Illinois Geologic Quadrangle Map
IGQ Red Bud-SG

Surficial Geology of Red Bud Quadrangle

Randolph, Monroe, and St. Clair Counties, Illinois

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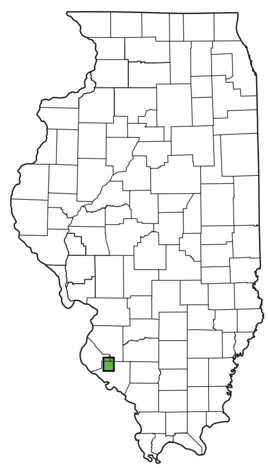
2010



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Introduction

This surficial geology map of the Red Bud 7.5-minute Quadrangle, located in Illinois about 30 miles southeast of downtown St. Louis, Missouri (fig. 1), provides an important framework for land and groundwater use, resource evaluation, engineering and environmental hazard assessment, and geological and archeological studies. This study is part of a broader geologic mapping program undertaken by the Illinois State Geological Survey (ISGS) in the St. Louis Metro East area (Phillips 2004, Grimley 2010), which includes Madison, St. Clair, and Monroe Counties in Illinois.

The Red Bud Quadrangle is located primarily in northern Randolph County but includes small portions of Monroe and St. Clair Counties (fig. 1). The area is about 10 miles northeast of the maximum extent of Illinois Episode glacial ice (fig.1) (Grimley et al. 2001). The pre-Illinois Episode till

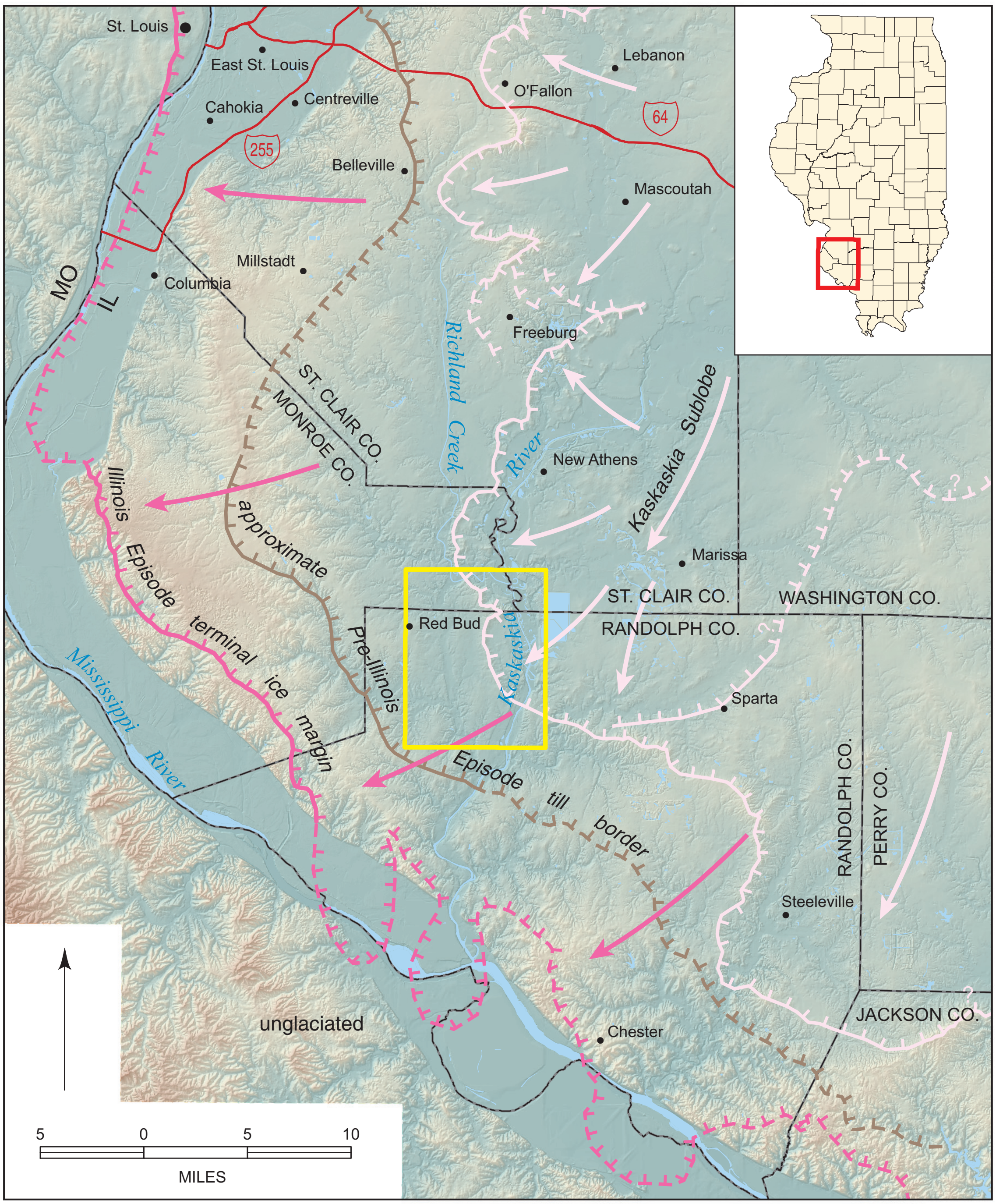

Figure 1 Shaded relief map of the St. Louis Metro East area (southern portion). The Red Bud Quadrangle is outlined in yellow. Dark pink arrows indicate approximate ice flow during the maximum Illinois Episode glacial advance. A recessional moraine is shown in light pink, with arrows indicating envisioned ice flow paths. The brown line represents the buried pre-Illinois Episode till border.

border appears to be only a mile or so south of this quadrangle (Kolb 2009). Glacial ice in southwestern Illinois generally advanced from the northeast, originating from the Lake Michigan Basin during the Illinois Episode and from the Lake Michigan Basin and/or the more eastern Great Lakes region during pre-Illinois Episode glaciations (Willman and Frye 1970). Various glacial deposits from both episodes in the region have been reported by MacClintock (1929), McKay (1979), and Phillips (2004). Glacial ice did not reach the study area during the Wisconsin Episode; however, glacial meltwater streams from the upper Mississippi River drainage basin deposited outwash throughout the middle Mississippi River valley. This outwash was the source of the loess deposits (windblown silt) that blanket uplands in southwestern Illinois. During the pre-Illinois and Illinois Episodes, outwash was deposited in the ancestral Kaskaskia River valley (Grimley and Webb 2009, Phillips 2009, Grimley 2010), which follows the current valley and drained to the south and southwest. In response to Mississippi River aggradation, large slackwater lakes formed in many tributary valleys, including glacial Lake Kaskaskia (late Wisconsin Episode) in the present-day Kaskaskia River valley (Shaw 1921, Willman and Frye 1970). Similar slackwater lakes formed during earlier glaciations. During interglacial (Yarmouth and Sangamon Episodes) and postglacial periods, the Kaskaskia River and its tributaries were incised in response to periods of downcutting of the Mississippi River (Curry and Grimley 2006). Thus, the Kaskaskia River valley has experienced a succession of cut-and-fill sequences over approximately the last 500,000 years. The lower Kaskaskia River valley is also the site of numerous archeological sites (Conrad 1966).

Methods

Surficial Map

The surficial geology map of the Red Bud Quadrangle is based in part upon soil parent material data (Wallace 1978, Higgins 1987, Natural Resources Conservation Service 1999, Leeper 2004), supplemented by data from reconnaissance outcrop studies, earlier outcrop studies in ISGS field notes, stratigraphic test holes obtained for this STATEMAP project, engineering borings from the Illinois Department of Transportation (IDOT) and county highway departments, and water-well records. 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. These include all outcrops and stratigraphic test holes and key engineering and water-well borings that were utilized for mapping or for developing the geologic framework in the area. Oil and gas borings are shown only where utilized for cross sections. The locations of many water-well borings were verified by plat books, permit maps, and/or field confirmations (for water wells only). Many data in this quadrangle are not shown due to 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. Data can be identified by county number label (5-digit portion of the 12-digit API number).

