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Illinois Department of Natural Resources
Illinois State Geological Survey

Quaternary Deposits and History of the Ancient Mississippi River Valley, North-Central Illinois

Fifty-first Midwest Friends of the Pleistocene Field Trip
An ISGS Centennial Field Trip
May 13–15, 2005

E. Donald McKay III, Richard C. Berg, Ardith K. Hansel, Timothy J. Kemmis, and Andrew J. Stumpf

Guidebook 35 2008

ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

ACKNOWLEDGMENTS

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Cover photo: *Andrew J. Stumpf and Ardith K. Hansel studying Quaternary deposits at the Clear Creek Section, N½ NW¼ NE¼ Sec. 19, T31N, R1W, Putnam County, Illinois, Florid 7.5-minute Quadrangle. Photograph by E. Donald McKay.*

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

ISGS Illinois State Geological Survey

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DEDICATION

This field trip was held during he 2005–2006 celebration of the Centennial of the Illinois State Geological Survey. We dedicate this field trip and guidebook to the many ISGS scientists and affiliates who have contributed to the understanding of the Quaternary geology of Illinois by publishing their findings in ISGS reports and maps since the establishment of the ISGS on May 12, 1905.

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INTRODUCTION

During most of Quaternary time, the Mississippi River, which has its modern headwaters more than 800 km (500 mi) north of the field trip area, flowed through central Illinois, draining the central midcontinent region and a substantial portion of the southern margin of several successive continental ice sheets. During the latter half of the Quaternary, continental glaciers entered, overrode, and buried the river valley in central Illinois at least six times. Sediments and soils preserved in those buried valleys contain a complex record of the events that impacted the watershed. Recent geologic mapping of the Middle Illinois River valley and the buried ancient courses of the Mississippi River in north-central Illinois (Fig. 1) has provided an opportunity for us to take a fresh look at the succession of deposits that fill the valley and to obtain insight into the details of the region's rich Quaternary record.

The Mississippi River no longer flows through central Illinois. It was diverted to its present course nearly 20,000 radiocarbon (^{14}C) years ago, during the last of its several encounters with the Lake Michigan glacial lobe, and today the Mississippi forms the western boundary of Illinois more than 50 km (80 mi) west of the field trip area. The present Illinois River (Fig. 2) found its course as the late Wisconsin Episode Lake Michigan Lobe retreated from its terminus and incised deeply into a part of the old valley of the Mississippi River. The modern Illinois River drains much of northeastern Illinois but has a much smaller watershed than did the Ancient Mississippi River.

This field trip examines surface exposures and data from cores that reveal the succession of glacial, proglacial (fluvial, lacustrine, and loessal), and interglacial deposits and paleosols along the Ancient Mississippi River valley. The complex sedimentary record punctuated by significant unconformities will be discussed.

The Illinois River serves as one of the nation's major commercial transportation corridors, linking Chicago on Lake Michigan with the Gulf of Mexico. The field trip traverses portions of Marshall and Putnam Counties along the middle Illinois River north of Peoria, Illinois, in a largely rural area that has major agricultural production, gradual suburban growth, historic coal mining, ongoing aggregate mining, and substantial groundwater resource potential. The impetus for recent geologic mapping in the area came from a need for geologic information to assist the planning and design of a highway upgrade proposed for Illinois Route 29, which parallels the west bank of the Illinois River north of Peoria from Chillicothe to the "big bend" in the river near Hennepin (Fig. 2). Detailed geologic information is particularly important for highway planning in this location because of the presence of environmentally sensitive habitats, including unique wetlands created by seeps and springs along the Illinois River bluff. Geologic mapping by Illinois State Geological Survey (ISGS) staff began in 2001 with significant support provided by the Illinois Department of Transportation (IDOT). New core drilling and field mapping for the IDOT project included mapping at the 1:24,000 scale (1 inch on the map represents 2,000 ft on the ground) and three-dimensional modeling of deposits overlying bedrock for Chillicothe, Lacon, Putnam, and Rome 7.5-minute Quadrangles. Most of the sites on the field trip route were discovered and/or worked in greater detail during that mapping project.

Regional Setting

The middle reach of the Illinois River is set in a large, deep valley ranging in width from less than 3 km (2 mi) to nearly 11 km (7 mi). The valley floor is as much as 90 m (300 ft) below the adjacent upland (Figs. 2 and 3). Several large Wisconsin Episode terraces are as much as 30 m (100 ft) above the normal pool elevation of the Illinois River and typically constitute the most

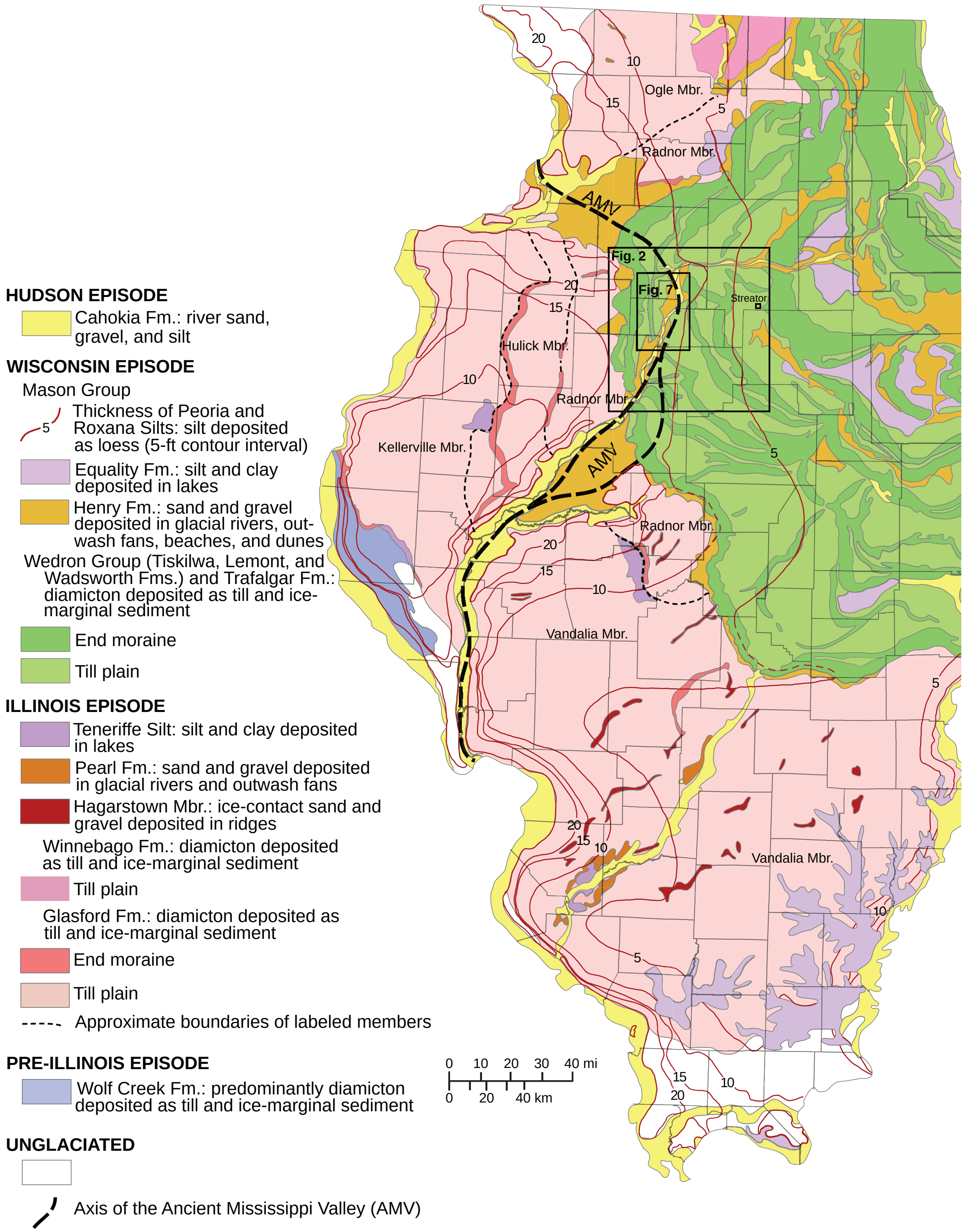

Figure 1 Quaternary deposits of Illinois (Lineback et al.1979a, Hansel and McKay unpublished).

Figure 2 The Illinois River valley (gold) and principal moraines in north-central Illinois. Refer to Figure 1 for outline of area shown. Moraines referred to in the text are shown in green.

extensive parts of the valley floor. The meander belt of the modern Illinois River occupies a narrow portion of the valley that itself crosses the valley from the east side to the west in the mapped area (Fig. 3). The valley is joined by short and steep tributary streams, which drain uplands bordering the valley to the east and west. The present Illinois River is a low-gradient channelized river with extensive, shallow, backwater lakes; a narrow floodplain; and numerous tributary-deposited alluvial fans.

The tributary streams that are deeply incised into the uplands expose Wisconsin and Illinois Episode glacial and fluvial deposits and Paleozoic bedrock that are examined on the trip. The flat

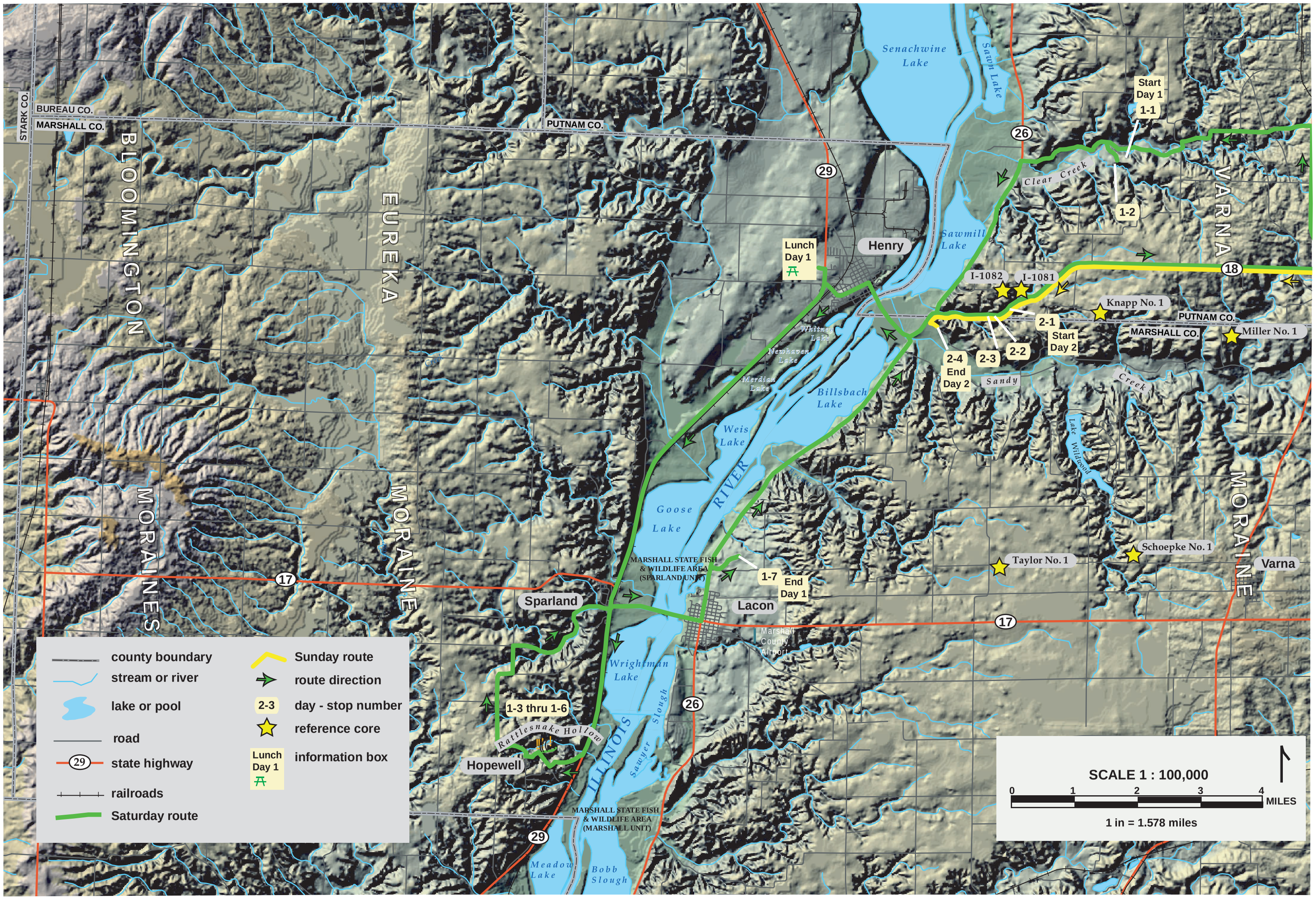

Figure 3 Shaded relief map of the Middle Illinois River valley, showing the field trip route, locations of stops, and reference cores. Map produced by Lisa R. Smith.

to gently rolling uplands adjacent to the valley are crossed by several broad, low, end moraines (Fig. 2) that range in width from less than a kilometer to several kilometers and have relief of 30 m (100 ft) or less. Most moraines mark successive margins of the Wisconsin Episode glacier as the ice front paused during its general northeastward retreat toward the Lake Michigan basin. Some moraines mark significant readvances during that overall retreat.

To minimize confusion related to the many names that are applied to the multiple generations of ancient and modern rivers in the area, the following terminology is used. The Middle Illinois River and the Middle Illinois River valley apply to that reach of the modern Illinois River and its valley between Hennepin and Peoria. Earlier courses of the Mississippi River flowed through this region, and the names Ancient Mississippi River and Ancient Mississippi River valley, respectively, are applied to the ancient river and its valley. The local bedrock valley, which was named the Middle Illinois Bedrock Valley by Horberg (1950), is generally parallel to but much wider than today's Middle Illinois River valley.

Previous Investigations

The Middle Illinois River valley and Ancient Mississippi River valleys were the foci of a number of early glacial stratigraphic studies (Leverett 1895, 1899; Leighton 1926, 1931, 1933; Leighton and Willman 1950). Detailed work by Horberg (1950, 1953) and McComas (1968) in the Middle Illinois River valley summarized the glacial geology and groundwater conditions, focusing on the widespread and productive Sankoty aquifer. Willman (1973) published a summary report and a set of maps at 1:62,500 scale covering the Illinois Waterway (from the confluence of the Des Plaines and Kankakee Rivers to Grafton). The area was also a focus of the Twenty-sixth Midwest Friends of the Pleistocene field trip (Follmer et al. 1979). Recent large-scale geologic mapping in the Peoria area by the authors began in 1996 and has provided insights into the glacial and bedrock geology of the area (Weibel and Stumpf 2001, Stumpf and Weibel 2005, McKay et al. unpublished).

Methods

Samples of Quaternary deposits were collected from 125 surface exposures and from more than 900 m (3,000 ft) of continuous core taken from 16 new boreholes drilled for detailed geologic mapping projects. The following analyses were run.

Grain Size Grain size was determined using a sieve plus hydrometer or pipette analyses. Size fractions determined with hydrometer and sieve are gravel (>2.0 mm), sand (2.0 mm to 62 µm), silt (62 to 4 µm), and clay (<4 µm). Pipette-determined silt fractions are coarse (62 to 32 µm), medium, (32 to 16 µm), fine (16 to 8 µm), and very fine (8 to 4 µm). Clay is reported as <4 µm (hydrometer) for diamicton samples and <2 µm (pipette) for loess and paleosols.

Mineralogy Clay minerals were determined by X-ray diffraction (XRD) analyses of glycolated oriented clay (<2 µm). Calcite and dolomite percentages were determined from XRD peak heights of bulk powder packs.

Radiocarbon Age Determinations Wood fragments and plant debris were collected for radiocarbon (^{14}C) dating via (1) conventional preparation and scintillation counting and (2) accelerated mass spectrometry (AMS) techniques (Table 1). Ages for both are reported in ^{14}C years before present (^{14}C yr B.P.) and in calendric years before present (cal yr B.P.). Ages were calibrated with version 1.4 of the CalPal program (Weninger et al. 2005).

Table 1 Age determinations using conventional radiocarbon dating (^{14}C), accelerated mass spectrometry (AMS), and optically stimulated luminescence (OSL) methods for samples collected from field trip sites and cores taken recently in the vicinity of the Middle Illinois River valley.

Site	Sample	Method	Lab no.	Elevation (ft)	^{14}C yr B.P.	cal yr B.P.	Material dated	Lithology	Stratigraphic unit
Core I1004	126	^{14}C	ISGS-5130	492	23,400 ± 260	28,310 ± 400	conifer wood	diamicton	Delavan Mbr. Tiskilwa Fm.
Core I1081	A	AMS	A-0535	529	20,780 ± 140	24,770 ± 250	terrestrial & aquatic plant debris	silt, calcareous, 5Y3/1	Equality Fm.
Core I1081	B	^{14}C	ISGS-5649	519	21,320 ± 570	25,630 ± 820	terrestrial & aquatic plant debris	calcareous, 5Y2/1 silt loam	Equality Fm.
Core I1081	C	AMS	A-0517	519	21,500 ± 80	25,600 ± 360	terrestrial & aquatic plant debris	silt loam, calcareous, 5Y2/1	Equality Fm.
Core I1081	D1	^{14}C	ISGS-5630	509	21,350 ± 200	25,500 ± 380	terrestrial & aquatic plant debris	silt loam, calcareous, 5Y4/1	Equality Fm.
Core I1081	D2	AMS	A-0518	509	21,650 ± 100	25,840 ± 510	terrestrial & aquatic plant debris	silt loam, calcareous, 5Y4/1	Equality Fm.
Core I1081	E	^{14}C	ISGS-5651	499	24,260 ± 760	29,140 ± 830	terrestrial & aquatic plant debris	silty clay loam, 5Y4/1	Equality Fm.
Stop 1-1	CC-9	^{14}C	ISGS-5268	522	41,010 ± 970	44,540 ± 1,040	conifer wood	silt loam, 10YR5/2 silt loam	Oakland facies
Stop 1-1	CC-2	^{14}C	ISGS-5269	518	>47,600	--	conifer wood	diamicton, 10YR5/2	Oakland facies
Stop 1-1	CC-1	^{14}C	ISGS-5264	511	>49,100	--	charcoal	silty sand, 10YR5/6-5/4	Ashmore Tongue
Stop 1-1	--	OSL	UNL-1203	543	--	96,070 ± 6,060	90- to 150-µm quartz grains	medium sand	Ashmore Tongue
Stop 1-2	--	OSL	UNL-1202	543	--	93,030 ± 8,750	90- to 150-µm quartz grains	sand	unnamed tongue, Equality Fm.
	--	AMS	CAMS-103615	542	48,900 ± 1,500	53,300 ± 2,800	spruce needles; bulrush seeds	clay, silt, & fine sand containing abundant shells & organic material	unnamed tongue, Equality Fm.
	--	AMS	CAMS-103616	542	>54,300	--	spruce needles; bulrush seeds	clay, silt, & fine sand containing abundant shells & organic material	unnamed tongue, Equality Fm.
	F3-1	AMS	AA57002	--	>49,900	--	wood	diamicton	Tiskilwa Fm.
	F3-3	AMS	AA57003	--	31,630 ± 370	35,580 ± 550	wood	diamicton	Tiskilwa Fm.
	F3-5	AMS	AA57004	--	31,380 ± 320	35,340 ± 450	wood	diamicton	Tiskilwa Fm.
	F3-7	AMS	AA57005	--	40,700 ± 1,400	44,400 ± 1,200	wood	diamicton	Tiskilwa Fm.
	F3-9	AMS	AA57006	--	35,010 ± 500	40,030 ± 900	wood	diamicton	Tiskilwa Fm.
	F3-12	AMS	AA57007	--	37,160 ± 660	41,940 ± 460	wood	diamicton	Tiskilwa Fm.
Friday2[3] --	^{14}C	ISGS-536	515	40,720 ± 860	44,300 ± 950		plant macrofossils; wood	clay, silt, & fine sand containing abundant shells & organic material	unnamed tongue, Equality Fm.
Stop 1-7	--	OSL	UNL-1205	~500	(~16,000)[5]	19,450 ± 1,450	90- to 150-µm quartz grains	sand	unit z Mackinaw facies
Stop 2-4	--	OSL	UNL-1206	520	--	118,990 ± 10,300	90- to 150-µm quartz grains	sand	base of unit II Pearl Fm.
Hennepin[4]	--	OSL	UNL-1204	--	(~18,500)[5]	22,100 ± 1,420	90- to 150-µm quartz grains	sand	second outwash unit below land surface Mackinaw facies

[1]Core site SW¼ SW¼ SE¼ Sec. 1, T14N, R9E, Putnam County, Putnam 7.5-minute Quadrangle; sample depth, 38.4 m (126 ft).

[2]Core site 400 m (1,300 ft) northeast of Stop 2-1.

[3]Stream exposure 150 m (500 ft) upstream of Stop 1-2.

[4]Active gravel pit in Illinois River intermediate terrace, NW¼ Sec. 25, T33N, R2W, Putnam County, DePue 7.5-minute Quadrangle.

