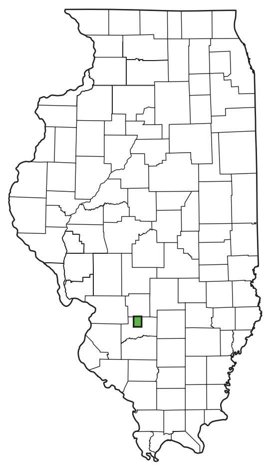
Illinois Geologic Quadrangle Map
IGQ Stolletown-SG

Surficial Geology of Stolletown Quadrangle

Bond and Clinton Counties, Illinois

David A. Grimley and Johanna M. Gemperline

2015



ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Prairie Research Institute
ILLINOIS STATE GEOLOGICAL SURVEY
615 East Peabody Drive
Champaign, Illinois 61820-6918
(217) 244-2414
http://www.isgs.illinois.edu

Introduction

Stolletown 7.5-minute Quadrangle is located in the Kakaskia River basin of Clinton and Bond Counties, southwestern Illinois (Figs. M1and 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 Stolletown Quadrangle is the first 1:24,000 quadrangle surficial geology mapping project in Clinton or Bond County, with most of the area in northern Clinton County except the northernmost 0.5-mile strip in Bond County (Fig. M2).

The Stolletown Quadrangle is entirely within an area covered by glacial ice during the Illinois and pre-Illinois episodes (Figs. M1 and M2; Grimley et al. 2001; Hansel and McKay 2010; Curry et al. 2011). 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 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), during recession and disintegration (Webb et al. 2012). 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 temporal and spatial variants of glacial surging or streaming (Grimley and Phillips 2011a; Webb et al. 2012) followed by stagnation and ablation (Leighton 1959; Jacobs and Lineback 1969). During the advance and retreat of the middle Pleistocene glacial ice margins, proglacial outwash was deposited in parts of the southwest-trending, ancestral lower Kaskaskia River valley, a buried bedrock valley that underlies and closely follows the present valley (Grimley 2008, Grimley and Webb 2010; Phillips 2009). In response to periods of downcutting of the Mississippi River (Curry and Grimley 2006), the Kaskaskia River and its tributaries were incised during interglacials (Yarmouth and Sangamon Episodes) and during the early part of the Hudson Episode (early Holocene). Glacial ice did not reach the study area during the Wisconsin Episode; 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 (Grimley et al. 2001). The Kaskaskia River valley was likely a relatively minor last glacial meltwater stream for a relatively short time (from ~25,000–22,500 years B.P.); thus it did not serve as a major Wisconsin Episode loess source (Grimley and Phillips 2011a).

Methods

Surficial Map

This surficial geology map is based in part on soil parent material data (Phillips and Goddard 1983; Hamilton 2002), supplemented by data from outcrop studies and stratigraphic test holes obtained for this STATEMAP project, engineering borings from the Illinois Department of Transportation and Clinton County Highway Department, and water-well records. Electrical resistivity transects were also utilized to help with mapping of surficial sandy deposits, both from extensive early studies of the ISGS in cooperation with the Clinton County Highway Department (Dobrovolny 1953, and unpublished original data from the ISGS Geophysics Section) and from two new transects obtained for this mapping project (shown on map). Map contacts were also adjusted according to the surface topography, geomorphology, and observed landform–sediment associations.

Localities of important data used for the surficial geology map, cross sections, or landform–sediment associations are shown on the map. All outcrops and stratigraphic test holes are shown on the surficial map, as are key engineering, coal, and water-well borings that were utilized for mapping or for developing the geologic framework. Oil- and gas-type borings are shown only where utilized for cross sections. Some of the stratigraphic and coal borings had geophysical logs that were useful in confirming the unit contacts or bedrock surface elevation where geologic samples were lacking. The locations of many water-well borings were verified by plat books, permit maps, field confirmations (for water wells only), or their combination. Many data in this quadrangle, particularly petroleum-type borings, are not shown because of poor descriptions of surficial materials or unconfirmed locations. 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). Data can be identified based on their location and the labeled county number (5-digit portion of the 12-digit API number).

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 the purpose of this map) are from studied outcrops, stratigraphic test holes, engineering boring records, water-well records, and coal and oil/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 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 were also utilized (not shown). A total of 259 data locations were used in the map and buffer area, including 2 outcrops, 12 stratigraphic tests, 25 engineering borings, 81 water-well borings, 19 coal borings, and 120 oil- and gas-type borings. The bedrock surface was modeled utilizing a "Topo to Raster" program in ArcMap 10.0 (ESRI) using a vertical standard error of 4 feet and with "drainage enforcement," which attempts to make a hydrologically correct surface. This program incorporated a combination of two information types: (1) the 259 data points coded with bedrock top elevations, and (2) several digitized "streams" (ArcMap term) that forced the bedrock surface model to conform to a typical stream drainage, guided by geological insights and surface topography where appropriate. The bedrock surface elevation in the Stolletown Quadrangle ranges from about 331 to 456 feet above sea level (125 feet relief).

A drift thickness map (Fig. M4) was created by subtracting a grid of the bedrock topographic surface from a land surface digital elevation model (DEM), using a 30-m cell size. Areas with drift thickness of less than 0 feet were replaced with the value of the surface DEM by using a conditional statement in ArcMap 10.0. The resulting drift thickness map had some irregular, detailed, or small polygons, which were generalized to some extent in Figure M4. Drift thickness ranges from 0 (bedrock outcrops) to 178 feet thick.

Surficial Deposits

The surficial deposits are divided into four landform–sediment associations: (1) bedrock-controlled uplands with thin loess and till deposits (mainly southeastern areas); (2) glacial ridges and knolls containing either ice-contact sandy deposits, diamicton, or mixed lithology and capped with loess; (3) broad, flat terraces with thick successions of loess-covered glaciofluvial sediments; and (4) postglacial river valleys with alluvial sediments. In buried bedrock valleys (Fig. M3), older concealed deposits (5), associated with a pre-Illinois Episode glaciation, are preserved as well. Areas of anthropogenically disturbed ground consist mainly of spoil piles at sand and gravel pits and small areas of fill below roadways in floodplains.