Cross Sections

The cross sections portray unconsolidated deposits as they would be seen in a vertical slice through the earth down to bedrock (vertically exaggerated 20 times). The lines of cross section are indicated on the surficial map. Data used for subsurface unit contacts (in approximate order of quality for this purpose) are from studied outcrops, stratigraphic test holes, engineering boring records, water-well records, 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 deeply into bedrock is not shown. All data occur directly on the cross section line, except one water well (27626) in eastern A–A′ that was projected.

Bedrock Topography and Drift Thickness Maps

Maps of bedrock topography (fig. 2) and drift thickness (fig. 3) are based on data from which a reliable bedrock elevation could be determined (fig. 2). Data within about a mile of the map (not shown) were also utilized. A total of 283 data locations were used, including 20 outcrops, 4 stratigraphic tests, 40 engineering borings, 195 water well borings, and 24 oil and gas test borings. The bedrock surface was modeled utilizing a "Topo to Raster" program in ArcMap 9.3 (ESRI) using a vertical standard error of 2 feet and with "drainage enforcement," which attempts to make a hydrologically correct surface. This program incorporated a combination of three information types: (1) the 283 data points coded with bedrock top elevations, (2) a few digitized contour lines coded with bedrock top elevations (to follow outcrop occurrences and surface topographic expression), and (3) digitized "streams" (ArcMap term) that forced the bedrock surface model to conform to typical stream drainage, guided by geological insights and surface topography when appropriate.

The drift thickness map (fig. 3) was created using a multistep process. First, a grid of the bedrock topography surface was subtracted from a land surface digital elevation model (DEM), both with a 30-m cell size. Next, areas where the bedrock elevation model was higher than the actual land surface (drift thickness values <0) were corrected through the use of additional "streams" in ArcMap, and the drift thickness was recalculated. Any remaining bedrock elevations that were above land surface were replaced with the surface DEM values at those locations, using a conditional statement in ArcMap. This step corrected the final bedrock topography map and provided for a recalculated drift thickness map with all values ≥0. The resulting drift thickness map had many irregular, detailed and small polygons. In order to create

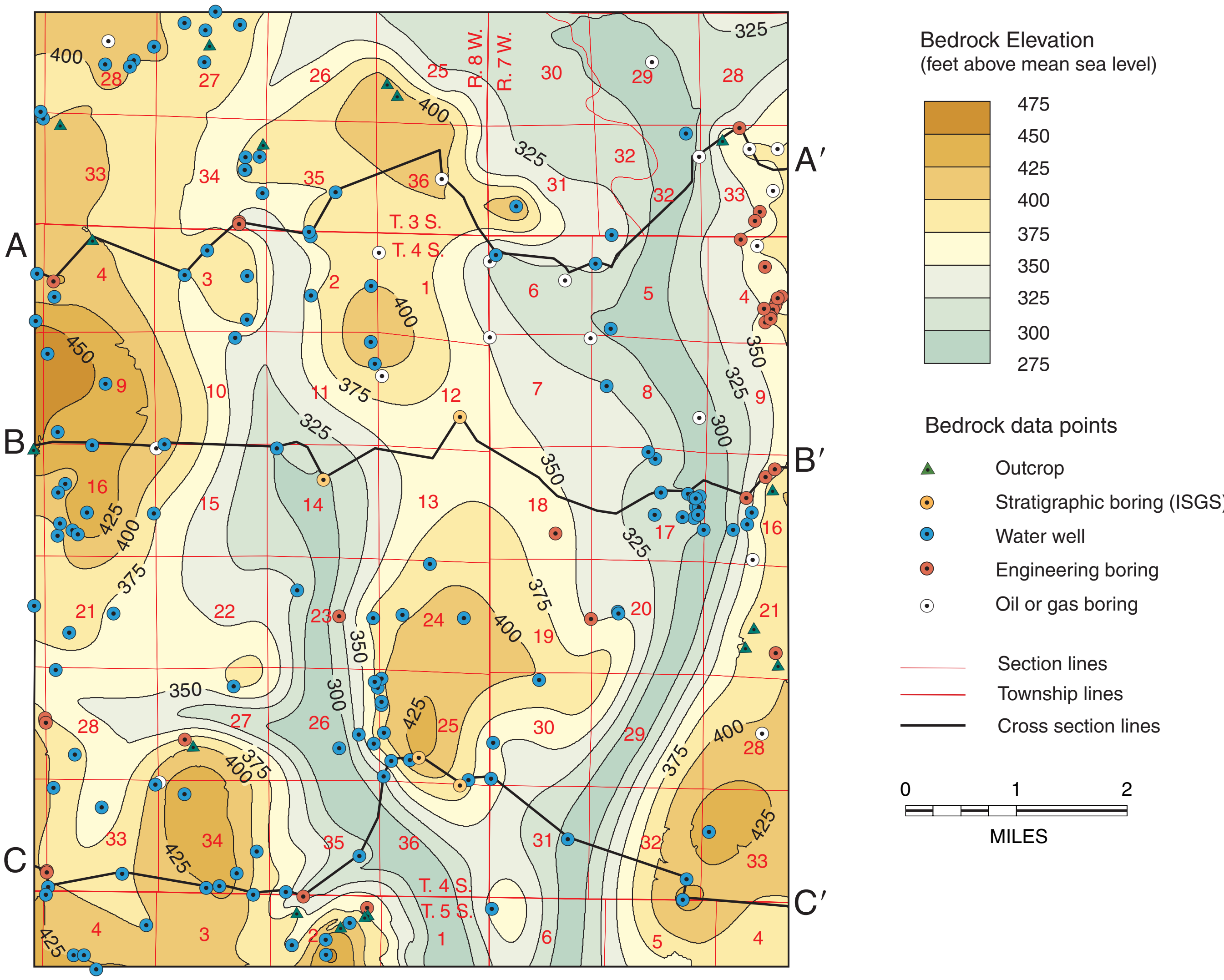

Figure 2 Bedrock topography of the Red Bud Quadrangle. Localities of all data that reliably indicate the bedrock surface are shown (many data are not shown on surficial map). Map scale is 1:100,000.

a more generalized map still true to the original data, the "Topo to Raster" program was again used with inputs of (1) 25-foot contours derived from the calculated drift thickness map and (2) drift thickness values from the original 283 data point locations. Settings used in the "Topo to Raster" program included a vertical standard error of 5 feet, the use of "SPOT" data (point data) as the primary data, and no drainage enforcement.

Surficial Deposits

The surficial deposits can be divided into four landform-sediment associations: (1) bedrock-controlled uplands with a thin cover of glacial and windblown (loess) sediment (western and southeast areas); (2) upland moraines and ridges containing diamicton and ice-contact sediment capped with loess; (3) broad terraces and tributary valleys containing thick successions of glacial and postglacial fluvial, lacustrine, and deltaic sediments, with loess cover on the older terraces; and (4) the Kaskaskia River valley floodplain, underlain primarily by fluvial sediment (with some lacustrine) deposited from glacial to recent times. There are also older concealed deposits associated with early glaciations and preglacial events. Their occurrence and thickness are more closely related to the bedrock surface topography (fig. 2). Finally, areas of anthropogenically disturbed ground consist mainly of spoil piles (from dredging) along the Kaskaskia River navigation channel, construction of Baldwin Lake (east side of map), and fill underneath roadways in floodplains.

Bedrock-Controlled Uplands

Bedrock-controlled highlands (fig. 2) with a relatively thin cover of glacial deposits (fig. 3) are found in the western, southeastern, and small areas in the central quadrangle (about 23% of map area). Due to the >5-feet-thick loess cover, such areas are generally mapped Peoria and Roxana Silts without any pattern for morainal areas or subsurface fluvial/lacustrine deposits. The north-south to northwest-southeast–trending bedrock highs (fig. 2), which underlie these areas, reflect the strike of more resistant Mississippian and Pennsylvanian limestone or sandstone units (Devera 2004).

