally north–south trending bedrock surface high in this quadrangle (Fig. M3) likely reflects the strike of more resistant Pennsylvanian limestone or sandstone units. This bedrock high is one of a regional series of ancient, buried cuestas, with sandstone or limestone constituting the uppermost bedrock in ridges and shales mainly constituting the uppermost bedrock in preglacial valleys. In the northeastern Pleasant Mound Quadrangle, along Avery Branch, an archived ISGS field description (G. Ekblaw 1931) reports 3 feet of exposed Pennsylvanian sandstone that is micaceous with thin shale partings. No other bedrock outcrops were found during this mapping or have been reported in the quadrangle.

Below surficial loess and accretionary deposits, the uplands are mainly underlain by deposits of diamicton (a massive, unsorted mixture of clay, silt, sand, and gravel), with minor sand and gravel lenses. Diamicton, weathered diamicton, associated sorted sediment, or some combination of these are mapped together as Glasford Formation and are interpreted as till, debris flow, and ice-marginal sediment. The Glasford unit is shown on the surficial map where the loess cover has been eroded to less than 5 feet thick along slopes. Surface soils with till or paleosol parent material within 5 feet of ground surface, mainly the Hickory and Atlas soil series, were mapped in the U.S. Department of Agriculture county soil survey reports (Phillips and Goddard 1983; Hodges 1997) in many sloping areas of the quadrangle. However, several areas on slopes mapped as Hickory loam or Atlas clay loam soil series are likely weathered Pearl Formation outwash or Berry Clay Member (see later section on outwash terrace) rather than Glasford till, or some mixture of sand, diamicton, loess and accretionary sediment.

In the northwestern part of the quadrangle, 3 or 4 prominent curvilinear lineations are notable in the surface topography. Three drillholes and two geophysical transects (Fig. 1) were acquired as an attempt to understand these ridges, along with the intervening lowlands. Sandy or gravelly deposits (lenses) are less than 2 or 3 feet thick, based on the boreholes located on the ridgetops. Boreholes 23699 and 23700 both contain about 5 feet of last glacial loess over Glasford till, including an upper alteration zone. Borehole 23703, on the northern part of the longest ridge (~3 miles in length) contains about 5 feet of loess over an alteration zone (Sangamon Geosol) developed into lacustrine sediment over till and ice-marginal sediment. The calcareous and vaguely stratified lacustrine sediment (Teneriffe Silt) occurs from 9 to 15 feet (Fig. 2), but was not delineated in cross section A-A′ because of its thinness and unknown lateral extent. The Glasford diamicton from 15 to 22 feet contains some silt and sand beds (as thin as 2 to 5 cm) within a pebbly loam diamicton unit. Older till, including the fine-grained Smithboro facies, and paleosols occur below (Fig. 2). The electrical resistivity transects (Fig. 1) also confirm that little sandy material occurs within the ridges; the low resistivities imply more fine-grained material (loess, paleosol, lacustrine) or till. Some minor sandy deposits could occur in the lowlands, based on the geophysics, but there is no evidence for a substantial thickness of coarse-grained material. Given the lack of glaciofluvial deposits and predominance or till and diamicton in these ridges, a fluvial or glaciofluvial origin can be ruled out. The geomorphology of the ridges, being so thin and elongate, are also not consistent with a morainal origin. Therefore, our favored interpretation is that these are glacially streamlined landforms, namely subglacial lineations (Ely et al. 2016). The shape of the feature in Section 8 (T4N-R2W), and its till composition, is consistent with it being an Illinois Episode drumlin, and suggests ice flow to the southeast. The elongate, streamlined landforms, stretching across sections 19, 29 and 30 (T5N-R2W) and from section 30 to 31, could be termed mega-flutes and may imply fast flowing glacial ice (Anderson and Fretwell 2008). Based on the occurrence of these landforms at this location, it is now suspected that they were formed by a late surge of glacial ice in the Springfield Sublobe that flowed from NW to SE into the Kaskaskia Basin (Figs. M1, M2), after the Kaskaskia Sublobe ice margin had receded or ablated from this area. This interpretation is a slight modification of prior ideas on the history of the Kaskaskia Sublobe (Grimley and Phillips 2011a; Grimley et al. 2017).