(1) Bedrock Controlled Uplands
Bedrock-controlled uplands (Fig. M3) with a relatively thin cover of loess and till deposits (Fig. M4) are found mainly in the southeastern parts of the quadrangle (~21% of map area). Because of a more than 5-feet-thick loess cover, many such areas are mapped as Peoria and Roxana Silts, with the subsurface till mainly visible in the cross sections (map sheet 2). The western strip of the quadrangle is also shallow to bedrock in many areas (<40 feet), but the areas proximal to Shoal Creek generally have thin sand and gravel deposits, rather than till, below the loess cover.

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 north–south- to northwest–southeast-trending bedrock surface highs of this quadrangle (Fig. M3) reflect the strike of a more resistant Pennsylvanian limestone or sandstone unit, such as the Carthage Limestone (formerly Shoal Creek Limestone; Jacobson et al. 1985). The regional bedrock surface topography pattern portrays a 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 western Stolletown Quadrangle, at least one outcrop exposes small ledges (a few feet thick) of Pennsylvanian limestone and shale bedrock along the eastern bank of Shoal Creek in the southeastern quarter of Section 24, T3N, R3W (no. 27091). Other similar outcrops are suspected along some steep banks of Shoal Creek and have been observed within a mile of the western edge of this quadrangle (ISGS archived field notes of Weller in 1928, Eckblaw in 1931, and Jacobson in 1980). The uplands or high terraces adjacent to Shoal Creek valley are generally overlain by thin sand and gravel deposits, and in turn are blanketed by last glacial loess.

The southeastern uplands contain a relatively thin cover of diamicton (a massive, unsorted mixture of clay, silt, sand, and gravel), with minor sand and gravel lenses, and are blanketed by windblown silt (loess) and underlain by Pennsylvanian bedrock. Where mapped, the loess (Peoria and Roxana Silts combined) is typically 5 to 8 feet thick, with thinner deposits on steeper eroded slopes. The loess was deposited during the last glaciation (Wisconsin Episode) when 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 (Hamilton 2002). The Peoria Silt is the upper, younger loess unit and is contained mostly within the modern soil solum. The Roxana Silt, with a slight pinkish or darker brown hue, is the lower loess unit (Hansel and Johnson 1996) and ranges from a heavy silt loam to a loam near the unit base, where it has been pedogenically mixed with sandy Illinois Episode deposits. Both loess units in this quadrangle are slightly to moderately weathered, leached of carbonates, fairly thin, and relatively similar in physical properties, so they have not been distinguished for mapping purposes.

Below the loess, the diamicton, weathered diamicton, associated sorted sediment, or a combination of these is mapped together as Glasford Formation and is 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 parent material within 5 feet of ground surface, mainly the Hickory soil series, were mapped in the U.S. Department of Agriculture county soil survey reports (Phillips and Goddard 1983; Hamilton 2002) in many sloping areas of the quadrangle. However, in some areas along Shoal and Beaver Creek valleys, core sample and outcrop observations from this study, along with subsurface boring data, show that many areas mapped as Hickory soil series in the areas between Beaver and Shoal Creek valleys are probably weathered Pearl Formation outwash (see later section on outwash terrace) rather than Glasford till, or some mixture of sand and diamicton. In spite of this discrepancy, till is found below loess deposits in the southeastern and eastern uplands of the quadrangle. Exposures of Glasford till or intertongued Glasford-Pearl were observed in other outcrops in the eastern quadrangle (e.g., 27057 in Sec. 2, T3N, R3W).

Strong alteration features are prevalent in the upper 4 to 6 feet of the Glasford Formation (when 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 traditionally delineates the Glasford Formation from overlying 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). Compared with overlying loess deposits, the Glasford till is considerably more pebbly and dense, has a lower moisture content (10–15%), and has a greater unconfined compressive strength (Q_u, Table 1). The upper 5 to 10 feet of Glasford Formation, where uneroded, is generally more weathered, has a higher water content, can have more small sand lenses, and is less stiff than the majority of the unit. Carbonate leaching typically extends about 8 to 12 feet into the Glasford Formation, below the top of the Sangamon Geosol. Relatively unaltered Glasford till in this quadrangle has about 48 to 60% illite in the clay mineral fraction and has a loam texture with about 15 to 20% clay (<2 μm), 40 to 50% silt, and 30 to 45% sand (Table 1). Much of the Glasford till on the map and in cross sections is the Vandalia facies, based on its physical properties (Jacobs and Lineback 1969; Willman and Frye 1970). However, a lower unit of the Glasford till, found below a 30-foot-thick tongue of sand in stratigraphic test boring 27085, may be correlative with the Smithboro facies, a slightly finer grained, less sandy, and less illitic till. Sand and gravel lenses in the Glasford Formation are relatively uncommon on the bedrock-controlled uplands, but some occur. Pre-Illinois Episode deposits are generally absent from the bedrock surface highlands of the southeastern and western portions of the quadrangle (see cross sections C–C′ and D–D′) because of a combination of more limited deposition and postdepositional fluvial, Illinois Episode glacial erosion, or both.

(2) Glacial Ridges and Knolls

Areas of Illinois Episode glacial ridges or knolls (~5% of the map area) consist of three mapped types: (A) sandy ridges—esker-type ridges or other hills with coarse-grained material, predominantly glaciofluvial sand and gravel (sandy facies, Hagarstown Member, Pearl Formation); (B) mixed lithology ridges—ridges composed of an assortment of sorted sediment (mainly sand) and diamicton (mixed facies, Hagarstown Member, Pearl Formation); and (C) till hills—knolls, quasi-circular in map view, that are mainly composed of diamicton (Glasford Formation) with some inclusions of older paleosol or bedrock residuum (interpreted as ice-pressed hills). All three mapped ridge-sediment associations are blanketed by about 6 to 8 feet of Wisconsin Episode loess deposits, below which the Sangamon Geosol has developed into the upper portion of the Illinois Episode glacial deposits. The various ice-contact glacial hills are consistent with the idea of ice stagnation in the region (Jacobs and Lineback 1969). An electrical resistivity survey, in conjunction with subsurface drilling, aided differentiation of fine-grained, mixed, and sandy glacial ridge deposits.