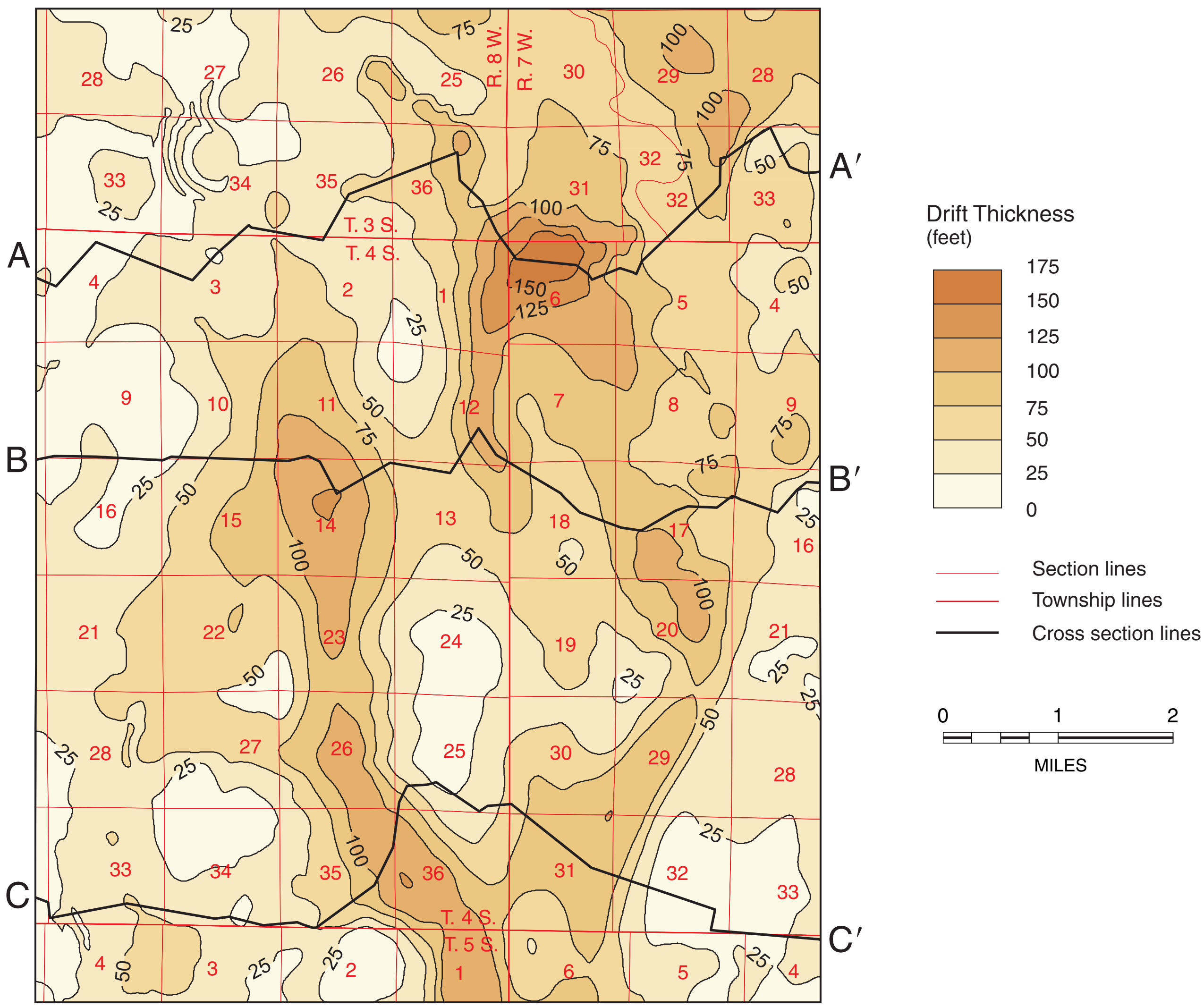

Figure 3 Drift thickness of the Red Bud Quadrangle. Drift includes all unconsolidated sediments above bedrock (e.g., loess, till, alluvium, lake sediment). Data point locations are the same as in figure 2. Map scale is 1:100,000.

The Paleozoic rock units regionally dip gently northeastward toward the Illinois Basin. Thus, the bedrock topography 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 Red Bud Quadrangle, the trend of the buried bedrock ridges begins to curve from a more north-south direction to a more west-east direction (on the eastern side of the Kaskaskia River). Small areas of limestone, sandstone, and shale bedrock were found to outcrop along creek banks as indicated on the map. A few areas, such as in Sec. 3 and Sec. 34, T4S, R8W, have localized sinkholes and small streams disappearing into a karstic network, reflecting shallow limestone bedrock (<20 feet of drift).

The bedrock-controlled uplands are overlain by a relatively thin cover of diamicton (typically massive, unsorted mixture of clay, silt, sand, and gravel), with minor sand and gravel lenses, and are blanketed by windblown silt (loess). Where mapped, the loess (Peoria and Roxana Silts) is typically 6 to 12 feet thick, with thinner deposits on more steeply eroded slopes. The loess was deposited during the last glaciation (Wisconsin Episode) when silt-size 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. In the modern soil solum (generally the upper 4 to 4.5 feet), the loess is altered to a heavy silt loam or silty clay loam (Wallace 1978, Leeper 2004). The Peoria Silt is the upper, younger loess unit. The Roxana Silt, with a slight pinkish hue, is the lower loess unit (Hansel and Johnson 1996). Both loess units in this quadrangle are slightly to moderately weathered, leached of carbonates, and fairly similar in physical properties.

Diamicton, weathered diamicton, and/or associated sorted sediment (together mapped as Glasford Formation) were observed underneath the last glacial loess deposits in outcrops (such as 22445; Sec. 33, T3S, R8W) and shallow stratigraphic test holes (such as 26613; Sec. 25, T4S, R8W). U.S. Department of Agriculture county soil survey reports

(Higgins 1987, Leeper 2004) noted such material within 5 feet of ground surface in many sloping areas and was used as a guide for surficial mapping of the Glasford Formation. This unit was also encountered in the subsurface in several stratigraphic and engineering test borings. In most cases, the diamicton deposits are interpreted as till, although some deposits may include debris flows.

Strong pedogenic alteration features, prevalent in the upper 4 to 6 feet of the Glasford Formation (when not buried by other Illinoian deposits), include root traces, fractures, carbonate leaching, oxidation or color mottling, strong soil structure, clay accumulation, and/or clay skins. These features provide evidence of a buried interglacial soil known as the Sangamon Geosol, which helps mark the upper boundary of the Glasford Formation with overlying Wisconsin Episode loess (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. Compared with overlying loess deposits, the Glasford till is considerably more pebbly and dense, has a lower moisture content (11–19%), and has 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, and is less stiff than the majority of the unit. Carbonate leaching typically extends 10 to 20 feet into Illinois Episode deposits, below the top of the Sangamon Geosol. Thus, in upland areas without a covering of late Illinoian outwash or lake deposits, the thin Glasford Formation is sometimes completely leached of carbonates.

Relatively unaltered Glasford till in this quadrangle has a lower illite content (35–50% illite in the clay mineral fraction) than areas of Glasford till mapped to the north in St. Clair and Madison Counties. The till has a loam to silt loam texture with about 17–26% clay (<2 µm), 50–60% silt, and 18–33% sand (table 1). Sand and gravel lenses in the Glasford Formation are relatively uncommon on the bedrock-controlled uplands, but are more abundant in adjacent lowlands, terraces, and ice-contact ridges. Pre-Illinois Episode deposits are very thin to absent in upland areas, due to a combination of more limited deposition on bedrock highs and post-depositional fluvial and glacial erosion during the Illinois Episode.

Glacial Ridges and Knolls

Areas of ice-marginal ridges (~8% of map area) consist of two basic types: (1) morainal ridges containing mostly diamicton with some sorted sediment (Glasford Formation) and (2) ice-contact interlobate ridges comprising predominantly sorted sediment and interstratified beds of diamicton (Hagarstown Member; Willman and Frye 1970, Killey and Lineback 1983). Both areas of Illinois Episode deposits are blanketed by ~7 to 12 feet of Wisconsin Episode loess deposits, below which the Sangamon Geosol has developed into the upper portion of the glacial deposits.

