STATEMAP
Williamson County-SG

Surficial Geology of Williamson County, Illinois

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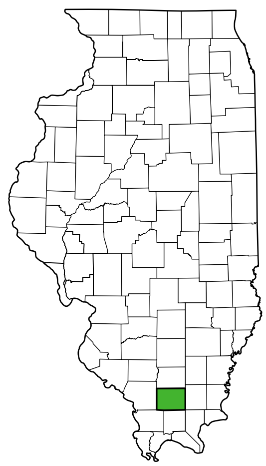

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Introduction

Surficial geologic maps, such as the one accompanying this report, 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 southern Illinois. Other county surficial geology products include St. Clair and Madison Counties (Grimley and Phillips 2006, 2011).

Williamson County, located in southern Illinois, straddles the border between the glaciated Mt. Vernon Hill Country and the unglaciated Shawnee Hills (Figs. M1, M2; Horberg 1950). The Mt. Vernon Hill Country is characterized by broad lowlands and uplands with irregular to rounded hills. The lowlands are generally underlain by glacial, glaciofluvial, lacustrine, and alluvial sediments that partly or completely mask the pre-glacial bedrock topography (Fig. M3). The highest upland hills in northern Williamson County, dissected by small creeks, are underlain by Pennsylvanian sedimentary bedrock and mantled with loess and thin to patchy Illinois Episode till deposits. In the Shawnee Hills, resistant sandstone layers of Pennsylvanian age are gently inclined northward, forming a series of south-facing escarpments (cuestas) near the southern border of the county. These escarpments occur in the southern part of the Illinois Basin (Nelson 2020). A significant portion of Williamson County has been mined for Pennsylvanian coal, from both surface and underground mines.

The Laurentide Ice Sheet reached Williamson County at least once, and likely twice during the Pleistocene. During a pre-Illinois Episode glaciation, ice likely advanced to southern Illinois from the Lake Michigan basin, the eastern Great Lakes region, or both (Willman and Frye 1970). It is suspected that parts of northern Williamson County were covered during a pre-Illinois Episode glaciation, but the exact position of the ice margin is not well known (Hansel and McKay 2010; Curry et al. 2011). After the ensuing Yarmouth interglacial episode, glacial ice once again advanced across the region during the Illinois Episode (second to last glaciation), originating from the Lake Michigan basin and reaching just south of Williamson County and as far southwest as St. Louis, Missouri. The southernmost advance of Pleistocene continental glaciers in the Northern Hemisphere occurred during the Illinois Episode just 2 km south of Williamson County, in northern Johnson County, Illinois (Willman and Frye 1980; Hansel and McKay 2010). Williamson County itself was mostly, but not completely, covered by glacial ice during the Illinois Episode (Figs. M1 and M2; Hansel and McKay 2010; Curry et al. 2011; Grimley et al. 2017).

During advance and retreat of the pre-Illinois and Illinois Episode glacial ice margins, proglacial outwash (from perhaps multiple sublobes) was deposited in medium to large valleys that drained away from the ice margin (including the Big Muddy River and Crab Orchard Creek valleys). In some areas, short-lived proglacial lakes formed due to ice blockage of north-flowing river valleys. In response to periods of downcutting of the Mississippi, Ohio, and Wabash Rivers during interglacials (Yarmouth Episode, Sangamon Episode, early Holocene) these valleys and their tributaries were periodically incised (Curry and Grimley 2006). Glacial ice did not reach the study area during the Wisconsin Episode (late Pleistocene); however, meltwater streams that drained glacial lobes in the upper Midwest deposited large quantities of outwash in the Mississippi River valley, which served as the dominant source of loess deposits (windblown silt) that blanket uplands in southern Illinois (McKay 1979; Fehrenbacher et al. 1986). As a result of glacial aggradation in the Mississippi and Wabash Valleys, large slackwater lakes formed in the Big Muddy and Saline River Valley drainage basins during peak of the last glaciation (Frye et al. 1972; Heinrich 1982; Trent and Esling 1995). Such backwater lakes likely also existed during earlier glaciations as both valleys are superimposed on preglacial bedrock valleys. After the lakes drained at the close of the last glaciation, streams in Williamson County assumed their present courses, eroding uplands and depositing alluvium along their valleys. Extensive coal mining, both at the surface and underground, has altered the landscape in many parts of the county, as shown by areas of disturbed ground (dg) on the geologic map. The coal mines generally occur in a WNW-ESE band that generally follows the strike of the Pennsylvanian bedrock (Nelson 2020).

Early surficial geologic studies in Williamson County, at scales of 1:62,500 or smaller, include those of Cady (1910), Savage (1910), Shaw and Savage (1912), and Lamar (1925). The modern era of 1:24,000 scale geologic mapping began in the 1980s and 1990s with funding from the U.S. Geological Survey. These maps focused on bedrock geology near the southern border of the county. Surficial geologic maps of six quadrangles (Herrin, Johnston City, Pittsburg, Crab Orchard Lake, Marion, and Crab Orchard) lying entirely or largely in Williamson County, were published in 2010 (Follmer and Nelson 2010a, 2010b, 2010c, 2010d, 2010e, 2010f). This effort left narrow strips along the western, southern, and eastern edges of the county yet to be mapped. The surficial geology of the Carbondale Quadrangle has also been mapped (Nelson 2013a, 2013b). A series of bedrock geologic quadrangle maps also has been published and compiled into a Williamson County bedrock geologic map (Nelson 2020), a companion to the present publication.