[5]Approximate age in ^{14}C yr B.P. estimated via backcalculation from OSL-determined cal yrs B.P. using CalPal version 1.4 (Weninger et al. 2005).

Optically Stimulated Luminescence Age Determinations Sample preparation for optically stimulated luminescence (OSL) age determinations (Table 1) was carried out under amber light conditions. Samples were wet-sieved to extract the 90- to 150-µm fraction, and then treated with 1 *N* HCl to remove carbonates. Quartz and feldspar grains were extracted by flotation using a 2.7 g/cm^3 sodium polytungstate solution and then treated for 75 minutes in 48% HF, followed by 30 minutes in 47% HCl. The sample was then resieved, and the <90-µm fraction was discarded to remove residual feldspar grains. The etched quartz grains were mounted on the innermost 2 mm of 1-cm aluminum disks using Silkospray.

Chemical analyses were carried out by Chemex Labs, Inc. (Sparks, Nevada) using a combination of inductively coupled plasma mass spectrometry (ICP-MS) and atomic emission spectrometry (ICP-AES). Dose-rates were calculated using the method of Aitken (1998) and Adamiec and Aitken (1998). The cosmic contribution to the dose-rate was determined using the techniques of Prescott and Hutton (1994).

The OSL analyses were carried out on a Riso Automated OSL Dating System Model TL/OSL-DA-15B/C, equipped with blue and infrared diodes, using the single aliquot regenerative dose (SAR) technique (Murray and Wintle 2000). A 280°C "optical wash" was used after each SAR cycle for the three older samples (Murray and Wintle 2003). A preheat of 240°C for 10 seconds was used, with a cutheat of 160ºC, based upon a preheat plateau test between 180 and 280ºC on Sample UNL1205. A dose recovery test (Murray and Wintle 2003) on Sample UNL1205 recovered 30.98 ± 0.41 Gray (Gy) from an applied dose of 29.81 Gy. Thermal transfer for the same sample was 0.29 ± 0.05 Gy. Examination of the growth curves for the samples showed them to be below saturation. The OSL-determined ages are based upon a minimum of 17 aliquots. Individual aliquots were monitored for insufficient count-rate, poor quality fits (i.e., large error in the equivalent dose, De), poor recycling ratio, strong medium versus fast component, and detectable feldspar. Aliquots deemed unacceptable based on these criteria were discarded from the data set prior to averaging.

OSL Results Optical ages for samples UNL1204 and UNL1205 are within 1-sigma errors. Optical ages for samples UNL1202 and UNL1203 are within 1-sigma errors. The optical age for sample UNL1206 is within 2-sigma errors of the same age. Samples appear well suited for optical dating, with good dose-recovery and low thermal transfer and recuperation. There is no indication of partial bleaching.

Stratigraphic Nomenclature

Major lithostratigraphic and pedostratigraphic units for the glacial and interglacial episodes of the Quaternary Period in Illinois are shown in Figures 4 and 5. Diachronic temporal units, episodes and subepisodes, are used. These units are based on events that begin and end at different times in different places and are interpreted from lithostratigraphic and pedostratigraphic units (Hansel and Johnson 1996, Johnson et al. 1997, Karrow et al. 2000). Because of correlation uncertainties and a paucity of age determinations of the oldest Quaternary deposits, glacial and interglacial episodes that predate the Illinois Episode are referred to collectively as the pre-Illinois Episode. The latest part of this time, based on the Yarmouth Geosol, is referred to as the Yarmouth Episode.

The lithostratigraphic classification and terminology used herein follow those of Hansel and Johnson (1996) for the Wisconsin Episode and Willman and Frye (1970) for older deposits. Stratigraphic units that occur in the Ancient Mississippi River valley in central Illinois are presented and discussed in detail in Appendix A and are shown here in table form (Fig. 5) and schematic cross section (Fig. 6).

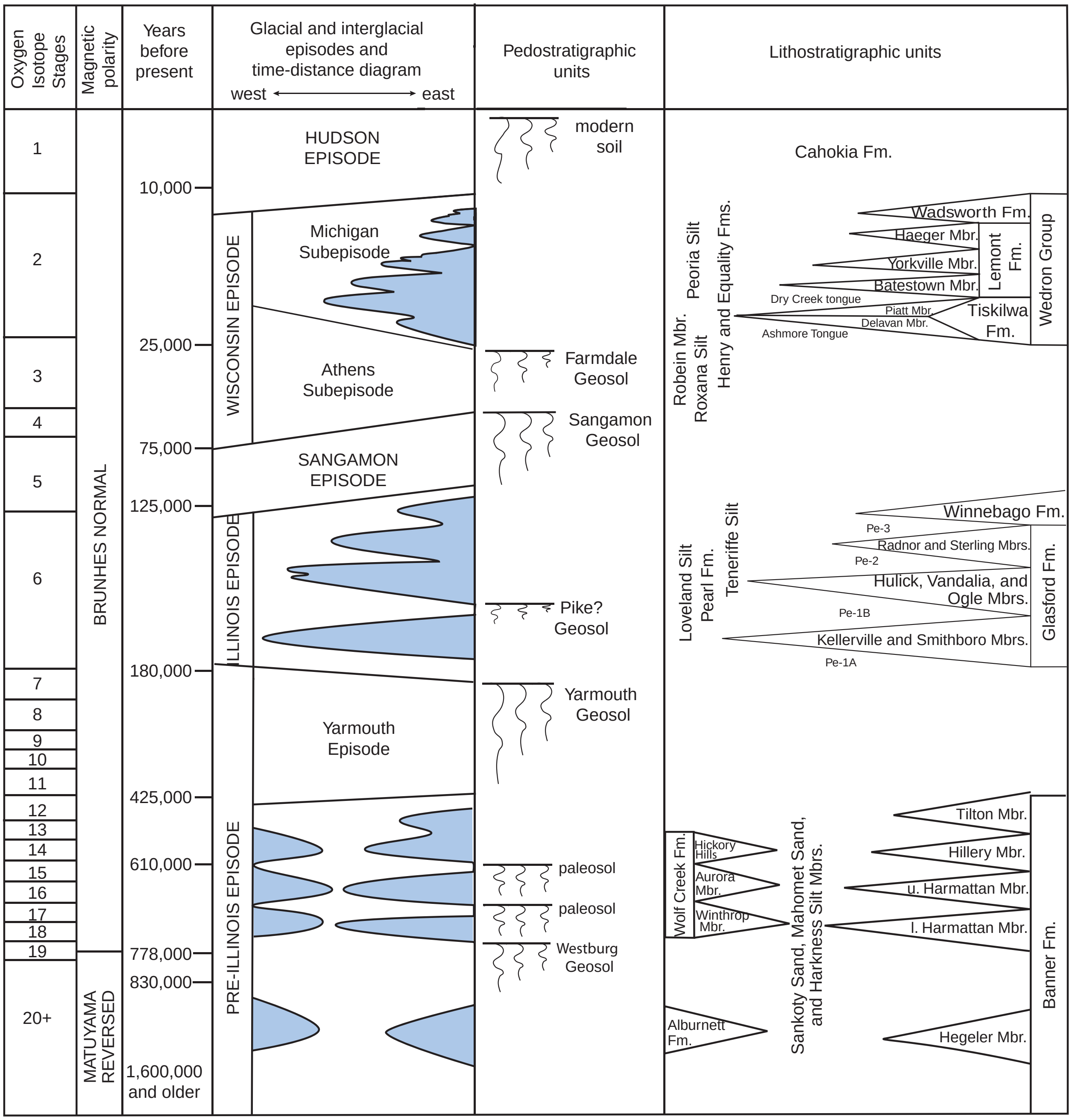

Figure 4 Timetable of Quaternary glacial and interglacial events and primary lithostratigraphic and pedostratigraphic units upon which they are based in Illinois (Hansel and McKay unpublished). Pe-1A, Pe-1B, Pe-2, and Pe-3 are informal tongues of the Pearl Formation recognized in this study in the Ancient Mississippi River valley of north-central Illinois. Note that glacial deposits of the Wolf Creek and Alburnett Formations were deposited by glaciers that entered Illinois from the northwest, whereas those of the Wedron, Glasford, and Banner Formations were deposited by glaciers from the north and northeast. Years before present are shown on a nonlinear axis.

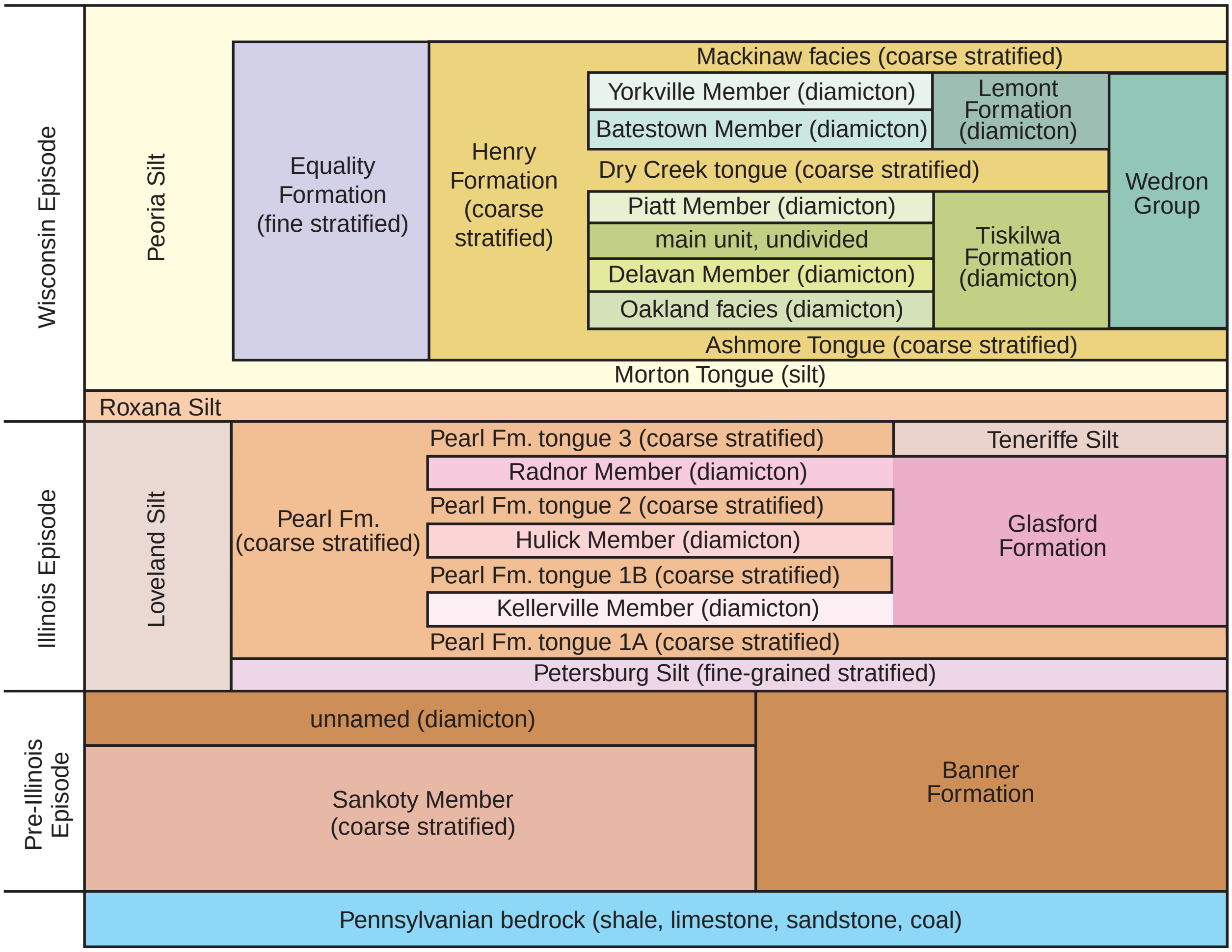

Figure 5 Quaternary lithostratigraphy of the Middle Illinois River valley region in north-central Illinois. The principal lithology of each lithostratigraphic unit is in parentheses.

Differentiation of Diamictons

Reliable differentiation of lithologically similar diamictons is key to correlation of diamictons and the units with which they intertongue. As previously noted, diamictons deposited in Illinois by glacial lobes from different spreading centers differ significantly in mineralogy. All of the Ancient Mississippi River valley diamictons sampled to date appear, however, to have been deposited by the Lake Michigan glacial lobe. Therefore, the field differences between the several gray diamictons in the area are subtle. The reddish brown color of the diamicton of the main body of the Wisconsin Episode Tiskilwa Formation makes it a distinctive unit, but the upper and lower diamicton members and facies of that formation are gray and resemble the Illinois Episode diamictons. Grain size and mineralogy have been used successfully for many years to characterize units and guide correlations of diamictons, and both parameters are helpful for correlation in the Ancient Mississippi River valley area. Valuable, too, are the marker beds (Wisconsin Episode loesses and the Sangamon Geosol) present in the Ancient Mississippi River valley (Figs. 5 and 6).

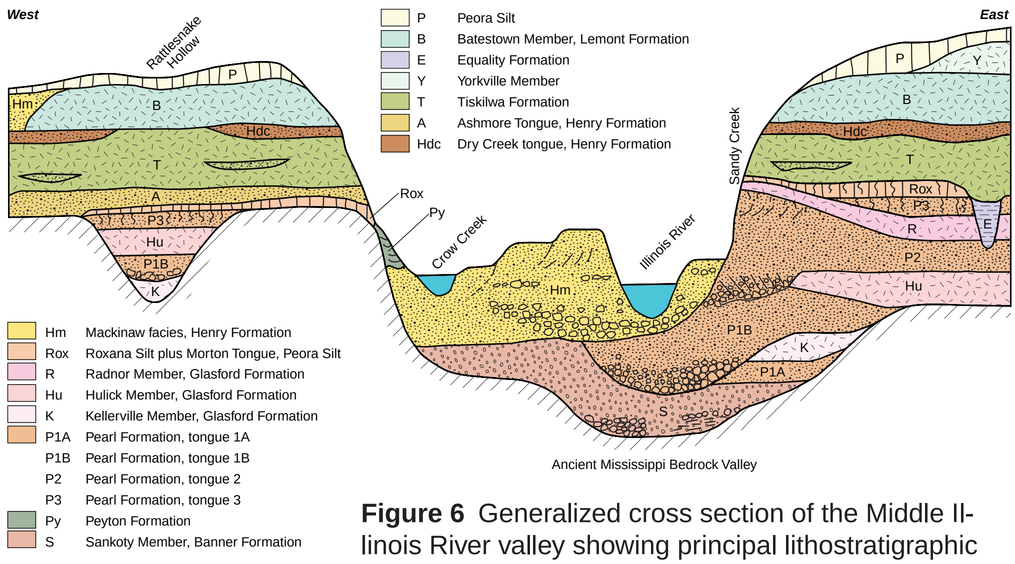

Figure 6 Generalized cross section of the Middle Illinois River valley showing principal lithostratigraphic units present at the approximate latitude of Henry, in Marshall County, Illinois.

QUATERNARY HISTORY OF THE ANCIENT MISSISSIPPI VALLEY

Heritage of Large Rivers and Glaciers

The Ancient Mississippi River valley in central Illinois has a long and complex history. The origin and location of the river in preglacial times are poorly known, but better known are a number of later events, especially several glacial events, that resulted in major changes in the valley's width, depth, and location.

During the past several hundred thousand years, continental glaciers have repeatedly overriden the Ancient Mississippi River valley and blocked its river. Each of these events left sedimentary evidence that records and helps us piece together that history of glacier-river interaction. Following all but the last of its earlier glacial encounters, the river was not permanently diverted but returned to its central Illinois course. The cumulative result is the thick, complex, and varied sedimentary succession that fills the Middle Illinois Bedrock Valley (Fig. 7) and includes one of the most prolific and complex aquifers in the state.

Each glacial encounter with the Ancient Mississippi River produced a similar succession of events and deposits. As advancing glaciers entered the river's headwaters, sediment-laden meltwater entered the watershed and aggraded its valley surface with sand and gravel outwash. Tributaries to the main valley were ponded by the higher water and floodplain of the main-stem valley, and lakes formed in the tributaries. Barren outwash surfaces in the main valley were periodically exposed to wind and winnowed of sand and silt, forming dunes and transporting silt as loess onto adjacent uplands. With continued advance, glaciers reached the valley, pushed the river to the west side of the valley, and eventually crossed it, blocking the river and creating a lake upstream of the blockage. Glacial diamicton was then deposited on the proglacial valley fill, sometimes burying detached blocks of glacial ice and nearly filling the valley with drift. After each glacier reached its terminus west of the valley and retreated back eastward, meltwater incised, in most places, a new river course near the course of the former one. Drainage from the retreating glacier margin locally eroded deeply into the newly exposed deposits but elsewhere left sedimentary evidence of former courses. With further glacial retreat, large volumes of meltwater periodically flooded the river, further cutting and filling the new valley.

The sedimentary record in the Ancient Mississippi River valley of central Illinois indicates that this pattern of glacier advance, valley aggradation, glacier overriding, river blockage, valley burial, glacier retreat, valley incision, and episodic flooding occured at least six times, once during the pre-Illinois Episode, three times during the Illinois Episode, and twice during the Wisconsin Episode.

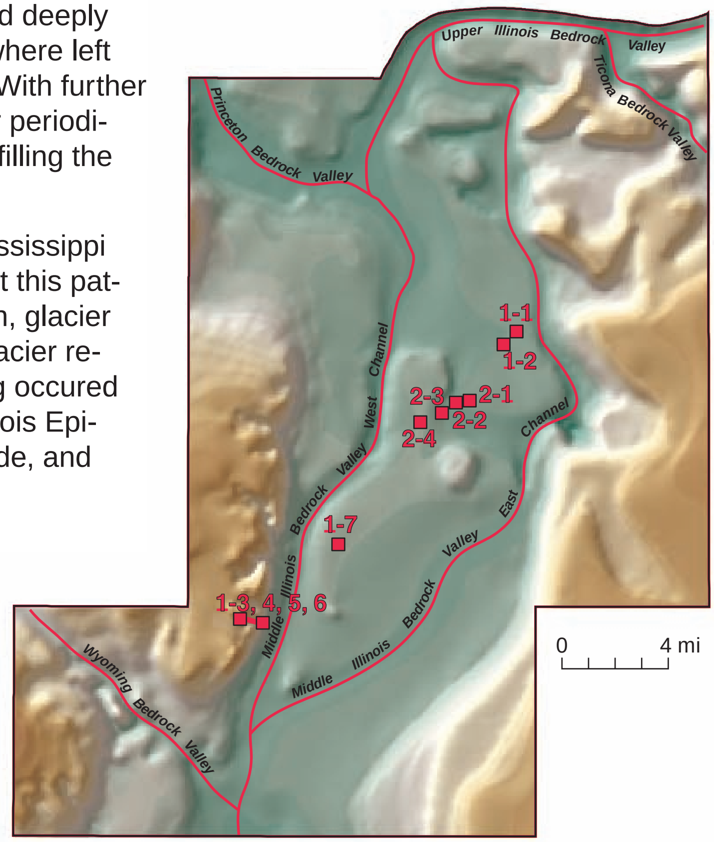

Figure 7 Bedrock topography and bedrock valleys in the Middle Illinois River valley area of north-central Illinois between Hennepin and Chillicothe from a bedrock surface model. Field trip stop numbers are shown in red. Location of the area shown is outlined on Figure 1.

Because this pattern of events was repeated, the glacial and fluvial deposits preserved in the Ancient Mississippi River valley are complicated. Several challenges to reconstructing the history of such a succession exist. Deep exposures containing multiple units are few. Drilling and coring are required to sample the lower half of the valley-fill succession, and recovery of coarse deposits via wireline coring is often poor. Shear-wave seismic reflection techniques support interpretation of contacts between units with greatly contrasting lithologies, principally with the bedrock surface and the uppermost thick sand body/till contact. Seismic reflection does not aid correlation within complex multiple till and interbedded sand successions. Evidence from the earliest valley fill is scant, is found only in cores, and has been largely eroded from the record. Age determination techniques such as OSL, although promising, have not yet been widely applied to pre-Wisconsin sediments in the area.

Despite these challenges, we can use the new data to build on previous work, notably by Horberg (1950, 1953), Horberg et al. (1950), McComas (1968, 1969), and Willman and Frye (1970). Subsurface complexity, however, is so great, available subsurface data from reflection seismic lines so ambiguous, and new cored drill holes so expensive and sparse, that the tracing of all but major lithostratigraphic boundaries in the subsurface is severely hampered. Thus, subsurface mapping of the details at large scale (1:24,000) is very difficult.

Following is a discussion of available lithostratigraphic, pedostratigraphic, and sedimentologic evidence and its implications for glacial and fluvial history of the Ancient Mississippi River valley.

Preglacial Record

No sediment is known to exist in central Illinois that might record the first million or so years of the Quaternary Period (Fig. 4). Thus, the present understanding of the early Quaternary history of the region is based largely upon the morphology of the preglacial bedrock surface (Fig. 8a) interpreted from water-well and test drilling records. Leverett (1899), using the scant subsurface data available to him at the time, suggested that the preglacial Mississippi River flowed southeastward across northwestern Illinois, joining the preglacial Fox River and turning south near Hennepin to proceed along the course of the Middle Illinois River valley. Horberg (1950) used an extensive collection of well records to map the bedrock surface of Illinois and the course of the Ancient Mississippi River valley and other bedrock valleys in detail.

