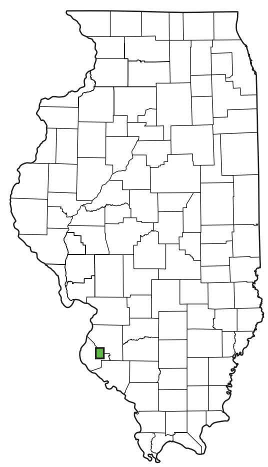
Illinois Geologic Quadrangle Map
IGQ Paderborn-SG

Surficial Geology of Paderborn Quadrangle

Monroe and St. Clair Counties, Illinois

Andrew C. Phillips

2010



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Introduction

The Paderborn 7.5-minute Quadrangle (fig. 1) is located about 5 miles east of bluffs that overlook the Mississippi River valley. Highest elevations on the west, supported by the Waterloo-Dupo Anticline (Nelson 1995), descend eastward to the wide Prairie du Long valley, a tributary to the Kaskaskia River. The margins of the Illinois and pre-Illinois Episode glaciations lie only a few miles west. The city of Waterloo, the largest town in the area (population 7,614; State of Illinois 2000), is centered about 1 mile west of the map margin. The main land use is agriculture. The Waterloo Mine (limestone) is the physically largest industry. Future residential development is expected because of the picturesque rural setting immediately on the outskirts of Belleville, and the ready access to St. Louis by highway and light rail.