Exposures of Glasford till in the quadrangle, below loess and Berry Clay Member, were observed at several outcrops, such as in cutbanks along Avery Creek (e.g., outcrops 23650, 23706 in Secs 14 and 15, T5N, R2W) and Willow Branch (e.g., outcrops 23654, 29166). At the Willow Branch outcrops and the eastern Avery Branch outcrop, 2 to 5 feet of loamy sand, silt, fine sand or gravelly sand (proglacial Pearl Formation, Mascoutah facies) also occurs between the Berry Clay Member and the Glasford Formation till. Compared with overlying loess and accretionary deposits, the Glasford till is considerably more pebbly, more dense, has a lower moisture content (~8–13%), and has a greater unconfined compressive strength (Qu; Table 1). An upper till unit of the Glasford Formation in some deeper stratigraphic test holes is correlated to the Vandalia facies, based on its physical and chemical properties (Jacobs and Lineback 1969; Willman and Frye 1970; Hartline 1981). A lower till unit of the Glasford Formation, that is slightly finer grained, less sandy, and less illitic, is correlative with the Smithboro facies (Jacobs and Lineback 1969; Hartline 1981; Grimley and Gemperline 2015). The Vandalia and Smithboro facies of the Glasford Formation have been most clearly documented in stratigraphic test borings 23703 (this project) and 23704 (from L. Hartline [1981] Master's thesis). The Smithboro facies was also noted in one of the outcrops along Avery Creek (Sec. 15, T5N, R2W), in part based on laboratory data; other outcrops with till contain the Vandalia facies. The exposure in Sec. 31-T5N, R1W (county # 29166) contains many thin and discontinuous sand lenses (tectonized or injected ?) within part of the Vandalia facies. This site also contained an inclusion or rip-up clast of Smithboro facies till, with conifer wood fragments, within the lower part of the Vandalia unit. In the Pleasant Mound Quadrangle, relatively unaltered till of the Vandalia facies has about 60–72% illite in the clay mineral fraction and has a loam texture with about 12–20% clay (<2 μm), 35–50% silt, and 28–54% sand (Table 1). In comparison, till classified as the Smithboro facies has about 35–55 % illite in the clay mineral fraction (with 20–45 % expandable clay minerals). The Smithboro facies is more silty (> 50 %) than the Vandalia facies and generally has > 20 % clay and < 25 % sand (Table 1). The Smithboro facies also has a lower gravel content (generally < 5 %) than the Vandalia facies (typically 5 to 10 % gravel). Finally, the Smithboro facies can have a slight organic aroma, and has more silty inclusions and small fragments of conifer wood. Overall, the characteristics of the Smithboro facies likely reflect glacial incorporation of proglacial palustrine, loessal, paleosol, and lacustrine sediments. Sand and gravel lenses or channels within the Glasford Formation occur locally on uplands.



Electrical resistivity survey lines overlain on high resolution topography.

Figure 1 Electrical resistivity transects (W-W′, X-X′, Y-Y′, and Z-Z′) acquired in the Pleasant Mound Quadrangle (transect locations on surficial geology map). The resistivity values are depicted using a logarithmic scale ranging from 10 ohm-m to 320 ohm-m.