The bedrock surface in the Middle Illinois River valley area (Fig. 7) includes uplands capped with Pennsylvanian limestone, gently rolling shale slopes, and the deep, wide Ancient Mississippi River valley and its several large tributary valleys cut down to Mississippian limestone at their deepest points (Horberg 1950, Weibel et al. unpublished). Also exposed at the bedrock surface are sandstone beds and several coal seams.

To date, all deposits overlying the Paleozoic bedrock in north-central Illinois have been found to contain erratics and are considered Quaternary in age. For classification purposes, therefore, the oldest deposits are considered part of the pre-Illinois Episode.

Pre-Illinois Episode

Pre-Illinois Episode deposits are generally thin and have been sampled only in the subsurface. Where old sand and gravel deposits are overlain by younger deposits of similar lithology, age is very uncertain. No absolute age determinations are available locally for pre-Illinois Episode sediments, but regional evidence of dated pre-Illinois Episode deposits in Illinois, Iowa, Missouri, Nebraska, and Wisconsin are helpful in reconstructing the history.

The Ancient Mississippi River valley lies at the juncture between northwestern-derived (Keewatin) and northeastern-derived (Labrador) pre-Illinois Episode glacial advances (Fig. 8b). The southern limit of pre-Illinois Episode glacial deposits occurs far south (320 km [200 mi]) of the Middle Illinois River valley in Illinois. Earlier studies postulated that the early Middle Illinois Bedrock Valley developed as a consequence of pre-Illinois Episode (Kansan and Nebraskan) glaciations that advanced into Illinois from the northwest and northeast (Horberg 1950, Willman and Frye 1970). It was thought that these early glaciers neared, but did not override, the Ancient Mississippi River valley and diverted western drainage into central Illinois (Fig. 8b). Reversed paleomagnetic measurements from sediments in tributaries to the upper Mississippi in Wisconsin suggest that the river north of Illinois was deeply entrenched prior to 790,000 years ago and perhaps as much as 2.1 million years ago (Baker et al. 1998). Questions remain, however. Was the upper Mississippi connected with the Ancient Mississippi River of central Illinois at that early time? When was the Middle Illinois Bedrock Valley first deeply incised? Was the deepest incision preglacial, pre-Illinoian, or later?

Pre-Illinois Episode glacial deposits are widespread both to the west and east of the Ancient Mississippi River valley (Figs. 1 and 8b). West of the Ancient Mississippi River valley, deposits were by ice from a northwestern (Keewatin) spreading center. In western Illinois, these deposits have mineralogical compositions dominated by distinctively western sources, notably smectite-rich Cretaceous rock sources, and are correlated with the Wolf Creek and Alburnett Formations of Iowa (Hallberg and Baker 1980, Wickham 1979) (Fig. 4). The deposits contain abundant expandable clay minerals and little carbonate, like the bedrock and old diamictons of central Iowa.

Paleomagnetic data from western Illinois and Iowa suggest that the older of these units (Alburnett Formaiton) predates the Brunhes-Matuyama geomagnetic reversal occurring at about 778,000 years ago (Hallberg 1986, Miller et al. 1994). Recent age determinations based on inventories of cosmic-ray produced aluminum and beryllium radionuclides (^{26}Al and ^{10}Be) in intercalated paleosols and tills at a site 300 km (200 mi) southwest of the field trip area in Missouri suggest that the western-source tills there are older than 1.6 to 2.4 million years (Balco et al. 2005). These results indicate that a glacial lobe from the Keewatin spreading center was extensive very early in the Quaternary or, indeed, before the Quaternary. If these early glaciers reached a latitude just to the north of St. Louis, they likely also entered western Illinois and influenced early Mississippi River drainage. We have not found deposits with mineralogies of the Wolf Creek and Alburnett Formations in the Middle Illinois River valley area.

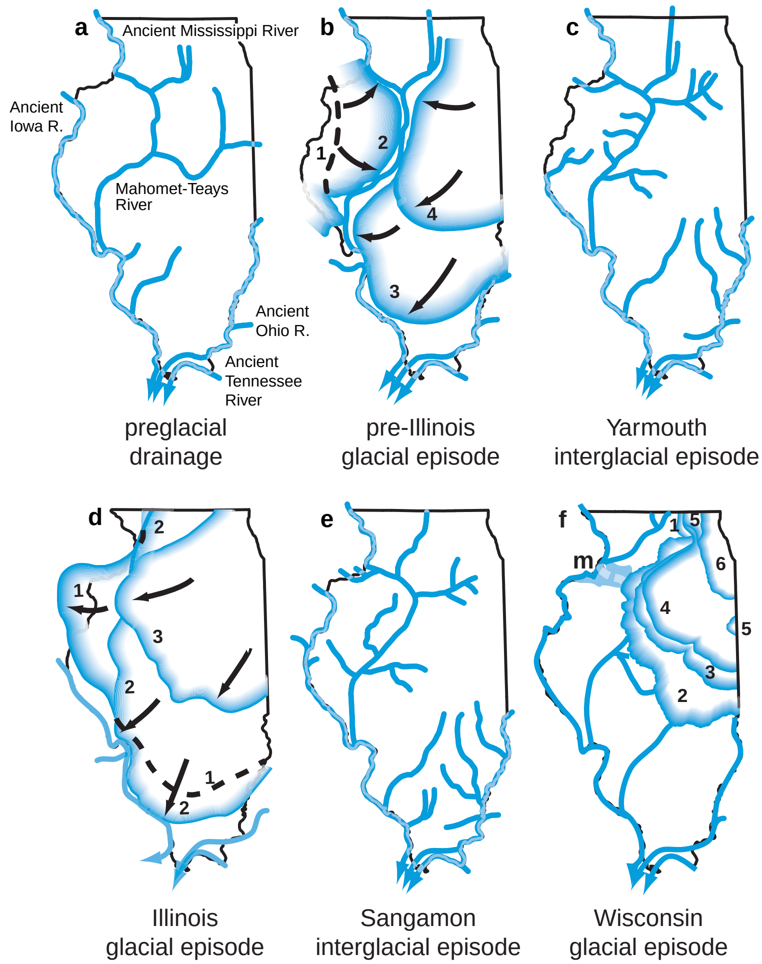

Figure 8 Maps showing Quaternary drainage history and inferred maximum ice-margin positions in Illinois during (a) preglacial, (b) pre-Illinois, (c) Yarmouth, (d) Illinois, (e) Sangamon, and (f) Wisconsin Episodes. Numbers indicate the sequence of ice-margin positions (Hansel and McKay unpublished). m, Wisconsin Episode Glacial Lake Milan.

East of the Ancient Mississippi River valley, pre-Illinois Episode glacial sediments are also widespread. These deposits have mineralogical compositions that differ markedly from western-source deposits. Glacial tills rich in illite, calcite, and dolomite (Johnson 1964, 1986; Johnson et al. 1971, 1972; Kempton et al. 1991) were deposited by glaciers flowing from the northeastern (Labrador) glacial spreading center via the early Lake Michigan and Huron-Erie lobes. These deposits are included in the Banner Formation in Illinois (Willman and Frye 1970) (Fig. 4). The mineralogy of some of these deposits is difficult to distinguish from that of the Illinois Episode deposits, which also had a northeastern Lake Michigan Lobe source (Fig. 8b).

Gray, illite-rich, dolomitic, loam diamicton, suspected of being pre-Illinois Episode tills, has been found recently in the deep subsurface in four new cores in the field trip area. The clay mineralogy and texture of these tills are similar to the Lake Erie Lobe Kansan till described by Johnson (1964) from areas southeast of the field trip but also resemble later Illinois Episode tills (Hulick Member). These deposits lie near the bottom of the Ancient Mississippi River valley at elevations below about 122 m (400 ft) and rest upon bedrock or thin outwash. Furher research is needed to evaluate the correlation of these units.

Yarmouth Episod

The Yarmouth Episode was an extraordinarily long interglacial stage in Illinois that is represented by a very well-developed paleosol, the Yarmouth Geosol in western and southern Illinois, where it is developed in pre-Illinois Episode drift (Figs. 4 and 8c). Deep weathering of the Yarmouth solum is more than twice the thickness of the Sangamon Geosol in the same area (Willman and Frye 1970). Grimley et al. (2003) have recently suggested that the time required for Yarmouth Geosol formation was more than three times the 50,000 years estimated for Sangamon Geosol formation. An intact profile of the Yarmouth Geosol in central Illinois should be a deeply weathered and distinctive feature; however, neither intact Yarmouth paleosol profiles nor evidence of erosively truncated weathering profiles that can be attributed to weathering during the Yarmouth Episode have been found in the study area. Widespread erosion during the Illinois and later episodes, for which there is abundant evidence, apparently removed the ancient soil virtually everywhere.

The Ancient Mississippi River is thought to have flowed through central Illinois during the Yarmouth Episode, and some of the river deposits (Sankoty Sand Member) previously interpreted as pre-Illinois Episode outwash may date in part to the Yarmouth.

Illinois Episode

A deep Ancient Mississippi River valley existed when the first Illinois Episode glacier from the northeast (Lake Michigan Lobe) reached the area, and the valley was overridden during that and each of two later Illinois Episode glacial advances. Limits of these three advances are 150, 80, and 30 km (95, 50, and 20 mi) west of the valley (Figs. 1, 4, and 8d). The earliest of these advances reached farthest west, and the youngest was least extensive. Diamicton of the oldest advance (Kellerville Member) overlies pre-Illinois Episode till and the Yarmouth Geosol in eastern Iowa (Wickham 1979, Hallberg et al. 1980, Hallberg 1986). This and later well-documented glacial advances deposited diamictons composed of debris with Lake Michigan Lobe compositional affinities (i.e., dolomite content greater than calcite), illite content greater than expandables, and lobe-specific erratics, such as a distinctive jasper-rich conglomerate. Our research in the Middle Illinois River valley area indicates that significant thicknesses of fluvial deposits occur between the successive Illinois Episode till units in the Ancient Mississippi River valley, which confirms for the first time that retreats and readvances occurred across the valley in this region during the Illinois Episode. Earlier work (Willman and Frye 1970, Lineback 1979b) has cited evidence of soil development (Pike Geosol) on the oldest diamicton as being indicative of a significant hiatus between early and middle Illinois Episode advances (Kellerville and Hulick Memebers), but evidence of weathering on the Kellerville Member has not been found in this study. The ages of the retreats and readvances remain unknown, but are thought to be limited to Oxygen Isotope Stage (OIS) 6 between about 180,000 and about 130,000 years B.P. The sole OSL age determination on Illinois Episode outwash was from beneath the upper diamicton (Radnor Member) and yielded an age of about 119,000 cal yr B.P. (Sample UNL-1206) (Table 1).

Following each Illinois Episode retreat, the Ancient Mississippi River reoccupied its partially filled valley (although it did not everywhere follow the same course), downcut into the deposits in its previous courses, incised its main stem, developed new tributaries, built terraces and levees, and flooded slackwater lakes. With each incision, the river eroded large parts of the older record and left remnants of former valley fills. If the valley was a significant loess source during the Illinois Episode, little evidence was found in the field trip area. The only Illinois Episode loess found in the area to date overlies the youngest Illinois Episode till (Radnor Member). Significant incision and thick Illinois Episode outwash and lacustrine sediments that postdate the Radnor Member suggest that the latest Illinois Episode glacial events upstream in the Ancient Mississippi River valley, perhaps including northeastern Illinois, may have continued to impact the valley in central Illinois for some time.

Sangamon Episode

At the end of the Illinois Episode, the Ancient Mississippi River valley flowed through central Illinois (Fig. 8e), and the valley and adjacent land resembled the modern landscape. The main valley was deep and was flanked by till plain uplands cut by deeply incised tributaries. During the Sangamon Episode, the Ancient Mississippi River flowed at a relatively low elevation (<143 m [470 ft]), which appears to be typical of the river during interglacial times. The adjacent uplands were 30 to 45 m (100 to 150 ft) higher than the interglacial floodplain but 15 to 30 m (50 to 100 ft) lower than the modern uplands. Preserved on that Sangamon Episode landscape are weathering profiles of the Sangamon Geosol (Figs. 4 and 6). Upland soils developed in thin loess and till are common, but also preserved are soils developed in fluvial sediments, mainly in former tributaries to the Ancient Mississippi River valley. To date, few Sangamon Episode main-stem alluvial deposits have been identified, and only one sample has been dated via the OSL method. It is likely that Wisconsin Episode meltwater deeply eroded Sangamon Episode valley deposits and soils along the main stem of the Ancient Mississippi River valley, but additional OSL age determinations are needed.

Wisconsin Episode

The record of events of the early Wisconsin Episode (Fig. 4) prior to about 55,000 ^{14}C yr B.P. in central Illinois is contained in thin sediments in the upper part of the profile of the Sangamon Geosol and in deposits of a few lakes and bogs that have been sampled for pollen and fossils (Curry and Baker 2000). About 55,000 yr B.P. (Dorale et al. 1998), an early Wisconsin glacier entered the headwaters of the Ancient Mississippi River watershed north of Illinois, and the Ancient Mississippi River valley in central Illinois began to carry significant amounts of fresh outwash. Loess (Roxana Silt) deposition began about that time on adjacent uplands and continued with only minor cessations for nearly 25,000 years. Deposition paused briefly between about 28,000 and 24,500 ^{14}C yr B.P., and during this time a weak soil (Farmdale Geosol) formed in the upper part of that first Wisconsin loess. With the advance of the glacier into the headwaters of the Ancient Mississippi River valley about 24,500 ^{14}C yr B.P., outwash transport resumed along the Ancient Mississippi River (McKay 1979), and deposition of late Wisconsin Episode loess (Peoria Silt) began. Shortly thereafter, a shift toward highly dolomitic loess marked the introduction of dolomitic outwash from the Lake Michigan and/or Green Bay Lobes into the watershed.

For the next 3,000 or 4,000 years, the advancing Lake Michigan glacier margin moved southwestward across northeastern Illinois, reaching the Ancient Mississippi River valley about 20,350 ± 85 ^{14}C yr B.P. (Curry 1998). During this advance to the Bloomington Morainic System, the Tiskilwa Formation, which includes distinctive reddish brown till, was deposited. Before reaching its Wisconsin Episode limit, the glacier blocked Mississippi River drainage and formed Glacial Lake Milan in the valley upstream of the blockage (Figs 1 and 8f). High water in the lake spilled over a divide at Rock Island, and the flow of the Ancient Mississippi River was diverted into the present course of the Mississippi. As the Lake Michigan Lobe retreated from its terminal moraine (Fig. 2), the Mississippi did not breach the moraine, and the river diversion was complete. Meanwhile, the Ancient Mississippi River valley in the field trip area had been nearly filled with glacial and fluvial deposits left by the Wisconsin Episode advance.

A long period of retreat of the glacial margin lasting several thousand years and moving northeastward toward the Lake Michigan Basin was characterized by numerous still stands, readvances, and moraine building. The Eureka Moraine, west of the field trip area, marks a significant readvance and is composed of olive-brown to gray, loamy diamicton (Batestown Member) that is distinctively different from the reddish brown Tiskilwa Formation it overlies. In the eastern part of the field trip area, the Varna Moraine marks another readvance and is approximately the western extent of olive-brown to gray, silty clay loam diamicton (Yorkville Member). As the Wisconsin glacier retreated east of these moraines, meltwater from the Lake Michigan Lobe and, later, also from the Saginaw and Erie Lobes, followed a low area on the land surface above the buried Ancient Mississippi River valley, incised, and widened the Middle Illinois River valley. Late in the glacial retreat toward Lake Michigan, large volumes of meltwater entered the headwaters of the upper Illinois River, Kankakee River, and Fox River valleys, creating periodic torrents that are thought to have had major impacts on the geomorphology of the postglacial valley. It has been suggested that a single particularly massive release of water may have incised and widened the Illinois River valley, carving several of the prominent terraces and resulting in much of the valley's present geomorphology (Willman and Frye 1970, Hajic 1990).

Hudson Episode (Recent)

The postglacial Illinois River inherited an oversized, meltwater-deepened valley. Compared with its glacier-fed ancestors, the low-gradient modern river in its relatively small watershed (compared with the much larger pre-diversion Ancient Mississippi watershed) has little power to modify its valley. Throughout the Hudson Episode, the modern channel has migrated within a narrow meander belt, creating small-scale bars, natural levees, and backwater lakes. It gradually has blanketed the lowest-level outwash terrace with overbank silt and clay. Today, tributaries deliver more sediment to the main stem than it can remove, depositing large alluvial fans where tributaries enter the main valley.

Ancient Mississippi Valley History

A summary of the history of the Ancient Mississippi River valley alluvial fill (Fig. 9) in the area between Hennepin north of the field trip area and Chillicothe to the south has been reconstructed from the new field observations, cores, seismic surveys, and age determinations presented in this report. Key to piecing together

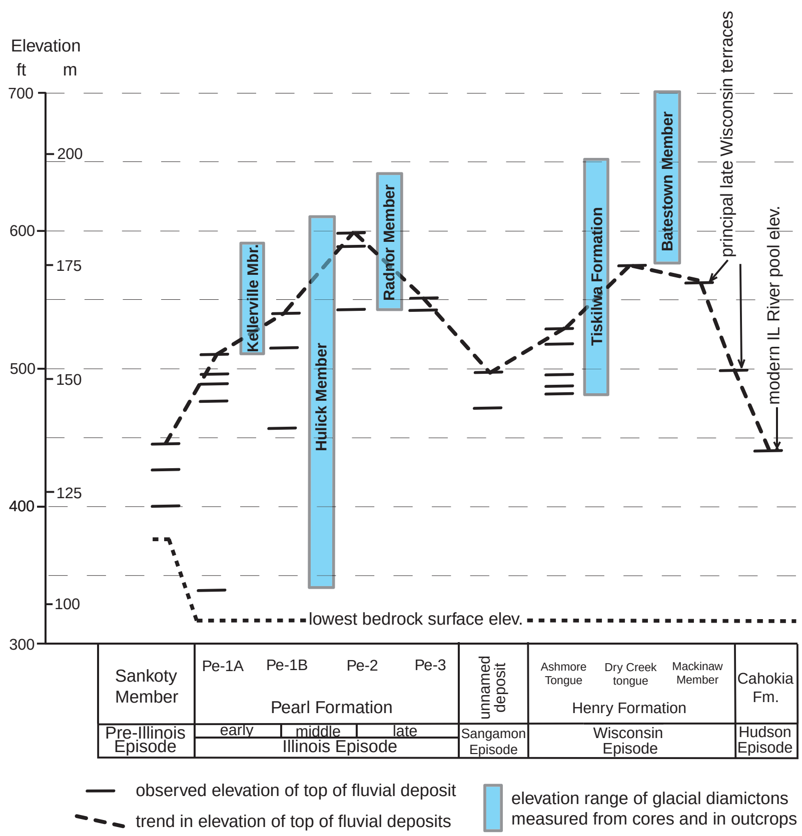

Figure 9 History of the changes in the elevation of the surface of fluvial deposits and bedrock in the Ancient Mississippi River and Middle Illinois River valleys in north-central Illinois during the Qua-

this history is the stratigraphic framework of the area developed by Willman and Frye (1970) and refined by Hansel and Johnson (1996). Within this framework, the relative ages of fluvial units were determined largely from their position with respect to the succession of well-characterized glacial diamictons, marker beds, and paleosols with which they intertongue.

Prior models for valley filling in the Ancient Mississippi River valley area were based on stratigraphic frameworks and conceptual models of fluvial system response available at the time. A common theme was that interglacial episodes (Afton, Yarmouth, Sangamon, and Hudson) were times of river incision and that glacial episodes were times of significant filling (e.g., Horberg 1953). Our new data, particularly those from drilling, reveal stratigraphic relationships that allow revision of relative ages for fluvial-fill units and allow refinement of the geomorphic model of fluvial system response in the Ancient Mississippi River valley. The few available absolute ages for deposits pre-Wisconsin Episode, however, leave significant room for further refinement.

The principal changes in interpretation of the record in the Ancient Mississippi River valley are derived from the following observations and conclusions: (1) pre-Illinois Episode till is absent from most (perhaps all) of the Middle Illinois Bedrock Valley; (2) till previously considered Kansan dates to the Illinois Episode; (3) multiple Illinois Episode tills are interbedded with the thickest fluvial fill; (4) during glacial times, significant incision, scour, and aggradation occurred in the valley; and (5) during interglacial intervals, the valley was characterized by stability.

The Sankoty Sand was originally described as having a distinctive lithology of typically reddish, quartz-rich, well-rounded medium to coarse sand that is atypical of other unconsolidated deposits or bedrock in Illinois (see Appendix A). Sankoty Sand was thought to be the oldest valley-fill deposit in the Ancient Mississippi River valley and was considered to be pre-Nebraskan or pre-Kansan in age (Horberg et al. 1950, Horberg 1953). Willman and Frye (1970) continued use of the term Sankoty Sand and made the unit a member of the Banner Formation.