The morainal ridge west of the town of Grigg (fig. 4), locally called Ralls Ridge, is dominated by Glasford diamicton (mainly till) but does contain interbeds of sand and gravel (up to 15 feet thick) as well as fine sand and silt beds. Such

Figure 4 View west to the moraine, locally known as Ralls Ridge, in Sec. 18, T4S, R7W. The photograph was taken from Griggs Road, immediately south of the town of Grigg. The flat plain in the foreground is the Equality Formation terrace.

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

Unit	Geotechnical properties[1]			Particle size and composition[2]					Geophysical data[3]	
	w (%)	Q_u (tons/ft^2)	N	Sand (%)	Silt (%)	Clay (%)	Clay mineralogy	Carbonate content	Natural gamma	MS
Cahokia Formation	20–30	0.3–2.0	2–15		ND,[4] variable		ND	none	ND	ND
Cahokia Formation (clayey facies)	21–35	0.5–1.5	4–10		ND		high expandables	none	ND	ND
Cahokia Formation (sandy facies)	~35	ND	2–10		ND		ND	none	ND	ND
Equality Formation[5]	24–50	0.25–2.25	3–20	0–10	50–70	20–50	high expandables	leached to moderate	high	8–35
Henry Formation	ND		11–20		ND		ND	leached to moderate	low	ND
Peoria and Roxana Silts	22–26	1.25–2.5	ND	0–10	60–85	15–32	high expandables (25–35% illite)	none (leached)	moderate	10–80
Berry Clay Member/Teneriffe Silt	20–31	0.75–3.0	ND	10–20	55–75	10–35	ND	ND	high	8–32
Hagarstown Member		ND			variable		ND	leached to moderate	ND	5–55
Pearl Formation, Mascoutah facies	ND	< 0.25 to 1.25	10–40		ND		ND	leached to moderate	low	15–30
Glasford Formation[5]	11–19	2.0– >4.5	15–40	18–33	50–60	17–26	33–50% illite	10–25% (unleached)	moderate	7–35
Petersburg Silt[5]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lierle Clay Member	21–25	3.5–4.0	ND	12–20	29–50	25–55	high expandables (11–21% illite)	none (leached)	ND	9–15
Omphghent member[5]	18–21	2.5–4.5	15–20	10–20	50–60	22–40	39–44% illite	9–14 %	moderate-high	10–30
Harkness Silt Member	21–33	1.75–4.0	10–25	0–13	30–80	20–73	50–68% illite	10–35%	high	8–35
Canteen member (clayey facies)	18–24	1.5–3.5	ND	10–40	19–40	35–40	26–37% illite (high in kaolinite/chlorite)	0–7 %	moderate-high	8–20
Mississippian limestone	ND	>4.5	>50		ND		ND	very high	low	3–6
Mississippian shale	14–25	3.0 to >4.5	30 to >50		ND		ND	low	high	8–15

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

[2]Particle size and compositional data are based on a limited data set (~60 samples) from 8 stratigraphic borings. 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 Scintag X–ray diffractometer (about one–fourth more illite than previous results by H.D. Glass with General Electric diffractometer). Carbonate content determined on <74–μm fraction.

[3]Geophysical data: natural gamma, relative intensity of natural gamma radiation (data from 2 stratigraphic borings). MS, magnetic susceptibility ($\times 10^{-8}$ m^3/kg) (detailed data from 8 stratigraphic borings).

[4]ND, no data available.

[5]Excludes sand and gravel lenses and strongly weathered zones.

observations are based on cores 26604 (Sec.12, T4S, R8W) and 26615 (Sec. 19, T4S, R7W) from the crest of the ridges, as well as confirmation from several well-described water-well logs. The predominance of fine-grained material was also confirmed from an electrical resistivity survey transect across Ralls Ridge along the north border of Sec.12, T4S, R8W (green line on map). Within the two stratigraphic test holes, several inclusions of greenish paleosol or weathered shale were found sheared within the till (fig. 5). The alternation of noncalcareous, clayey inclusions (up to a few feet thick) with unoxidized, calcareous till and the lack of normal paleosol horizonation in core samples clearly indicates incorporation of frozen pieces of the substrate rather than an intact paleosol. Slickensides on fracture surfaces, probably from glacial shearing of the incorporated clay, were observed in one of the cores as well. Many of the inclusions appeared to be of the Lierle Clay Member, which would have been the surficial soil material in adjacent lowland areas prior to being overrun by glacial ice.

The morphology of Ralls Ridge, its presence adjacent to a similar-sized lowland to the east, and the composition of the ridge suggests that it may be a type of moraine known as a push moraine (Boulton 1986, Boulton et al. 1999). This type of moraine is thought to form by glaciotectonic deformation and incorporation of material in frozen sheared-planes from the up-ice direction. In this case, it appears the glacier, advancing from the east or northeast, may additionally have been held up along a bedrock topographic high (fig. 2) that likely caused the glacier to stall in the area of Ralls Ridge. One scenario is that an ice stream (or sublobe) was present in the Kaskaskia Basin (fig. 1) and progressed downgradient until it encountered bedrock highs and formed moraines such as Ralls Ridge (Webb 2009). The broad topographic lowland and soft geologic substrate in the Kaskaskia Basin would have been conducive to a paleo-ice stream (Stokes and Clark 2001), with more slowly flowing or stagnant ice in adjacent areas. The dimensions of the basin and the distribution of many glacial landforms observed today, including moraines and stagnant ice landforms, appear consistent with such a hypothesis.

Interlobate ridges or isolated knolls consist of more sorted sediments intermixed with sandy diamicton and are mapped as Hagarstown Member, Pearl Formation. The occurrences of such hills with Hagarstown Member, such as the areas around Sec. 36, T3S, R8W, and Sec.17, T4S, R7W, also appear to be influenced by the location of bedrock highs over which glacial ice flowed. Bedrock highs in the path of ice flow may have diverted flow around them partially so that local-scale interlobate areas developed at the terminus of a southwest-flowing ice stream. Stratigraphic test hole 23239 (50 feet depth) and several small exposures in outcrop were used to help characterize the material in these ridges.

Figure 5 Two-inch diameter core samples from the southern part of Ralls Ridge (moraine), with sheared inclusions of older paleosol within the Glasford Formation (26615; Sec. 19, T4S, R7W).

Materials range from sand (glaciofluvial) to laminated silty clay loam (lacustrine) to sandy loam diamicton with erratic pebbles and faint strata (debris flows). Two electrical resistivity transects (green lines on map) confirmed the occurrence of fine-grained deposits, with areas of coarse-grained deposits near the ridge crest (T. Larson, unpublished report, 2009). The sediment record can be explained by an ice-proximal condition that provided glacial meltwaters (depositing fluvial sediment), locally disrupted drainage to form lakes (resulting in lake sediment), and provided a means for debris flows during melting seasons as the ice wasted away. Such deposits and landforms are consistent with ice stagnation in the vicinity of the bedrock highs while the adjacent areas of push moraines were being reinforced with active ice from the Kaskaskia Basin. The lithologic complexity and heterogeneity of the Hagarstown Member in the Red Bud Quadrangle is typical of many other ridges in eastern St. Clair County (Phillips 2004) and has sometimes been described as the Hagarstown mixed facies (Grimley 2010). Other studies in south-central Illinois have noted significant sand and gravel deposits in glacial ridges (Jacobs and Lineback 1969), and this unit has been termed the Hagarstown sandy facies when dominated by coarse-grained material (Grimley 2010); however, the sandy facies was not predominant enough to be mappable in the Red Bud Quadrangle. Areas of near-surface Hagarstown Member (mixed facies) are here mapped (solid reddish brown color) where the loess cover has been eroded to <5 feet thick and is indicated by stippling in map areas where the loess cover is >5 feet. The upper 3 to 10 feet of the Hagarstown Member, below the loess, is typically altered to a clay loam to sandy clay loam and contains pedogenic alteration features, such as clay skins and root traces that formed during interglacial soil development (Sangamon Geosol).