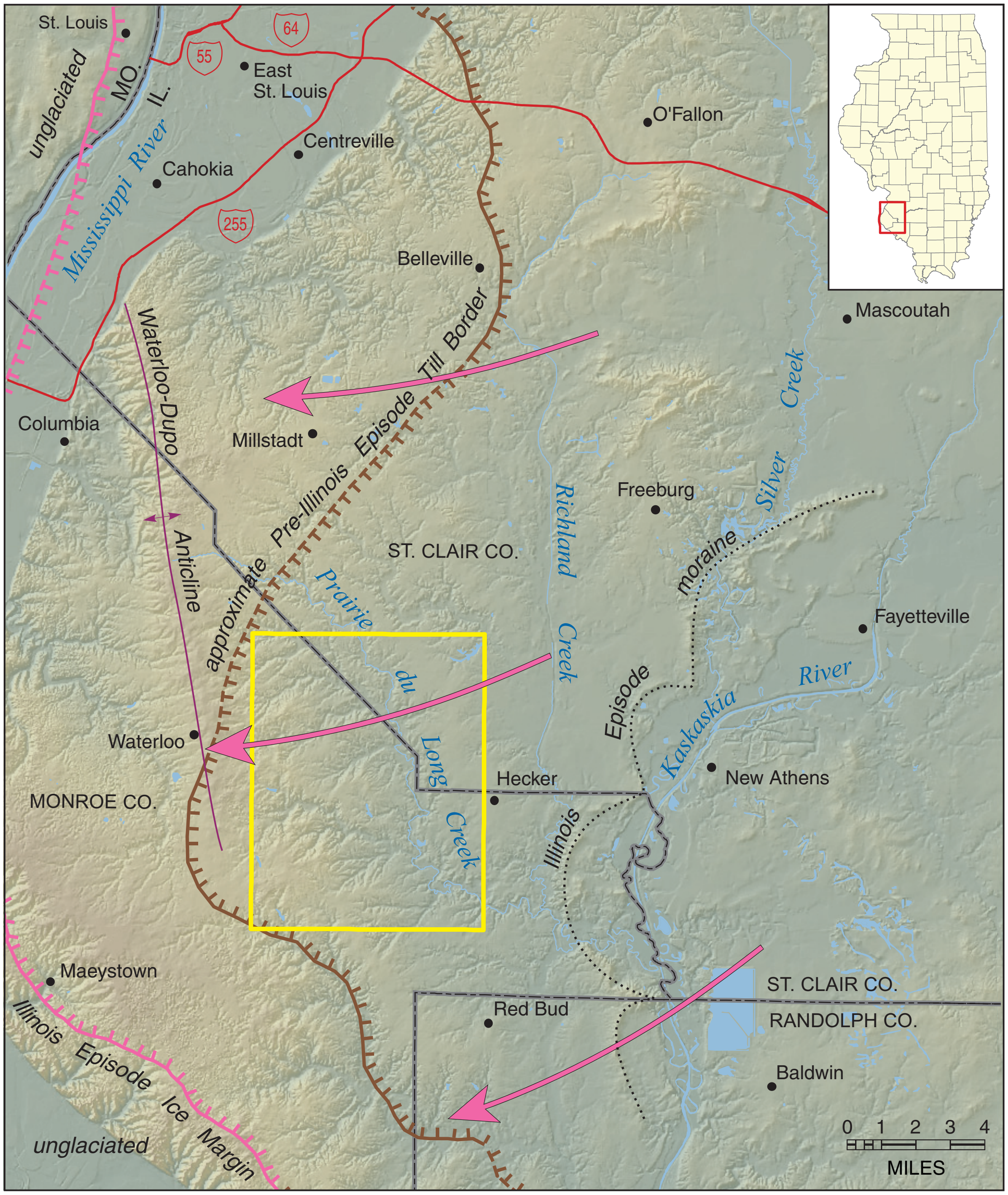

Figure 1 Shaded relief map of the St. Louis Metro East area (southern portion). The Paderborn Quadrangle is outlined in yellow. Pink arrows indicate approximate ice flow direction during the Illinois Episode. The prominent ridge trending south-southeast–north-northwest through Waterloo is the axis of the Waterloo-Dupo Anticline. Sharp ridges immediately west of the Kaskaskia River valley are a moraine complex.

Several interesting geologic and hydrologic features occur within the quadrangle and surrounding area:

- The quadrangle contains much of the Prairie du Long watershed. Surface water quality is important because the creek flows into the Kaskaskia River State Fish and Wildlife Area, and communities downstream of the confluence rely on the Kaskaskia River for drinking water. Surface water quality can be quickly compromised by chemical and sediment constituents in runoff.
- The westernmost extents of pre-Illinois Episode glaciations were within or immediately west of this quadrangle. Pockets of pre-Illinois Episode till or erratics occur, but the glacial limit is not yet confirmed.
- Patches of karst occur mainly in the west. They consitute both subsidence and groundwater contamination hazards.

This map depicts geologic materials within 5 feet of the ground surface. The cross sections provide two-dimensional views of the extent of surficial and buried units down to bedrock. Previously published geologic maps of the area have been at scales of 1:500,000 (Lineback 1979, Stiff 2000) and 1:250,000 (Jacobs 1971). Devera (2002) mapped the bedrock geology at 1:24,000. This project builds upon this earlier work by adding new observations of the surface and subsurface, incorporating them into a digital database, and interpreting them at large scale. The bedrock topography was constrained, a buried bedrock valley was identified, the variability of major units was characterized, the occurrence of the pre-Illinois Episode succession across the quadrangle was delineated, and areas with relatively good and relatively poor geologic control were distinguished. Prediction of the occurrence of buried units far from the lines of cross section should be made with care; additional studies are necessary if greater detail is desired. This product can be used for preliminary geologic assessments of construction siting issues, geologic hazards, groundwater and materials resources, environmental protection, and other activities. The work is part of the Illinois State Geological Survey (ISGS) St. Louis east metropolitan area ("Metro East") mapping project, which provides critical geologic data to this rapidly developing area.

Methods

The surficial map was constructed by interpretations of parent materials from soil surveys (Natural Resources Conservation Service 2005, 2006) that were validated with outcrop observations and modified to conform to topography, interpretations of borehole data, and compilation of field notes and groundwater reports from previous ISGS research. Some landforms were interpreted by aerial photograph analysis. Borehole data sources included new borings acquired for this project and boring records stored in the ISGS Geological Records Unit and the ISGS Geological Samples Library. The quality of the geologic and locational descriptions of archived data vary considerably in detail and accuracy. Stratigraphic boring descriptions and geotechnical logs typically provided the most detail and could be located most accurately. Descriptions provided by water-well drillers were generally of low value because few lithologic units above bedrock were distinguished, and locations were largely imprecise. Outcrops described in this study provide critical two-dimensional perspectives of map unit variability and contact characteristics, but exposures are limited to near-surface units. Only those data that were valuable for interpretation of the surficial geology and could be confidently located (n=157) are shown on the surficial geologic map.