Our data show that the Sankoty unit, which was widely mapped along the course of the Ancient Mississippi River valley by Horberg (1953) and McComas (1969), contains many beds that differ significantly from the "distinctive" lithology. The lithology of the sand and gravel unit that was mapped as Sankoty in the Ancient Mississippi River valley is quite complex. The distinctive Sankoty-like lithology occurs not only at the base of the succession but also interbedded with yellowish brown, dolomite-rich, Illinois and Wisconsin Episode sand and gravel deposits. Reworking of the older Sankoty-type deposits locally might explain some of the occurrence of Sankoty-type lithologies in younger deposits, but we consider it more likely that the Ancient Mississippi River repeatedly carried Sankoty-type lithologies from source areas upstream of Illinois.

We have restricted our usage of the term Sankoty Sand Member to the reddish sand and gravel deposits deep in the Ancient Mississippi River valley below the lowest Illinois Episode diamicton (Kellerville Member). These deposits occur mostly below an elevation of about 134 m (440 ft) (Fig. 9).

Cores collected recently show that the sand underlying the Kellerville Member diamicton is reddish, but sand that underlies possible pre-Illinois episode diamicton in the area is not red, which raises significant questions about the definition, composition, and correlation of the Sankoty Sand Member.

We conclude that the Sankoty unit, as originally used, in the Middle Illinois Bedrock Valley is a composite of several sand and gravel units. The Sankoty includes lower beds that most closely resemble the originally described distinctive lithology as well as thick upper units, some of which match, but many of which differ markedly from the initial concept of the unit's lithology. Across large areas, these multiple gravel units rest gravel-on-gravel and are practically insepa-rable. Deep core drilling has, however, allowed sampling and identification of the diamictons that intervene stratigraphically in the sand and gravel succession and provided a means for its stratigraphic classification. Although the absolute age of the Sankoty Sand Member remains uncertain, its stratigraphic position beneath Illinois Episode tills in the valley, its composition (low carbonate content and red staining), and its elevation (low in the valley) suggest that it formed, at least in part, during an early interglacial episode—the Yarmouth Episode—at a time when the Ancient Mississippi River was deeply incised. Low-carbonate and reddish sediments and rock occur widely in the upper Mississippi River watershed (Curry and Grimley 2006) but are rarer in Illinois, which suggests the upper Mississippi watershed was the source area for the Sankoty unit along the Ancient Mississippi River valley in central Illinois. The low elevation of the Sankoty in the deep parts of the Ancient Mississippi River valley places the unit in a valley position con-sistent with the low elevations of later interglacial deposits (i.e., Sangamon and Hudson Episode sediments), further substantiating its interpretation as an interglacial deposit (Fig. 9).

Cores from near the eastern margin of the Middle Illinois Bedrock Valley indicate that the An-cient Mississippi River valley's alluvial surface aggraded as the earliest Illinois Episode glacier advanced into central Illinois. Early Illinois Episode sand (tongue Pe-1A of the Pearl Formation) overlies the Sankoty Sand Member and has an uppermost surface elevation of 155 m (510 ft). An example is core Schoepke No. 1 (location shown in Fig. 3), where the deposit is 30 m (100 ft) thick and is buried by early Illinois Episode diamicton (Kellerville Member).

During the retreat phases of the first two Illinois Episode glacial advances in central Illinois, the Illinois glacier margin retreated to an unknown position east of the Ancient Mississippi River val-ley. Meltwater cut a new valley that, upon readvance, aggraded to an elevation higher than that attained during the previous retreat and readvance (Fig. 9). This succession of advance events culminated with a high-level aggradation to an elevation of 183 m (600 ft) that was buried by the late Illinois Episode diamicton (Radnor Member). This surface is the highest aggradation level in the Ancient Mississippi River valley in north-central Illinois.

Subsurface data suggest that the repeated Illinois Episode incisions cut deeply into older Illinois Episode deposits and that the Illinois Episode glacier remained east of the Ancient Mississippi River valley long enough during each retreat for the incision and aggradation cycle to occur. The retreats appear to have been relatively brief. No paleosol evidence has been found in the field trip area to support interpretations that an intra-Illinois Episode retreat lasted sufficiently long for a soil (Pike Geosol) to form (Willman and Frye 1970) or that the warm episode be classified as an interglacial interval (Lineback 1979b).

The latest Illinois Episode glacial events in northeastern Illinois deposited the Winnebago For-mation (Fig. 4), which postdates the Radnor equivalent (Sterling Member) in northeastern Illinois (Berg et al. 1985, Johnson 1986). There is evidence in the Knapp No.1 core (location shown on Fig. 3) that suggests that a significant incision and aggradation cycle occurred in the Ancient Mississippi River valley after Radnor deposition. That cycle may relate to glacial events in the upper watershed during deposition of the upper part of the Winnebago Formation. Upon final retreat of the Illinois Episode glacier, the Ancient Mississippi River incised its valley, establishing a fluvial surface at or below 151 m [495 ft].

During the Sangamon Episode, the elevation of the Ancient Mississippi River floodplain was below 151 m (495 ft). Few Sangamon Episode deposits remain in the main stem of the river where they were largely reworked or eroded during the Wisconsin Episode. Measurements that limit the elevation of the Sangamon Episode fluvial surface shown in Figure 9 come from developed Sangamon Geosols and fluvial deposits, which occur in tributaries to the Ancient Mississippi River valley. Thus, the elevations of the Sangamon Geosol in the tributary settings are considered as the upper limits for the elevation of the Ancient Mississippi River during the Sangamon Episode.

The fluvial surface in the Ancient Mississippi River valley yielded large amounts of loess and aggraded significantly as the Wisconsin Episode glaciation encroached on the upper part of the watershed about 55,000 yr B.P. The glacier reached Illinois about 24,500 ^{14}C yr B.P., and when it reached the Middle Illinois River valley area about 20,350 ± 85 ^{14}C yr B.P., the valley-fill surface had aggraded to 163 m (535 ft). With further advance, drainage was blocked long enough for the Ancient Mississippi River to cut through a divide in Rock Island County and establish its present valley in western Illinois.

Upon the last retreat of the Wisconsin Episode glacier from the Middle Illinois River valley area, the Illinois River incised deeply as floods issued from the margins of the Lake Michigan Lobe and glacial lobes farther east. Several periods of significant flooding probably occurred during which the river valley was widened and deepened and the principal terraces were cut or built at elevations between 170 m (560 ft) and 152 m (500 ft) in the Middle Illinois River valley. At the end of the Wisconsin Episode, the Illinois River was left at a low elevation, near its modern elevation of 134 to 137 m (440 to 450 ft).

FIELD TRIP STOP DESCRIPTIONS: DAY 1

Stop 1-1: Clear Creek Section

Florid 7.5-minute Quadrangle
N½ NW¼ NE¼ Sec. 19, T31N, R1W, Putnam County
Wisconsin Episode Succession in Ancient Mississippi River Valley East of the Illinois River

Ardith K. Hansel, Andrew J. Stumpf, and E. Donald McKay III

Objective To examine a Wisconsin Episode valley fill in a portion of the Ancient Mississippi River valley to understand

1. Processes of till formation and deposition.
2. The influence of buried valleys on sedimentation and subglacial drainage.
3. Problems associated with radiometric dating of events on the basis of samples of detrital organic material.

Introduction The Clear Creek Section exposes about 32 m (105 ft) of Quaternary sediment in a steep, north-facing stream cut (Fig. 10) along the south side of Clear Creek, a westward flowing tributary of the Illinois River. The Clear Creek succession has been visited and studied by Survey scientists for over 50 years, but it wasn't until the Illinois Route 29 mapping project that its relationship to the Ancient Mississippi River valley was revealed. The succession was first described in 1953 by Leland Horberg, who interpreted all but the uppermost 6 m (19.2 ft) of the succession to be pre-Wisconsin in age. The section was revisited in 1959 by Horberg and John

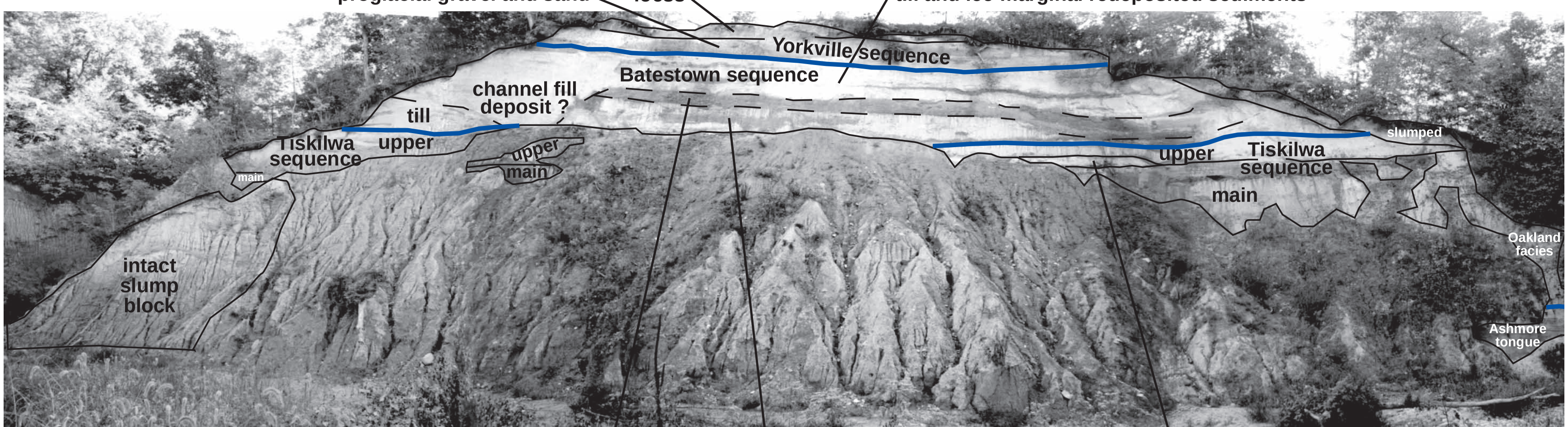

Figure 10 Photomosaic of the Clear Creek Section, NW¼ NW¼ NE¼ Sec. 19, T31N, R1W, Putnam County, Illinois, based on 2002 photos. Some stratigraphic units are indicated. Sequence boundaries are blue. Photographs by A.K. Hansel; photomosaic by D.L. Byers.

Kempton, who sampled it for clay mineral analysis. Murray McComas described the section in his doctoral dissertation (1969); he considered only the lower one-third of the section to be older than the Wisconsin Episode. Horberg (1953), Horberg and Kempton (1959 ISGS field notes), and McComas (1969) all reported the Sankoty Sand at the base of the section.

During the late 1980s, W. Hilton Johnson, Leon Follmer, and Ardith Hansel visited the section as part of a regional stratigraphic study with Mark Kerasotes (1989), who included a description of the section in his M.S. thesis (1989). Johnson and Hansel revisited the section many times during the 1990s for National Science Foundation-sponsored research (Grant EAR-9204838) on till genesis and ice sheet dynamics of the Lake Michigan Lobe. Basal Wisconsin tills (Tiskilwa and Batestown, Fig. 11) and deformed substrate materials were well exposed in the lower part of the section at that time.

On the basis of the similarities between the glacigenic sequences at Clear Creek and those at the Wedron Section and other nearby localities, Hansel et al. (1993) correlated all of the glacial sediments at the main Clear Creek Section with those of the Wisconsin Episode. The age of the tills at the section remained controversial, however, because wood dated from within what was interpreted to be basal Wisconsin Episode till (Tiskilwa Formation) did not yield finite radiocarbon ages (e.g., Samples I-2099 and I-2221 at >40,500 and >42,100 ^{14}C yr B.P., respectively). For this reason and because of concern by our colleagues that the glacial succession exposed at Clear Creek was at a much lower elevation than “typical Wisconsin Episode sediments” in the area, the stratigraphically controversial Clear Creek Section was not included as a reference section for the Wisconsin Episode deposits in the lithostratigraphic framework of Hansel and Johnson (1996).

Even so, based on regional lithostratigraphic correlations, Hansel and Johnson interpreted the succession at Clear Creek to be proglacial outwash, colluvial sediment, till intertongued with proglacial meltwater sediment associated with multiple advances, and loess deposited in a pre-late Wisconsin valley during the Wisconsin Episode. From 1992 through 1996, Hansel and Johnson took a number of geologists to the site to discuss subglacial sedimentation processes and the significance of such features as (1) erosion surfaces at the base of till beds (Fig.12), (2) channel-shaped deposits (Fig. 13) and pebble lags (Fig. 14) between till beds, (3) folded contacts at the base of till beds (Figs. 15 and 16), (4) poorly homogenized to well-homogenized till locally containing intact gastropod shells, (5) attenuated (and in places folded and faulted) lenses of substrate materials within till (Fig. 17), and (6) locally, deformed substrate materials (Fig. 18). Dave Voorhees, working with Johnson and Hansel, found microfabric evidence for deformation to high strain (Fig. 19), and Hansel measured strongly developed pebble orientation within parts of the basal till (Table 2). Hansel et al. (1993) suggested that the basal till (Tiskilwa and Batestown) at Clear Creek was deposited beneath active ice, in part by enfolding of substrate material at the base of a deforming bed. Unfortunately, today slumped debris covers most of the basal part of the section where those features were observed, although some poorly homogenized till can still be observed on the east side of the main section.

Description and Discussion In 2002, we studied the Clear Creek Section in conjunction with the Illinois Route 29 mapping project and in preparation for an International Union for Quaternary Research (INQUA) 2003 field trip (Stop 2 in Patterson et al. 2003). Figure 11, a composite sketch of the section, is based largely on our study and earlier observations for till beds in the Tiskilwa and Batestown sequences that had been recorded in the field notes and photographs of W. H. Johnson, A. K. Hansel, and D. Voorhees. Drilling and stratigraphic study as part of the Illinois Route 29 mapping project allowed us to better understand the Clear Creek succession in the regional context of its setting with respect to the Ancient Mississippi River valley. Analytical data for the Clear Creek Section are in Appendix B, Table B-1.

The sand at the base of the section (Ashmore Tongue of the Henry Formation) is interpreted to be a distal, outwash deposit of the Ancient Mississippi River, which flowed from Rock Island east to Princeton and then south to St. Louis before it was diverted 20,350 ± 85 ^{14}C years ago to its present course along the western border of Illinois (Glass et al. 1964, McKay 1979, Grimley et al. 1998, Curry 1998). An OSL result of 96,070 ± 6,060 cal yr B.P. (Sample UNL-1203; Table 1) obtained recently for a sample of the sand collected near the base of the exposure dates to the Sangamon Episode and is older than expected because the sand is neither weathered nor overlain by a Sangamon Geosol. This result will prompt additional age determinations at Clear Creek using the OSL method. Overlying the sand is organic-rich, poorly to well-homogenized diamicton (Fig. 17) containing deformed stratified sediment, lenses of older diamicton, abundant wood, and in places gastropods, some of which appear intact. This organic-rich, in most places poorly homogenized diamicton (Oakland facies) is fairly common within 80 km (50 mi) of the late Wisconsin ice margin, particularly in lowland positions, which is attributed to incorporation of organic-rich material (Farmdale Geosol and Robein Member, Roxana Silt) that the late Wisconsin Lake Michigan ice lobe overrode. Locally along its lower erosional contact, the Oakland facies is folded with the Ashmore sand (Fig. 15). Some of the Oakland facies appears to contain or be intertongued with an organic-rich silt derived from the Farmdale Geosol (Robein Member, Roxana Silt), which ranges from about >40,000 to 20,000 ^{14}C yr B.P.

In 2002, we collected and dated three samples (Samples I-5264, I-5268, I-5269; Table 1) of organic material from diamicton and sorted sediment of the Oakland facies at Clear Creek. One wood sample (I-5268) yielded a finite radiocarbon age (41,010 ± 970 ^{14}C yr B.P.); we concluded that the till succession was indeed from the last glacial episode and that the abundant wood in the basal part of the succession reflected paraglacial and subglacial reworking of substrate material. The radiocarbon ages for wood in the Tiskilwa till at the Friday3 Section (provided by Carlson et al., Stop 1-2; Table 1) also are consistent with a Wisconsin Episode age.

Overlying the organic-rich Oakland facies are three lithologically distinct till beds of the Tiskilwa Formation (Fig. 18). Locally, less than 1 m (3 ft) of gray (lower bed) Delavan till is present. The reddish gray, main Tiskilwa till is overlain by a grayer and less clayey, more illitic (upper bed) Piatt till. Each till bed of the Tiskilwa sequence has an erosional lower contact, and attenuated lenses of lower units are common in the basal part of each unit (Fig. 12). The contacts are locally marked by truncated channel-fill deposits or pebble concentrations (Figs. 13 and 14).

Multiple beds of till and sorted sediment of the Batestown sequence overlie the Tiskilwa sequence (Fig. 11). Rarely have these sediments been accessible for detailed study. Enfolding of the Batestown till and sand in the basal part of the sequence was studied by Johnson and Hansel (1995) (Fig. 16). The gravel near the top of the section likely represents proglacial fluvial sediment associated with the Yorkville sequence. In the upper part of the second gully east of the main section, clayey (Yorkville) till and ice marginal sediment overlying the Batestown sequence was reported in ISGS field notes (W. H. Johnson 1993). As much as 2 m (6.6 ft) of loess caps the section.

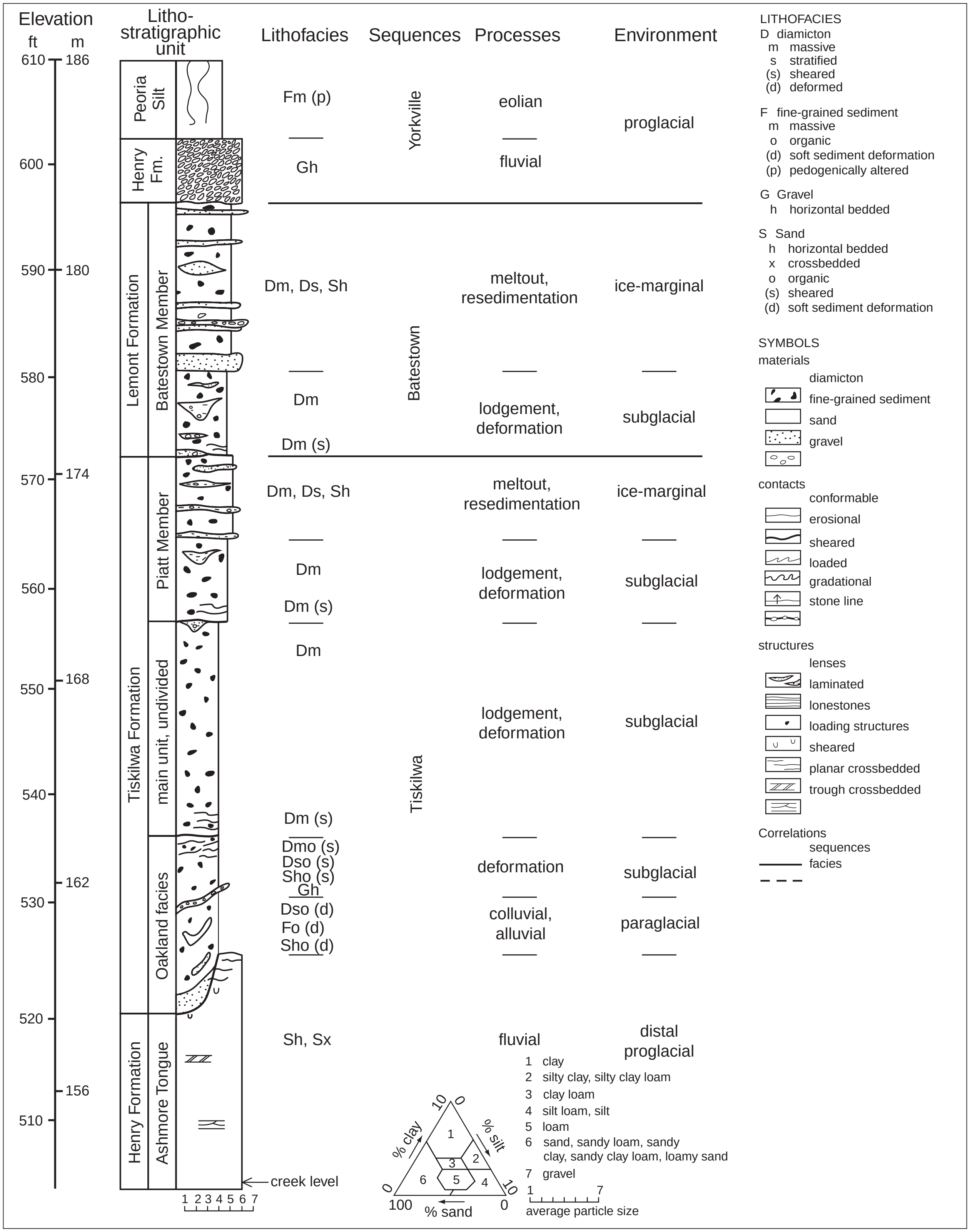

Figure 11 Composite lithofacies and interpreted sequences, processes, and glacial environments for the Clear Creek Section. Modified from Hansel and Stumpf (2003).