Broad Terraces and Tributary Valleys

Areas of broad terraces and tributary valleys (together about 50% of map the area) are found in much of the central and northeastern portion of the quadrangle along and adjacent to the Richland Creek, Black Creek, Horse Creek, and Doza Creek valleys and in the Horse Prairie lowland. These areas, which tend to overlie former topographic lows on the bedrock surface (fig. 2), have been periodically infilled with lacustrine and fluvial deposits. Surficial deposits below the loess cover include fine-grained and coarse-grained stratified materials; coarse-grained materials are more common in the vicinity of the Kaskaskia River valley. The various terrace levels were formed as a result of alternating periods of sediment aggradation (mainly during glacial times) and river incision (mainly during interglacial times). The terraces observed today were formed as a result of processes during the last two glaciations (Illinois and Wisconsin Episodes) as well as during interglacial and postglacial times. Approximately 6 to 12 feet of loess (Peoria and Roxana Silts) covering the Illinois Episode terraces in uneroded areas distinguishes these from the younger terraces. In some areas (elevations from about 420 to 430 feet), the Equality Formation interfingers with the Peoria Silt, a result of short-lived high-level overbank flooding. In Horse Creek valley and the Horse Prairie lowlands, thick pre-Illinois Episode slackwater deposits (as much as 50 feet thick) are preserved in the subsurface.

Two divisions within a loess-covered Illinois Episode terrace are mapped: (1) loess-covered stratified sand and gravel (Mascoutah facies, Pearl Formation) and (2) loess-covered accretionary or stratified fine-grained deposits (Berry Clay Member or Teneriffe Silt). Such areas are mapped as loess and given a colored diagonal line pattern to indicate where more than 5 feet of either the Pearl Formation (reddish orange) or the Berry Clay Member-Teneriffe Silt (brownish gray), respectively, are predicted to occur at depth. In most cases, areas mapped as having Pearl Formation also have a thin overlying deposit of Berry Clay Member, but such areas are mapped as Pearl Formation because of the practical importance of the coarser-grained deposits.

A Pearl Formation terrace is mapped principally in areas east of the Kaskaskia River, typically at a surface elevation of about 430 feet asl. The sandy material in this terrace, here classified as the Mascoutah facies, was formerly called the outwash facies of the Pearl Formation in recent mapping (Phillips 2009, Grimley and Webb 2009, Grimley 2010). The Mascoutah facies is herein named informally after the town of Mascoutah, which is located on a terrace containing these Illinois Episode outwash deposits, known from numerous borings and test holes (Phillips and Aper 2006, Grimley 2010). The Illinois Episode age for this high terrace is based on the presence of interglacial soil alteration features (Sangamon Geosol) at the top of the outwash sequence and below the loess deposits (Peoria and Roxana Silts). Due to the loess cover as well as accretionary and pedogenically altered material, elevations for the top of the underlying loose sand (typically fine to medium grained with some silt beds) in the Red Bud Quadrangle are more typically 405 to 425 feet asl. Outwash at these elevations is common along the lower Kaskaskia River valley in adjacent areas (Grimley 2010) and likely reflects the discharge of high-level glacial meltwater concurrent with disintegration of the Illinois Episode ice sheet in the Kaskaskia drainage basin. The Pearl sand and gravel of the Mascoutah facies is typically underlain by diamicton of the Glasford Formation, but these units may locally interfinger at moraine fronts or valley margins. The Mascoutah facies is mapped below loess in a thin strip of outwash plain adjacent and immediately west of Ralls Ridge (moraine). Further west of this strip, the unit has been eroded or has been buried by the younger Equality Formation.

Sand and gravel up to 50 feet thick also occurs below Glasford diamicton in some areas immediately west of the Kaskaskia River valley (cross sections A–A′ and B–B′), based on many water-well logs, one stratigraphic test hole (26616; Sec. 8, T4S, R7W), and the eastern portion of the southern electrical resistivity line. The sand and gravel deposits (primarily sand) are interpreted as Kaskaskia River valley outwash in advance of an approaching Illinois Episode ice front that ultimately buried its proglacial deposits during advance to the southwest and west. Since the sand deposits are found stratigraphically below Glasford diamicton, they cannot be classified as Pearl Formation according to the standard definition (Willman and Frye 1970). However, the lateral stratigraphic relations of the sub-Glasford sand would allow this body to be classified as a basal tongue of the Pearl Formation, analogous to the Wisconsin Episode Ashmore Tongue of the Henry Formation (Hansel and Johnson 1996). For the purposes of this map, the sand and gravel unit is here informally classified as the Grigg tongue of the Pearl Formation, named after its subsurface occurrence in numerous water wells near the town of Grigg and immediately southwards (Secs. 7, 8, 17–20, T4S, R7W). Similar deposits in the New Athens East and Mascoutah Quadrangles were referred to as a basal sand of the Glasford Formation (Grimley and Webb 2009, Grimley 2010). It is not entirely clear if the Grigg tongue is time equivalent to the basal Pearl Formation in the Kaskaskia Valley or if it is slightly older as a result of scouring in the main valley by late Illinois Episode meltwater torrents. It is possible that some of the Grigg tongue could include pre-Illinois Episode outwash.

The combined Berry Clay Member-Teneriffe Silt terrace includes (1) pedogenically altered, fine-grained accretionary deposits (Berry Clay); (2) stratified, fine-grained lake sediments (Teneriffe Silt); and (3) eolian silt additions; the combined thickness ranges from 5 to 20 feet. Because weathered Teneriffe Silt and Berry Clay Member are difficult to distinguish (especially from well log descriptions), these units are combined for mapping purposes. Some areas mapped Teneriffe-Berry Clay (and also Equality Formation) were formerly mapped as Pearl Formation at the statewide scale (Lineback 1979); however, sand and gravel more than a few feet thick was not typically observed, and so the terrace containing Pearl Formation (Mascoutah facies) has been restricted to areas proximal to the Kaskaskia Valley where >5 feet of Illinois Episode sand is known to occur.

The Berry Clay and Teneriffe Silt generally overlie Glasford till but may also overlie a tongue of the Pearl Formation. The upper portions of the Berry Clay-Teneriffe Silt map unit contains strong interglacial soil alteration features (Sangamon Geosol), and the units are buried by Wisconsin Episode loess (up to 10 feet thick). Similar to terraces underlain by the sandier Mascoutah facies, terraces underlain by the fine-grained Berry Clay-Teneriffe Silt mostly range from 430 to 435 feet asl. Deposits within the terraces appear to be in facies, with sandy terrace sediments occurring closer to the axis of the Kaskaskia River valley and fine-grained terrace materials deposited (perhaps concurrently) in slackwater lakes or as overbank alluvium in broad lowlands (Horse Prairie area).

The Berry Clay Member is typically a silty clay to silty clay loam, but can be clay loam diamicton where the unaltered parent material is more sandy. Although generally considered an upper member of the Glasford Formation (Willman and Frye 1970), the Berry Clay has locally been classified as a member of the Pearl Formation (Grimley 2010). The slow accretion of Berry Clay in lowlands, and its alteration, likely occurred during the Sangamon Episode (interglacial).