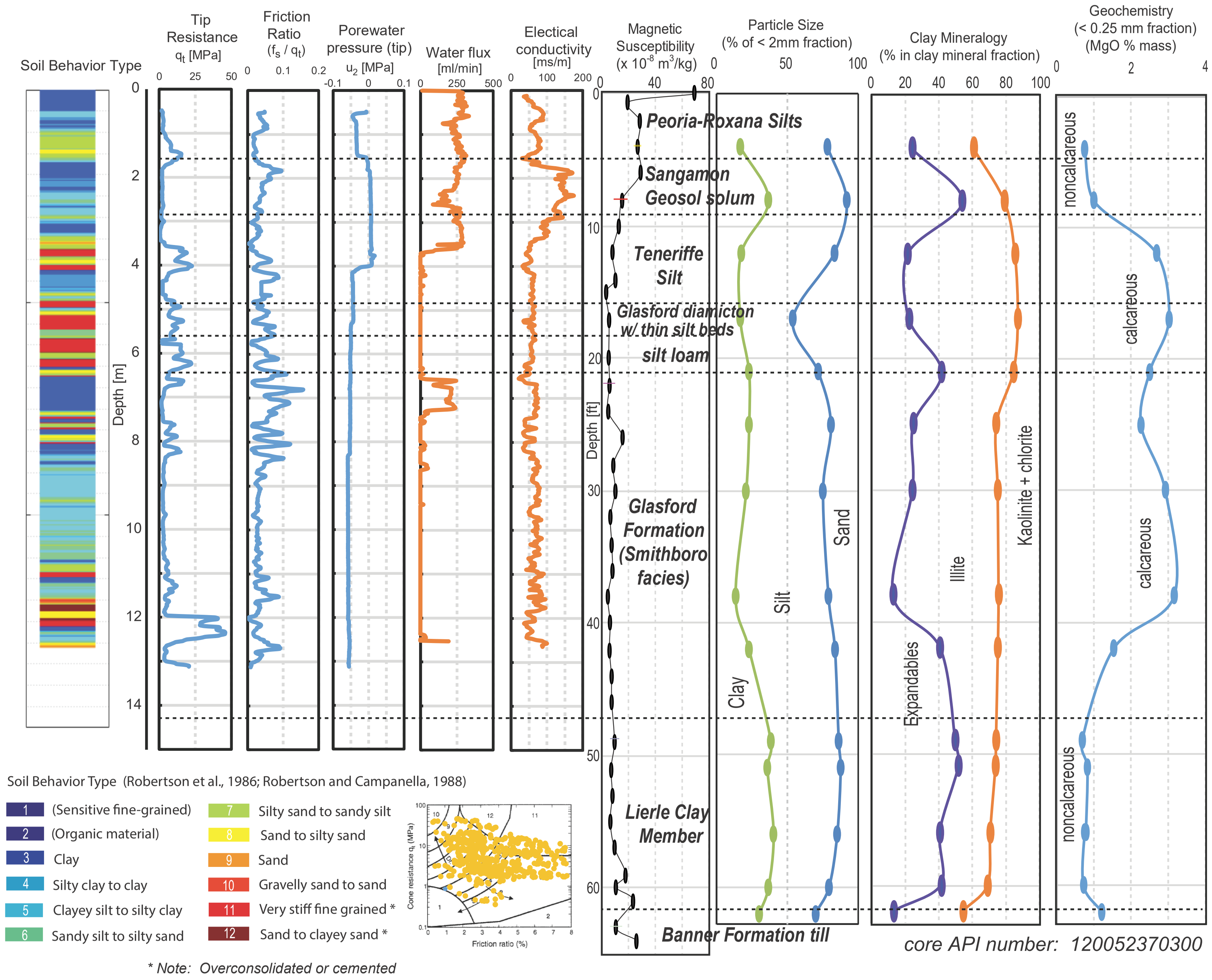


Figure 2 Cone-penetration and hydraulic profiling log of core PLM-5 (county no. 23703), along with other analytical laboratory data. The tip resistance, friction ratio (f_s/q_t), and porewater pressure (from tip), are from the CPT system. The water flux (water ejected from HPT port) and electrical conductivity data are from the HPT system. The 12 soil classification types are based on the empirical relationship between the tip resistance (q_t) and the friction ratio (f_s/q_t). Soil classification types 1 and 2 (sensitive and organic soils) are not present at this site.

Table 1 Values shown in table indicate typical ranges of the various physical and chemical properties within typical materials for each geological unit in the Pleasant Mound Quadrangle. Data for the Glasford and Pearl Formation units are from relatively unaltered portions (below the Sangamon Geosol solum).

	Geotechnical properties[1]			Particle Size and Compositional Data[2]						
Unit	**w (%)**	**Q_u (tons/ft^2)**	**N**	**sand**	**silt**	**clay**	**Clay mineralogy**	**Carbonate (field test)**	**MgO mass % (< 250 µm fraction)**	**MS**
Cahokia Formation	16–31 (26)	0.3–1.3 (23)	3–15 (23)	silt loam to silty clay loam to sandy loam			ND[3]	Mainly noncalcareous	ND	ND
Peoria and Roxana Silts	18–29 (4)	1.25–1.75 (10)	ND	0–28	50–70	17–25	24–55% expandables 25–45% illite	Noncalcareous	0.7 – 0.9	20–70
Berry Clay Member, Pearl (or Glasford) Fm.	18–33 (4)	1.5–3.75 (8)	ND	silty clay loam to sandy clay loam			sparse data	Noncalcareous	0.8 – 1.2	15–55
Hagarstown Member (sandy facies), Pearl Fm	15–20 (5)	<0.25 to 1.75 (8)	ND	55–93	4–38	3–15	55–66 % illite (sparse data)	Leached to calcareous	0.8 – 3.1	4–55
Hagarstown Member (mixed facies), Pearl Fm	11–27 (4)	< 0.5 to 3.5 (9)	ND	20–92	4–60	4–25	40–66 % illite	Leached to calcareous	0.8 – 3.5	4–50
Mascoutah facies, Pearl Fm. (outwash)	20-23 (5)	<0.25 – 1.0 (3)	5–27 (12)	ND	ND	ND	ND	Leached to calcareous	ND	ND
Glasford Formation (Vandalia facies)	7–14 (38)	3.5 to 8.0 (38)	25–110 (31)	28–54	35–50	12–20	60–75% illite (Vandalia facies)	Calcareous (where unaltered)	2.6 – 3.3	5–35
Glasford Formation (Smithboro facies)	14–22 (7)	1.5 – 3.5 (7)	20-50 (8)	16–25	54–62	20–23	35–55% illite (Smithboro facies)	Calcareous	1.5 – 3.2	5–15
Grigg tongue, Pearl Fm. (outwash)	ND	ND	ND	fine sand to gravelly sand			ND	Calcareous	ND	ND
Lierle Clay Member, Banner Formation	17–23	2.25 – 3.0 (3)	ND	12–21	43–52	36–40	40–55% expandables	Noncalcareous	0.7 – 1.1	6–23
Banner Formation (till, outwash)	ND	ND	ND	silt loam to clay loam diamicton to gravelly sand			41% illite (one sample only)	Weakly to moderately calcareous	1.0 – 1.6	10–30 (sparse data)
Pennsylvanian bedrock	10–17 (16) (shale)	>4.5	>50 (16)	ND			ND	None to very high (in limestone)	ND	ND

[1] Geotechnical properties are based on tens of measurements (total for all units) from ~20 engineering (bridge) borings and 5 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). Number in parentheses after geotechnical properties indicates number of cores/borings used for data; each core may have one or more depths with data.

[2] Particle size, clay mineralogy, and %MgO are based on a dataset (~52 samples) from 5 stratigraphic borings and 4 outcrops. Sand = % >63 µm; silt = % 2–63 µm; clay = % < 2 µm (proportions in the <2–mm fraction from hydrometer analyses). Clay mineralogy = proportions of expandables, illite, and kaolinite/chlorite (in <2–µm clay mineral fraction) using Scintag X–ray diffractometer. MgO mass % was measured by X-ray fluorescence. MS, mass-based magnetic susceptibility ($\times 10^{-8}$ m^3/kg) from tens of measurements in the laboratory on 5 stratigraphic borings and 4 outcrops using a Bartington MS2 meter and MS2B attachment.

[3] ND, no data available.