(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). Such deposits consist of poorly to well sorted sand, gravelly sand, and gravelly till that, together, have been termed the Hagarstown sandy facies [unit pl-h(s)] (Grimley 2008), a unit similar to the original definition of the Hagarstown Member (Willman and Frye 1970; Killey and Lineback 1983). In the Stolletown Quadrangle, glacial hills mapped as pl-h(s) are found in the northern quadrangle (mainly Secs. 1 thru 5, T3N, R3W), with a few in the southern part of the quadrangle (Secs. 7 and 8, T2N, R3W). The two largest areas of sandy facies Hagarstown were observed in ice-walled channel deposits of the Keyesport sand and gravel pit (Secs. 1 and 2, T3N, R3W and Sec. 36, T4N, R3W) and in an eskerine feature (Secs. 4 and 5, T3N, R3W).

The Keyesport sand and gravel pit has previously been studied in some detail (Grimley and Phillips 2011a; Webb et al. 2012). Because of the deep excavations, the area of the pit is mapped as disturbed ground (dg) in a northeast–southwest-oriented polygon. The excavated area is a result of progressive mining to the southwest over the past several years along a track of particularly thick and coarse sand with some gravel. From prior observations of geologists and operators, the previously existing train of glacial hills was composed of mainly sandy facies Hagarstown Member. Considerable sand deposits, though somewhat thinner, were also found in the lower surface elevation areas between the small hills but within the northeast–southwest alignment. Sand and gravelly sand (up to 20% gravel) was up to 100 feet total thickness in the highest glacial hills that were mined in Section 2, T3N, R3W. According to observations on the southeast wall of the sand pit (water table was pumped down), areas immediately

Table 1 Typical ranges of the various physical and chemical properties of typical samples for each geological unit.

Unit	Geotechnical properties[1]			Particle size and compositional data[2]							
								Carbonate content			
	w (%)	Q_u (tons/ft^2)	N	Sand (%)	Silt (%)	Clay (%)	Clay mineralogy	Calcite	Dolomite	Total	MS
Cahokia Formation	15–35 (44)	0.3–2.5 (45)	3–15 (45)	silt loam to silty clay loam to sandy loam			ND[3]	Noncalcareous			ND
Peoria and Roxana Silts	20–21 (2)	0.75–2.0 (6)	ND	0–30	45–70	15–30	35–60% expandables; 24–35% illite	Noncalcareous			60–90
Berry Clay Member, Pearl (or Glasford) Formation	ND	1.0–3.0 (2)	ND	clay loam to sandy loam			>50% expandables	Noncalcareous			ND
Hagarstown Member (sandy facies), Pearl Formaition	ND	<0.25–2.0 (3)	ND	50–95	5–20	<30	ND	Leached to calcareous			ND
Mascoutah facies, Pearl Formation (outwash)	10–20 (6)	<0.25–0.75 (4)	5–50 (27)	>85	<10	<5	ND	Leached to strongly calcareous			>35
Glasford Formation (till)	10–15 (37)	2.0–8.0 (39)	20–75 (35)	30–45	40–50	15–20	49–60% illite; 28–41% kaolinite + chlorite	3–8	8–17	15–25	25–40
Lierle Clay Member, Banner Formation	15–20 (1)	3.0–>4.5 (3)	ND	silty clay loam to silty clay			ND	Noncalcareous to weakly calcareous			10–30
Banner Formation (lacustrine)	20–25 (1)	3.0–4.5 (1)	ND	silty clay			similar to Banner till (limited data)	Weakly to moderately calcareous			15–20
Banner Formation (till)	13–15 (1)	3.0–4.5 (1)	ND	25–36	43–50	20–26	50–55% illite; 40–47% kaolinite + chlorite	3–5	4–9	7–15	25–36
Pennsylvanian bedrock	8–15 (7) (shale)	>4.5	>50	ND			ND	None to very high			2–18 (higher for shale, lower for limestone)

[1]Geotechnical properties are based on hundreds of measurements (total for all units) from about 50 engineering (bridge) borings and 6 stratigraphic test borings in the quadrangle. w (moisture content) = mass of water/mass of dry solids; 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.

[2]Particle size and compositional data are based on a limited data set (~40 samples) from 6 stratigraphic borings and 1 outcrop. Sand = % >63 µm; silt = % 2–63 µm; clay = % <2 µm (proportions in the <2-mm fraction). Clay mineralogy = proportions of expandables, illite, and kaolinite/chlorite (in <2-µm clay mineral fraction) using the ISGS Scintag X-ray diffractometer. Carbonate content determined on the <74-µm fraction from 5 stratigraphic borings and 3 outcrops. MS = magnetic susceptibility ($\times 10^{-5}$ SI units) from 1 stratigraphic boring (no. 27085) using a Bartington MS2 portable meter and MS2F probe attachment.

[3]ND = no data available.

Figure 1 High-angle reverse faults in the Hagarstown Member sandy facies on the southwestern wall of the Keyesport sand and gravel pit in northeast Section 2, T3N, R3W (photograph from 2006). Deposition of the sand, with some gravelly beds, is inferred to have been an ice-walled channel during the ablation of the Kaskaskia Sublobe of the Illinois Episode ice sheet. The Sangamon Geosol solum is visible at the top (Peoria and Roxana Silts have been stripped).

southeast of the mined tract contain finer, proglacial glaciofluvial sand that appears to be inset into the pl-h(s) deposits and therefore is mapped as the Mascoutah facies, Pearl Formation. Areas northwest of the mined tract have thinner Pearl sand (<20 feet) over Glasford till deposits. The main deposits of economic interest in the Keyesport pit exhibited planar-bedded to cross-bedded sand with some high-angle reverse faulting (Fig. 1), suggesting an ice-proximal glaciofluvial environment, probably an ice-walled channel formed in stagnant ice (Grimley and Phillips 2011a; Webb et al. 2012). Two optically stimulated luminescence ages on fine sand deposits were determined as 153 ± 19 ka (UNL-1872) and 147 ± 19 ka (UNL-1873) (Webb et al. 2012), consistent with a correlation to marine oxygen isotope stage 6 for the Illinois Episode glaciation.

The other notable sandy facies ridge deposit [pl-h(s)] was mapped based on stratigraphic test hole 27094 in Section 5, T3N, R3W. A 45-foot-depth boring here encountered 30 feet of gravelly loamy sand from about 15 to 45 feet, below which hard till prevented further drilling by the ISGS (AMS Powerprobe rig). The upper 15 feet consists of 8 feet of last glacial loess above 7 feet of weathered Hagarstown sand. The curving shape of the hill, only about 25 feet in relief above the surrounding plain, is suggestive of an esker but is somewhat smaller and gentler in form than a classic esker. We hypothesize that a subglacial tunnel here may have lasted only briefly in the fast-melting stagnant ice as the inflow of ice from the main ice sheet to the northeast was cut off.