Teneriffe Silt deposits were most notably observed in an outcrop (26606) on the east side of an interlobate ridge, where about 15 feet of rhythmically laminated (2- to 10-mm [0.1- to 0.4-inch] beds), fine-grained silty lacustrine sediment (Teneriffe Silt) was exposed above sand and gravel and diamicton of the Glasford Formation. The sedimentology of this lake sediment suggests seasonal or daily meltwater discharge providing silty sediment from an adjacent ice margin, with slightly more clayey deposits (darker, thinner beds) settling out during periods of meltwater cessation (i.e., winter or cold periods). The genesis of the lake may have been from blockage of drainage between an ice lobe (or ice stream) in the Kaskaskia Basin on the east side and the interlobate ridge on the west side. Other occurrences of Teneriffe Silt (stratigraphic boring 26601; Sec. 14, T4S, R8W) may have been the result of either slackwater or ice-dammed conditions in the Kaskaskia River valley during the late Illinois Episode. Slackwater environments may have resulted from glaciofluvial aggradation in the Mississippi and/or Kaskaskia River valleys. The apparent lack of faulting in the planar-bedded lake deposits suggest that they were deposited in proglacial lakes rather than supraglacial lakes, which would have been later affected by ice collapse. The Teneriffe Silt includes significant Sangamon Geosol weathering in its upper 4 to 6 feet, where it is leached of carbonate and altered to a silty clay loam texture (originally silt). Thus, the altered zone is difficult to distinguish from the Berry Clay Member. The Teneriffe Silt was deposited during the late Illinois Episode and may intertongue with sandy Pearl Formation beds where the outwash or fan sediments were deposited subaqueously in an ice-proximal lake, such as it seems in boring 26601.

Extensive areas of the younger terraces (Wisconsin Episode) are found throughout the map area at elevations typically at 415 to 425 feet asl and contain lake sediment related to last glacial slackwater conditions in tributary valleys. Similar to the Illinois Episode fine-grained terraces, deposition coincided with the peak of the Wisconsin Episode glaciation when Mississippi River sediment aggradation was at its peak, causing slackwater conditions far up the low-gradient Kaskaskia River valley and its tributaries (sometimes called glacial Lake Kaskaskia). The terraces are typically capped with about 3 feet of Peoria Silt (but not Roxana Silt), which includes the upper modern soil profile. Deposits in this terrace, mapped as Equality Formation, consist of faintly to well-stratified silt loam to silty clay with minor beds of loamy sand or fine sand. Secondary carbonate nodules are in places found along bedding planes. The environment of deposition was primarily lacustrine; sediments probably consisted of significant amounts of redeposited loess into a lake or lowland area. Sandy beds may indicate periodic shallowing of the lake with renewed fluvial or shoreline conditions prior to lake inundation once again. Near the edge of terraces (e.g., in borings 26614 and 26601), the lake deposits may be interstratified with loessal material with a few feet of lake sediment or fine sand intertonguing within the mid-lower Peoria Silt. These areas probably represent shoreline areas of the lake that were short lived and contain intermixed lake sediment, shoreline deposits, redeposited loess (slopewash), and loess.

In lower unweathered or unoxidized zones, the Equality Formation is calcareous and may be fossiliferous, containing small gastropods, bivalves, or sparse conifer wood. Fossil gastropod and bivalve shells were found at outcrop 26597 (Sec. 2, T5S, R8W) just east of the bridge on the south side of Horse Creek. Mollusks in the upper part of the Equality Formation (stratified, silt loam) included *Pisidium* sp. (small pill clams) and the gastropods *Valvata tricarinata* and *Amnicola* sp., all of which are aquatic and common to permanent shallow lakes. At the base of the unit, three species of large freshwater mussels (4 to 7 cm [1.5 to 3.0 inches]) (*Quadrula quadrula, Obovaria olivaria,* and *Actinonaias ligamentina*) were found immediately above the bedrock contact along with the gastropods *Campeloma decisum* (fig. 6), *Pleurocera acuta*, and *Sphaerium* sp., sparse conifer wood, and a few rounded pebbles. This fauna and sedimentology suggest fluvial conditions prior to inundation by a lacustrine environment. The overall assemblage is generally consistent with fluctuating water levels in a slackwater lake, an interpretation also noted by Shaw (1921) for deposits in glacial Lake Kaskaskia. Fragments of the freshwater mussels were radiocarbon dated at 13,700 ± 90 ^{14}C years before present (ISGS-6444), confirming a last glacial age. Fossil

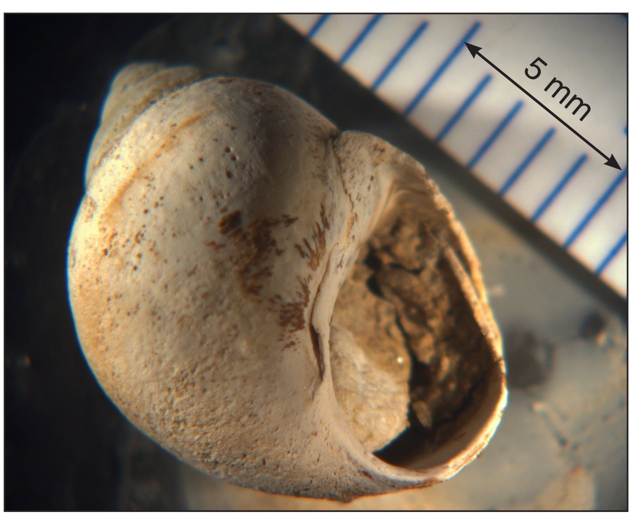

Figure 6 A fossil shell from the Equality Formation at outcrop 26597 adjacent to Horse Creek (NE¼, Sec. 2, T5S, R8W). The shell is of an aquatic gastropod called *Campeloma decisum.* Fossil wood from this site was radiocarbon dated at 13,700 ± 90 ^{14}C years. The scale bar is in millimeters.

conifer wood, from the basal Equality Formation at the same site, was dated at 13,100 ± 100 ^{14}C years before present (ISGS-6525), essentially confirming the shell age. Other ages on shells and wood in the Equality Formation in nearby quadrangles range from about 22,000 to 15,000 ^{14}C years before present (Grimley and Webb 2009), corresponding to the maximum extent of the last glaciation in northeastern Illinois (Hansel and Johnson 1996) and in the Upper Midwest. Earlier periods of Equality Formation deposition in slackwater lakes (as early as 44,000 ^{14}C years before present) are also known in the St. Louis region (Curry and Grimley 2006).

Postglacial stream deposits in the valleys of Horse Creek, Black Creek, Richland Creek, Doza Creek, and other tributaries are mainly fine grained (silty clay loam to silt loam) and weakly stratified. These deposits, mapped as Cahokia Formation, can include loamy zones or beds of fine sand. The Cahokia Formation in these valleys is less than 20 feet thick and consists mainly of reworked loess, till, and other fine-grained sediments. The unusual appearance of the valley in Horse Prairie is likely due to stream capture. It appears that a creek once flowed south as a major tributary to Horse Creek, but was captured by Black Creek as it deepened its valley and provided a shorter higher gradient path to the north. Much of this large tributary valley remains streamless, yet the landform and alluvial deposits remain as a record of the former floodplain.

Due to periodic flooding during postglacial times, areas mapped as the Cahokia Formation have relatively youthful, modern soil profiles that generally the lack B horizons found in upland soil profiles (Wallace 1978, Leeper 2004). At higher elevations with less frequent flooding, the high-level Cahokia Formation (clayey facies) is mapped on a Hudson Episode terrace. This terrace may be a few thousand to several thousand years old based on stronger B horizon development in the modern soil.

Kaskaskia River Valley

Near-surface deposits in the postglacial Kaskaskia River valley (about 15% of map area) consist of interstratified fine to medium sand with silt loam, silty clay loam, and silty clay. Sandy deposits (up to 25 feet thick) in channels and point bars of the Kaskaskia River are mapped as sandy facies of the Cahokia. These deposits are typically fine to medium sand, moderately well sorted, and noncalcareous. They range in age from recent in modern point bars to possibly several thousand years old (mid to early Holocene) at higher elevations and in the subsurface. The clayey facies of the Cahokia Formation is divided into two units: c(c)-2, older deposits within low terraces with surfaces between 390 and 405 feet asl, and unit c(c)-1, younger deposits at lower elevations on the modern floodplain. Deposits of both units range from silt loam to silty clay loam to silty clay and are interpreted mainly as overbank flood deposits and swale fills. Both c(c)-2 and c(c)-1 may be interstratified laterally with the Cahokia sandy facies, c(s). Deposits of c(c)-2 are relatively thin (5 to 30 feet thick) and overlie Cahokia sandy facies or the last glacial deposits of the Equality or Henry Formations. Many abandoned meander channels within the modern floodplain are now infilled with clayey sediment c(c)-1 up to about 20 feet thick. Some of the most recent meanders, easily viewed on the topographic map and containing oxbow lakes, were abandoned upon completion of the lower Kaskaskia River channelization project in 1974. Archeological studies were conducted in the valley in advance of the channelization project, which straightened the Kaskaskia River for navigation from Fayetteville to its confluence with the Mississippi River. Numerous archeological sites with projectile points, tools, and fire-cracked rocks have been noted in the lower Kaskaskia River floodplain, terraces, and adjacent lands (Conrad 1966). A few sites were noted in this quadrangle on surfaces immediately east of the Kaskaskia River floodplain.