The cross sections depict the thickness, horizontal extent, and relationships of subsurface geologic units down to bedrock. Units thinner than 5 feet are not shown. Horizontal accuracy of data used in the cross sections range between approximately 5 to 200 feet and vertical accuracy is 1 to 5 feet. Surficial contacts were correlated between observation points by interpreting landform-sediment relationships on topographic maps. The trend of buried unit boundaries is assumed to be well-known within 1,000 feet of each observation point based upon limited outcrop observations. However, local relief of those surfaces may be significant. Buried unit boundaries extending further than 1,000 feet from well-known observation points are shown by dashed lines. Stratigraphic nomenclature follows that of Hansel and Johnson (1996) and Willman and Frye (1970), as appropriate.

The bedrock topography (fig. 2) was constructed by computer modeling. The data included 725 borehole records with reliable bedrock observations, 51 field observations, and areas of delineated bedrock outcrop. These were supplemented with inferred elevations from 10 borehole records that did not reach bedrock but were intersected by preliminary surface models. Inferred point elevations, contours, and digital surficial elevation data were used where preliminary bedrock surfaces rose above the surface topographic model. The Topo to Raster model (ESRI 2008, based on Hutchinson 1989) interpolates a surface that ensures a reasonable drainage network.

Geologic Setting

The landscape in the Paderborn region was constructed during the preglacial episode and at least three episodes of glaciation (the pre-Illinois, Illinois, and Wisconsin Episodes), which were separated by relatively warm interglacials, including the present-day postglacial episode. To the west, bedrock-controlled uplands with relatively thin glacial cover are steeply incised, and the valleys, such as Rockhouse Creek, feature dramatic rock bluffs. East of Prairie du Long Creek are gently rolling uplands with relatively thick glacial cover. Larger river valleys are low sloping and locally eroded into bedrock. The occurrence of concealed deposits is partly controlled by the bedrock topography (fig. 2).