Areas mapped as 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 10 feet of the Hagarstown Member, below the loess, is typically altered to a clay loam and contains pedogenic alteration features, such as clay skins and root traces that formed during interglacial soil development (attributed to the Sangamon Geosol).

(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 2008). Many small hills mapped as the mixed facies [pl-h(m)] in the Stolletown 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. Hills mapped as pl-h(m) are distributed throughout the quadrangle and tend to be smaller, rounder type hills than the sandy facies hills, which tend to be more elongate and steeper. Many of the pl-h(m) hills could be considered kames, though a considerable mix of ablation drift, debris flows, and ice-contact glaciofluvial sands is presumed. Some of the mixed-lithology hill may be ice-pressed hills (see below). Areas of near-surface mixed facies Hagarstown are mapped solid reddish brown (pl-h) where the loess cover has been eroded to less than 5 feet thick and is stippled with a mixed pattern [pr/pl-h(m)] where the loess cover is greater than 5 feet.

(C) Till Hills The predominance of fine-grained material in some circular hills (in map view pr/g(i)) was identified from subsurface drilling and two electrical resistivity transects (Fig. 2), shown as green lines on the surficial map. From three stratigraphic test holes (nos. 27085, 27095, 27096) in two large hills in Section 15, T3N, R3W, the dominant material within the upper 50 feet, below a thin loess cover, was found to be dense, stiff, Glasford till with only minor sand lenses. Within the Glasford till unit, several inclusions of greenish or brownish weathered shale or pre-Illinois Episode paleosol, up to several inches long, were found. Such inclusions, along with the stiffness and high Q_u of the till deposits (>4.5), are suggestive of subglacial or lateral incorporation of deformable substrate rather than supraglacial sedimentation or englacial infilling of moulins. The inclusions (interpreted mostly as weathered local Pennsylvanian shale) are noncalcareous, pebble-free, and with a greasy feel, in contrast to the surrounding calcareous till matrix. The drilled till-cored hills overlie a deep part of the ancestral Beaver Creek valley, suggesting that the inclusions could have been derived from bedrock highlands to the east. Several other hills in the Stolletown Quadrangle, circular in map view (~800 to 1,600 feet [250 to 500 m] diameter, ~15 to 50 feet [5 to 15 m] high) and protruding from the flat Illinois Episode outwash plain, are also candidates for having fine-grained materials, but confirmative data are lacking.

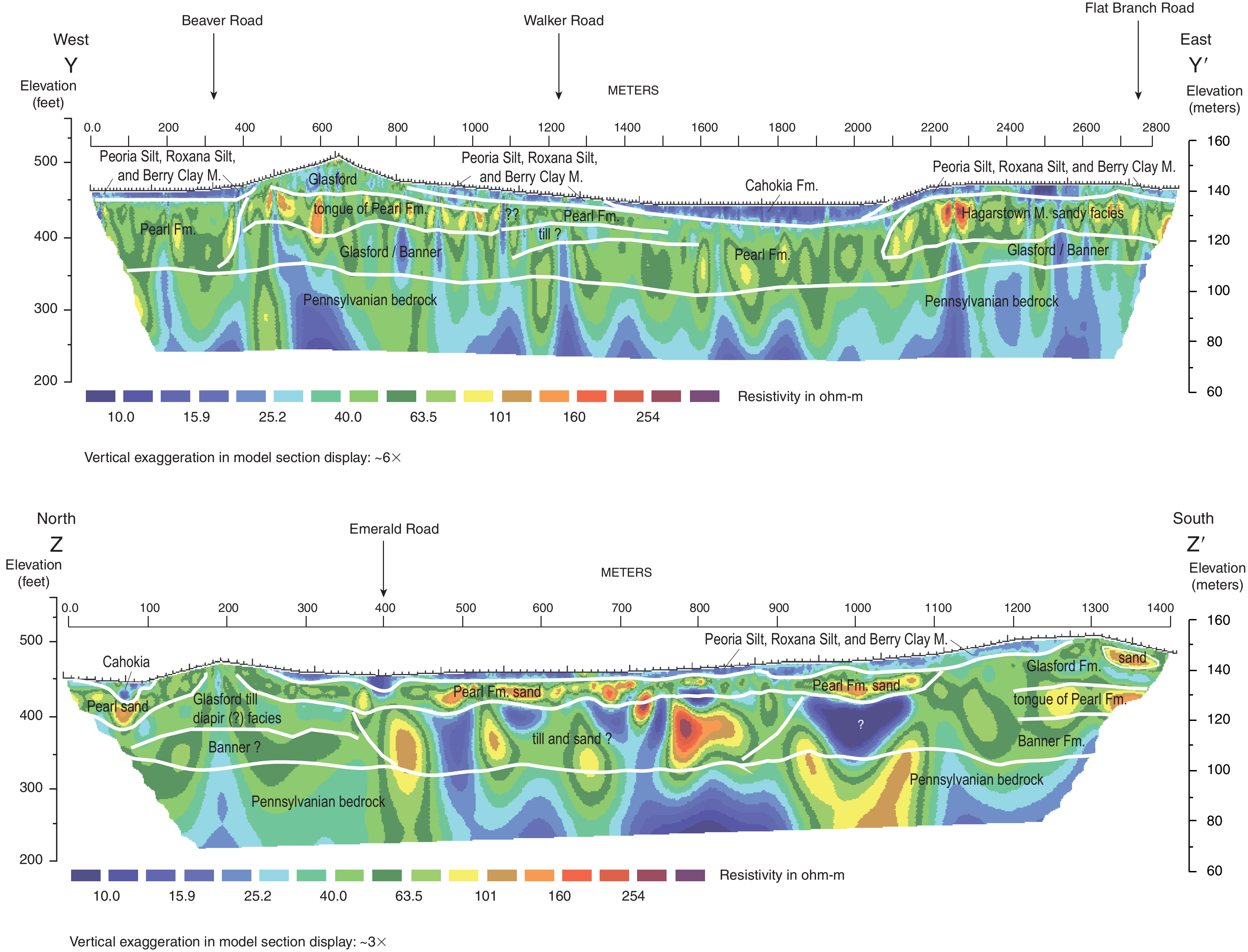


Figure 2 Two electrical resistivity profiles. Lower resistivities are found in fine-grained deposits (clayey). Higher resistivities are found in coarse-grained (sandy) deposits or local bedrock (mainly limestone). To show greater detail, profile Z–Z′ is shown at a horizontal scale two times larger than Y–Y′.