In many areas in the Kaskaskia River valley, fine- to medium-grained sand deposits found immediately below the Cahokia and/or Equality Formations are interpreted as Henry Formation (typically Wisconsin Episode age). The exact age of these deposits is unknown and may include Sangamon Episode fluvial deposits. As the distinction among alluvial units can be subtle and difficult to differentiate, areas noted as Henry Formation in cross section may include sandy Cahokia Formation in the upper portions or Pearl Formation near the unit base. In general, the Pearl Formation tends to contain more coarse sand and gravel than the Henry Formation in the Kaskaskia River valley area (probably due to closer proximity to the ice margin), but there may be considerable overlap in the grain size of these units. Sand in the Henry Formation can be noncalcareous or calcareous and may be intercalated with, overlain, or underlain by calcareous silt loam beds of the Equality Formation.

Of considerable significance in the Kaskaskia River valley are thick sand deposits (up to 55 feet thick), with some gravel, that occur in the subsurface below 30 to 40 feet of younger Cahokia, Henry, and Equality Formations (see cross sections). The sand and gravel unit (but mostly sand) classified as the Mascoutah facies, Pearl Formation, can be traced in the subsurface for several miles up-valley to the northeast (Grimley 2010, Phillips 2009, Grimley and Webb 2009). The Pearl Formation outwash is considered to be predominantly Illinois Episode in age, although basal portions may possibly include pre-Illinois Episode fluvial deposits that cannot be differentiated based on the limited data. Below the Pearl Formation, some occurrences of pre-Illinois Episode Banner Formation are interpreted, but limited descriptions make it difficult to differentiate further. In sum, the Kaskaskia River valley contains a complex record of fluvial and glacial deposits from perhaps the past 500,000 years, all overlying Paleozoic bedrock.

Concealed Deposits (Mainly in Bedrock Valleys)

In ancestral bedrock valleys tributary to the Kaskaskia River valley, early Illinois Episode fine-grained deposits (Petersburg Silt) and pre-Illinois Episode deposits (classified as the Banner Formation) are preserved between the overlying Glasford Formation and bedrock below (see cross sections). Such areas, including the extensive bedrock valley in the west-central portion of the quadrangle, have experienced numerous alternating periods of fluvial incision and alluvial/lacustrine infilling from the pre-Illinois Episode to the present.

The Petersburg Silt, a stratified silt loam to silty clay with some fine sand beds, interpreted from a few wells logs and engineering borings, is less than 20 feet thick and is found mainly in the bedrock valley underlying the Horse Prairie lowland (cross sections B–B′ and C–C′) and other tributary bedrock valleys of pre-Illinoian age. The Petersburg Silt occurs stratigraphically below the Glasford Formation by definition (Willman and Frye 1970) and above pre-Illinois Episode deposits. This unit is mainly interpreted as slackwater lake sediment resulting from impoundment of the Kaskaskia River valley and its tributaries in response to Mississippi River valley aggradation during the advance of the Illinois Episode ice sheet. The lake would have been present prior to the area being buried by glacial ice and the deposition of Glasford till and ice-marginal sediment. Fossil gastropods in the Petersburg Silt, indicative of shallow lacustrine conditions and fluctuating water levels, have been noted in nearby mapping areas (Grimley and Webb 2009). A thick succession of Petersburg Silt was not encountered in deep borings drilled in the Red Bud Quadrangle, since the deep bedrock valley beneath the Horse Prairie lowland appears to have been largely filled in by earlier lake sediments (pre-Illinoian). However, due to relatively similar physical characteristics, it is difficult to distinguish the Petersburg Silt from the older Harkness Silt Member without continuous core samples and paleosol separation.

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 Formation, Glasford Formation, or Petersburg Silt (Willman and Frye 1970). The Banner Formation does not occur near the surface, but is found mainly in preglacial tributary bedrock valleys or lowlands (fig. 2 and cross sections) where it has 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 thus sporadic and is generally absent from bedrock highlands. The Banner Formation here is divided into four units (stratigraphically from top to bottom): (1) pedogenically altered sandy clay loam to clay loam accretionary or fluvial deposits (Lierle Clay Member); (2) diamicton, primarily of glacial origin (Omphghent member); (3) calcareous, laminated, fossiliferous, silty clay loam to silty clay (Harkness Silt Member); and (4) stratified silty clay loam to loamy sand to sandy gravel (Canteen member).

The uppermost unit of the Banner Formation, the Lierle Clay Member, is typically an accretionary deposit in paleo-lowlands or depressions. The unit is clay-rich, leached of carbonates, and high in expandable clay minerals (Willman and Frye 1970). Pedogenic alteration (including clay skins, iron staining, and soil structure), mottled colors, and some faint laminations within this unit likely record interglacial soil development of the Yarmouth Geosol in a lowland environment. Iron and manganese concretions are sometimes abundant, and rare pebbles of angular chert are present.

The Omphghent member of the Banner Formation is interpreted mainly as till and ice-marginal sediment. Direct observations of Omphghent till are limited to stratigraphic test boring no. 26601 on cross section B–B′, where it is a calcareous, yellowish brown (oxidized), pebbly silty clay diamicton. The Omphghent was about 12 feet thick and included a 6-inch cobble of locally derived, fossiliferous Mississippian limestone. Pebbles of sandstone, chert, shale and siltstone were also noted. The till had been oxidized by Yarmouth Geosol interglacial soil development, but the strongest development of the soil solum was restricted to the overlying Lierle Clay Member. The Omphghent member, however, can contain strong weathering in its upper portion where the Lierle Clay is not present. Sand and gravel lenses may be present within the Omphghent member, but few were observed. The more clayey character and relative thinness of the unit, compared with its occurrence farther north (Phillips and Grimley 2004), are probably related to its nearness to the terminus of pre-Illinois Episode ice, suggesting relatively thin ice (of limited duration) and thus more local influence to till composition. Kolb (2009) has noted thin (<5 feet thick) and strongly weathered pre-Illinoian till about 1 mile south of the southwestern corner of this quadrangle (south of Ruma) and MacClintock (1929) noted about 12 feet of pre-Illinoian till exposed several miles to the southeast, but these are the southwestern limits of confirmed Banner till observations.

A thick succession (~55 feet) of calcareous, laminated, silty clay to silty clay loam was observed below the Omphghent diamicton in stratigraphic boring 26601. These lake deposits, which infilled a preglacial bedrock valley, are classified as the Harkness Silt Member of the Banner Formation (Willman and Frye 1970) and may be the thickest occurrence of Harkness Silt recorded in Illinois. The Harkness Silt in this boring is mainly grayish brown, but some of the lower portions have a slight pinkish hue. The environment of deposition of the Harkness Silt was lacustrine, likely a slackwater environment. Several gastropod and bivalve (*Pisidium* sp.) shells, 2–10 mm (0.1–0.4 inches) in size, were visible in the core, along with aquatic vegetation, small bits of conifer wood fragments, and needles (probably *Picea* sp.) that likely washed into the lake. Gastropods identified include *Fossaria* sp. (from shallow aquatic, temporary lakes) and *Gyraulus* sp. (permanent shallow lakes); *Fossaria* is more common in upper portions of the unit, as the lake shoaled. *Valvata tricarinata* and *Probythinella lacustris* (clear water, permanent lakes), as well as a distinctive ostracode, *Pelocypris tuberculatum* (fig. 7), were found in the basal, more pinkish brown portion of the Harkness Silt and indicate a deeper, less turbid lake, perhaps when loess deposition was minimal. During deposition of this basal zone, the pre-Illinois Episode ice of this advance likely had not yet advanced significantly into the Mississippi River drainage basin.