Strong alteration features are prominent in the upper 4 to 6 feet of the Glasford Formation (where not buried by other Illinois Episode deposits), including root traces, fractures, carbonate leaching, oxidation or color mottling, strong soil structure, clay accumulation, clay skins, or their combination. These features are evidence of a buried interglacial soil known as the Sangamon Geosol, which marks the boundary between the Glasford Formation and overlying Wisconsin Episode loess deposits (Willman and Frye 1970). Oxidation and fracturing, with iron staining on the fracture faces, can extend 10 to 20 feet or more into the Glasford till (or diamicton) in some areas. The upper 5 to 10 feet of the Glasford Formation, where uneroded, is generally more weathered (related to the Sangamon Geosol), is leached of carbonates, has a higher water content, has a higher proportion of sand or silt lenses, and is less stiff than the majority of the unit.

Surficial loess deposits (Peoria and Roxana Silts combined) are typically 5 to 6 feet thick where uneroded, with thinner deposits on steeper eroded slopes. The loess deposits cover Illinois Episode deposits (Glasford or Pearl Formations) are shown on the surficial map where ~5 feet or thicker. The loess was deposited during the last glaciation (Wisconsin Episode) when mainly silt-sized particles in Mississippi River valley glacial meltwater deposits were periodically windswept and carried in dust clouds eastward to vegetated upland areas, where they gradually settled across the landscape. Loess deposits are typically a silt loam where unweathered, but in the modern soil solum (about the upper 4 feet), they are altered to a heavy silt loam or silty clay loam. The Peoria Silt is the upper, younger loess unit and is contained mostly within the modern soil solum. The Roxana Silt, typically with a slight pinkish or darker brown hue in other areas, is the lower loess unit (Hansel and Johnson 1996) but is not easily distinguishable in the field as it has been pedogenically mixed with Peoria Silt above (modern soil profile) and/or with Sangamon or Illinois Episode deposits below (upper Sangamon Geosol). Both loess units in this quadrangle are slightly to moderately weathered, leached of carbonates, and relatively similar in physical properties (Table 1); thus, they have not been differentiated for mapping purposes.

(2) Glacial Ridges and Knolls

Areas of Illinois Episode glacial ridges and knolls in the Pleasant Mound Quadrangle (~8% of the map area) consist of two mapped types: (A) sandy ridges—esker-type ridges, fans, or other hills with coarse-grained material, predominantly glaciofluvial sand and gravel (mapped as the sandy facies, Hagarstown Member, Pearl Formation); (B) mixed lithology ridges—ridges composed of intercalated sorted sediment (mainly sand) and diamicton (together mapped as the mixed facies, Hagarstown Member, Pearl Formation). Both ridge–sediment associations are blanketed by about 5 to 6 feet of Wisconsin Episode loess deposits, below which the Sangamon Geosol has developed into the upper portion of these Illinois Episode glacial deposits. The various ice-contact glacial hills are generally consistent with the idea of ice stagnation in the region (Leighton 1959, Jacobs and Lineback 1969). Some of the hills in the southeastern part of the quadrangle may represent an ice-walled distributary fan system, similar to that described southwest of Vandalia in southwestern Fayette County (Grimley and Phillips 2011a). Electrical resistivity surveys acquired for this project, in conjunction with subsurface drilling, aided differentiation of mixed and sandy glacial ridge deposits in the northwestern quadrangle, and in differentiating both Hagarstown Member deposits from the denser and somewhat less sandy Glasford Formation till units.

(A) Sandy Ridges Prior studies in southern Illinois have noted significant sand and gravel in glacial ridges of the Vandalia region (Jacobs and Lineback 1969) and southwestward (Grimley and Phillips 2011a; Grimley and Gemperline 2015). Such deposits consist of poorly to well sorted sand, gravelly sand, and gravelly diamicton that, together, have been termed the Hagarstown sandy facies [unit pl-h(s)] (Grimley 2010), a unit similar in concept to the original definition of the Hagarstown Member (Willman and Frye 1970; Killey and Lineback 1983). In the Pleasant Mound Quadrangle, glacial hills mapped as pl-h(s) are found mainly in the southeastern part of the quadrangle and have up to 90 feet of sandy material below the loess cover and Sangamon paleosol (*e.g.*, Fig. 1 and cross sections B–B′; and C–C′). Areas mapped pl-h(s) are boldly stippled with a reddish brown color in areas where the loess cover is greater than 5 feet. The upper 5 to 8 feet of the Hagarstown Member, below the loess, is typically altered to a clay loam to sandy loam and contains pedogenic alteration features, such as clay skins and root traces that formed during interglacial soil development (attributed to the Sangamon Geosol). This buried weathered zone is distinctly reddish-brown where present in well drained areas, as observed in test borings into the glacial ridges and in exposures along the bluffs of Lake Carlyle (Sec 25-T4N-R2W).

In the southeastern part of the quadrangle, various sandy ridges are about 15 to 100 feet in relief above the surrounding plain and are about 0.25 to 1.0 km wide. The distribution of shape of the ridges, and its continuation into a possible ice-walled distributary system the northeastern Keyesport Quadrangle (Grimley and Walkowska 2017), is suggestive of an esker or ice-walled channel system. The high ridge, at the eastern end of cross section B-B′, is at the southwestern end of a 5 to 13 km long esker system that parallels the Kaskaskia Valley on its northwestern side (Fig. M2). This particular esker (or ice-walled channel) system would have been a major outlet for meltwater drainage along the central axis of a disintegrating Kaskaskia Sublobe (Figs. M1, M2) during the end of the penultimate glaciation (Illinois Episode).