We hypothesize that the till-bearing hills in the Stolletown Quadrangle may be ice-pressed ridges (Stalker 1960; Boone and Eyles 2001). In this model, the hills could have formed subglacially from differential loading as stagnant ice sank into fine-grained, deformable, water-saturated till. The presence of irregular basal ice topography, crevasses, or supraglacial ponds would have provided areas with highly variable ice thickness that would propagate ice and sediment failure. For instance, an ice thickness of about 150 m with supraglacial ponds inset more than 50 m (>$^1/_3$ less ice) results in differential loading that can cause internal deformation of the ice and till substrate, perhaps leading to the formation of the observed 10-m-high till hills. Glaciers in the quadrangle may have been as much as 700 m thick based on modeling of the Illinois Episode advance (Gemperline 2013). High pore water pressures, important as a condition for deformation, may have been facilitated (prior to ice disintegration) by a location near the center of the Kaskaskia sublobe, within the Kaskaskia River basin (Figs. M1 and M2). Although ice-pressed hills are probably not the dominant hill-type in the region, this concept should be considered for other hills with fine-grained material in the middle Kaskaskia River basin.

(3) Illinois Episode Outwash Terrace; Glaciofluvial
Of considerable significance across most of the central quadrangle between Shoal and Beaver Creek valleys and northeastward (~55% of the map area) are up to 55-foot-thick sand deposits, with some gravel, that occur in the subsurface below Cahokia Formation or Peoria-Roxana loess deposits (see cross sections B–B′ and C–C′ for example). The sand and gravelly sand unit in this terrace is classified as the Mascoutah facies, Pearl Formation (Grimley and Webb 2010) and can be traced as a deposit a few miles wide in the subsurface for several miles up-valley to the northeast (Grimley and Phillips 2011a) and down-valley to the southwest (Grimley 2008; Grimley and Phillips 2011b). This Pearl outwash is considered to be predominantly Illinois Episode in age, though basal portions could possibly include pre-Illinois Episode fluvial deposits. Portions of the Pearl Formation that occur below the Glasford Formation are classified as the Grigg tongue of the Pearl Formation (Grimley and Webb 2010). Other tongues of the Pearl Formation, where it is intercalated with the Glasford Formation, are unnamed and labeled as Pearl Formation undivided (pl) in cross sections. The Pearl sand and gravel is typically underlain by Glasford diamicton, Banner Formation, or bedrock.

Areas of the loess-covered Illinois Episode terrace with the Mascoutah facies of the Pearl Formation occur mainly in the area between Shoal and Beaver Creek valleys, as well as eastward north of Flat Branch Creek valley. Terrace areas are mapped with a diagonal, colored line pattern where more than 5 feet of the Pearl Formation is predicted to occur at depth. From aerial photographs, many areas of the terrace apparently display a relict braided stream pattern typical of a former glacial meltwater stream (Fig. 3). In most cases, areas with the Mascoutah facies are overlain by 5 to 10 feet of the finer grained and pedogenically altered Berry Clay Member of the Pearl Formation. Approximately 5 to 12 feet of last glacial loess and stratified fine-grained deposits (Peoria and Roxana Silts) cover the Illinois Episode Pearl Formation deposits in uneroded areas of the terrace. The Mascoutah facies (and older tongues of the Pearl Formation) is typically a fine to medium sand in upper parts of depositional sequences, but tends to coarsen to a gravelly coarse sand a few feet above debris flow beds or subglacial till contacts (both Glasford Formation). The percentage of gravel can be up to 35% in gravelly beds but is typically 10% or less.

The 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 Stolletown Quadrangle are typically 465 to 435 feet above sea level (asl; terrace elevation ranges from 480 feet asl in the northern quadrangle to 450 feet asl in the southern quadrangle). The Berry Clay Member generally overlies the Mascoutah facies of the Pearl Formation in the quadrangle, but also locally overlies the Glasford Formation. The Berry Clay typically contains strong interglacial soil alteration features (Sangamon Geosol) and is buried by Wisconsin Episode loess (up to 10 feet thick). The Berry Clay Member is typically a clay 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 has more recently been classified as a member of the Pearl Formation (Grimley 2008; Grimley and Webb 2010). Some deposition and most alteration of Berry Clay likely occurred during the Sangamon Episode (interglacial).

The Pearl Formation also interfingers with the Glasford Formation as proglacial outwash and was deposited in advance of the approaching Illinois Episode glacial front, as well as during its retreat. The Pearl Formation outwash, in general, was deposited in association with glacial meltwaters emanating from the ice margin when it was northeastward in Bond, Fayette, and Montgomery Counties (Fig. M2). The topographic gradient on the large outwash plain between Shoal and Beaver Creek valleys, rising upward to the north or north-northwest (from 450 to 480 feet asl), suggests that the latest meltwater pulse was related to meltwaters released into the Shoal Creek valley lowland region in western Bond and Montgomery Counties. However, some earlier pulses of glacial meltwater, related to the Grigg tongue, unnamed tongues of the Pearl Formation, or basal parts of the Mascoutah facies, must have originated from ice-walled channels and meltwater systems to the northeast in eastern Bond and western Fayette Counties. Ice-walled fan and esker systems have previously been identified in the Vandalia region (Jacobs and Lineback 1969; Grimley and Phillips 2011a) and at