Methods

Our new surficial geologic map of Williamson County is extensively revised from the quadrangle maps of previous authors. Multiple sources of new data includes outcrop studies, subsurface boring records, archived samples, geophysical data, lidar surface topography, and soil survey maps. Much of the original data is compiled from prior work, but some is newly acquired as part of this USGS-STATEMAP county compilation project. A considerably amount of linework was revised based on lidar surface digital elevation maps, which were not fully available until 2012.

We also introduced conceptual differences in mapping style to align the Williamson County map more closely with previous county-scale maps in southern Illinois (Grimley and Phillips 2006, 2011). For instance, areas that were previously mapped as Glasford Formation, but covered by 5 to 10 feet of loess (Peoria and Roxana Silts), are now mapped as loess, except along eroded slopes where the loess is < 5 feet thick. The unit that Follmer and Nelson (2010a–f) called "Glasford stratified deposits" has been re-interpreted as either loess overlying Glasford Formation (mapped as loess) or loess over Teneriffe Silt (hachured), where stratified fine-grained deposits occur in the subsurface. Finally, three cross sections were created to display Quaternary deposits of Williamson County in the third dimension.

As part of the prior surficial mapping phase for Williamson County in 2001-2004, twenty-three stratigraphic test holes were drilled by the ISGS in 2003 using a Power Probe. These holes were continuously cored from ground surface to refusal (to top of bedrock in many area) and provided continuous samples for geologic study. Additionally, twenty-two shallow test holes, typically < 20 feet (6 m) depth, were drilled by the Natural Resources Conservation Service (NRCS), using a Giddings rig, in conjunction with ISGS mapping in 2002 (14 cores) and 2004 (8 cores). Detailed descriptions of continuous samples obtained from this drilling were reexamined. Summary descriptions of strata penetrated and location information for these holes can be found in the ISGS Wells and Borings Database (accessible online at https://maps.isgs.illinois.edu/ILWATER/).

Field notes of previous Illinois State Geological Survey (ISGS) geologists, archived at the ISGS, describe scores of geologic exposures, many of which no longer exist because of erosion, sedimentation, slumping, and human activities. Additional outcrops were visited by the authors. All available subsurface boring logs and records were used to characterize Quaternary sediments, including stratigraphic, engineering, water well, coal, and petroleum type subsurface borings or cores. Aside from stratigraphic test holes, the most useful records are logs of bridge borings (including engineering properties) mostly acquired from Illinois Department of Transportation (IDOT) in connection with highway and bridge construction. Original records are archived at IDOT district offices in Carbondale and less completely, at the ISGS Geologic Records Unit and website (maps.isgs.illinois.edu/ILWATER).

Additional outcrop studies, subsurface data compilation, and geophysical data collection was performed in 2019–2020. About 20 archived sample sets, available from the ISGS Samples Library, were also examined and described. Fossil mollusk shells from a sample set and from a sampled outcrop along the Big Muddy River were submitted for radiocarbon dating (Table 1; nine ages) to better understand the chronology of sedimentation in glacial Lake Muddy. Additional inferences on the surficial geology and geomorphology were deduced from lidar digital elevation maps, historical topographic maps, and aerial photographs. The Williamson County soil report (Williams et al. 2009), focusing on the uppermost 5 feet of surficial materials, was also a valuable guide to mapping the surficial geology.

Two areas were profiled for electrical resistivity tomography in summer 2020 in the Big Muddy River Basin of northwestern Williamson County. For the electrical earth resistivity tests, 64 stainless steel rods were pushed into the ground at 5 m intervals. The rods were connected through multi-core cable to a computer-controlled resistivity meter (ABEM Terrameter LS). A control program sequentially switches various combinations of electrodes, operates the instrument, and stores the data. Profiles of continuous resistivity measurements were obtained at 5 m spacing and up to 30 m deep. When calibrated with borehole records, these resistivity surveys enable interpretation of the subsurface geology.

Surficial Deposits

The surficial deposits of Williamson County are here divided into six landform–sediment associations: (1) Bedrock-controlled landscapes (unglaciated or thin glacial cover); (2) Rolling glacial drift plains and bedrock valley fills; (3) High terraces composed of Illinois Episode outwash and/or lake sediment (4) Glacial Lake Muddy and Glacial Lake Saline (related to Wisconsin Episode glaciation); (5) Postglacial river valleys; (6) Anthropogenically disturbed ground resulting from coal mining (predominantly), waste disposal, and construction of highway or railway embankments. Most of the county has unconsolidated deposits < 75 feet in thickness and, in many areas, much less. However, parts of northwestern and central Williamson County are mantled by thick Quaternary (unconsolidated) deposits, more than 75 feet thick to possibly more than 150 feet (Fig. M4).