(B) Mixed-Lithology Ridges Interlobate ridges or isolated knolls that consist of sorted coarse-grained sediments intermixed with sandy diamicton and fine-grained deposits (till, lake sediment, etc.) are mapped as the mixed facies, Hagarstown Member (Pearl Formation). The mixed facies was coined to capture the lithologic complexity and heterogeneity of the Hagarstown Member in many areas (Grimley 2010). Some small hills mapped as the mixed facies [pl-h(m)] in the Pleasant Mount Quadrangle are of unknown sediment composition and were mapped as the mixed facies if a dominance of sandy or fine-grained material could not be determined with reasonable confidence. Others were documented by drilling, geophysics (Fig. 1) or water-well logs or sample sets to have a mixed lithology, including stratigraphic tests holes in Secs. 23 and 35, T5N, R2W (county nos. 23702 and 23701). Stratigraphic test hole 23702 (county no.), on an irregular shaped hill (~75 feet in relief) in the town of Pleasant Mound, is an example of this type of mixed lithology (Fig. 3). Hills mapped as pl-h(m) are distributed throughout the quadrangle and tend to be rounder type hills (circular in cross section) than the sandy facies hills; however, there are exceptions. Many of the pl-h(m) hills could be considered kames, presumably a mix of ablation drift, debris flows, and ice-contact glaciofluvial sands. Some of the mixed-lithology hills could be ice-pressed or ice-squeezed hills as were noted in the Stolletown Quadrangle to the southwest (Grimley and Gemperline 2015), yet none were recognized here based on data thus far. Areas of near-surface mixed facies Hagarstown are mapped solid reddish brown [pl-h (m)] where the loess cover has been eroded to less than 5 feet thick and are stippled with a mixed pattern [pr/pl-h(m)] where the loess cover is greater than 5 feet.

(3) Illinois Episode Outwash in Terraces and Lowlands
Across much of the eastern and southern parts of the quadrangle (~50% of the map area) are proglacial sand deposits, with some gravel, up to 40 feet thick and mainly distributed across a regional terrace surface. Glaciofluvial deposits within the terrace occur in the subsurface below Peoria-Roxana loess and the Berry Clay Member, including the Sangamon Geosol, or locally below Cahokia alluvium (see cross sections C–C′ and D–D′). This proglacial, Illinois Episode, sand and gravelly sand unit is classified as the Mascoutah facies, Pearl Formation (Grimley and Webb 2010). The Mascoutah facies is typically a fine to medium sand, but can also contain beds of gravelly coarse sand. Where the Mascoutah facies is within the alteration zone of the Sangamon Geosol, it can range from sandy loam to loamy sand to clay loam.

Mascoutah facies outwash (Pearl Formation), in the Pleasant Mound Quadrangle, occurs mainly in a broad flat terrace that slopes gently to the south or southeast and with a surface elevations between 465 and 500 feet asl. This terrace surface is up to 5 km wide and is located a few km northwest of Carlyle Lake and the Kaskaskia River Valley (Fig. M2). The Mascoutah facies in this regional terrace can be traced for about 50 miles to the southwest within the Kaskaskia River Basin (Grimley 2010; Grimley and Phillips 2011a, 2011b; Grimley and Gemperline 2015). An Illinois Episode age for the terrace is based on the presence of interglacial soil alteration features (Sangamon Geosol) at the top of the outwash sequence and below loess deposits (Peoria and Roxana Silts). Because of the loess cover as well as accretionary and pedogenically altered material (Berry Clay Member), elevations for the top of the underlying loose sand (with some gravelly beds) in the Pleasant Mound Quadrangle are typically 450 to 485 feet asl.

Outwash in the terrace is typically underlain by Glasford diamicton. Portions of the Pearl Formation, similar in lithology to the Mascoutah facies, that occur below the Glasford Formation are classified as the Grigg tongue of the Pearl Formation (Grimley and Webb 2010), such as in eastern parts of cross sections A-A′ and C-C′. Sand and gravelly sand in the Grigg tongue is preserved in parts of the eastern Pleasant Mound quadrangle (cross sections A–A′ and C–C′). The Grigg tongue is perhaps up to 35 feet thick, based on a described sample set associated with a water-well boring (county no. 01285, in hill, Sec. 36-T5N-R2W). This glaciofluvial deposit likely records the first advance of the southwest-flowing Illinois Episode ice front into the ancestral Kaskaskia Valley.

In most cases, except below recent alluvium, areas with the Mascoutah facies are overlain by 5 to 15 feet of the finer grained and pedogenically altered Berry Clay Member of the Pearl Formation. An additional 5 to 6 feet of last glacial loess (Peoria and Roxana Silts) covers the Berry Clay Member, such that loose sand deposits are typically 13 to 20 feet below ground surface. Thus, the terrace is mainly mapped as loess on the surficial geologic map, but is portrayed with a diagonal colored line pattern where more than 5 feet of the Pearl Formation is predicted to occur at depth based on available data. In a few lowland areas that feed into the main terrace area, a dashed diagonal line pattern is indicated; in such areas, the Pearl Formation is suspected in the subsurface, but we have lower confidence in its presence (based on electrical resistivity transects, water well descriptions, or geomorphic interpretations rather than direct viewing of samples). Some of these low confidence areas may alternatively have a sandy facies of Glasford Formation till or may contain thin deposits of Pearl Formation. New stratigraphic test holes are needed to confirm its presence and characteristics.