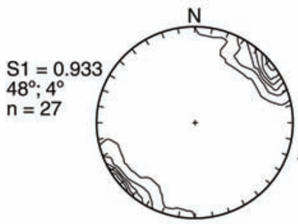

Figure 12 Lithologically distinct Tiskilwa till beds (main and lower) show erosional basal contacts and highly attenuated lenses of substrate materials. Diamicton homogeneity increases upward within beds. Pebble fabric in the lower till bed shows the strong orientation of pebbles parallel to regional ice flow from the northeast.

Figure 13 Channel-fill deposit at the base of the erosional contact between lithologically distinct till beds (upper and main) of the Tiskilwa sequence.

Figure 14 Pebble lag at the erosional contact between lithologically distinct till beds (upper and main) of the Tiskilwa sequence.

Figure 15 Folded basal contact of Tiskilwa sequence till (Oakland facies, Fig. 18) with underlying sand (Ashmore Tongue).

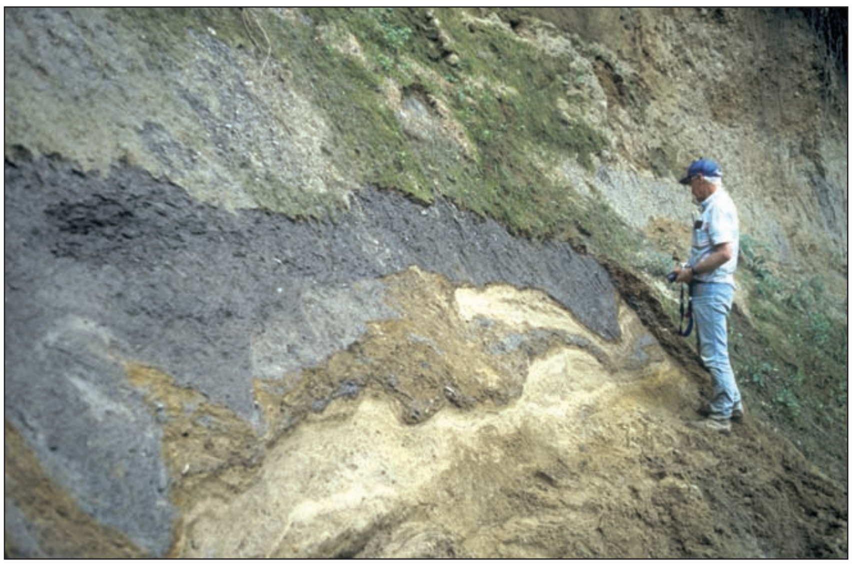

Figure 16 Folded basal contact of Batestown sequence till (Fig. 18) with underlying sand.

Figure 17 Heterogeneous diamicton interpreted to be poorly homogenized till (Oakland facies) in the basal part of the Tiskilwa sequence. The matrix is organic-rich silt loam that contains abundant wood clasts and folded and attenuated laminae of pink and green diamicton and sorted sediment. Hansel et al. (1993) interpreted the laminae results from enfolding of older diamicton and proglacial substrate materials competent enough to maintain some integrity in a subglacial deforming bed.

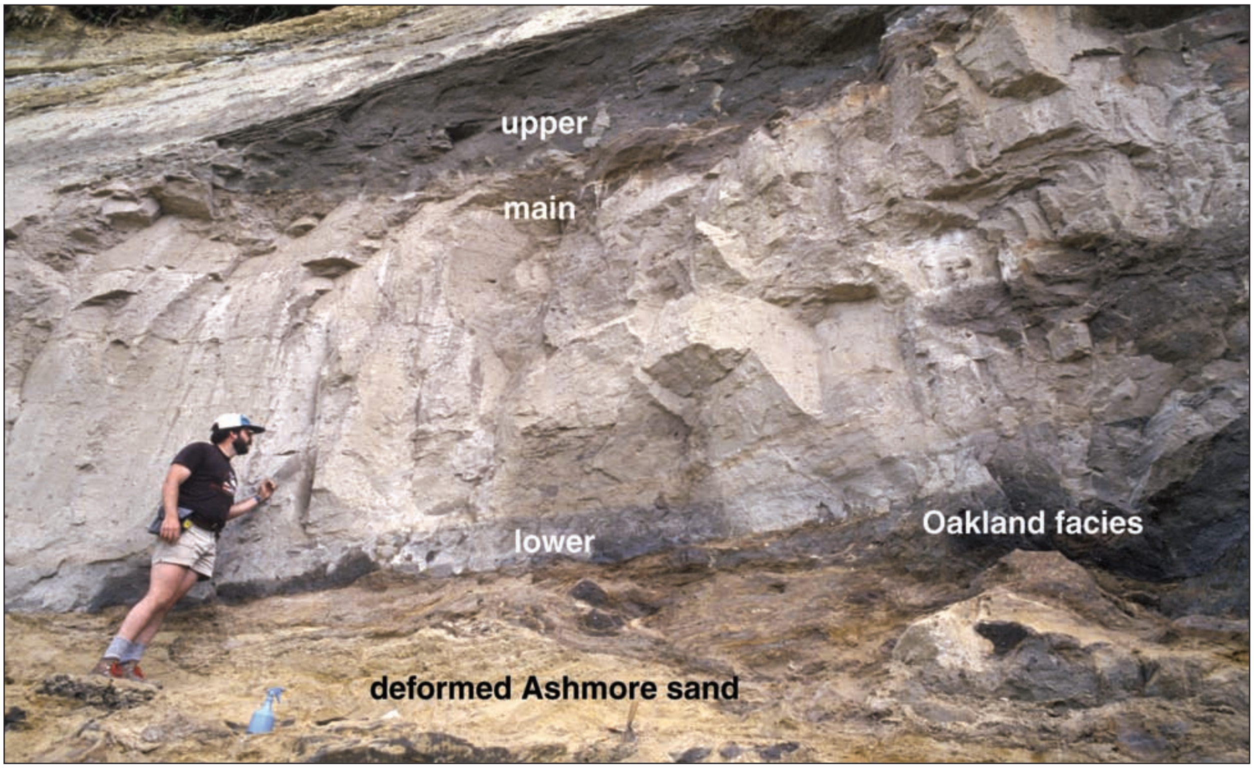

Figure 18 Lithologically distinct till beds (upper, main, lower) of the Tiskilwa sequence showing the erosional basal contacts overlying deformed sand (Ashmore Tongue) and diamicton (Oakland facies).

Figure 19 Photomicrograph (plane-polarized light) showing a concentration of silt grains on the lee side of a sand grain within an attenuated pink, clayey diamicton lamina within the Oakland facies (Fig. 17). Provided by David Voorhees.

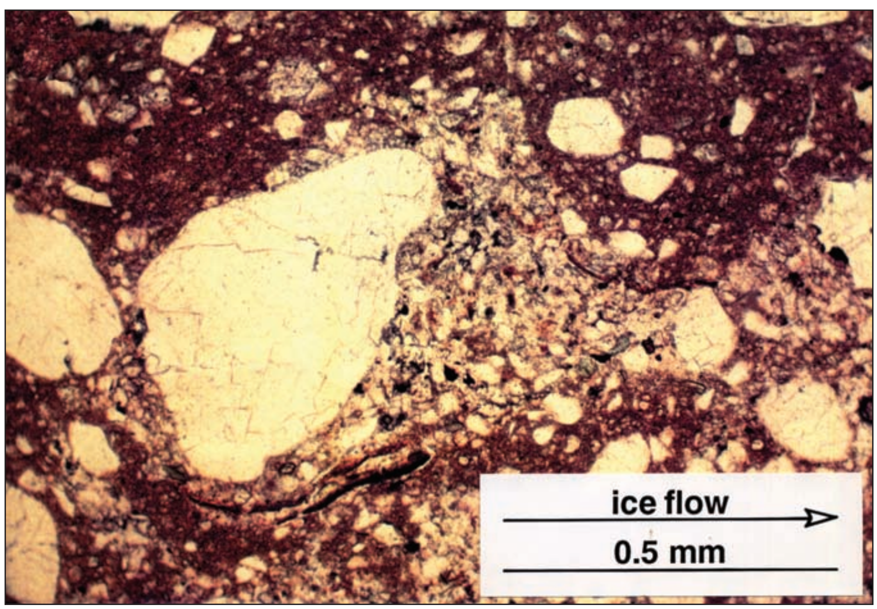

Table 2 Pebble fabric data by lithostratigraphic unit at the Clear Creek Section.

Identification	S_1[1]	Azimuth (°)	Dip (°)	Material
Oakland facies, Tiskilwa Formation				
AKH1	0.662	23	14	heterogeneous diamicton
AKH2	0.893	0	13	green diamicton lamina
AKH3	0.840	70	20	wood clasts in diamicton
AKH4	0.537	23	3	heterogeneous diamicton
Delavan Member, Tiskilwa Formation				
AKH5	0.939	48	4	homogeneous diamicton
AKH6	0.924	59	7	homogeneous diamicton
Tiskilwa Member, main				
AKH7	0.868	61	9	homogeneous diamicton
Batestown Member, Lemont Formation				
AKH8	0.860	56	15	homogeneous diamicton

[1]S_1, eigenvalue.

Stop 1-2: Friday3 Section

Florid 7.5-minute Quadrangle

NE¼ SE¼ NW¼ Sec. 19, T31N, R1W, Putnam County

Wisconsin Episode Succession in Ancient Mississippi River Valley East of the Illinois River

Andrew J. Stumpf, Ardith K. Hansel, and B. Brandon Curry with contributions from Anders Carlson, John Jenson, Peter Clark, and Jason Thomason

Objective To examine Wisconsin Episode valley fill in part of the Ancient Mississippi River valley that contains a tongue of proglacial lake sediment and organic material between tills of the Tiskilwa and Batestown sequences (Fig. 20).

Introduction The Friday3 Section is located along a tributary of Clear Creek, southwest of Stop 1-1. The exposure occurs in a high, south-facing cutbank on a meander of the stream. The lower half of the exposure is the most readily accessible, and its base lies at an elevation of 158 m (520 ft), which is about 42 m (138 ft) above the bedrock surface in the Ancient Mississippi River valley. Stop 1-2 offers another opportunity to examine Tiskilwa and Batestown units that are similar to those exposed at Stop 1-1, but here these units are separated by a tongue of proglacial lake sediment.

Description At the base of the Friday3 is a gray to reddish brown, loam to clay loam diamicton (Tiskilwa till) from 5 to 8 m (15 to 25 ft) thick (Fig. 20). The red hue is a distinguishing feature of the Tiskilwa Formation. The diamicton ranges from dense to very dense and has iron staining on fractures and joint faces. The lower 2 m (7 ft) of the diamicton is darker gray, siltier, and organic-rich (Oakland facies). Scattered throughout the diamicton are intact aquatic gastropod shells and pieces of wood. The wood fragments are more abundant in the lower part of the section and are aligned in the direction of regional glacier flow (i.e., from northeast to southwest). Macrofabric data from the diamicton also indicate a dominant northeast to southwest flow direction. The diamicton in the upper 1 m (3 ft) is sandier, looser, and weakly stratified (Piatt Member).

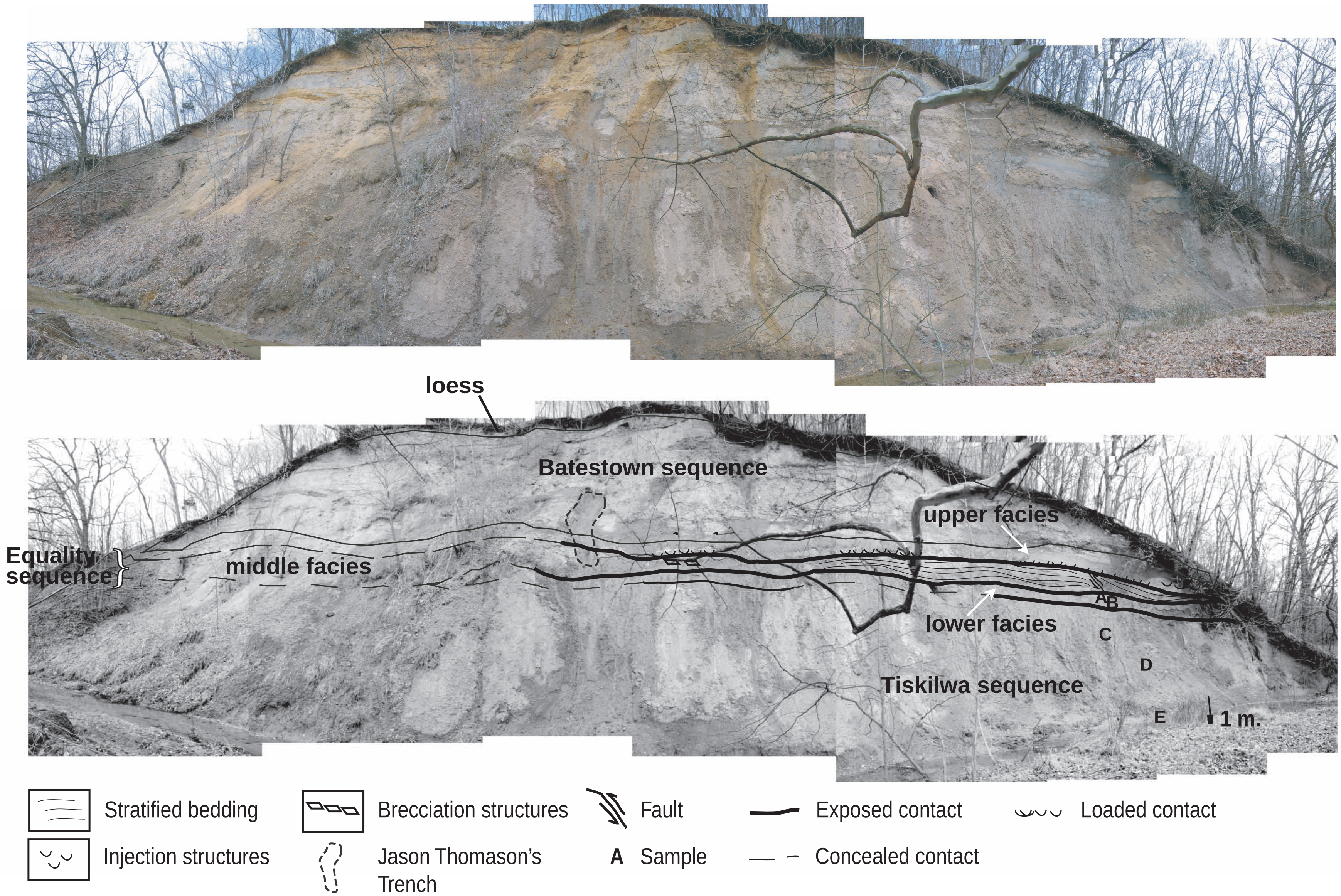

Figure 20 Photomosaics of the Friday3 Section, NE¼ SE¼ NW¼ Sec. 19, T31N, R1W, Putnam County, Illinois, based on 2005 photos. Some stratigraphic units are indicated. Sequence boundaries are shown in the lower black and white mosaic. Photographs and mosaics are by A.J. Stumpf.

Radiocarbon dating of wood from the diamicton collected by Anders Carlson and colleagues (Table 1 and Fig. 21 on Sidebar 1) yielded ages between 31,400 ^{14}C yr B.P. and >49,900 ^{14}C yr B.P. These ages are similar to radiocarbon ages obtained on organic material for Tiskilwa Formation diamicton at Clear Creek (Stop 1-1 discussion) and at other sites in the region (Hansel and Johnson 1996).

Particle size and clay mineral data obtained for the Tiskilwa Formation diamicton at Friday3 (Appendix B, Table B-2) are similar to data collected for this diamicton from other sites in Illinois (e.g., Wickham et al. 1988). Generally, the diamicton decreases in silt content toward the top.

The Tiskilwa Formation diamicton at Stop 1-2 is overlain by 3 to 5 m (10 to 16 ft) of brown to pinkish gray diamicton and clay, silt, and fine sand containing abundant shells and organic material. These fine-grained sediments (here classified as an unnamed tongue of the Equality Formation) are indurated and overconsolidated. Some beds are folded, faulted, and/or deformed. The deposit is subdivided into three zones (Fig. 20): a lower zone containing beds of pebbly diamicton or sand and gravel forming an irregular and transitional contact with the underlying diamicton that grades upward to a massive, organic-rich silt; a middle zone composed predominantly of bedded very fine- to medium-grained sand with interbeds of laminated silt and clay that are locally folded and faulted; and an upper zone of laminated to nearly massive calcareous silt, very fine- to fine-grained sand, or clay with abundant wood, shells, and plant macrofossils.

In the unnamed tongue of the Equality Formation, shells, wood, and other organic material are most common in the upper facies, especially where bedding or laminae in the sediment are more diffuse. Significant concentrations of woody plant detritus are also found in sandier intervals of the laminated sediment. Two samples containing spruce needles and bulrush seeds from these intervals returned AMS ages of 48,900 ± 1,500 and >54,300 ^{14}C yr B.P. (Sample CAMS 103615 and 103616). A third radiocarbon sample containing plant macrofossils and wood from an exposure (Friday2) 150 m (500 ft) upstream of Friday3 yielded 40,720 ± 860 ^{14}C yr B.P. (Sample ISGS-5515). Sand grains from the unnamed tongue at Friday3 returned an OSL age of 93,030 ± 8,750 (Sample UNL-1202). As a group, all of these ages are considerably older than the overlying Batestown Member and the underlying Tiskilwa Formation.

Abundant fossils of gastropods (Appendix B, Table B-3), ostracodes (Appendix B, Table B-3), and charophytes collectively indicate that the laminated sediment was deposited in a quiet, permanent pond with abundant aquatic vegetation. The water depth cannot be determined, but was within the photic zone, the depth to which sunlight can penetrate the water column. These conditions are suggested by the abundant species of *Gyraulus* spp. and abundant shells of *Pisidium milium, Pisidium compressum,* and *Pisidium subtrancatum* (Clarke 1981, Sparks 1961) as well as the relative abundance of ostracode species that prefer living among aquatic vegetation compared with the number of benthic species (388:66). The ostracode assemblage lives today in dilute, bicarbonate-charged water under cool, relatively dry, continental conditions. Comparison of the four most abundant ostracodes in this assemblage with the North American Non-Marine Ostracode Database (NANODe) (Forester et al. in review) suggests similarity of ostracodes in two lakes in the United States (out of 756 sites). The two lakes, Moose Lake and Mina Lake, occur in Minnesota where precipitation is about 72% that of Peoria, Illinois (roughly 650 vs. 900 mm/yr), and where winters are longer, drier, and colder. The lakes are relatively dilute (222 to 403 mg of total dissolved solids/L). A more definitive reconstruction of paleohydrology and paleoclimate would likely result from comparison of the Friday3 assemblage with a Canadian database owned by L. Denis Delorme (e.g., Curry and Delorme 2003).

Till Genesis Study for the Tiskilwa Till

Anders Carlson[1], John Jenson[2], and Peter Clark[1]

We described and sampled two exposures of Tiskilwa till in Putnam County, Illinois: the Friday3 and Clear Creek sections. Samples were collected for grain-size analysis every 0.6 m. Macrofabric was measured every meter, and samples for thin sections were collected at the same locations. This discussion of the Friday3 section is supplemented with information from the Clear Creak Section.

The Tiskilwa till is a reddish brown, massive, homogeneous, fine-grained diamicton that is 5 to 6 m thick in the study area (Fig. 21). It overlies the gray, more heterogeneous Delavan till with an ~0.6 m gradational contact. Thin sections from the base of the Tiskilwa till reveal small (<0.5 cm) inclusions of Delavan till in the Tiskilwa till matrix. At the Clear Creek section, the base of the Delavan Till grades into underlying proglacial sediment. The tan Piatt till overlies Tiskilwa till at both sections, either with an abrupt contact or separated by a 10- to 20-cm-thick layer of sorted sediment. The Tiskilwa till has a uniform grain size throughout the sections, averaging 45% sand, 30% silt, and 16% clay (Fig. 21). The Delavan till is slightly siltier, averaging 45% sand, 42% silt, and 13% clay. At the Clear Creek section, sand inclusions in the Tiskilwa and Delavan tills are up to 1 m thick, have abrupt contacts with the surrounding till, and are deformed in the direction of ice flow. Some inclusions contain balls of Tiskilwa till within the sand and have diapirs of till rising into the sand.

The macrofabric is strong throughout the Tiskilwa till with principle eigenvalues (S1) between 0.74 and 0.85. Thin sections similarly indicate strong alignment of particles in the Tiskilwa till matrix. Principle eigenvectors (V1) of the macrofabrics are consistent with regional ice flow but shift direction upward through the section from N40°E to N60°E and back to N40°E near the top of the Tiskilwa till.