(1) Areas with thin or absent glacial cover (bedrock-controlled)

Outcrops of near-surface Pennsylvanian sedimentary rocks are numerous in southern Williamson County. The most resistant rock type is sandstone, which forms cliffs and ledges in the southern part of the county. Non-resistant rocks such as shale, coal, and limestone crop out only in steep ravines, gullies, and artificial cuts. Only small, scattered bedrock outcrops occur north of Crab Orchard Lake and the South Fork of the Saline River. Several hills that rise above the general level of the plain near the northeastern corner of the county are composed of bedrock mantled by loess. Such topography characterizes the Mt. Vernon Hill Country (Horberg 1950). Near-surface bedrock is mapped where it outcrops or is within about 5 feet of the ground surface. Contacts were guided

Table 1 Radiocarbon Sample Results (Accelerator Mass Spectrometer Method) from gastropods shells in Equality Formation samples

UCIAMS#	ISGS#	Site	Depth (ft)	Material	$\delta^{13}C$	±	RCYBP[1]	±	Comments
237878	A5062	WLM-2f*	12	aquatic shell fragments	N.A	N.A	19790	360	small sample size
237879	A5063	WLM-2f*	17	two shells (*Pomatiopsis lapidaria*)	N.A	N.A	20910	80	
237880	A5064	WLM-2f*	18	shell (*P. lapidaria*)	N.A	N.A	20470	80	
237881	A5065	WLM-2f*	18	shells (*P. lapidaria*; *Fossaria dalli*)	N.A	N.A	20560	100	
237882	A5066	WLM-2f*	18	two shells (*Pomatiopsis lapidaria*)	N.A	N.A	20830	80	
237883	A5067	WLM-2f*	19	shells (*Fossaria*, *Discus*, *Succineidae*)	N.A	N.A	21350	270	small sample size
236386	A5000	SS-31106**	40–50	aquatic mollusk shell fragments	-9.7	0.1	20530	45	
236387	A5001	SS-31106**	70–80	Sphaerium (bivalve)	-9.2	0.1	20550	45	
236388	A5002	SS-31106**	80–90	aquatic mollusk shell fragments	-10.1	0.1	20920	50	

Samples were leached with dilute HCl (10%) prior to hydrolysis with 85% phosphoric acid. Sample preparation backgrounds have been subtracted, based on measurements of ^{14}C-free calcite. All results have been corrected for isotopic fractionation according to the conventions of Stuiver and Polach (1977), with $\delta^{13}C$ values measured on prepared graphite using the AMS spectrometer. These can differ from $\delta^{13}C$ of the original material and are not reported.

[1] RCYBP = radiocarbon years before present.

* WLM-2f is a sampled outcrop of Equality Formation (NE, sec. 18, T8S, R1E); lat. 37.8298; long. -89.1359.
** Sample Set # 31106 has an API number of 121990212900 (NW, sec. 3, T8S, R1E); lat. 37.8582; long. -89.0928.

in many areas by county soil survey mapping, based in part on soil probings (Williams et al. 2009). Many areas mapped as bedrock are characterized by numerous rock outcrops and considerable float of rock, largely sandstone.

Areas with patchy till exposures near the glacial border were described by Willman and Frye (1980), Nelson and Weibel (1996), and early geologists from archived ISGS field notes (*e.g.*, MacClintock, Cady). Striking topographic features occur in the Shawnee Hills section of southern Williamson County. Streams such as Sugar Creek, South Fork Saline River, and north-flowing tributaries of Crab Orchard Creek are incised deeply; intricate and deep V-shaped gullies are separated by sharp ridges. This topography has been generally stabilized by vegetation cover, largely forest, except along the bottoms of the most active streams.

Uneroded upland areas, in both glaciated and unglaciated areas of the county, are mantled by last glacial loess deposits (wind-blown silt). Loess deposits (including both the Peoria and Roxana Silts) are mapped where 5 feet or greater, attaining a maximum thickness of about 12 feet in the southwestern part of the county. The only areas that lack loess cover are artificial excavations, deeply eroded hillsides, modern floodplains (where Cahokia Formation is mapped) and the lowest (youngest) terraces in the northwestern part of the county (map unit e-1).

Last glacial loess deposits in Williamson County consist of the Roxana Silt (older) and Peoria Silt. The Peoria Silt was deposited during the late Wisconsin Episode (~ 29 to 15 cal ka; Nash et al. 2018) and generally is yellowish brown to grayish brown in color, with moderate mottling. The older Roxana Silt (~ 55 to 30 cal ka) tends to be medium brown, with a slight pinkish-brown hue in some zones where thicker deposits are found. Due to overprinting by the modern soil, the Peoria and Roxana silts are difficult to distinguish in the field where their combined thickness is less than about 6 feet. In unglaciated areas, the Loveland Silt (Illinois Episode loess) is found below the Roxana Silt. The Loveland Silt, typically thinner than the Peoria Silt, is strongly modified by development of the Sangamon Geosol (last interglacial paleosol). Intense color mottling, high clay content, and development of blocky structure and cutans in the Bt horizon are typical in the Sangamon Geosol.

(2) Areas with thicker glacial drift or bedrock valley fills
During the Illinois Episode, the penultimate glaciation of the southern Laurentide Ice Sheet, continental glaciers covered most of Williamson County and extended into northern Johnson County. This was the southernmost advance of Pleistocene continental glaciers in the Northern Hemisphere. The southern limit of the Glasford Formation in Illinois occurs ~ 2 km south of the county line (Willman and Frye 1980). The north-facing dip-slope of Pennsylvanian sandstone in the Shawnee Hills of Johnson County was the final barrier that the ice sheet could not surmount.

The Glasford Formation (Willman and Frye 1970) represents glacial till and ice-marginal sediment associated with the Illinois Episode glaciation. The Glasford Formation occurs through most of Williamson County, except in areas beyond the glacial border where loess rests directly on bedrock (see cross sections). Also, underneath glacial Lake Muddy (Fig. M2), the Glasford Formation was eroded, likely during the last interglacial (Sangamon Episode), and replaced by younger valley fill deposits.