The Berry Clay Member generally overlies the Mascoutah facies of the Pearl Formation in the quadrangle, but can also overlie the Glasford Formation. The Berry Clay typically contains strong interglacial soil alteration features (Sangamon Geosol) and is buried by Wisconsin Episode loess. The Berry Clay Member is typically a clay loam to sandy loam where the unaltered parent material is more sandy (where it overlies Pearl Formation sand). Although originally classified as an upper member of the Glasford Formation (Willman and Frye 1970), the Berry Clay was more recently classified as a member of the Pearl Formation

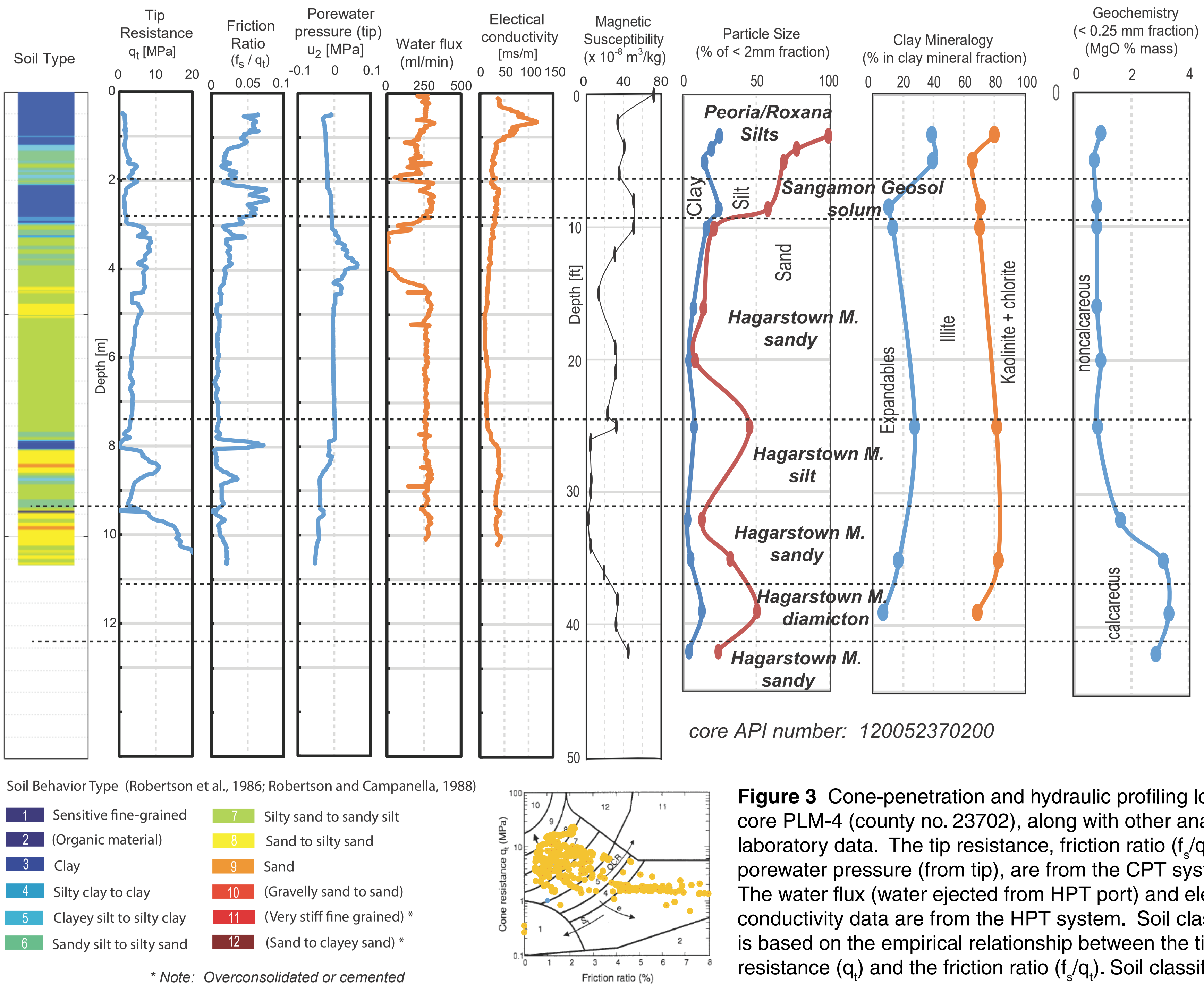


Figure 3 Cone-penetration and hydraulic profiling log of core PLM-4 (county no. 23702), along with other analytical laboratory data. The tip resistance, friction ratio (f_s/q_t), and porewater pressure (from tip), are from the CPT system. The water flux (water ejected from HPT port) and electrical conductivity data are from the HPT system. Soil classification is based on the empirical relationship between the tip resistance (q_t) and the friction ratio (f_s/q_t). Soil classification types 2, 10, 11, and 12 are not present at this site.

(Grimley 2010; Grimley and Webb 2010). Some deposition and most alteration of Berry Clay likely occurred during the Sangamon Episode interglacial.

Overall, Pearl Formation outwash in the Pleasant Mound Quadrangle was deposited in advance of the approaching Illinois Episode glacial front (Grigg tongue), as well as during ice margin recession (Mascoutah facies). The Mascoutah facies of the Pearl Formation would have been deposited in association with glacial meltwaters emanating from the ice margin when it was receding northeastward within Bond and Fayette Counties (Fig. M2). Some pulses of glacial meltwater likely originated from ice-walled channel and esker meltwater systems to the northeast in eastern Bond and western Fayette Counties (Jacobs and Lineback 1969; Grimley and Phillips 2011a). Glacial meltwaters may also have been associated with a late surge of glacial ice to the southeast (and later ablation) by the Springfield Sublobe, that may have formed the glacial lineations present in the northwest part of the quadrangle. This could explain sloping of the outwash plain to the southeast in some areas and the NW-SE orientation of two elongate lowlands that may contain thin outwash deposits.