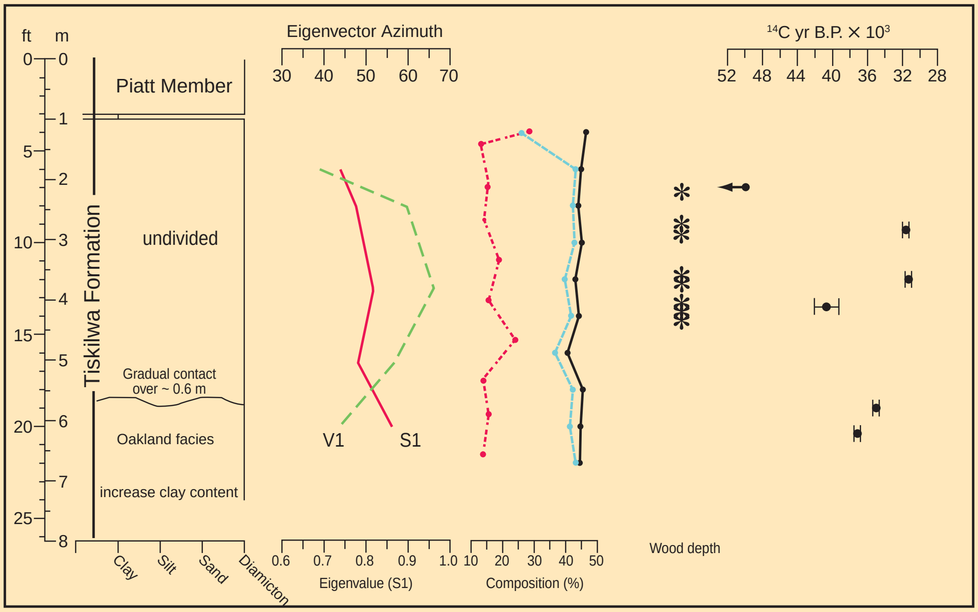

Figure 21 Friday3 Section. From left to right: Till unit thickness; eigenvalues (S1; solid line) and eigenvectors (V1; dashed green line); and the location of wood in the till and radiocarbon ages (the radiocarbon date at 2.1 m is >49,900 ^{14}C yr B.P.

The consistently strong fabrics suggest that the till underwent a uniform degree of strain throughout its thickness while the shift in eigenvectors may reflect initial thickening and subsequent thinning of the Lake Michigan lobe over the study area, causing a change in ice flow direction. The deformed sand inclusions are likely remnant canals that were incised into the till at the base of the ice and subsequently deformed. The presence of Tiskilwa till balls in the sand indicates that the deposition of the sand postdates the surrounding till and that the sand was not incorporated into the basal ice and subsequently deposited with the till.

We propose a time-transgressive depositional model for the Delavan and Tiskilwa tills. Ice advance incorporated local proglacial sediment into the basal Delavan till. This till isolated the heterogeneous proglacial sediment from the ice base and allowed the deposition of the more homogeneous Tiskilwa till. The deformed sand inclusions and gradational contacts between the Tiskilwa and Delavan tills and the underlying sediment imply a deforming bed mechanism of transport and deposition. However, the preservation of the shifting macrofabric orientation indicates that this deforming layer was less than 1 m thick. If the till was actively deforming to a greater depth, then earlier ice flow directions recorded by the macro fabric would be erased by later ice shifts in flow direction during maximum extent and retreat.

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Features consistent with intense deformation were observed in the middle and upper facies, such as isoclinal folding, kink banding, convoluted beding, and ball and pillow structures (Fig. 22). No shear structures have been observed in these deposits, but only a preliminary investigation has been completed

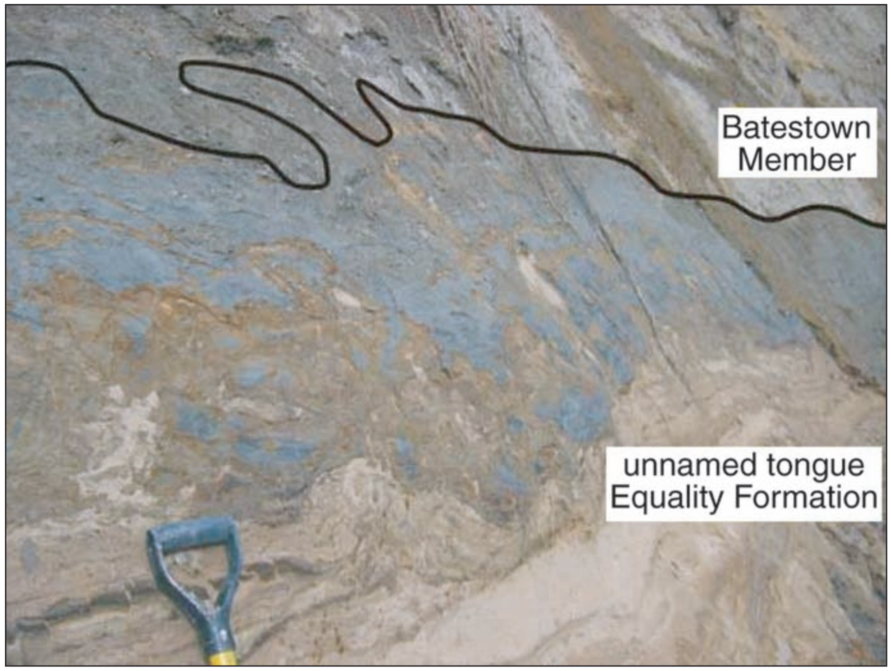


Figure 22 The lower contact of the Batestown Member diamicton with the underlying unnamed tongue of the Equality Formation. Note the convoluted bedding and deformation of interbeds.

Overlying the Equality Formation tongue is a grayish brown, silt loam diamicton (Batestown Member, Lemont Formation) ranging from 5 to 10 m (15 to 30 ft) thick and containing several broad lenses of sand and gravel (Fig. 20). An abrupt erosional contact marked by a thin, coarsening-upward sequence of sand and gravel is mapped at 1 to 2 m (3 to 7 ft) below the top of the section. Above the sand and gravel, the diamicton is slightly coarser, contains more beds of sand and gravel, is oxidized, and is fractured. Ring-shear tests conducted by Jason Thomason (Sidebar 2, Fig. 23) on samples of the Batestown Member diamicton indicate a polyphase shift in the sense of strain (ice-flow direction).

Discussion

Radiocarbon ages obtained for organic material and an OSL age of sand grains from the Equality Formation indicate that the organic material and sand predate the Wisconsin Episode. As discussed at Stop 1-1, old ages for organic material in the Oakland facies and main Tiskilwa Formation are common. Carlson et al. (Sidebar 1) found Wisconsin Episode ages for wood within the Tiskilwa till that underlies this deposit. Deformation within the Equality Formation indicates internal shear but neither verifies nor eliminates the alternate interpretations of the deposit being (1) a proglacial lake into which old carbon and sediment entrained in the Tiskilwa and/or Batestown diamictons were shed or (2) a glacially entrained block of older organic-rich sediment transported and deposited at the base of the Batestown diamicton. The alignment of wood fragments and stretched shells in the general direction of ice flow parallels the AMS fabrics of Thomason (Fig. 24).

Till Genesis Study for the Batestown Till

Jason Thomason

Landscapes formed by southern lobes of the Laurentide Ice Sheet have frequently been associated with deformation of subglacial sediments. However, the degree to which those sediments (commonly till) have been sheared has never been quantified. Using a large ring-shear device, a basal till of the Lake Michigan Lobe (Batestown Member, Lemont Formation) was sheared to different prescribed strains that ranged through nearly three orders of magnitude. Anisotropy of magnetic susceptibility (AMS) analysis was conducted with laboratory samples. The degree of alignment of magnetic particles was quantified by determining the fabric defined by directions of maximum magnetic susceptibility of multiple samples. Laboratory results show that these fabrics become stronger and increasingly parallel to the shearing direction with strain and do not become steady until shear strains of 20 to 30 (Fig. 23). Thus, a proxy for strain has been developed for application to field studies.

Field samples of the Batestown till were taken from the Friday3 section near Henry, Illinois.

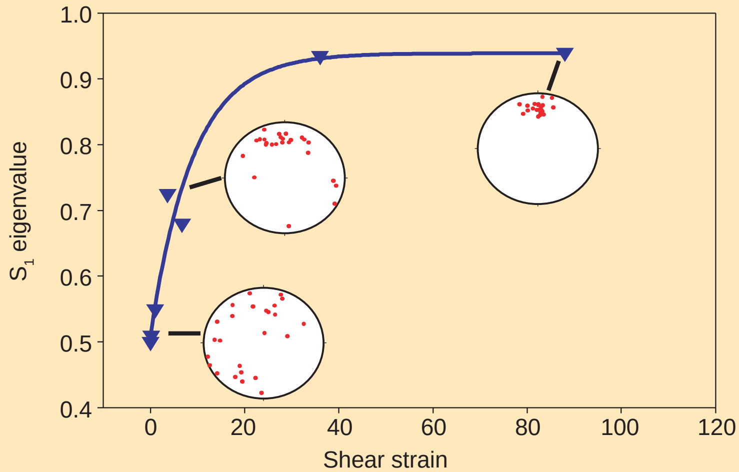
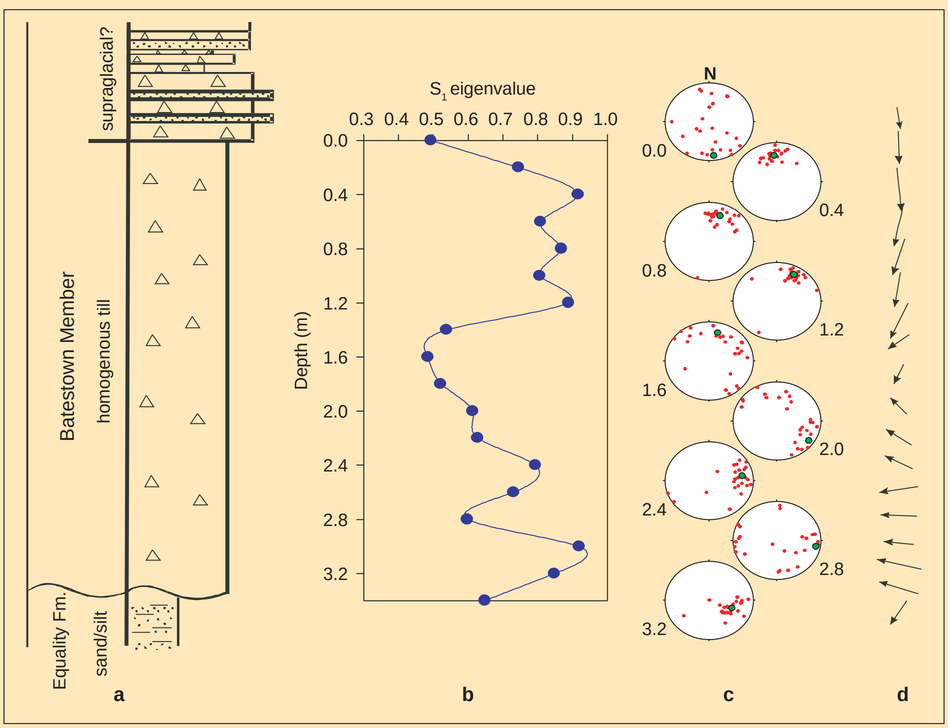


Figure 23 Results of laboratory AMS analyses of sheared Batestown till. Microfabric strength (S1, eigenvalue) as a function of strain for laboratory experiments. Sense of shear for each stereoplot is bottom north, top south. Twenty-five samples were used for each test.



Intact samples (each 8 cm³) were extracted at 20-cm intervals (25 samples per interval) along a vertical profile that spanned the entire till thickness (~3.4 m). Magnetic susceptibility analyses have been completed (Fig. 24). Based on the laboratory calibrations, field data indicate that significant portions of the Batestown till have been deformed to shear strains of at least 10. Patterns of fabric strength and direction suggest that strain accumulated as the basal till accreted over time rather than during a single deformation event. However, further field work is needed to test this hypothesis.

Figure 24 (a) Local stratigraphy of the Friday3 Section. (b) AMS fabric strength (S1, eigenvalue) as a function of depth for the Batestown till. (c) Lower hemisphere stereoplots (every 0.4 m) of directions of maximum susceptibility (the green dot in each plot is the eigenvector direction). (d) Vectors of inferred ice-flow direction with depth (the length of each vector is proportional to the AMS fabric strength).

Stops 1-3, 1-4, 1-5, and 1-6: Rattlesnake Hollow Sections

Chillicothe 7.5-minute Quadrangle
SW ¼ Sec. 27, T12N, R9E, Marshall County
Wisconsin and Illinois Episode Successions in Bedrock Uplands West of the Illinois River

E. Donald McKay III, Richard C. Berg, and Andrew J. Stumpf

Introduction The Rattlesnake Hollow Sections provide relatively well-exposed local examples of the geologic units and unconformities that occur throughout the Middle Illinois River valley. When discovered early in our work, these sites were assumed to reveal the stratigraphic record in a fairly straightforward way. Detailed work in the hollow, however, has shown that the record is instead typical of the complexity of the Ancient Mississippi River valley and vicinity. The hollow contains several of the major Quaternary units and is missing several others that are cut out along some significant unconformities. In addition, its setting along the western margin of the Ancient Mississippi River valley is an important factor in the origin of the deposits and unconformities.

Rattlesnake Hollow is a short, modern, eastward-flowing tributary of the Illinois River, which is incised into the drift-covered bedrock upland west of the Ancient Mississippi River valley. The modern valley of Rattlesnake Hollow intersects and exhumes a buried bedrock bench, having an unknown width and orientation and lying 23 to 30 m (75 to 100 ft) below the general level of the local bedrock upland. Exposed along the hollow and resting on the low bedrock bench are some of the oldest Quaternary deposits known to be preserved in the area.

The Rattlesnake Hollow route begins about 1.6 km (1 mi) upstream of its mouth and continues as a walk downstream east about 0.4 km (0.25 mi). Four stops offer unique opportunities to view some of the Wisconsin Episode deposits and then study the underlying, older Quaternary deposits in several closely spaced exposures (Fig. 25). Data from these sites are given in Appendix B, Tables B-4, B-5, and B-6.

The Lake Michigan Lobe glacier advanced into western Illinois crossing the Ancient Mississippi River valley at least three times during the Illinois Episode. These ice advances terminated at limits 150, 80, and 30 km (95, 50, and 20 mi) west of the Ancient Mississippi River valley. Sediments deposited during these three advances are widespread east and west of the valley and interfinger with the valley fill. This interfingering allows for the relative dating of glacial and fluvial events.

Rattlesnake Hollow contains exposures of part of this succession. Early and middle Illinois Episode diamictons (Glasford Formation, Kellerville and Hulick Members) are preserved and exposed in Rattlesnake Hollow. Both members have lithologies that are typical of these units. Late Illinois Episode diamicton (Glasford Formation, Radnor Member) has not been found exposed in Rattlesnake Hollow but is widespread regionally, extending 30 km (20 mi) west of the Ancient Mississippi River valley.

Discussion Drilling data from the Ancient Mississippi River valley shows that significant thicknesses of proglacial fluvial sediments interfinger with each of the three Illinois Episode diamictons, indicating that the margin of the Illinois Episode glacier retreated east of the Ancient Mississippi River valley after deposition of each of the three diamicton units. As the Illinois Episode and later glaciers advanced westward into the valley, the river was constricted against the western bedrock upland, where erosion cut into drift deposits and bedrock. During final retreat of Illinois Episode ice from the area, the Ancient Mississippi River incised a channel east of the

Rattlesnake Hollow exposures and remained there throughout the Sangamon Episode and the early to middle Wisconsin Episode. Sangamon Episode deposits have not been recognized in the main stem of the Ancient Mississippi River valley, where fluvial sediments of that age were likely swept from the valley by Wisconsin Episode meltwater. In Rattlesnake Hollow, three well-preserved and exposed profiles of the Sangamon Geosol are developed in fluvial sediments. These poorly to moderately drained paleosol profiles may be the best exposed examples in Illinois of the Sangamon Geosol formed in a Sangamon or late Illinois Episode fluvial deposit graded to the Ancient Mississippi River.

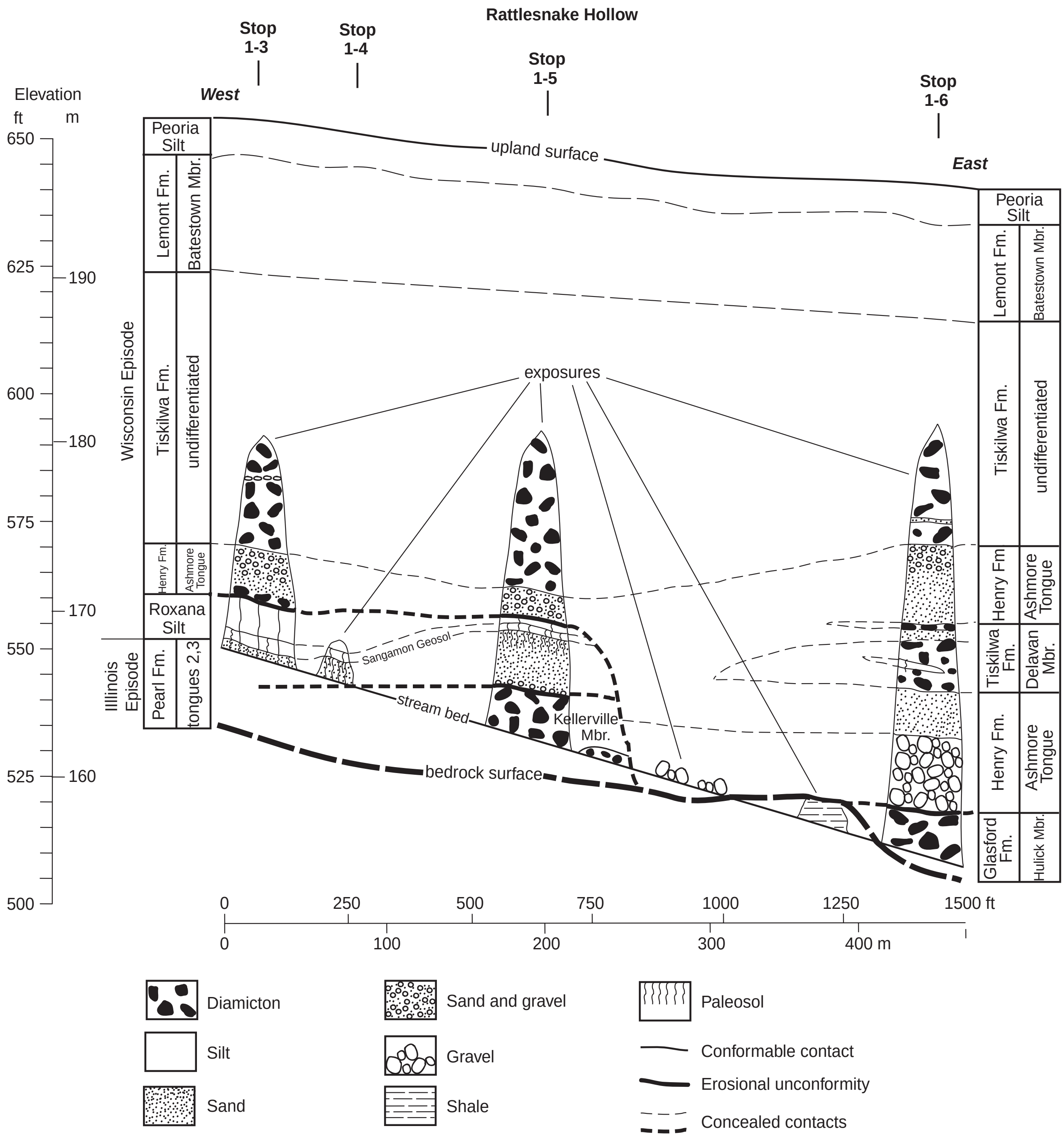


Figure 25 Cross section showing lithofacies and lithostratigraphic correlations between field trip Stops 1-3, 1-4, 1-5, and 1-6 in Rattlesnake Hollow, Marshall County, Illinois.

Wisconsin Episode meltwater entered the Ancient Mississippi River valley as early as 55,000 ^{14}C yr B.P., carrying and depositing silt on bars and floodplains that served as the local source of loess (Roxana Silt) blown onto nearby uplands. This early Wisconsin loess is preserved in Rattlesnake Hollow, although in most exposures it is overconsolidated, deformed, and partially truncated. When late Wisconsin ice emerged from the Lake Michigan basin, highly dolomitic outwash was introduced into the Ancient Mississippi River watershed. Yellowish brown to gray, dolomitic Peoria loess was deposited. The Morton Tongue of the Peoria Silt, which underlies the Tiskilwa Formation regionally, is absent from the outcrops in Rattlesnake Hollow.

Just before 20,000 ^{14}C yr B.P., the Wisconsin Episode glacier reached and overrode the Ancient Mississippi River valley and Rattlesnake Hollow, constricting the river against the western upland and depositing the diamictons that form the upper 30 m (100 ft) of the local glacial succession. The lower part of those units and the fluvial and eolian deposits that underlie them are accessible on our traverse. Both the lower diamicton (grayish brown Delavan Member) and upper diamicton (reddish brown undivided main unit of the Tiskilwa Formation) are present.