The Glasford Formation is dominantly composed of silt loam to silty clay loam diamicton. The pebble (and larger) content generally varies from less than 1% to about 5%. Relatively unaltered diamicton is typically is dark gray to olive gray, becoming strongly mottled in yellowish and orange-brown where weathered. Paleosol characteristics (Sangamon Geosol) are strongly developed in the upper 10 feet and the till is commonly leached of carbonates to a depth of 20 feet. In places, the Glasford Formation contains lenses of laminated, yellowish-orange, fine to coarse sand and fine gravel, in horizontal to contorted layers. The Glasford Formation ranges up to 90 feet thick, within the thickest deposits filling preexisting bedrock valleys (cross section C-C′).

The gravel fraction is largely rounded quartz and chert pebbles together with angular fragments of sandstone and other Pennsylvanian sedimentary rocks. Cobbles and boulders include locally derived Pennsylvanian sandstone, siltstone, shale, coal, and limestone along with a wide variety of metamorphic and igneous rocks such as quartzite, schist, gneiss, basalt, and granitic to gabbroic rocks, originating from the Canadian Shield. Crystalline erratics are mostly rounded; the largest are 3 to 4 feet in diameter. Inclusions of Pennsylvanian sandstone slabs up to 20 feet across were observed, large enough to be mistaken for bedrock outcrops, especially if bedding is horizontal. Most of these probably lie close to their point of origin.

Most outcrops show a network of joints that are lined with iron oxide and outline polygons. The Glasford commonly exhibits burrows several inches to nearly one foot in diameter and up to several feet long. Fragments of subfossil wood are locally present. Jackson and Miller (1983) studied the paleoecological of fossil material in glacial till (likely Glasford Formation) of adjacent Jackson County. They identified *Picea*, *Larix* and *Abies* wood macrofossils or needles, as well as many other boreal indicators that suggest the presence of a spruce-fir-tamarack forest, along with intervening alkaline wetlands, immediately prior to glacial advance.

Shaw and Savage (1912) described deposits of old, lithified alluvium underlying glacial till. The old alluvium is about 3 to 5 feet thick and consists of slightly rounded pebbles and blocks of rock (mostly sandstone) in a matrix of consolidated silt and sand. We observed an outcrop that may represent a deposit of this material slightly outside the map area along Indian Creek in NE 1/4 NW 1/4 NW 1/4, Sec. 25, T10S, R1E, Jackson

County (Carbondale Quadrangle). Here, well-indurated alluvium, 3 feet thick, underlay Glasford diamicton and lay directly upon sandstone. The alluvium was composed mainly of slabs of sandstone, as long as several feet and embedded in a matrix of rounded gravel. The presence of pebbles of igneous rock implies that this may actually have been deposited during the early Illinois Episode. Such deposits of preglacial alluvium are too small and too thin to map at scales of 1:24,000 and smaller.

(3) Illinois Episode Outwash and Lake Sediment in High Level Terraces

Loess-covered terraces in the Big Muddy River Basin, along Pond Creek, and in Crab Orchard Creek Valley on the east side of Marion are underlain by loamy sand to fine sand to gravelly sand in some areas. These deposits, which contain Sangamon Geosol alteration in their upper portion (to clay loam), are classified as the Pearl Formation (Willman and Frye 1970). The Pearl Formation is found in loess-covered terraces that are level to very gently sloping. The mapped distribution of this unit is based on several stratigraphic test holes, a few sample sets, electrical resistivity profiles (Fig. 1) and many subsurface boring descriptions. Mapping of this unit was also based on geomorphic identification of terrace surfaces from lidar surface topography.

Sediments of the Pearl Formation are yellowish brown, gray, and brown. The lower part is generally well sorted, fine sand containing a few lenses of silty clay. Secondary calcite is plentiful in the lower Pearl, but the upper 20 feet is commonly leached and the upper 10 feet displays strong pedogenic features of the Sangamon Geosol. The genetic interpretation of the Pearl Formation is outwash from proglacial meltwater when glacial ice was present in northern Williamson County. In the Big Muddy River Basin, the Pearl Formation is commonly logged as "quicksand" in coal borings. More detailed logs specify loose, water-bearing sand that is white to gray and fine to coarse-grained. Scattered silt and clay layers are present and a basal gravel is common. The sand is less than 25 feet thick in most holes but locally is more than 50 feet thick. In some areas the Pearl Formation intertongues with the Glasford Formation, with the basal tongue beneath Glasford till being classified as the Grigg tongue of the Pearl Formation (Grimley and Webb 2010).

The Teneriffe Silt occurs in loess-covered high terraces, mainly in the Big Muddy River Basin of northern and north-central Williamson County. Surface elevations for these terraces are typically between 400 and 425 feet asl. In these areas, it consists of mottled gray to olive-gray silty clay to clay loam having a few lenses of sand and gravel in the lower part. These deposits are likely remnants of a proglacial or slackwater lake that formed in the Big Muddy River Basin as the Illinois Episode glacial ice receded. The upper 10 feet bears strong pedogenic features attributed to the Sangamon Geosol, whereas the lower part is calcareous and bedded. The Teneriffe Silt, consisting of lacustrine and loess deposits, rests either on bedrock or sand of the Pearl Formation (see cross sections and Fig. 1), and probably grades laterally into the coarser grained Pearl Formation. The Teneriffe Silt may also intertongue with the Pearl Formation. Last glacial loess (Peoria and Roxana Silts) overlies the Teneriffe Silt. In some areas, the Teneriffe Silt has been eroded by stream incision, with these areas later infilled by younger sediments (Equality and Cahokia Formations). Thinly bedded to laminated Teneriffe Silt, up to 15 feet thick, has also been locally identified at elevations as high as 500 feet in the southern part of the county (such as in NW, Sec. 21, T10S, R2E; site originally described by Paul MacClintock in 1920s); in these areas the sediment likely records ice blockage of north-flowing tributary valleys.