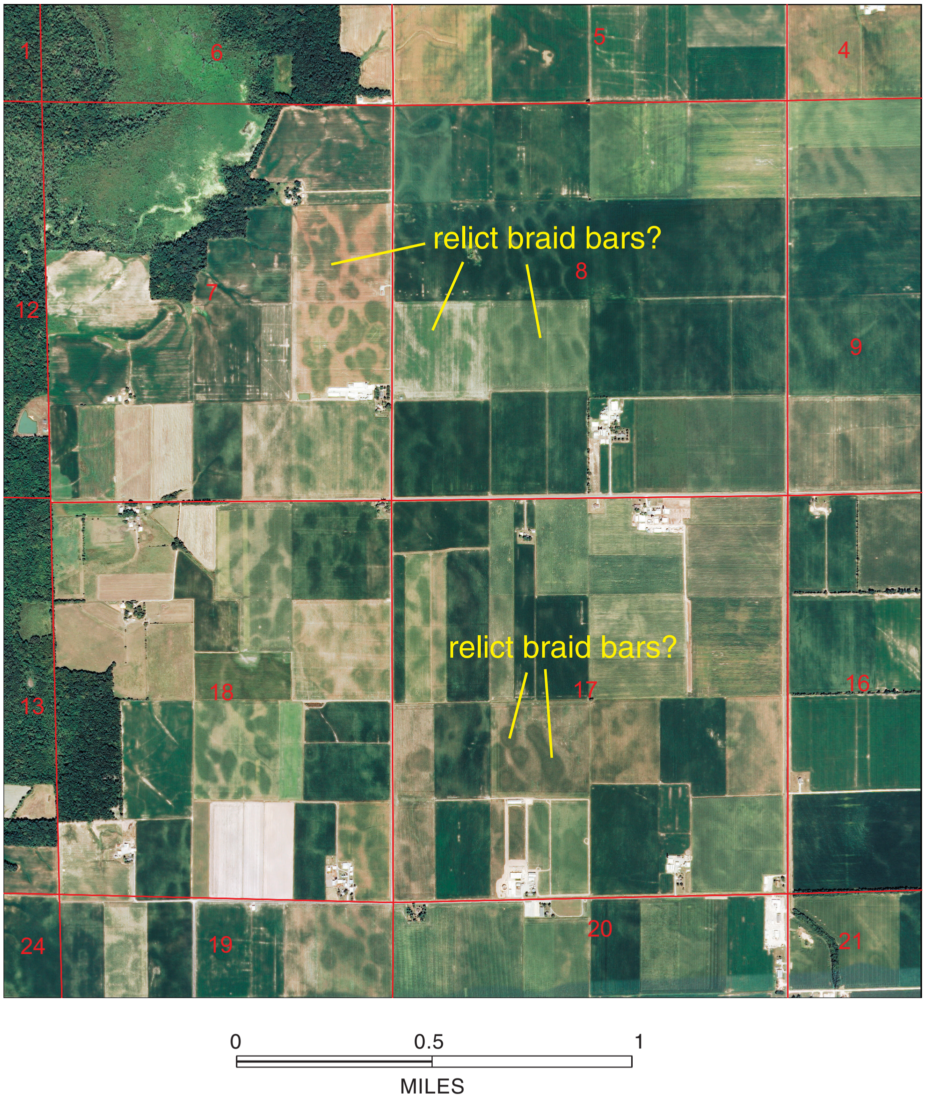


Figure 3 Aerial photograph of a possible relict braided stream pattern on the Illinois Episode terrace between Shoal and Beaver Creek valleys (T3N, R3W, Clinton County, Illinois). The possible paleo-braid bars are 150 to 300 feet in width. Alternatively, these could be ice-wedge polygons, but the smooth edges and south-pointing direction of features seem more in line with fluvial bars. The terrace is a flat plain with an average slope to the south or south-southeast of about 4 feet per mile from about 480 feet above sea level (asl) in the northern parts of the quadrangle to 450 feet asl in the southern parts. Surface elevations of the terrace in this image in the center of the Stolletown Quadrangle are between 460 and 470 feet asl. Image is from the U. S. Department of Agriculture National Agriculture Imagery Program (NAIP, 2011).

the Keyesport sand and gravel pit in northeastern Stolletown Quadrangle (Grimley and Phillips 2011a; Webb et al., 2012). Sand and gravelly sand in the Grigg tongue are of probable glaciofluvial origin and likely record ancestral Beaver Creek valley outwash in advance of the first approach of the Illinois Episode ice front that ultimately buried the proglacial deposits during its southwesterly advance.

(4) Postglacial River Valleys

Postglacial (Holocene) stream and alluvial fan deposits in Shoal Creek, Beaver Creek, Flat Branch Creek, and other creek valleys costitute about 20% of the mapped surficial areas of the quadrangle. The deposits occur in Holocene floodplains and valleys and consist mainly of fine-grained (silt loam) material that are weakly stratified and can include loamy zones or beds of fine sand. These deposits are mapped as Cahokia Formation and are typically less than 25 feet thick. The sediment is alluvial and mainly consists 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 compared with profiles for upland soil (Hamilton 2002).

Areas mapped as sandy facies Cahokia Formation occur only in Shoal Creek valley and were based on sandy soil parent materials in the Clinton County Soil Survey (Hamilton 2002). These areas appear to be point bars or channel facies of the Holocene alluvial deposits. Such areas typically contain loamy sand or fine sand beds within 5 feet of the surface and interfinger with siltier Cahokia deposits.

Areas mapped as fan facies Cahokia Formation occur on the edges of river valleys, adjacent to the valley wall. In such areas, loess and other sediment likely washed downslope and covered earlier floodplain or older terrace surfaces. Modern soils on the fan deposits, having B horizons, are better developed than those in the main floodplain (Hamilton 2002), suggesting they are somewhat older Holocene deposits. Fan facies sediments are generally silty to fine sandy. Some areas mapped as Cahokia fan facies are possibly eroded terraces that may have in situ or reworked Pearl Formation sand at depth. Other areas are the normal occurrence of alluvial or colluvial fan deposits.

(5) Concealed Deposits (Mainly in Bedrock Valleys)

In a buried bedrock valley that trends through the central quadrangle (Fig. M3) and is tributary to the Kaskaskia River valley, early Illinois Episode proglacial or ice-contact deposits (Grigg tongue, Pearl Formation) and pre-Illinois Episode deposits (classified as the Banner Formation) are preserved (see cross sections). This buried bedrock valley (here termed Beaver Bedrock Valley) experienced numerous periods of meltwater, alluvial, and glacial events during the Illinois and pre-Illinois episodes, and is an area of relatively thick glacial drift, generally 75 to 150 feet thick (Fig. M4).