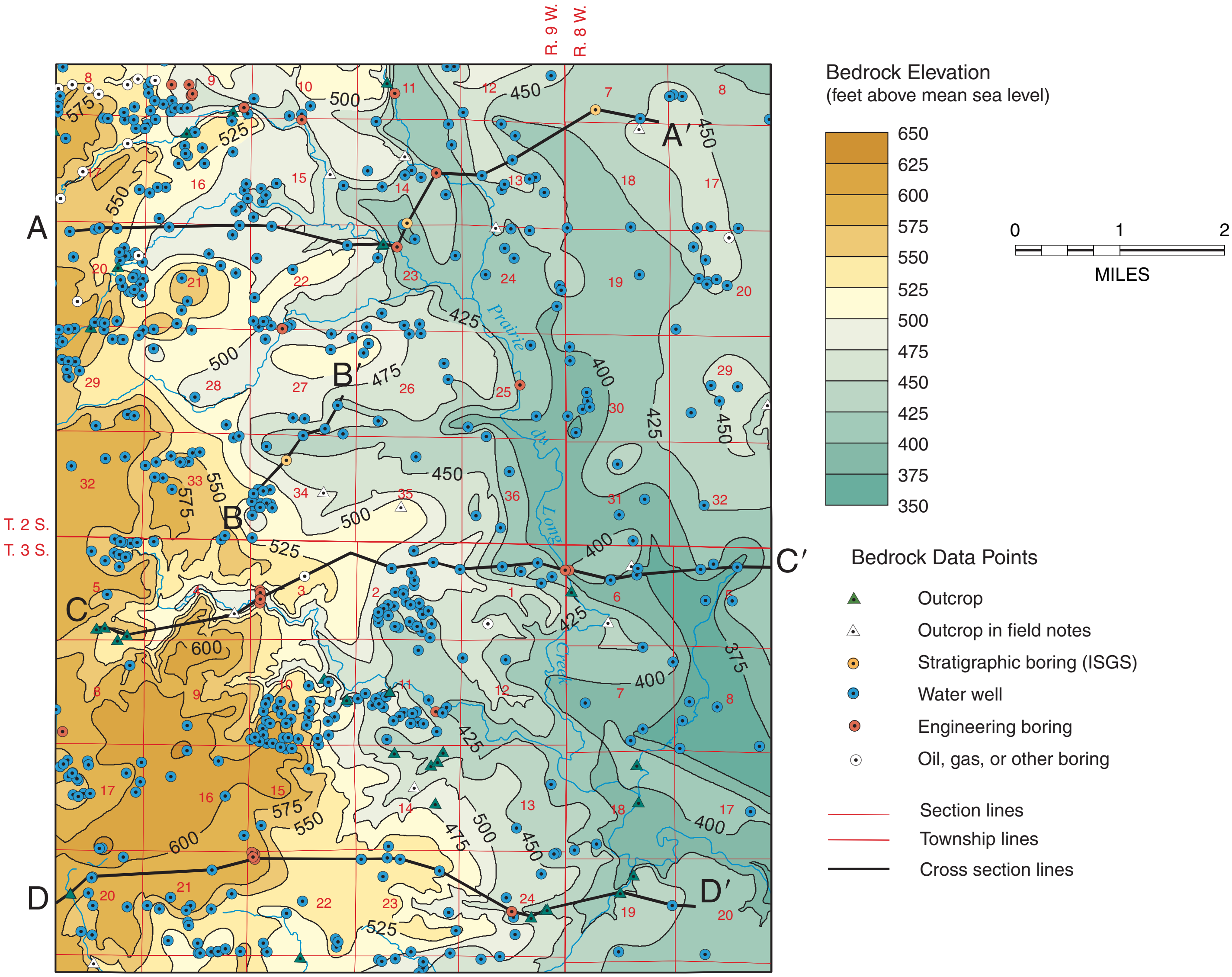

Figure 2 Bedrock topography of the Paderborn Quadrangle with shaded relief. Localities of all borehole and outcrop data that reliably indicate the bedrock surface are shown (many data are not shown on the surficial map). In the southeast, the main valley is buried by 70 to 100 feet of sediment. Bedrock crops out in most tributary valleys west of Prairie du Long Creek. Scale is 1:100,000.

Geologic History

Before the earliest known Quaternary glaciation, erosion had exposed much of the land surface to bedrock. Stream incision created steep valleys with up to 100 feet of relief (fig. 2). Erosion was partly controlled by rock type, with limestones and sandstones upholding the highs and the softer shales being eroded out of the lows, especially east of Prairie du Long valley where tributary bedrock valleys are broader and lower. Sinkholes formed in limestone uplands in the west. The drainage pattern was similar to today, although the trunk valley lies eastward of lower modern Prairie du Long Valley (fig. 2). Stream sediment, lake sediment, and colluvium may have accumulated in valley bottoms. During the pre-Illinois and the Illinois Episodes, glaciers flowed over the region from the northeast to the southwest (Grimley et al. 2001) (fig. 1). Pre-Illinois Episode ice certainly reached the quadrangle, and there is some evidence in patches of well-weathered diamicton and erratic (igneous and metamorphic) pebbles in lag deposits on the bedrock surface that the ice extended west of Waterloo, although it was probably thin. Illinois Episode ice crossed the quadrangle entirely and reached the edge of the Mississippi Valley (Goodfield 1965, McKay 1986, Grimley 2009). The glaciers sculpted the preexisting landscape and left deposits of diamicton (a poorly sorted mixture of rocks, sand, silt, and clay) as till at the glacier bed or as debris flows sloughed off glacier margins or in crevasses. Some bedrock valleys were completely buried with glacial deposits. For example, there is no surficial expression of a 60-foot-deep bedrock valley trending northeast-southwest across Sections 19 and 30, T2S, R8W (fig. 2). Cross section A–A′ depicts several buried bedrock valleys east of Prairie du Long Creek. Meltwater likely flowed down Prairie du Long Creek when the ice front lay just to the east. Most of that glaciofluvial sediment was later eroded.