(4) Glacial Lake Muddy and Glacial Lake Saline (Wisconsin Episode slackwater lakes)

During the Wisconsin Episode, the last major glacial episode, the Laurentide Ice Sheet did not reach southern Illinois. However, glaciers in the upper Midwest region (including northeastern Illinois) seasonally fed meltwater streams, which deposited large quantities of sediment in the Mississippi and Wabash River Valleys. The sediment dams, at the mouths of tributaries, led to impoundment of the Big Muddy River and Saline River valleys and inundation by backwaters. Seasonally high water levels formed extensive slackwater lakes known as glacial Lake Muddy and glacial Lake Saline (Shaw 1911; Willman and Frye 1970; Frye et al. 1972; Heinrich 1982; Trent 1994; Trent and Esling 1995). Shaw (1911) and Shaw and Savage (1912) named Lake Muddy and recognized its Pleistocene age and significance.

Fine-grained and stratified sediments deposited in these former lakes, up to 80 feet thick, are classified as the Equality Formation (Willman and Frye 1970; Hansel and Johnson 1996). The Equality Formation is mapped mainly in the Big Muddy River Basin of northwestern Williamson County, and also underlies Cahokia Formation in the valleys of Crab Orchard Creek and South Fork Saline River (see cross sections). The contact between the Cahokia and Equality Formation can be difficult to identify. In the Big Muddy River Basin, two terrace levels that contain the Equality Formation are evident. Deposits of e-1 occur within a lower terrace that has a surface elevation of 370 to 380 feet asl. The e-1 deposits range from clay to silty clay with silt loam at the surface and a few silt interbeds; the lower part can be rhythmically laminated. Deposits of e-2 occurs within a higher terraces, generally with surface elevations of 383 to 395 feet asl. The e-2 deposits are also mostly fine-grained, consisting of silty clay to silty clay loam to silt loam, with some silt or fine sand beds. The Equality Formation can be massive to crudely stratified to rhythmically laminated. Its color is uniform dark gray in the lower part, oxidizing to olive-gray and brown, with Fe-oxide and Mn-oxide stains in the upper 20 feet (6 m). The sediment is generally massive in the upper part, becoming more distinctly bedded at depth with numerous silt layers. At depth (below 15 feet or so) the Equality Formation is typically calcareous