Interglacial soil development (Yarmouth Geosol), where preserved within the uppermost Banner Formation (pre-Illinois Episode diamicton, sand, gravel, and silt), by definition helps distinguish this unit from Illinois Episode deposits in the Pearl and Glasford Formations (Willman and Frye 1970). The Banner Formation does not occur near-surface, being found mainly in an ancestral (preglacial) bedrock valley that parallels present-day Beaver Creek valley. Deposits in this infilled valley have been protected from erosion during later geologic events. In many areas, the Banner Formation was likely removed by stream incision and erosion during the succeeding interglacial (Yarmouth Episode) or by the Illinois Episode glacial advance and associated meltwater streams. The unit's distribution is mainly restricted to buried valleys, lowlands, or tributary valleys and is generally absent from bedrock highlands.

The uppermost part of the Banner Formation is the Lierle Clay Member, a predominantly accretionary deposit in paleo-lowlands or depressions. The unit is typically a silty clay, is leached of carbonates, and has a high proportion of expandable clay minerals (Willman and Frye 1970). Pedogenic alteration, along with some faint laminations within this unit, likely record interglacial soil development of the Yarmouth Geosol in a lowland environment. The Lierle Clay was found only in stratigraphic test boring 27085, where it is a silty clay about 5 feet thick. The deposit here contains evidence of glacial shearing, suggesting that it could be a frozen inclusion that was transported a short distance. Yet the position of the Lierle Clay between two compositionally distinct till units (carbonate, water content, clay mineralogy) points to the deposit being in the correct stratigraphic order despite likely being mobilized locally.

Banner Formation till and ice-marginal sediment were directly observed only in stratigraphic test boring 27085, where it is a calcareous, gray to olive gray, pebbly, silty clay loam to clay loam diamicton. The main Banner subunit, the subglacial till, is about 21 feet thick and includes common clasts of bluish gray mudstone and weathered orangey brown shale fragments (oxidized), reflecting local Pennsylvanian shale incorporation. Above the subglacial till, and below the Lierle Clay Member, is a succession of 14 feet of alternating interbedded lake sediment, sand and gravel (glaciofluvial), and diamicton beds (glacial debris flows) that were deposited in a partially infilled lowland overlying a preglacial bedrock valley. The lake deposits within this sequence are a grayish brown, calcareous, laminated, silty clay to silty clay loam (~4 feet thick). It is inferred that such Banner deposits occur in other parts of the Beaver Bedrock Valley.

Economic Resources

Sand and Gravel

Economically minable deposits in the quadrangle potentially include sand with some gravel in the Pearl Formation, particularly in the Mascoutah facies and the sandy facies of the Hagarstown Member. The Mascoutah facies (Pearl Formation) varies from very fine and fine sand to coarse and very coarse sand with 20 to 30% gravel. However, the gravelly zones are limited and the modal texture is probably medium sand. The most economic sand and gravel deposits are probably within the sandy facies of the Hagarstown Member [pl-h(s)], yet mapping of this unit in some areas is difficult because of limited data. The Hagarstown sandy facies has been mined extensively at the Keyesport sand and gravel pit in a northeast–southwest tract about ¼ mile wide that includes esker or ice-walled channel deposits (Grimley and Phillips 2011a; Webb et al. 2012). The confinement of glacial meltwater streams in subglacial or ice-walled glacial meltwater streams (in a few areas) led to higher velocity outflows in comparison with the mostly proglacial outwash in the Mascoutah facies.

The mixed facies of the Hagarstown Member, Pearl Formation is generally 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 relatively limited and less desirable because of its occurrence below as much as 80 feet of finer grained deposits, including stiff and dense Glasford diamicton, which would have to be removed. Additional boreholes or geophysical tests would be necessary for site-specific projects to determine the economic viability of the various resources.

Groundwater

Groundwater is extensively used for household, public, and industrial water supplies in southwestern Illinois. Surface water resources such as the Kaskaskia River and bedrock aquifers are also utilized in the region. Yet saturated sand and gravel in the Pearl Formation (including the Hagarstown Member, Mascoutah facies, and Griggs tongue) or, to a much lesser extent, the Banner Formation, constitute the predominant glacial aquifer materials in the Stolletown Quadrangle. Known sand and gravel lenses are stippled in the cross sections. Aquifer material in the Pearl Formation (Mascoutah facies) in the area between Beaver and Shoal Creek valleys is extensive. Wells used for household and village water supply, such as the St. Rose water district, are screened in the Mascoutah facies, Pearl Formation. Saturated sand and gravel bodies within the Hagarstown Member sandy facies in constructional glacial hills and ridges are also utilized in some areas. A few water wells on the bedrock-controlled, thin drift southeastern areas do not encounter adequate water supply in unconsolidated surficial materials because of a lack of sand and gravel bodies. In such areas, bedrock aquifers are generally utilized for water supply, such as the 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). Groundwater in near-surface sand and gravel units (e.g., various facies of Pearl Formation and sandy facies Cahokia Formation) is most vulnerable to agricultural, surface mining, or industrial contaminants. 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. Deeply buried glacial aquifers, such as the Griggs tongue of the Pearl Formation or aquifers within the Banner Formation, generally have a lower contamination potential than do more shallow aquifers if the groundwater is protected by a considerable thickness of unfractured, clay-rich till or clayey lake sediments. Aquifer material in the Pearl Formation (outwash facies) in the broad terrace between Beaver and Shoal Creek valleys is typically protected only by about 8 to 15 feet of fine-grained loess, accretionary sediments (Peoria and Roxana Silts), or clayey Sangamon Geosol profile (altered into upper Pearl Formation), but in some areas along the valley edges and ravines, the 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 are 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 with loose sand, disturbed ground (fill), and soft clay in Illinois (Bauer 1999). Areas with near-surface Cahokia Formation sand and clay or some areas of fill (disturbed ground) can be especially susceptible to seismic shaking because they are relatively soft and unconsolidated and have low density. These conditions amplify earthquake ground motions.

Acknowledgements

Appreciation is extended to the many landowners who allowed access to their property for outcrop studies and drilling. Timothy Larson processed the two acquired electrical resistivity profiles. Grain size and clay mineral data were provided by Hue-Hwa Hwang and Shane Butler, respectively. Assistance and advice were provided by many 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 G12AC20408. 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.