During the last (Wisconsin Episode) glaciation, ice only advanced into the northeastern quadrant of Illinois, reaching to about 100 miles to the northeast of the Paderborn Quadrangle. However, the glacial meltwater indirectly but significantly affected southwestern Illinois. Large volumes of sediment were discharged into the Mississippi and Kaskaskia Rivers. High sediment aggradation in the Mississippi and Kaskaskia Rivers created slackwater conditions in tributary valleys, such as the Kaskaskia River and Prairie du Long Creek, respectively. Thick deposits of fine sediment accumulated in these temporary lakes. During glaciation, silt was eroded by westerly winds off the unvegetated, extensive, sandy floodplains in the Mississippi Valley and then was deposited across the upland landscape as blankets of loess. Between glaciations, streams continued to erode some sediment out of their valleys, and soils developed on the fresh land surface.

The elevations of the sediment-filled channel bottoms were probably at their highest just after glaciation. With the cessation of the large sediment supply, there has since been general incision of the valleys into older sediments and lowering of land surface. Postglacial stream sediment is derived mainly from erosion of the loess covering the uplands. Erosion has also exposed older Quaternary sediments and bedrock. Clearing of forests during early European colonization, and possibly earlier during Amerindian civilization centered at the Cahokia site in the Mississippi Valley, led to a period of extensive upland erosion and sediment accumulation in creek valleys. Relatively recent stream incision into these and older deposits is attributed to the large water discharges with initially low sediment loads brought about by recent climate changes, land use changes, or both. Straightening of the Richland and Kaskaskia channels in the mid-twentieth century increased flow rates and may thus have changed channel migration or incision rates locally.

Sediment Assemblages and Properties

Bedrock-Controlled Uplands

The bedrock surface descends from about 700 feet above sea level (asl) on top of the Waterloo-Dupo Anticline (Nelson 1995) (fig. 1) in the southwest corner of the map to 330 feet asl east of the lower reaches of Prairie du Long Creek (fig. 2). Bedrock highs are supported by Paleozoic limestones and relatively resistant sandstones, whereas the lows are underlain by shale and less resistant sandstone. The strata dip southeast at 2 to 3 degrees (Devera 2002).

A strong preglacial weathering profile into the bedrock was preserved where protected from erosion by Illinois Episode ice in depressions on the bedrock surface. The soil is cumulic and may include lenses of colluvium ranging from clay to gravel. The bedrock is covered by till, which is in turn draped with a layer of loess. The maximum thickness of the assemblage is about 80 feet. The Glasford Formation till is regionally pervasive. In the Paderborn Quadrangle, the Glasford Formation thins westward. In one outcrop at Waterloo Quarry (cross section C–C′), the till was eroded so that the loess lay directly on bedrock. The Peoria Silt and the underlying Roxana Silt loess units are not differentiated here because their geotechnical properties are very similar. They have been studied extensively by McKay (1979), Wang et al. (2003), and others. Original textures of silt loam to heavy silt loam have been modified within the modern solum to heavy silt loam to silty clay loam (Natural Resources Conservation Service 2005, 2006). The loess thins from about 10 feet closest to its Mississippi Valley source area in the west to 8 feet on uneroded uplands in the east. The mapped area of Peoria and Roxana Silts may include some loess-derived stream sediment in the low-order stream valley.

Along side slopes and valley walls, where erosion has thinned the loess blanket to 5 feet or less, the Glasford Formation is shown on the surficial map. Sediments in the Glasford Formation include diamicton, weathered diamicton, clay, and associated sorted sand and gravel. The diamicton was deposited mainly as till but includes ice-front debris flow and minor outwash stream deposits. The diamicton is loamy, is very stiff, and has low water content. Lenses of sand and gravel, up to 10 feet thick and hundreds of feet wide, have been described in the upper part and base of the Glasford Formation in neighboring quadrangles in Madison County (Phillips 2004b, Phillips and Grimley 2004). Few sand and gravel lenses were found here (cross section D–D′). The upper part of the Glasford Formation within the weathering profile of the Sangamon Geosol has relatively low strength and high moisture content, in part due to higher clay content. As mapped, it may also include up to 5 feet of pebble-free silty clay to clay. This sediment is likely a mixture of colluvium and loess and correlates with the Berry Clay-Tenneriffe Silt complex of Phillips (2008) and Grimley and Webb (2010).