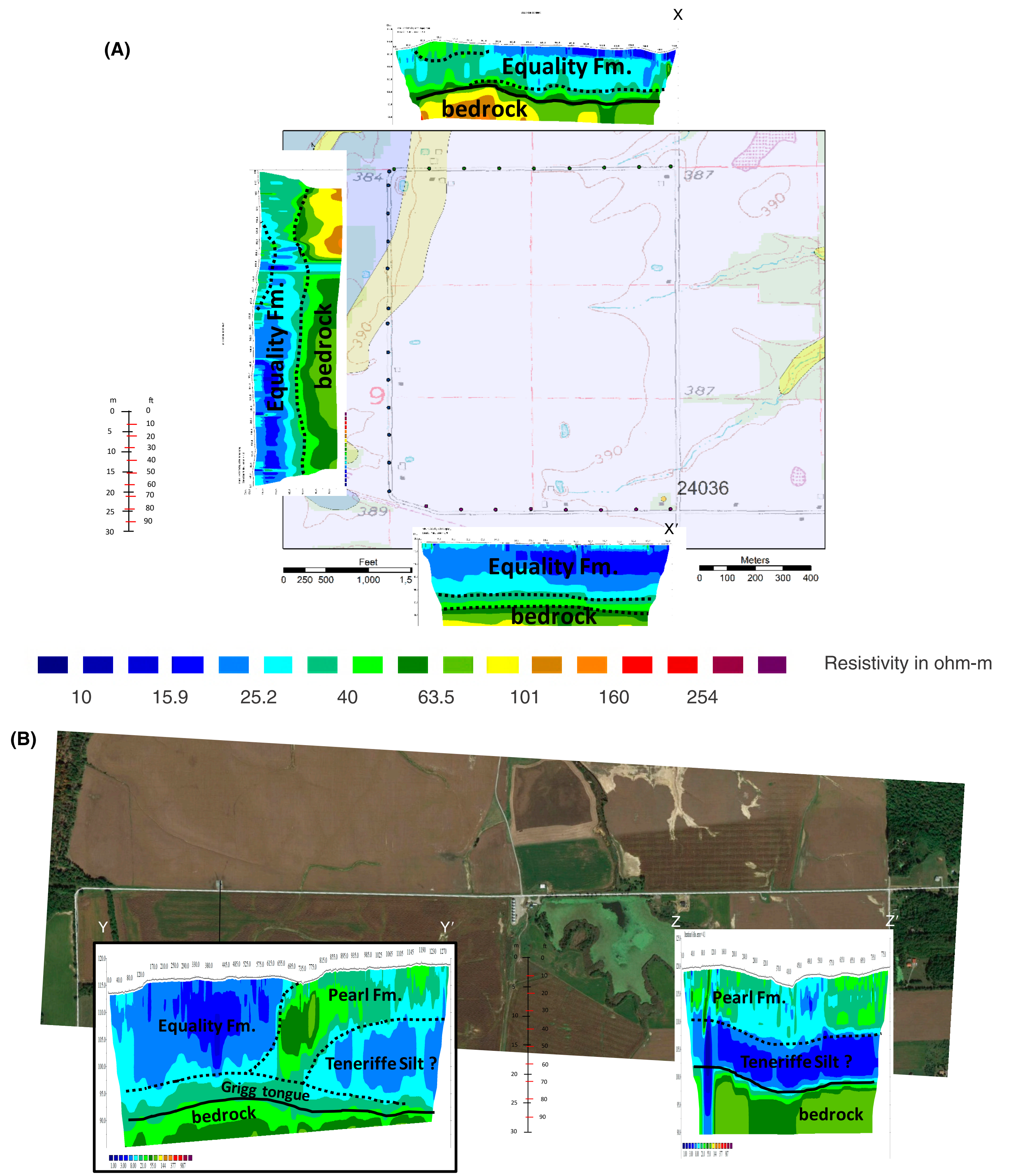

Figure 1 Electrical resistivity transects X-X', Y-Y', and Z-Z'. (A) Three profiles in section 9, T8S, R1E, forming 3 sides of a rectangle (X-X' on the surficial geology map). Most of the surface deposits are fine-grained lacustrine deposits (Equality Formation), but a narrow, linear feature crosses in northwest corner of the study area is the sandy silt facies, interpreted as a natural levee or bar that formed as glacial Lake Muddy drained. (B) Two profiles (Y-Y' and Z-Z') along Stiritz Road crossing the center of parts of sections 9 and 10, T8S, R2E. This study area is near the southeast margin of glacial Lake Muddy. Fine-grained low-lying lake deposits (western part of Y-Y') from the last glaciation have a cut-and-fill relationship to older (likely Illinois Episode) medium-grained sand to loamy sand (Pearl Fm.) overlying a fine-grained deposit in eastern Y-Y' and Z-Z'. The Pearl Fm. is overlain by a thin last glacial loess cover (not annotated).

and unoxidized; such zones may contain plant debris, wood fragments, and aquatic to amphibious mollusk shells. In IDOT bridge-boring logs, the Equality Formation (e-1, e-2) tends to be softer (Qu [unconfined compressive strength] ~ 0.5-1.5 tons per square foot) and have higher water content (25 to 35%) than the Glasford Formation (Qu > 1.5 and water content < 25%).

One well-exposed outcrop of Equality Formation within a high terrace (e-2) occurs along a cutbank of the Big Muddy River in the NE ¼, Section 18, T8S, R1E. This locality was sampled for fossil gastropods shells for the purpose of radiocarbon dating. Most shells visible at the outcrop were *Pomatiopsis lapidaria*, an amphibious gastropod that is typical of floodplains and shorelines (Baker 1931). Other freshwater aquatic mollusk shells that were identified include *Fossaria* sp., *Pisidium* sp., *Sphaerium* sp., and *Succineidae*. Shaw (1911, 1915) reported, from other sites with sediment now classified as the Equality Formation, more than a dozen species of fossil mollusks. Some of these species currently inhabit freshwater lagoons, quiet streams, and lily ponds, and some are today found no farther south than Wisconsin.

Nine radiocarbon ages on the aquatic to amphibious mollusk shells from the Equality Formation range all range between 21,400 and 19,800 ^{14}C years before present (25,800 to 23,800 calibrated years before present). This age range is similar to ^{14}C age determinations by Frye et al. (1972) and Heinrich (1982) for deposits from the type area of the Equality Formation in glacial Lake Saline; here 6 ages were reported from peat, organic matter or mollusk shells between 21,800 and 20,500 ^{14}C years before present. Furthermore, Grimley and Phillips (2015) noted similar radiocarbon ages at the Highbanks Road Section in glacial Lake Kaskaskia in St. Clair County, Illinois (4 ages between 21,300 and 19,000 ^{14}C years before present). Thus, slackwater lake level history and sediment aggradation in glacial Lake Muddy, Lake Saline, and Lake Kaskaskia during the last glacial maximum may have been coincident. All of these slackwater lakes were thus probably similarly affected by significantly enhanced sediment loads in the Mississippi and Wabash River valleys during the peak of the last glaciation when the southern Laurentide Ice Sheet was at its maximal extent in Illinois (Curry et al. 2018) and Indiana (Loope et al. 2018).

In areas where the Equality Formation beneath the high terrace (e-2) is thick, this unit may be divided into two informal members. These are the Texas City member (upper) and the Cottage Grove member (lower), as defined by Heinrich (1982). The Cottage Grove member generally has a somewhat reddish-brown or pinkish-brown hue, is mainly noncalcareous (and thus not fossiliferous) and is found at elevations below about 350 feet asl. The Cottage Grove member is probably equivalent to the lower Equality Formation of Curry and Grimley (2006) in the St. Louis region, and is likely chronocorrelative with the Roxana Silt (loess) based on its color and stratigraphic position. Reddish-brown silty clay beds, that fit Heinrich's description of the Cottage Grove member, were observed in core samples, at one outcrop, and in subsurface boring descriptions.

A silty facies [e(z)] occurs in a meandering band on the high terrace of the Big Muddy River and bears well drained, oxidized soils. The silty facies includes silt loam to fine sandy loam as thick as 10 feet, overlying deposits of e-2 on the high terrace. The silty to fine sandy facies most likely represents bars or natural levees that formed when the Big Muddy River began to cut downward through the lake sediments and drain Lake Muddy.