The Canteen member, the basal unit of the Banner Formation, includes mainly noncalcareous to calcareous, faintly stratified, fine-grained sediment, but also can include beds of colluvial diamicton and beds of sand or gravelly sand near the unit base. In some areas of southwestern Illinois, weak to moderate soil structure, indicative of a paleosol, has been observed in the upper portion of the Canteen mem-

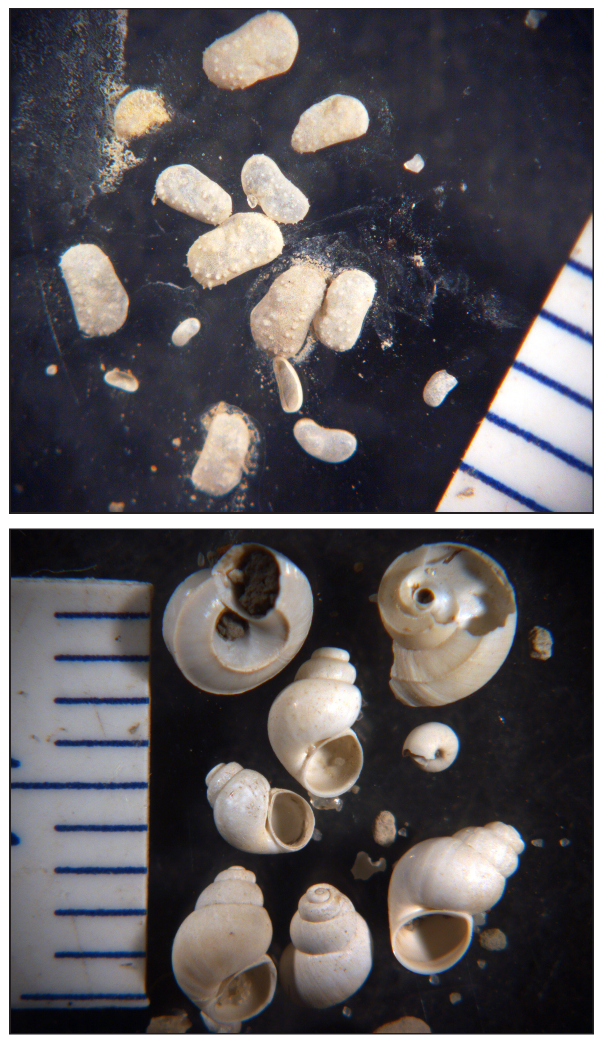

Figure 7 Ostracode (top) and aquatic gastropod (bottom) fossils were found in samples from 119 feet depth from the base of the Harkness Silt (pre-Illinois Episode) in core 26601 (cross section B–B′). The ostracodes are mainly *Pelocypris tuberculatum*. Gastropods include *Valvata tricarinata* and *Probythinella lacustris* (flat-topped). The fossils indicate a lacustrine environment–permanent lake with oligotrophic waters. The scale bar is in millimeters.

ber. Regionally, the Canteen member generally infills the deepest portions of preglacial bedrock valleys, particularly in tributaries to the Kaskaskia River valley (Phillips and Grimley 2004). The Canteen member deposits are essentially preglacial alluvium and colluvium, deposited in the early to early-middle Quaternary. In this quadrangle, the Canteen member was found to occur at elevations below about 330 feet, based on boring data, but was directly observed only in boring 26601. Pebbles in the gravel fraction of the Canteen member diamicton beds include angular shale, sandstone, and chert, all typical of local bedrock sources. The preglacial interpretation of the Canteen member is substantiated by the lack of glacial erratics, low magnetic susceptibility, low carbonate content and its high kaolinite and chlorite content. Such characteristics are typical of a more weathered Paleozoic bedrock source. The lower foot or so, above Paleozoic bedrock, can in places include residuum or sandy gravel with subangular to rounded chert, sandstone, and ironstone (such as in 26601). Such rounded gravel may reflect reworking of the Grover Gravel, a Pliocene or early Quaternary fluvial deposit (Willman and Frye 1970).

Economic Resources

Sand and Gravel

Potentially minable deposits in the quadrangle may include sand with some gravel in the Henry and Pearl Formations. The Hagarstown Member of the Pearl Formation (mixed facies) is not thought to be a reliable source for construction purposes here based on the limited quantities and lack of continuity of coarse sand and gravel. The Henry Formation and Mascoutah facies, Pearl Formation in the Kaskaskia River valley have potential reserves, but are buried by about 20 to 30 feet of Cahokia Formation, and flooding is common in this area. The Henry Formation may be finer grained and may be interstratified with fine-grained Equality Formation in areas. The Mascoutah facies of the Pearl Formation is a fine- to medium-grained sand in many places and thus is less coarse than desirable. The Grigg tongue of the Pearl Formation appears to be extensive, fairly thick, and relatively continuous in some areas. However, this unit is buried below 40 to 50 feet or more of younger finer-grained deposits, including stiff and dense 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 developing these resources.

Groundwater

Groundwater is extensively used for household, public, and industrial water supplies in southwestern Illinois. Surface water resources, such as from the Kaskaskia River, are also present in this quadrangle. Saturated sand and gravel in the Henry Formation, Pearl Formation (Hagarstown Member, Mascoutah facies, and Grigg tongue), and Banner Formation constitute the predominant glacial aquifer materials in the Red Bud Quadrangle. Known sand and gravel lenses are stippled in the cross sections. Aquifer material in the Henry and Pearl Formations (outwash facies) in the Kaskaskia River valley is fairly extensive (three-dimensional view on map sheet 2) and is used for household and village water supply (Baldwin and Red Bud). In upland areas, saturated sand and gravel bodies within the Hagarstown Member are sometimes utilized. The Grigg tongue of the Pearl Formation is extensively utilized for household water supply near the town of Grigg and immediately south (Secs. 17–20, T4S, R7W). Many water wells on the bedrock-controlled ridge in the far western areas (near Red Bud) and southeastern areas do not encounter adequate water supply in unconsolidated surficial materials due to a lack of sand and gravel bodies and thin drift cover. In such areas, bedrock aquifers in Mississippian sandstones or fractured limestones are commonly utilized for water supply. Poole and Heigold (1981) noted that Quaternary deposits in the lowland underlying Horse Prairie are predominantly fine grained, based on several electrical resistivity profiles. They therefore recommended that a groundwater supply for the town of Red Bud would be best obtained from sand underlying the Kaskaskia River valley, about 5 miles to the east.

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., the Hagarstown Member and Cahokia Formation sandy facies) 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. Due to 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 Grigg tongue of the Pearl Formation or aquifers within the Banner Formation generally have a lower contamination potential than 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 Henry and Pearl Formation (outwash facies) in the subsurface of the Kaskaskia Valley is in some areas moderately protected by 20 to 30 feet of fine-grained lake sediments (Cahokia or Equality Formations), but in other areas may be in contact with overlying sandy materials that can provide for easy transport of surface contaminants.

Seismic Hazards

Near-surface fine sand in the Pearl, Henry, and Cahokia Formations are 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 Equality Formation or especially Cahokia Formation sand and clay can be susceptible to seismic shaking because they are relatively soft and unconsolidated and have low density. These conditions amplify earthquake ground motions.

Acknowledgments

Appreciation is extended to the many landowners who allowed access to their property for outcrop studies and drilling. Assistance and advice were provided by many ISGS staff. Kevin Cummings, Alison Price, and Sarah Bales (Illinois Natural History Survey) helped with identification of the large freshwater bivalves. Brandon Curry identified the ostracode species. Field and lab assistance were provided by Andrew Ostendorf and Julia Waldsmith. This research was supported in part by the U.S. Geological Survey (USGS) National Cooperative Geologic Mapping Program under USGS STATEMAP award number 08HQAG0084. 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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