Exposures along the highwall of Waterloo Quarry offer a look at the underlying Petersburg Silt, draped into a depression on the bedrock surface (cross section C–C′). This massive silt loam is interpreted as loess deposited during the advance of Illinois Episode ice. The Petersburg Silt is not pervasive in this quadrangle, but has been found in other depressions and buried bedrock valleys.

Low Relief Uplands

Underneath the gently undulating land surface east of Prairie du Long Creek are the thickest unlithified sedimentary deposits found in the quadrangle. Below the Wisconsin Episode loesses is Illinois Episode till with thin loess or colluvial deposits in depressions on the surface. A key distinguishing feature of the till from the Peoria and Roxana Silts is the occurrence of a well-developed paleosol, the Sangamon Geosol, in the upper few feet. Characteristics include well-defined peds, large iron and manganese concentrations, and a clear textural B horizon. The A horizon is usually truncated.

River Valleys

River valley floodplains are filled with postglacial stream sediment (Cahokia Formation) up to 20 feet thick. It lies either on bedrock or is set into either the Equality or Glasford Formation. The Cahokia Formation is generally fine grained because the sediment source was primarily loess, but the texture varies from silty clay deposited in backwater environments and abandoned meanders to gravelly loam sediments associated with deposition near channels. Layers of sand occur at depth, and up to several feet of sand and gravel that was concentrated by stream processes from older deposits (till or outwash) may occur at the base of the unit.

A terrace at an elevation of 410 to 415 feet subtly breaks the surface of the modern floodplain in the lower Prairie du Long Creek valley. During the Wisconsin Episode, aggradation in the Mississippi Valley caused slackwater conditions in the Kaskaskia River and its tributaries. Lakes filled with fine sediment constitute the Equality Formation. Subsequent incision left Equality terraces at elevations of about 410 to 415 feet. Laminated to massive silt loam to silty clay is capped with about 3 feet of Peoria Silt and no Roxana Silt. Equality Formation buried below the Cahokia Formation was correlated upstream to geotechnical borings at State Route 156 (cross section C–C′). A possible correlation to the lower part of borings at Reheis Road (Sec. 25, T2S, R8W) is not depicted on the map. However, the occurrence of the Equality Formation in this quadrangle is generally patchy. The valley bottom is too high upstream of the confluence of Gerhardt Creek with Prairie du Long Creek to accommodate these lake deposits.

Terrace forms with upper elevations of 420 to 460 feet constrict the Prairie du Long Creek valley at several locations downstream of the confluence of Gerhardt Creek. The terraces were not carefully studied for this project, but may reflect important elements of the regional history. They are tentatively depicted here as comprising the Peoria and Roxana Silts overlying the Glasford Formation based on soil survey data (Natural Resources Conservation Service 2005, 2006). At outcrop 23269, 30 feet of weakly weathered, weakly stratified, uniform loam was classified in the Teneriffe Silt, a unit of wind- and water-lain fine sediment (Willman and Frye 1970) that overlies the Glasford Formation. The landforms may be attributed to one of several origins. Erosion by meltwater retreat of the Illinois Episode glacier may have created benches into the underlying till. Alternatively, damming by the ice margin when it was forming the moraine that occurs just west of the Kaskaskia River (fig. 1) (see Grimley and Webb 2010) may have formed a lake in Prairie du Long Creek valley that was then filled with loess-derived sediment. In either scenario, the mechanism that caused deep incision rather than widening of the valley at these locations is not understood.

Concealed Deposits

Filling the lowermost portions of bedrock valleys and completely covered by the Glasford Formation and younger deposits are deposits that are rarely or never seen in outcrop. Petersburg Silt was described as loess draped over high bedrock. In a sample set for boring 22587 (cross section C–C′), the Petersburg Silt comprises gray silt loam with common spruce fragments. It appears to fill a buried valley and is interpreted as slackwater lake sediment, which is the more typical depositional environment for the formation. The damming mechanism could have been either ice crossing the Kaskaskia Valley or backwater effects from aggradation in the Mississippi Valley. The Petersburg Silt is generally very stiff because it was overconsolidated when overridden by the Illinois Episode glacier.