High terrace deposits (e-2) of the Big Muddy basin are overlain by a thin cover of Peoria Silt (~ 2 feet thick) that was likely deposited after about 19,000 RCYBP. Low terrace deposits of the Equality Formation (e-1) occur at the surface or are veneered by modern floodplain sediments.

An unusual feature of Lake Muddy, west of Williamson County, is that the surface of the upper terrace slopes upstream (Shaw 1915). It is above the 410-foot contour at the outlet of the lake near Murphysboro, but ten miles upstream near Herrin it is between 390 and 400 feet. The reverse slope of the Big Muddy terrace is probably the result of aggradation in the Mississippi Valley from glacial meltwater (Shaw 1911; Trent 1994). This sediment-laden water coursed upstream into the Big Muddy basin and built a delta upstream from the inlet.

(5) Postglacial stream deposits

IIn Williamson County, the Cahokia Formation consists of floodplain deposits in modern (Holocene) stream valleys. Along the larger streams the material is mostly silt loam to silty clay that is mottled in shades of gray and brown. The lower part tends to be weakly bedded and contains increasing content of sand and gravel. Secondary calcite nodules commonly occur below the solum of the modern soil. The Cahokia has a maximum thickness of about 30 feet.

In the southern part of the county, the Cahokia Formation contains a high percentage of coarse material, from sand to boulder size, along small streams. These sediments are reworked from loess, the Glasford Formation, and from local Pennsylvanian bedrock. In this unglaciated to borderline glaciated area, glacial sediments are thin to absent and streams mainly flow northward directly across bedrock once the thin loess cap and patchy Glasford till deposits have been eroded.

(6) Anthropogenically disturbed area

Disturbed ground (map unit "dg") comprises land disturbed by human activities, including surface and underground coal mining, Anthropogenically disturbed ground consist of areas extracted for coal (now abandoned), coal mine spoil piles, industrial areas, waste disposal, and fill associated with highway and/or railway embankments. By far the most extensive area of disturbed ground was created by strip mining for coal in a belt that extends across the county from

Carterville and Cambria east-southeast toward Crab Orchard and Stonefort. Prior to the advent of reclamation laws in the 1960s, most mine operators left a rugged landscape of parallel ridges that became overgrown by trees and brush; today these areas serve mainly as wildlife habitat. From the 1960s forward, laws mandated restoring ground to its original contour and replacing earth materials in more or less their original succession. These reclaimed surface mines are being used for crop production, grazing, and residential and commercial development. Some underground mine sites are marked by piles of waste rock removed from the coal at the tipple. Subsidence of abandoned underground mines is an ongoing problem for landowners, but we have made no attempt to map areas that have undergone subsidence. Much of the area mapped as disturbed ground occurs in a WNW-ESE band that is associated with former mining of the Herrin Coal (Pennsylvanian). More details on coal mine extraction in Williamson County is available from Nelson et al. (2020) and online (https://isgs.illinois.edu/research/coal/maps/county/williamson). The latter source contains information for those concerned about mine subsidence. Most of the surface mining in Williamson County took place in the early to middle 20th century, whereas underground mining still continues today.

Pre-glacial Drainage

Illinois Episode glaciers buried many former stream valleys in Williamson County with glacial ice and infilled some with glacial till deposits. The preglacial topography, as deduced from outcrop and borehole mapping, can help reveal the courses of streams prior to middle Pleistocene glaciations. The most resistant sandstone is that of the lower Tradewater Formation in the southern part of the county. This sandstone forms a cuesta having an extensive NNE-facing dip-slope. Numerous consequent streams, including Little Grassy, Grassy, and Wolf Creeks, flowed down this dip-slope in pre-glacial time much as they do today (Nelson and Weibel 1996).

The best documented preglacial valley is revealed by closely spaced engineering test holes at the Lake of Egypt dam (Secs. 25 and 26, T10S, R2E). Borehole records indicate the preglacial bedrock valley is approximately 500 m wide and its bed is ~30 m lower in elevation than the present floor of Saline Creek. Grassy Creek currently flows into Devil's Kitchen Lake. It originally ran north from a point just east of the lake and followed the valley of what is now Caney Branch. Where Grassy Creek enters the lake today, it flows through a narrow canyon eroded in sandstone. The pre-glacial valley just northeast of this canyon is filled with till of the Glasford Formation. An ISGS test hole in the preglacial valley penetrated 100 feet of till without reaching bedrock (county # 24030 on cross section C-C′).

Middle Wolf and Wolf Creeks formerly joined at the south end of Herrin Lake. The combined streams continued northward and joined with Little Wolf Creek. All three streams followed gently sinuous courses that deviate slightly from their present trends. Little Saline Creek joins the South Fork Saline River just north of Lake of Egypt. From this point the pre-glacial South Fork ran straight north, rather than northeast as it does today. Drilling shows that the bedrock floor of the pre-glacial valley is 70 feet lower in elevation than the present valley floor. Sugar Creek currently flows northeast to the South Fork and thus feeds the Ohio River. Before the middle Pleistocene, Sugar Creek likely ran north from Creal Springs along what is now the valley of Cana Creek.