(4) Postglacial River Valleys
Postglacial (Holocene) stream deposits in Hurricane Creek, Willow Branch, Spring Branch, Keyesport Branch, Little Beaver Creek, and other unnamed creek valleys constitute about 5% of the mapped surficial areas of the quadrangle. An additional area of postglacial alluvium also occurs in the Kaskaskia Valley that is submerged underneath Lake Carlyle. These stream deposits, mapped as Cahokia Formation, consist mainly of fine-grained (silt loam) material that is weakly stratified and soft. The Cahokia Formation can also include zones of sandy loam or beds of fine sand. The Cahokia Formation may be up to 20 feet thick in the alluvium of Hurricane Creek Valley and in the former Kaskaskia Valley underneath Lake Carlyle. The Cahokia alluvium is generally <15 feet thick in the smaller tributary valleys such as Willow Branch and Spring Branch valleys. The alluvial sediment consists mainly of reworked loess, till, and outwash that was eroded along ravines, slopes, and river banks and redeposited. Because of periodic flooding during postglacial times, areas mapped as the Cahokia Formation (undivided) have relatively youthful modern soil profiles that generally lack B horizons (Phillips and Goddard 1983).

(5) Concealed Deposits (pre-Illinois Episode)
Below the loess and Illinois Episode glacial deposits, various pre-Illinois Episode deposits (classified as the Banner Formation) are preserved (see cross sections). Deposits of the pre-Illinois Episode Banner Formation (diamicton, sand, gravel, and silt) occur only in the subsurface in the Pleasant Mound Quadrangle. Interglacial soil development (Yarmouth Geosol), where preserved within the uppermost Banner Formation, is the primary basis to distinguish Banner Formation sediments from Illinois Episode deposits in the Pearl and Glasford Formations (Willman and Frye 1970; Curry et al. 2011). Several borings or sample sets in the quadrangle have been interpreted to contain an interglacial paleosol in an accretionary deposit, classified as the Lierle Clay Member of the Banner Formation (Willman and Frye 1970). This deposit is typically a dark greenish gray to light olive brown silty clay loam to silty clay, is mainly noncalcareous, has pedogenic characteristics of a gleyed interglacial paleosol (Yarmouth Geosol), and contains only rare pebbles. Of particular note is its presence in stratigraphic testholes 23703 (this project) and 23704 (Hartline 1981), both on cross section A-A′. The paleosol was also documented in sample sets from water well boring no. 1265 in western cross section B-B′. A few other water well descriptions make note of a greenish-grey clay, which we interpret to be the Lierle Clay (and top of pre-Illinois Episode deposits), at similar elevations of 450 to 500 feet asl in the western part of the quadrangle. Below the Lierle Clay Member, testhole 23703 encountered 3 feet of weathered till that is greenish gray, silty clay loam in texture, and weakly dolomitic. This unit is classified with the Banner Formation (Willman and Frye 1970; McKay and Hansel 2010), a pre-Illinois Episode unit that may include diamicton, silt, or sand and gravel deposits. The few feet of till observed at the base of this boring had many small weathered shale fragments and resembled the Omphghent till member of southwestern Illinois (McKay 1979; Grimley et al. 2001). It is suspected that 10 or 20 more feet of the Banner till may exist below the depth penetrated by this testhole. Other water wells borings and sample sets suggest the Banner till may be as much as 60 feet thick in part of the western quadrangle (cross section B-B′), and locally includes thin deposits of sand and gravel outwash.

In most areas in the eastern part of the quadrangle, Banner Formation deposits from pre-Illinois Episode glaciation were removed by stream incision and erosion during the succeeding interglacial (Yarmouth Episode) or during the ensuing Illinois Episode glacial advance. Thus, the Banner Formation present today is a remnant of a once extensive covering of pre-Illinois Episode deposits, that were considerably eroded during later geologic events. Some possible remnants in the eastern quadrangle are mapped in cross section D-D′ and in eastern B-B′.

Economic Resources

Sand and Gravel
Economically minable deposits in the quadrangle may include sand with some gravel in the Pearl Formation, particularly in the sandy facies of the Hagarstown Member and the Mascoutah facies. The Mascoutah facies (Pearl Formation) varies from very fine and fine sand to coarse and very coarse sand with 20 to 30% gravel. However, gravelly zones are limited and the modal texture is probably medium sand. The most economic sand and gravel deposits are within the Hagarstown Member sandy facies, with the thickest deposits occurring in the southeastern part of the quadrangle (eastern cross sections B-B′ and C-C′). The Hagarstown sandy facies

has been mined extensively at the Keyesport sand and gravel pit in the Stolletown Quadrangle (Grimley and Gemperline 2015), which includes esker or ice-walled channel deposits (Grimley and Phillips 2011a; Webb et al. 2012). Confined glacial meltwater streams in subglacial or ice-walled glacial meltwater streams may have led to higher velocity outflows and coarser-grained sediment in comparison with the mostly proglacial outwash in the Mascoutah facies. The mixed facies of the Hagarstown Member, Pearl Formation is mostly not a reliable source for construction aggregate because of its variability and lack of continuous coarse sand and gravel. The Griggs tongue of the Pearl Formation is also not desirable because of its occurrence below as much as 90 feet of finer grained deposits, including stiff and dense Glasford diamicton, which would have to be removed.