Pre-Illinois Episode Quaternary deposits (Banner Formation) have been found extensively in outcrop only in northern Madison County (McKay 1986, Phillips 2004a). A 2-foot-thick deposit of well-weathered diamicton and gravel lag on the bedrock surface with crystalline cobbles was found at Waterloo Quarry and was interpreted as a remnant of pre-Illinois Episode till in a sinkhole (point 23232, cross section C–C′). By contrast, thick successions of pre-Illinois Episode sediment were identified in core from boreholes that penetrated buried bedrock valleys (cross sections A–A′, B–B′, and C–C′). Banner Formation deposits are distinguished from the Glasford Formation by the weathering profile of an interglacial soil (Yarmouth Geosol) developed in the upper part, by selected physical and chemical properties, and by stratigraphic position. The Yarmouth Geosol was truncated by the Illinois Episode glacier and may only be recognized as a zone of oxidation or leached of carbonate. The top of the Yarmouth Geosol is interpreted from water-well records by descriptions of "greenish," "yellow," or "brown" sediments below gray sediment of the lower Glasford Formation.

Three units of the Banner Formation were distinguished: (1) diamicton interpreted to be till (Omphghent member, an informal stratigraphic unit); (2) bedded clay and silt deposited in glacial or slackwater lakes (Harkness Silt Member); and (3) weathered, non-glacial, pebbly to loamy textured sorted sediments (Canteen member, Phillips 2004b). The Omphghent member is typically uniform in this region. Relative to the Glasford Formation, it has moderate strength, moisture content, and low pebble content. Regionally it has a silt loam texture, a bit finer than the Glasford Formation (cf. Phillips 2004b, Phillips and Grimley 2004).

The Harkness Silt Member was found in boreholes 30807 (cross section A–A′) and 23233 (cross section B–B′). The silt loam to silty clay loam sediment is laminated to bedded. Organic matter, especially woody and herbaceous fragments, is dispersed throughout. Shell fragments are less common. Granule to fine pebble clasts in the upper part of the Harkness Silt in 30807 are interpreted as ice-rafted debris, indicating that glacial ice was in contact with the lake.

A weak paleosol (sediment leached of carbonate to dolomitic and olive color), variable textures, lack of erratic pebbles, and clay mineralogy similar to bedrock distinguish the Canteen member within the Banner Formation (cross sections A–A′ and B–B′). The unit may contain stream, lake, and slope sediment and additional paleosols. The sediments are interpreted to be non-glacial in origin and directly overlie bedrock. The Canteen member is restricted to bedrock valleys (cross sections, fig. 2). It has been found in boreholes penetrating buried bedrock valleys from St. Clair to northern Madison Counties (e.g., Phillips 2004b, Grimley 2006, Grimley and Phillips 2006).

Geologic Resources

Groundwater Resources
Groundwater resources within the Quaternary sediments are meagre. Of the 780 water wells in the Paderborn database, only about 10 appear to be shallow, large-diameter wells exploiting small sand lenses and water leaking along joints within the Glasford Formation. Most wells are completed in bedrock aquifers at least 50 to 150 feet below the bedrock surface. There are no municipal wells within the quadrangle.

Mineral Resources
The St. Louis and Salem Limestones are mined at the Columbia Quarry Co. Plant 7 in the southwest quadrant of the map (cross section C–C′). A limestone quarry in the northeast quadrant of the map, 1 mile west of Hecker, is no longer active. There are no commercial resources of aggregate or fill in the Quaternary sediments.

Geologic Hazards

Groundwater Contamination
Contamination potential by nitrates and pesticides for shallow aquifers over most of the quadrangle is low to moderate (Keefer 1995). In the subsurface, the Sangamon Geosol also provides a clay-rich horizon, up to 3 feet thick, that could substantially retard downward groundwater flow (Herzog et al. 1989). However, thin sediment cover in some areas and small lenses of sand within the upper part of the Glasford Formation may provide pathways for contaminants to underlying layers (Berg et al. 1984). Towards the Waterloo-Dupo Anticline, the occurrence of karst with thin Quaternary sediment cover increases the potential contamination hazard for water wells.

Acknowledgments

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