References

Bauer, R.A., 1999, Compilation of databases and map preparation for regional and local seismic zonation studies in the CUSEC region: Collaborative research: Organization of CUSEC State Geologists with assistance from USGS and administrative support from CUSEC, Final Technical Report for External Grant, award no. 1434-HQ-97-GR-03150, 23 p.

Berg, R.C., 2001, Aquifer sensitivity classification for Illinois using depth to uppermost aquifer material and aquifer thickness: Illinois State Geological Survey, Circular 560, 14 p.

Boone, S.J., and N. Eyles, 2001, Geotechnical model for great plains hummocky moraine formed by till deformation below stagnant ice: Geomorphology, v. 38, p. 109–124.

Curry, B.B., and D.A. Grimley, 2006, Provenance, age, and environment of mid-Wisconsin Episode slackwater lake sediment in the St. Louis Metro East area, U.S.A.: Quaternary Research, v. 65, p. 108–122.

Curry, B.B., D.A. Grimley, and E.D. McKay III, 2011, Quaternary glaciations in Illinois, *in* J. Ehlers, P.L. Gibbard and P.D. Hughes, eds., Developments in Quaternary Science, v. 15: Amsterdam, Elsevier, p. 467–487.

Dobrovolny, J.S., 1953, Prospecting for commercial sand and gravel using electrical earth resistivity, Clinton County, Illinois: Illinois Academy of Science Transactions, v. 46, p. 154–163 [reprinted in ISGS Circular 188].

Gemperline, J.M., 2013, Controls on the extent of the Laurentide Ice Sheet in southern Illinois: University of Illinois at Urbana-Champaign, master's thesis, 42 p.

Grimley, D.A., 2008, Surficial geology of Mascoutah Quadrangle, St. Clair County, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle Map, IGQ Mascoutah-SG, 2 sheets, 1:24,000; report, 9 p.

Grimley, D.A., and A.C. Phillips, 2006, Surficial geology of Madison County, Illinois: Illinois State Geological Survey, Illinois Preliminary Geologic Map, IPGM Madison County-SG, 1:100,000.

Grimley, D.A., and A.C. Phillips, eds., 2011a, Ridges, mounds, and valleys: Glacial-interglacial history of the Kaskaskia Basin, southwestern Illinois, 55th Midwest

Friends of the Pleistocene Field Conference: Illinois State Geological Survey, Open File Series 2011-1, 144 p.

Grimley, D.A., and A.C. Phillips, 2011b, Surficial geology of St. Clair County, Illinois: Illinois State Geological Survey, Illinois County Geologic Map, ICGM St. Clair-SG, 2 sheets, 1:62,500.

Grimley, D.A., A.C. Phillips, L.R. Follmer, H. Wang, and R.S. Nelson, 2001, Quaternary and environmental geology of the St. Louis Metro East area, *in* D. Malone, ed., Guidebook for field trip for the 35th Annual Meeting of the North-Central Section of the Geological Society of America: Illinois State Geological Survey, Guidebook 33, p. 21–73.

Grimley, D.A., and N.D. Webb, 2010, Surficial geology of Red Bud Quadrangle, Randolph, Monroe, and St. Clair Counties, Illinois: Illinois State Geological Survey, Illinois Geologic Quadrangle Map, IGQ Red Bud-SG, 2 sheets, 1:24,000; report, 15 p.

Hamilton, G., 2002, Soil survey of Clinton County, Illinois: University of Illinois Agricultural Experiment Station and United States Department of Agriculture, 235 p.

Hansel, A.K., and E.D. McKay III, 2010, Quaternary Period, *in* D.R. Kolata and C.K. Nimz, eds., Geology of Illinois: Illinois State Geological Survey, p. 216–247.

Hansel, A.K., and W.H. Johnson, 1996, Wedron and Mason Groups: Lithostratigraphic reclassification of deposits of the Wisconsin Episode, Lake Michigan Lobe: Illinois State Geological Survey, Bulletin 104, 116 p.

Hartline, L.E., 1981, Illinoian stratigraphy of the Bond County region of west central Illinois: University of Illinois at Urbana-Champaign, master's thesis, 104 p.

Jacobs, A.M., and J.A. Lineback, 1969, Glacial geology of the Vandalia, Illinois region: Illinois State Geological Survey, Circular 442, 23 p.

Jacobson, R.J., C.B. Trask, C.H. Ault, D.D. Carr, H.H. Gray, W.A. Hasenmueller, D.A. Williams, and A.D. Williamson, 1985, Unifying nomenclature in the Pennsylvanian System of the Illinois Basin: Transactions of the Illinois Academy of Science, v. 78, p. 1–11.

Killey, M.M., and J.A. Lineback, 1983, Stratigraphic reassignment of the Hagarstown Member in Illinois, *in* Geologic notes: Illinois State Geological Survey, Circular 529, p. 13–16.

Kolata, D.R., compiler, 2005, Bedrock geology map of Illinois: Illinois State Geological Survey, Illinois Map 14, 2 sheets, 1:500,000.

Leighton, M.M., 1959, Stagnancy of the Illinoian Glacial Lobe east of the Illinois and Mississippi Rivers: Journal of Geology, v. 67, p. 337–344.

Phillips, A.C., 2009, Surficial geology of New Athens West Quadrangle, St. Clair County, Illinois: Illinois State Geological Survey, USGS-STATEMAP contract report, 2 sheets, 1:24,000.

Phillips, D.B., and T.M. Goddard, 1983, Soil survey of Bond County, Illinois: University of Illinois Agricultural Experiment Station and United States Department of Agriculture, 181 p.

Stalker, A.M., 1960, Ice-pressed drift forms and associated deposits: Geological Survey of Canada, Bulletin 57, 38 p.

Stuiver, M., P.J. Reimer, and R.W. Reimer, 2005, CALIB online program and documentation: http://radiocarbon.pa.qub.ac.uk/calib/ (accessed December 5, 2014).

Tuttle, M.P., 2005, Paleoseismological study in the St. Louis region: Collaborative research: U.S. Geological Survey, Final Technical Report, award no. 1434-HQ-99-GR-0032, 29 p.

Webb, N.D., D.A. Grimley, A.C. Phillips, and B.W. Fouke, 2012, Origin of glacial ridges (OIS 6) in the Kaskaskia Sublobe, southwestern Illinois, USA: Quaternary Research, v. 78, p. 341–352.

Willman, H.B., and J.C. Frye, 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey, Bulletin 94, 204 p.