Several creeks in southern Williamson County exhibit meanders entrenched into bedrock. The most obvious example is Sugar Creek northeast of Creal Springs. Short segments of Grassy Creek just below Devil's Kitchen dam, Wolf Creek north and south of Herrin Lake, and the South Fork Saline River just east of Neilson also exhibit incised meanders. In these examples, the creeks are tightly walled in by sandstone and possess floodplains only a few hundred feet wide. Another segment of the South Fork, in Secs. 8, 9, 17, and 18 of T10S, R3E, meanders tightly across a broader floodplain that is walled by sandstone into which large meander loops are incised. In one place the downcutting meanders isolated an "island" of sandstone.

Economic Resources

Coal Resources
Details on coal resources, while significant, are provided in Nelson (2020).

Groundwater
Groundwater resources in Williamson County are relatively limited, and are thus generally not used for public water supply. However, many rural residences, government facilities and commercial facilities utilize groundwater resources from wells, mainly from bedrock aquifers. Creal Springs is the only community that gets its public water supply from wells (from sandstone bedrock). Other towns rely on Crab Orchard Lake and other reservoirs.

Pennsylvanian sandstones are the most promising sources of groundwater. These sandstones are widespread, generally have good permeability, and can sustain output of 30 gallons (114 liters) per minute or more. For instance, the federal penitentiary south of Marion is served by eight wells that obtain groundwater from the Caseyville Formation. Most domestic wells in the county are finished in Pennsylvanian sandstone at depths of 50–300 feet (15–90 m). The Mt. Carmel, Trivoli, Anvil Rock, Palzo, and Murray Bluff sandstones (Nelson et al. 2020), among others, serve as aquifers. Most wells yield 5–20 gallons (19–76 liters) per minute; some produce 30–40 gallons (114–150 liters) per minute. A few wells 400–900 feet (120–270 m) deep yield more than 50 gallons (190 liters) per minute, collecting groundwater from multiple aquifers. Several wells north of Carterville were completed into abandoned mines that yield 200–5,000 gallons (260–

1,900 liters) per minute. This groundwater was not used for human consumption, as the mine water is typical acidic and mineral-laden.

Only a few wells utilize groundwater from aquifers within Quaternary units, such as within sand or gravelly sand of the Pearl Formation (Mascoutah facies or Grigg tongue) or sand and gravel lenses in the Glasford Formation. The water-bearing deposits of the Pearl Formation are found in the Big Muddy River Valley, Crab Orchard Creek Valley, and buried bedrock valley segments; aquifers in parts of these areas appear to be adequate for household use. In many other areas, the Peoria and Roxana Silt, Equality Formation, Teneriffe Silt, Berry Clay Member, Glasford Formation till, and Petersburg Silt units are dominantly fine-grained and do not yield significant groundwater supplies.

Environmental Hazards

Subsidence in Mined-Out-Areas

A significant part of the county was mined underground for coal in the early to middle 20th century (https://isgs.illinois.edu/research/coal/maps/county/williamson). Underground mined-out areas are located primarily in the northern part of the county, immediately north and northeast of the former surface mines. Coal, 6 to 7 feet thick, was mined from the Herrin (No. 6) Coal Member of the Carbondale Formation and was extracted primarily by the room-and-pillar method at depths ranging from less than 100 to more than 600 feet below the surface. Land subsidence in mined-out areas can be a serious potential problem for landowners, developers and construction projects (Bauer 2006). Areas of previous subsidence from underground mining are sometimes detectable with lidar elevation data, with subsidence of ~2 to 3 feet in some areas.

Seismic Hazards

Near-surface, fine sand or coarse silt in the Pearl, Equality or Cahokia Formations is potentially liquefiable where materials are saturated (below the water table) and subjected to strong ground shaking. These features likely formed during past earthquake activity in the New Madrid Seismic Zone or other seismic activity in southern Illinois or southeastern Missouri. Paleo-liquefaction features have been observed within the Big Muddy and Saline River Basins and elsewhere in southern Illinois (Munson et al. 1997). Seismic shaking hazards are also a matter of concern, especially in areas underlain by loose sand, disturbed ground (fill), and soft clay (Bauer 1999). Areas with near-surface Cahokia Formation sand or some areas of fill (disturbed ground) may be especially susceptible to seismic shaking because they are relatively soft and unconsolidated and have low density. These conditions amplify earthquake ground motions.

Mass Wasting

Landslides or slumps are common where streams undercut steep hillsides of thick unconsolidated sediments (Killey et al. 1985). Lithological contacts or discontinuities (such as loess-till contact or sediment-bedrock contact) are typical areas for slides or slumps to initiate. Slumps within glacial materials are common in southern Illinois. Nelson and Weibel (1996) discussed an instance where a landslide endangered a house near Grassy Creek about one mile north of the southern border of Williamson County. The stream undercut a steep slope below the house, enabling water-saturated glacial sediments to slide downslope.

Groundwater Contamination

Surface contaminants pose a potential threat to groundwater supplies in near-surface aquifers that are not overlain by a protective confining (clay-rich and unfractured) deposit, such as till or lake sediment (Berg 2001). The potential for groundwater contamination depends on the thickness and character of fine-grained alluvium, loess, or till deposits that overlie an aquifer, in addition to land use. Because of lateral and three-dimensional groundwater flow, the position of a site in the overall groundwater flow system also needs to be considered. Groundwater in near-surface sand and gravel units in the quadrangle (*e.g.*, Pearl Formation) is most vulnerable to agricultural, surface mining, or industrial contaminants. Deeply buried glacial aquifers, such as the Grigg tongue of the Pearl Formation or bedrock aquifers would have a lower contamination potential than more shallow aquifers if groundwater is protected by a considerable thickness of unfractured, clay-rich till or clayey lake sediments.

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