Groundwater

Groundwater is extensively used for household, public, and industrial water supplies in southwestern Illinois. Saturated sand and gravel in the Pearl Formation (including Hagarstown Member, Mascoutah facies, and Griggs tongue), sand lenses in the Glasford Formation and, to a lesser extent, the Banner Formation, constitute the predominant glacial aquifer materials in the Pleasant Mound Quadrangle. Known sand and gravel lenses are stippled in the cross sections. Wells used for household water supply are typically screened in one of these units. Surface water resources such as the Kaskaskia River are also utilized in the region. At some sites, bedrock aquifers (if available) are locally utilized for water supply, such as groundwater in Pennsylvanian sandstones.

Environmental Hazards

Groundwater Contamination

Surface contaminants pose a potential threat to groundwater supplies in near-surface aquifers that are not overlain by a protective confining (clay-rich and unfractured) deposit, such as till or lake sediment (Berg 2001). The potential for groundwater contamination depends on the thickness and character of fine-grained alluvium, loess, or till deposits that overlie an aquifer, in addition to land use. Because of lateral and three-dimensional groundwater flow, the position of a site in the overall groundwater flow system also needs to be considered. Groundwater in near-surface sand and gravel units in the quadrangle (e.g., various facies of Pearl Formation) is most vulnerable to agricultural, surface mining, or industrial contaminants. Deeply buried glacial aquifers, such as the Grigg tongue of the Pearl Formation or aquifers within the Banner Formation, generally have a lower contamination potential than more shallow aquifers if groundwater is protected by a considerable thickness of unfractured, clay-rich till or clayey lake sediments. Aquifer material in the Pearl Formation (outwash facies) is typically protected only by about 8 to 15 feet of fine-grained loess (Peoria and Roxana Silts), accretionary sediments (Berry Clay Member), or clayey Sangamon Geosol profile (altered into upper Pearl Formation), but in some areas along the valley edges and ravines, the upper Pearl Formation may be exposed, providing a more direct path to any surface contaminants.

Seismic Hazards

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

Cone-penetrometer testing and hydraulic profiling

Cone-penetration testing and hydraulic profiling tools (CPT-HPT) were fitted for use on a direct push drilling machine. These instruments couple the capabilities of a standard cone penetrometer with the hydraulic profiling technology. This is a new method being used with ISGS mapping and we are still in the process of integrating and interpreting this data with traditional field and lab methods. The CPT-HPT data provides information about the geotechnical and hydraulic properties of subsurface geologic units. The CPT system empirically characterizes the physical attributes (texture, moisture conditions) of sediments encountered by the probe at very high resolution (cm-scale). The HPT system, implemented contiguously with the CPT system, measures hydraulic parameters of the soil, such as the flux and pressure of fluid injected from the HPT port. The HPT system also measures the electrical conductivity of the fluids in the geologic materials, which can indicate changes in soil saturation or pore-water chemistry.

We conducted CPT-HPT soundings at two locations in the Pleasant Mound Quadrangle, at sites that were also drilled for continuous core samples. For drilling sites PLM-5 (county no. 23703) and PLM-4 (county no. 23702), the soundings penetrated 41.1 feet (12.5 meters) and 33.1 feet (10.1 meters), respectively, somewhat shallower than penetrated by drilling for sampling purposes. The results of these soundings were compared to the core samples and analytical data (Figs. 2, 3), collected at the same locations, to address the variability of estimated strength and hydraulic parameters with depth. These data also provided estimates of textural variability at a much finer resolution (centimeter scale) than typically resolved through discrete sampling (Figs. 2, 3). For example, at PLM-5, tip resistance (q_c) of the Vandalia facies, Glasford Formation is systematically greater than in the finer-grained Smithboro facies, Glasford Formation (Fig. 2). Furthermore, cm-scale variability in the tip and friction resistance are measured within each formation, in congruence with dynamic porewater pressure (u_2), which can have implications for potential geotechnical failure surfaces and geologic genesis. In boring 23702 (PLM-4), measurements of water flux ejected from the HPT port are discretely lower within the sandy-loam facies of the Hagarstown Member (Fig. 3); this unit is immediately below the Sangamon Geosol and is perhaps affected by the pedogenic clay illuviation that infilled pores within sandy ice-contact sediment (Hagarstown Member, Pearl Fm.). The pore pressure at the tip (u2) is also inversely related to the water flux in this zone. These data may have implications for groundwater recharge potential or foundation settlement hazards.

Acknowledgments

Appreciation is extended to the many landowners who allowed access to their property for outcrop studies and drilling. Geochemical, grain size and clay mineral data were provided by Morgan Bailey (ISGS), Kimberly Attig (ISWS) and Martin Pentrak (ISGS), respectively. Jason Thomason provided field assistance, data, and figures from the cone-penetration testing and hydraulic profiling tools. The CPT-HPT data acquisition was funded by the IDOT Statewide Geologic Mapping Program. Assistance and advice were provided by several other ISGS staff. This research was supported in part by the U.S. Geological Survey (USGS) National Cooperative Geologic Mapping Program under USGS STATEMAP award number G17AC00306, 2017. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

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