Four exposures in Rattlesnake Hollow at stops 1-3, 1-4, 1-5, and 1-6 (west to east) are discussed. The route traverses about 0.4 km (0.25 mi) distance and 55 m (180 ft) of elevation.

Objectives

1. To examine and discuss the Rattlesnake Hollow deposits that constitute the discontinuously preserved, seldom exposed, middle and lower part of the region's Quaternary stratigraphic succession in the Ancient Mississippi River valley.
2. To provide an overview of the succession of Quaternary sediments on the bedrock upland that delineates the western margin of the Ancient Mississippi River valley.
3. To consider how fluvial and glacial units and unconformities preserved in the bedrock upland correlate to units and events in the adjacent Ancient Mississippi River valley.
4. To identify principal marker beds (Sangamon Geosol and Roxana Silt) and consider evidence of significant erosion at some sites.

Stop 1-3: Rattlesnake Hollow West-A Section

Setting Stop 1-3 is a large cut on the north bank of the stream that exposes the upper part of the glacial succession in Rattlesnake Hollow.

General Description At the base of the exposure is the upper solum of a strongly developed paleosol (Fig. 26). Exposed is about 60 cm (2 ft) of strong brown, noncalcareous sandy loam with blocky structure, argillans, and root pores. This Bt horizon is overlain by about 60 cm (2 ft) of sandy silt with upper solum (E horizon) characteristics. Digging 10 to 20 cm (3.9 to 7.9 inches) into the slope removes the oxidized surface and reveals gray (reduced) sediments. The soil developed under poor drainage conditions in sandy parent material. The profile (Sangamon Geosol) developed in coarse stratified sediments of Sangamon or Illinois Episode age.

Conformably overlying the upper solum of the paleosol is 2.1 m (7 ft) of compact, leached to weakly calcareous, reddish brown silt loam that we interpret to be loess, the Wisconsin Episode Roxana Silt. The source of this loess was the Ancient Mississippi River valley east of this location. This occurrence of Roxana Silt is the thickest observed in the area, suggesting that this site was near the loess source. In places, the upper part of the silt body is laminated and sheared and includes attenuated, sheared pods of gravelly sand.

Unconformably overlying the Roxana is massive, medium- to coarse-grained gravelly sand (Ashmore Tongue of the Henry Formation) and thin beds of diamicton near the base. Its upper contact is marked by a change in slope and deeper gullying on the outcrop. These sediments are proglacial outwash and sediment flows that were deposited locally in front of the advancing Wisconsin Episode glacier in a setting where the Ancient Mississippi River could have been pinched against the bedrock upland.

The upper 8 m (25 ft) of the section is composed of reddish brown, loam-textured diamicton (Tiskilwa Formation) with numerous, thin lenses of sand and gravel. A few kilometers to the west, the diamicton forms the Bloomington Morainic System, the terminal moraine of the Lake Michigan Lobe.

Discussion The paleosol at the base of the section is the first of three paleosol profiles that we will examine in Rattlesnake Hollow. From evidence at this stop, the age and origin of the sandy parent material are uncertain. These sediments might have been deposited by a high-level Ancient Mississippi River or by an eastward-flowing tributary stream graded to the Ancient Mississippi River. They might also be proglacial fluvial or exhumed deposits of any of these origins. We focus on three alternative origins: The Sanga-

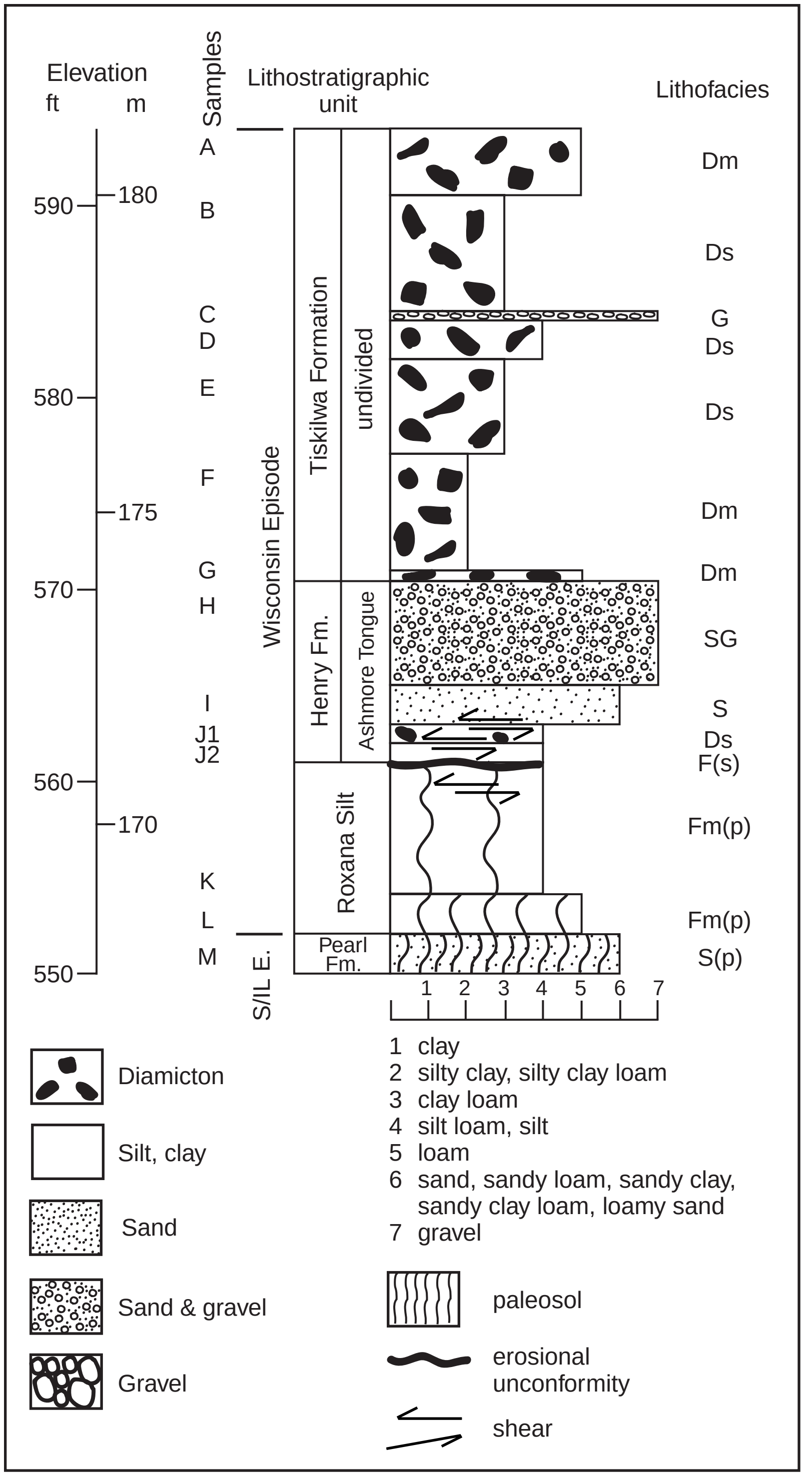


Figure 26 Lithostratigraphy and lithofacies interpretation for deposits exposed at Stop 1-3 in Rattlesnake Hollow, Marshall County, Illinois. Lithofacies code is given in Figure 11.

mon Geosol is developed (1) in fluvial sediment of a Sangamon Episode tributary graded to the Ancient Mississippi River to the east; (2) in late Illinois Episode glacial-fluvial sediment, deposited in a high-level Ancient Mississippi River channel during or after retreat of the late Illinois Episode (Radnor) glacier; or (3) in exhumed early or middle Illinois Episode sediment exposed by incision during the Sangamon and/or Illinois Episodes. These options are discussed as we examine the several exposures. Regardless of the origin of its parent material, the Sangamon Geosol's poor drainage indicates local conditions were wet during its formation. Such conditions are consistent with the lowland setting for the deposit during soil formation. Based on the information available at Stop 1-3, none of the three options can be eliminated.

Silt overlying the paleosol is typical of the mineralogy, texture, and color of the Roxana Silt but not its density. The silt is much more compact than the other loess units seen elsewhere on the trip that were also overridden by the Wisconsin glacier. At Stop 1-3, the silt is both overlain and underlain by sand, which facilitated drainage and consolidation of the loess unit during glacial loading. The upper part of the Roxana Silt, including the Farmdale Geosol, is missing from this exposure, as is the proglacial late Wisconsin loess (Morton Tongue). The latter, a yellowish brown to gray, calcareous silt, is a distinctive late Wisconsin Episode marker bed. Uneroded Morton Tongue elsewhere in the area is nearly as thick as the Roxana Silt, suggesting either that about 2 m (6.6 ft) of loess was eroded at this site or that the site was submerged during the time the Morton was deposited elsewhere. Pervasive evidence of shearing in the upper part of the Roxana Silt beneath the gravelly sand and the presence of attenuated pods of gravelly sand in the silt, as well as silt diapirs penetrating the overlying coarse deposit, suggest the gravelly sand acted not only as a drain during glacial overriding, but also as a rigid body transmitting glacially imparted shear into the underlying, relatively plastic silt body.

Stop 1-4: Rattlesnake Hollow West-B Section

Setting Stop 1-4 is a small stream exposure on the north bank of Rattlesnake Hollow. Its base (stream level) is about 1.5 m (5 ft) lower than the base of Stop 1-3. About 3 m (10 ft) of section is exposed.

Description Stop 1-4 exposes a complete profile of the Sangamon Geosol that correlates to the unit exposed at the base of Stop 1-3. At Stop 1-4, the lower part of the Roxana Silt conformably overlies the poorly drained paleosol profile developed in a loam-textured parent material. The profile, which has indistinct horizonation, displays a large number of closely spaced, prominent, burrow fillings that are interpreted to be krotovina (crayfish burrows). The filling material is dark-colored, organic silt loam that was derived from the upper-solum of the profile.

Discussion Sangamon paleosols, ubiquitous on the Illinoian till plain beyond the Wisconsin Episode glacial margin in west-central Illinois, are commonly preserved beneath the outer 65 to 80 km (40 to 50 mi) of Wisconsin Episode drift in central Illinois. Those preserved profiles represent the range of soil drainage conditions that existed on the low-relief Illinoian till plain where poorly drained soil profiles were common. Poorly drained paleosols commonly developed in sediments accreted by local slope wash into scattered depressions on the generally flat till plain (Frye et al. 1960). In early reports, these soils were called "Illinoian gumbotil" or "accretion gley profiles."

The profile of the paleosol exposed at Stop 1-4 is consistent with an interglacial (Sangamon) soil developed in alluvium in a wet lowland setting. Saturated conditions required by crayfish prevailed on the local low landscape position. Gradual alluvial sedimentation is indicated by the thickened upper solum and indistinct horizonation. The occurrence of glacial-fluvial sand deposits in the vicinity (see Stop 1-5) suggests that the parent material may include Illinois Episode outwash reworked by an interglacial stream.

Note the orientation of the krotovina in the lower part of the exposure. They slant in a way that is consistent with shear deformation of the deposit and in a direction consistent with Wisconsin glacial advance.

Stop 1-5: Rattlesnake Hollow Middle Section

Setting Stop 1-5 in Rattlesnake Hollow is downstream where stream level is about 5.5 m (18 ft) lower than Stop 1-3. The outcrop at Stop 1-5 is a large stream cut on the south bank of the stream.

Description At the base of the outcrop, 3.3 m (10 ft) of gray, calcareous, pebbly, silty clay loam diamicton contains scattered wood and coal fragments and a few intact gastropod shells (Fig. 27). Its matrix averages 15% sand, 49% silt, and 36% clay (Appendix B, Table B-5). Its clay fraction contains subequal amounts of expandable clay minerals and illite, averaging 40% of each. The unit contains much more dolomite than calcite. These characteristics are consistent with the unique composition of the Glasford Formation Kellerville Member, which can be found as far west as eastern Iowa.

Unconformably overlying the basal diamicton is 3.4 m (11 ft) of gravel, silt, and sand; a moderately drained profile of the Sangamon Geosol is developed in the upper part of the unit. Missing from the succession are the middle and upper Illinois Episode diamictons (Hulick and Radnor Member). The Sangamon Geosol is conformably overlain by 1 m (3 ft) of reddish brown, noncalcareous, silt loam, the Roxana Silt. As at Stop 1-3,

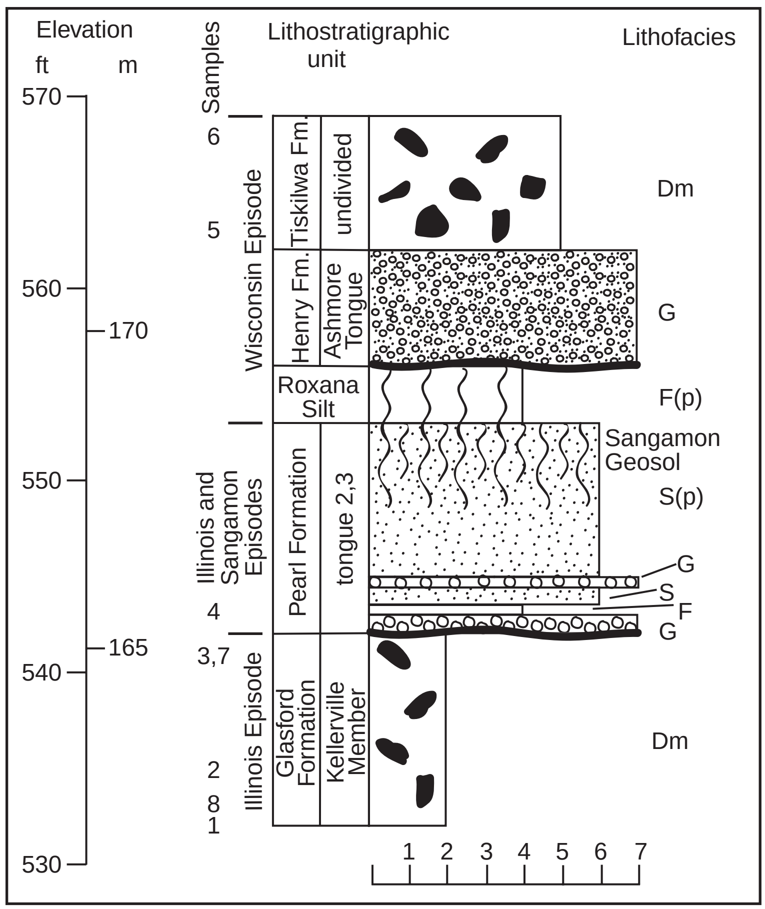


Figure 27 Lithostratigraphy and lithofacies interpretation for deposits at Stop 1-5 in Rattlesnake Hollow, Marshall County, Illinois. Lithofacies code is given in Figure 11.

the Morton Tongue is absent, and Roxana Silt is unconformably overlain by 1.8 m (6 ft) of calcareous gravel. Thick Wisconsin Episode diamicton forms the top of the succession. Only the base of the diamicton (Tiskilwa) is accessible.

Discussion The mineralogy and clast contents of the lowermost diamicton (early Illinois Episode Kellerville Member) reflect incorporation of substrate along the glacial flow path southwestward from Lake Michigan to central Illinois. Kellerville till is rich in dolomite and illite, as are the other Lake Michigan Lobe tills that incorporated dolomite eroded from the Niagaran bedrock that rims Lake Michigan and illite from Pennsylvanian shale that is the uppermost bedrock unit across much of central Illinois. The Kellerville is differentiated from the other tills by high levels of expandable clay minerals, which are thought to reflect incorporation of deeply weathered profiles of the Yarmouth Geosol (Glass and Killey 1988). Thus, the Kellerville is a silty, clayey diamicton, rich in expandable clay minerals and containing more dolomite than calcite. Common coal and shale clasts in the Kellerville also come from eroded Pennsylvanian rock. Intact gastropods in the diamicton at Stop 1-5 were probably transported only a short distance before deposition and may have come from alluvial sediments eroded from the nearby Ancient Mississippi River valley analogous to those at Stop 1-2 (Friday3).

Based on evidence at Stop 1-5, the stratified succession above the Kellerville Member can be interpreted as post-Kellerville, Illinois and/or Sangamon Episode, fluvial sediment that fills a channel incised in Illinois Episode deposits. The missing middle and late Illinois Episode diamictons may have been eroded during this fluvial event. We are uncertain whether these fluvial deposits are part of the fill of a local tributary to the Ancient Mississippi River valley or the same as deposits of the Ancient Mississippi River on a bedrock bench near the western edge of the valley. In any case, the intermediate drainage characteristics of the Sangamon Geosol reflect drainage provided by the underlying sand and suggest that this site was located somewhat above the floor of the valley at the time the soil formed.

Stop 1-6: Rattlesnake Hollow East Section

Setting From Stop 1-5 to 1-6, the small exposures of diamicton (Kellerville Member) in the modern stream bed give way to a concentration of large boulders. At the cutbank 100 m (328 feet) west (upstream) of Stop 1-6, Pennsylvanian shale is exposed and overlain by postglacial alluvium, but at Stop 1-6, the bedrock surface is below stream level.

Stop 1-6 is a large stream cut on the south bank of Rattlesnake Hollow, exposing 25 m (81 ft) of Quaternary deposits. Its base is at an elevation of about 156 m (513 ft), more than 11 m (37 ft) lower than the base of Stop 1-3. Stop 1-6 exposes more of the Illinois Episode deposits than do the other stops and reveals units not previously seen.

Description At stream level, a dark grayish brown, calcareous, loam diamicton is exposed (Fig. 28). The diamicton is 1.9 m (6.1 ft) thick. Its matrix averages 40% sand, 43% silt, and 17% clay, and it contains a large amount of illite (67%) and a relatively small amount of expandables (11%) in its clay fraction. It contains significantly more dolomite than calcite.

Overlying the diamicton is a succession of coarse, stratified sediments including, at the base, 4 m (14 ft) of very poorly sorted, massive, boulder gravel with rounded to angular clasts of both local (shale and limestone) and erratic lithologies up to 60 cm (2 ft) in diameter in a matrix of calcareous coarse sand (Fig. 29). This unit is overlain by 2.7 m (9 ft) of poorly sorted, calcareous, medium to coarse sand and fine gravel.

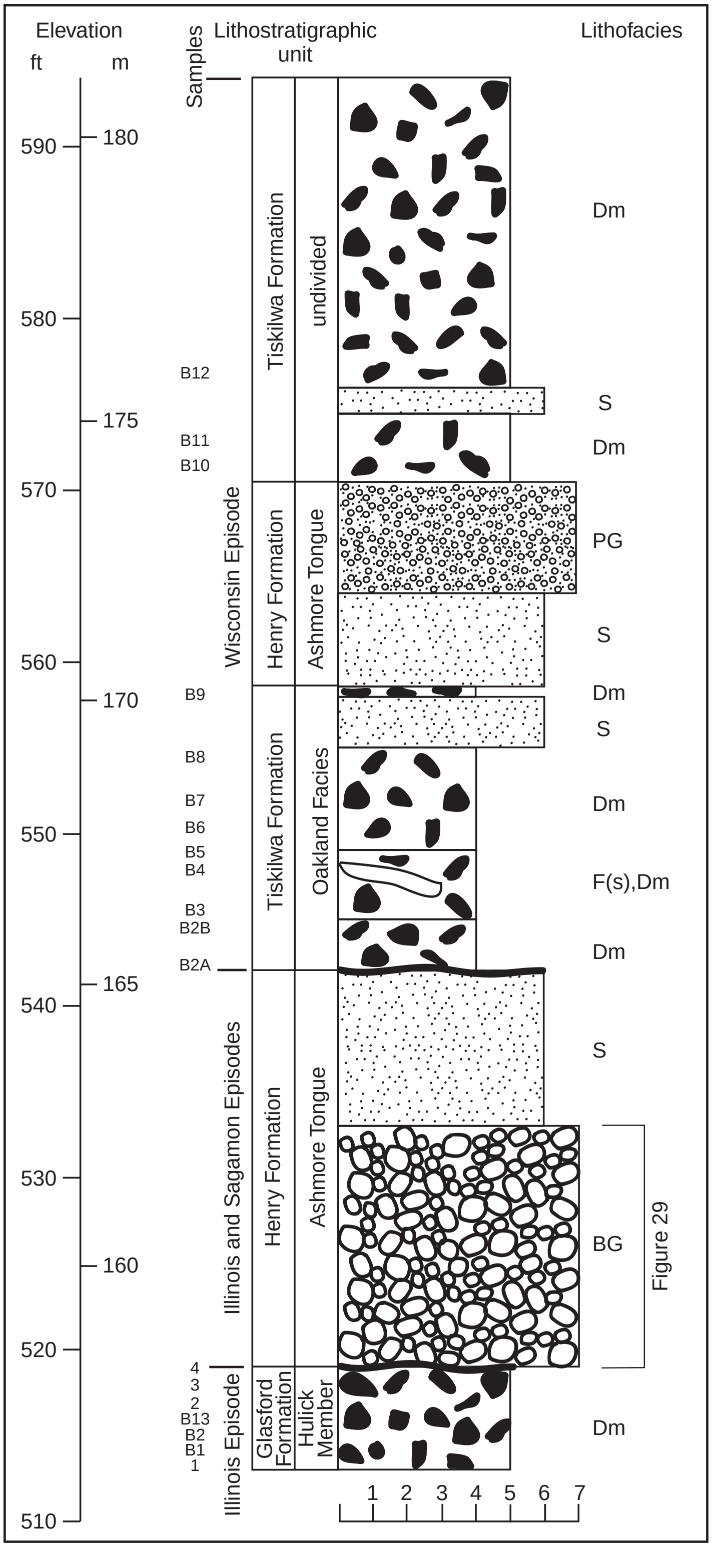


Figure 28 Lithostratigraphy and lithofacies interpretation for deposits exposed at Stop 1-6 in Rattlesnake Hollow, Marshall County, Illinois. Lithofacies code is given in Figure 11.

Figure 29 Boulder gravel exposed at Stop 1-6 in Rattlesnake Hollow.

Dark grayish brown, calcareous silt loam to silty clay loam diamicton, 4 m (13 ft) thick, overlies the sand and gravel on an abrupt planar contact. Included within the diamicton are sheared and attenuated beds and lenses of reddish brown silt loam that resemble the Roxana Silt at Stops 1-3, 1-4, and 1-5.

A sand-and-gravel unit, 4.75 m (15.5 ft) thick, overlies the silty diamicton unit and is interbedded with 15 cm (0.5 ft) of loam-textured diamicton 1 m (3 ft) above its base. The sand-and-gravel unit coarsens upward from medium and coarse sand to pea gravel.

The upper 7 m (23.5 ft) of the outcrop is brown to reddish brown, loam-textured calcareous diamicton.

Discussion The lithologies and mineralogies of the diamictons at stream level at Stops 1-5 and 1-6 differ mark-

Table 3 Mean values for grain size and clay mineral composition of samples of Illinois Episode Glasford Formation diamictons from Stops 1-5 and 1-6.[1]

Illinois Episode diamicton	Grain size (%)			Clay minerals (%)[2]			Texture/XRD[3]
	Sand	Silt	Clay	Exp.	Illite	K + C	(no./no.)
Stop1-6 Hulick Member	40	43	17	11	67	22	7/7
Stop 1-5 Kellerville Member	15	49	36	40	40	20	5/5

[1] Analytical data for the samples included in these averages are given in Appendix B, Tables B-5 and B-6.
[2] Exp., expandable clay minerals; K + C, kaolinite plus chlorite.
[3] XRD, x-ray diffraction.

edly. Table 3 shows the average texture and clay mineralogy of the Illinois Episode diamictons at the two stops. Compared to the diamicton at Stop 1-5, the diamicton at stream level at Stop 1-6 is sandier and less clayey, and its clay fraction contains much more illite than expandable clay minerals. Both diamictons contain much more dolomite than calcite. As we noted at Stop 1-5, the lowest diamicton exposed there correlates to the Kellerville Member. The composition of the Stop 1-6 diamicton is consistent with its being the middle Illinois Episode diamicton (Hulick Member).

The boulder gravel unit is interpreted as a lag deposit of locally derived clasts, eroded from diamicton and local bedrock by the Ancient Mississippi River as it was diverted against the western valley margin by an advancing glacier. The angular nature of many of the boulders, a number of which are brittle fissile shale, indicates they were likely deposited without much lateral transport from their source (i.e., they are a lag deposit). Evidence from the other Rattlesnake Hollow sites and boreholes in the area suggests that as much as 23 m (75 ft) of deposits, mainly the Radnor and Hulick Members, may have been eroded to produce this deposit. The deposit is also the source of the boulder concentration seen in the modern stream west of this site. The boulder bed clearly postdates the retreat of the middle Illinois Episode glacier that deposited the Hulick Member. The absence of late Illinois Episode diamicton (Radnor Member) indicates the deposit may be post-Radnor in age, and, thus, represents a latest Illinois Episode, Sangamon Episode, or Wisconsin Episode event. We interpret the fluvial deposits (boulder lag and overlying sand) as a deposit of the Ancient Mississippi River as its channel was constricted against the western bedrock upland when the first Wisconsin glacier moved into the Ancient Mississippi River valley. Absence of the Sangamon Geosol in the section favors this interpretation. We correlate the lag gravel and overlying sand to the Wisconsin Episode Ashmore Tongue.

The diamicton in the middle of the outcrop is correlated to the Oakland Facies (Tiskilwa Formation). Silt inclusions within the diamicton appear to be reworked Roxana Silt, perhaps entrained in the basal debris of the late Wisconsin glacier by the same process that produced shear deformation of the upper part of the Roxana evident in the exposure at Stop 1-3. The sand-and-gravel bed overlying the Oakland Facies at Stop 1-6 separates the Oakland from the rest of the Tiskilwa Formation. This sand-and-gravel unit is interpreted as having been deposited when the Wisconsin Episode ice margin briefly retreated at this location before advancing to its terminus a few miles to the west, where the glacier left a very large moraine complex (Bloomington Morainic System) (Fig. 2).

Stop 1-7: Midwest Material Company Site, Lacon

Lacon 7.5-minute Quadrangle
SE ¼ Sec. 24, T30N, R3W, Marshall County
Late Wisconsin Episode High Terrace Succession

Timothy J. Kemmis, Edward Hajic, Christopher J. Stohr, Andrew J. Stumpf, André Pugin, and Robert S. (Skip) Nelson

Introduction To interpret past environments, assess natural resources, and conduct environmental planning, it is just as important to understand the Quaternary fluvial record as it is to understand evidence from that of past glaciers, but detailed sedimentologic interpretation of Quaternary sand-and-gravel sequences in the Midwest has been done at only a few select, widely scattered sites. In this section, we present (1) a system for describing sand and gravel that is linked to flow-regime bedform concepts, (2) criteria for recognizing differences in the scale of unconformities in sand-and-gravel sequences, and (3) a method to accurately survey and measure thick, unstable sand-and-gravel exposures. At this stop, we will demonstrate relatively straightforward methods that can be used to interpret past outwash environments. The remaining challenge for this particular site, however, is determining the age and depth of the several meltwater incision and backfill events.

Objective To consider several questions about Wisconsin Episode outwash and the reoccupation of the Ancient Mississippi River valley during formation of the Illinois River valley:

1. What features do we look for in the outwash succession to interpret past streamflow conditions?
2. What comprises the sand-and-gravel succession underlying the terrace?
3. Were the deposits underlying the terrace deposited by a single event or by several?
4. If deposited by several events, can we relate the different units in the sand-and-gravel succession to specific glacial events or episodes?
5. Why did this reach of the Illinois River reoccupy the Ancient Mississippi River valley?
6. How can we accurately describe thick successions such as these from high, unstable exposures?

Setting The present Illinois River valley is a young feature carved into Wisconsin Episode glacial terranes (Fig. 1). The valley has two contrasting reaches in the area covered by the Lake Michigan Lobe: (1) the upper reach, oriented east-west and extending from the confluence of the Des Plaines and Kankakee Rivers to Hennepin, and (2) the upper middle reach, extending south from Hennepin to the margin of the Lake Michigan Lobe at Peoria.

The upper reach of the Illinois River valley northeast of the field trip area is a relatively uniform-width trench that is deeply incised through glacial sediments and into bedrock. Glaciofluvial and fluvial fill is relatively thin on the trench floor, but thicker sequences are preserved beneath a few high terrace remnants. The trench was carved during and after late Wisconsin Episode glacial retreat toward the Lake Michigan Basin as is indicated by breaches through the Marseilles moraine and older moraines and by entrenchment through moraine-dammed lacustrine deposits behind many of these moraines.

At Hennepin, the river turns sharply south through the field trip area and occupies the western edge of the former Ancient Mississippi River valley all the way to the western terminus of the

Lake Michigan Lobe at Peoria (Fig. 1). This reach, the upper Middle Illinois River valley, is incised deeply into the thick Quaternary succession being examined on this field trip. The bedrock valley floor in the field trip area is substantially lower than that of the upper Illinois River valley. The Illinois River valley occupies the western edge of the Ancient Mississippi River valley only; a substantial portion of the broad Illinois and pre-Illinois Episode Ancient Mississippi River valley to the east was not incised or exhumed by late Wisconsin Episode events.

The upper Middle Illinois River valley is dominated by late Wisconsin Episode terraces underlain by thick sequences of sand and gravel. The highest and oldest terrace is unusually broad, generally forming the widest part of the valley, and is discontinuously mantled with loess and eolian sand. Stop 1-7 is a quarry exposure of the sediment sequence beneath one of the high terrace remnants. The top of the high terrace at this location varies in elevation, partly because the surface is mantled by eolian sand and silt dunes and partly because the terrace surface slopes gradually toward the Illinois River. Elevations range from around 174 m (570 ft) above mean sea level near the upland wall down to 152 m (500 ft) toward the river side of the terrace. The elevation at the described section is 157 m (515 ft), which is about 47 m (155 ft) below the summit of the adjacent upland to the east (elevation 204 m [670 ft]) and about 20 m (65 ft) above the present river (elevation of about 137 m [450 ft]).

Younger late Wisconsin Episode terraces in the upper Middle Illinois River valley occur discontinuously as narrow remnants inset against the edge of the high terrace segments. The remaining parts of the valley consist of the modern floodplain and low-elevation Hudson Episode terraces into which large alluvial fans have encroached from the tributary valleys as tributary streams downcut and adjusted to the low levels of the last deglacial discharges in the Illinois River valley. The present Illinois River lacks sufficient slope and discharge to remove the alluvial fans formed from sediment delivered from the tributary valleys.

Several types of discharge events are likely to have occurred during the Wisconsin Episode as the margin of the Lake Michigan Lobe retreated toward the Lake Michigan basin, including seasonal meltwater floods, lake-filtered discharge from moraine-dammed proglacial lakes, and large-magnitude flood events related to failure of morainal dams. Large-magnitude (catastrophic) floods tend to be the most potent of these discharge event types, destroying much evidence of preceding events of lesser magnitude within a given river reach. Development of the present Illinois River valley was likely the result of numerous discharge events. These events include

1. meltwater drainage from the Fox River, a major Illinois River tributary, as at least five successive ice-margins shed meltwater into the Fox River valley;
2. breaching of several moraines and the subsequent drainage of their moraine-dammed lakes, including Glacial Lake Wauponsee that formed behind the Marseilles Morainic System and the associated meltwater discharge along the several hundred miles of the Des Plaines and Kankakee Rivers (attributed to the "Kankakee Torrent"); and
3. breaching of the moraine dam of the Valparaiso Morainic System, which held Glacial Lake Chicago after glacial retreat into the Lake Michigan basin.

Interpretation of Outwash Sand-and-Gravel Sequences This section presents a systematic approach to lithofacies logging and description in sand-and-gravel successions that can be used to relate the deposits to stream-flow conditions. In addition, we will discuss the significance of various order bounding surfaces that occur in the sand-and-gravel deposits.

A useful method for detailed description of sand and gravel was developed by Miall (1977), who devised a lithofacies code for braided-stream deposits that combines grain size and sedimentary structure. Kemmis et al. (1988) expanded this code, enabling the inclusion of more detailed description of gravel size and sorting as well as additional sedimentary structures observed in Wisconsin Episode outwash sequences. The significance of these lithofacies codes is that the sedimentary structures can be related to flow-regime bed forms to interpret past streamflow conditions (Appendix C). Recognition of lateral and vertical changes in sedimentary structure and grain size then enables interpretation of variations in streamflow conditions spatially and through time.

The sand-and-gravel sequences are marked by unconformities on a variety of scales. Geologists (e.g., Miall 1985, p. 270–273; Kemmis et al. 1988)(Appendix C) have noted a hierarchy to these unconformities or bounding surfaces. The smallest, or first-order, contacts constitute boundaries for individual cross-bed sets or beds. Second-order contacts form boundaries for cross-bed cosets or a related group of beds. Most third-order contacts are erosion surfaces that bound a particular channel fill, grouping together multiple groups of beds and/or cross-bed cosets of lower order. A fourth-order contact would include groups of channels, such as in a valley fill. Descriptions using a lithofacies code that can be related to flow-regime bed forms and recognition of these different order bounding surfaces are essential to interpreting the record of outwash sedimentation underlying Illinois River terraces.

A complication to gathering information about outwash sequences is accurately measuring bed thickness and elevation in high, unstable exposures such as this one. We used a reflectorless total station survey instrument to solve this problem (Appendix D).

The Outwash Succession Underlying the High Terrace The thickness of sand and gravel underlying the high terrace here and at most locations in the Illinois River valley has not been determined in detail because of limited subsurface information. The exposed sand and gravel appears to represent just over one-half its total thickness. The 19 m (63 ft) of exposed sand and gravel represents about 55% of the 35 m (113 ft) of sand and gravel encountered in an on-site boring that penetrated the complete succession, ending in very dense gray till.

The exposed sand and gravel provides a complex and interesting record. Close, careful examination of the outcrop, noting the sedimentary structures and the different bounding surfaces, reveals some important information about the sequence.

First, note that even though the sequence is complex, there is surprisingly little lateral variation across the outcrop—similar sedimentary structures are present at about the same elevation across the exposure. Description and characterization of this relatively consistent type of sequence can be made with lithofacies profiles. We described lithofacies profiles from three representative locations: one on the northern end of the outcrop, one near the center, and one near the southern end. The northern location is shown in Figure 30 and is described in Appendix E.

Second, look closely and observe the two major unconformities in the sequence. These third-order bounding surfaces are outcrop-wide angular unconformities that truncate groups of underlying beds. The significance of the unconformities is that they indicate major breaks in sedimentation and the beginning of new depositional events. Unfortunately, they leave no obvious clue as to each event's age.

Third, having noted the unconformities, we recognize that the deposits underlying the high terrace include at least the three groups of exposed sediments. We have informally designated these as Units z, y, and x from the top of the exposure downward. We can now examine the structures within each unit and gain an understanding of changing streamflow conditions.

The Lowest Exposed Unit: Unit x The lowest group of sediments, Unit x, is not completely exposed, so our understanding is only of the last phase of sedimentation for this group. At the time of the descriptions, 3.6 to 4.2 m (12 to 14 ft) of Unit x was present above the floor of the excavation, but only the upper 1.2 to 2.4 m (4 to 8 ft) was not covered with slump (and as discussed previously, about 16 m (52 ft) of sediments underlie the quarry exposures).

The exposed sequence consists of a succession of trough cross-bedded pebble gravel and sand units, facies PGms(t) and S(m), with an upward trend to more finer-grained trough cross-bedded sands at the top of the unit (Fig. 30 and Appendix E). Trough cross-beds are formed by migrating dunes in the higher-energy conditions of the lower flow regime (Appendix C). The sequence constituting this unit indicates valley-train outwash deposition of migrating pebbly sand and sand dunes in a large channel, with slightly lower-energy, finer-grained sediment (sand) deposited toward the top of the preserved sequence.

The Middle Unit: Unit y An angular unconformity with almost 2 m (nearly 6 ft) of relief across the section separates Unit x sediments from those of the overlying Unit y (Fig. 31). The unconformity indicates a distinct change in stream conditions and the initiation of a new sequence of

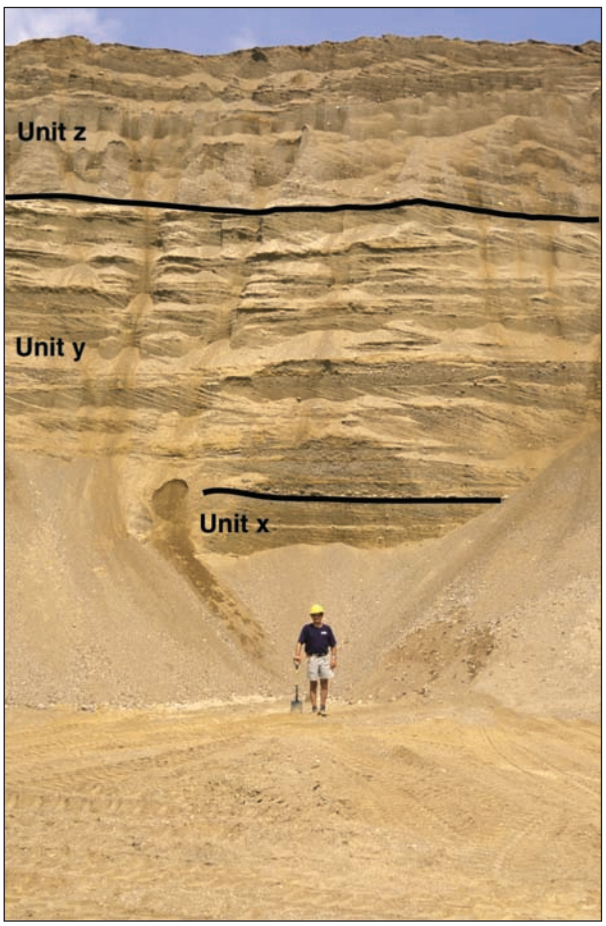


Figure 30 Overview of the described section at the north end of the outcrop. The shovel is 1 m high (3.3 ft).

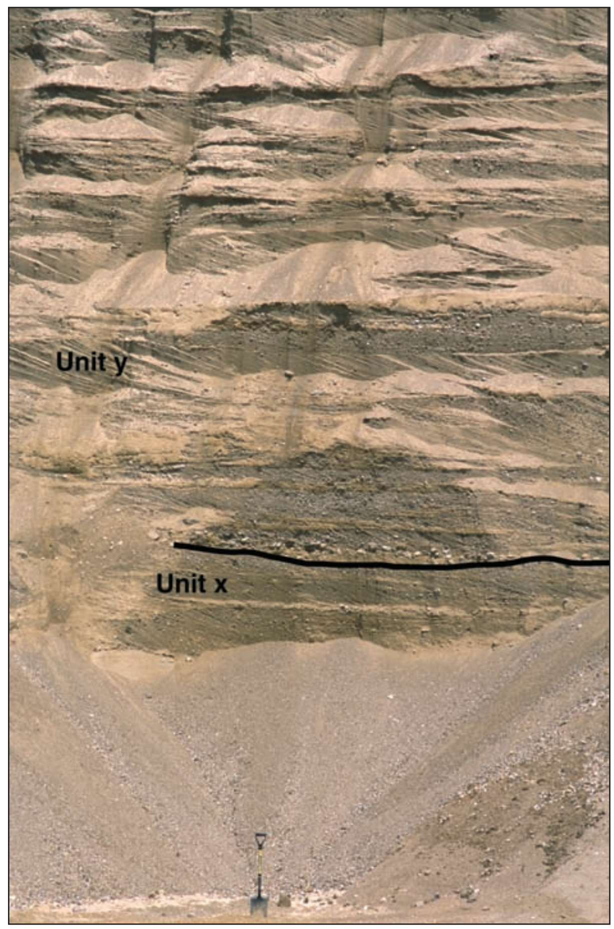


Figure 31 Close up of the unconformity between Unit x and overlying Unit y, showing planar-bedded cobble gravels and the overlying succession of trough cross-beds. The shovel in foreground is 1 m (3.3 ft) high.

sedimentation. At this location, the Unit y sediments are almost 8.5 m (28 ft) thick. High-energy conditions are indicated by the unconformity at the base of Unit y that indicates scour closely followed by deposition of planar-bedded, clast-supported cobble gravels, facies CGcs(pl). Planar-bed conditions occur at the transition between the lower and upper flow regimes (Appendix C) at higher-energy streamflow conditions than those of migrating dunes (trough cross-beds).

The rest of the Unit y succession is similar to that of the underlying Unit x, consisting primarily of an upward sequence of trough cross-bedded pebbly gravel, sandy pebbly gravel, and sand, facies PGms(t), PGms(t)-S(t), and S(t) (Fig. 31; Appendix E), indicating aggradation as dunes of sandy pebble gravel and sand migrated across a large channel floor. Thin diamicton beds are locally present and, in this case, are interpreted to have been deposited from successive events; the thin fine-grained sediment is interpreted to have been deposited under low-energy conditions as stream discharge waned in individual channels followed by deposition of gravel on and in the finer-grained sediment as discharge subsequently increased and the overlying sediments were deposited.

As in underlying Unit x, the Unit y sequence also tends to have more finer-grained sandy cross-beds near the top of the succession, indicating somewhat lower-energy conditions and consequent transport of finer-grained sediment with time.

The Uppermost Exposed Unit: Unit z Another angular unconformity, with nearly 2 m (6 ft) of relief across the outcrop, separates Unit z, which is about 6.4 m (21 ft) thick, from the underlying Unit y. Above this unconformity is the coarsest sand-and-gravel unit with the largest sedimentary structures in the exposure, indicating the highest-energy streamflow conditions of all the exposed units. Unit z consists of large, very thick, and very deep channel fills (Fig. 32) composed of planar-bedded, matrix-supported cobble and pebble gravels, facies CGms(ccf)-PGms(ccf), in which the U-shaped planar beds mimic the channel form.

These thick channel fills, typically 3.5 to 4.2 m (12 to 14 ft) in thickness, are overlain by two to three sets of trough cross-bedded pebble gravels, facies PGms(t) to the top of the exposure.

The Unit z sequence indicates high-energy conditions and scour of the underlying unit y sequence and deposition of planar-bedded cobble and pebble gravels in large, deep channels, probably during major floods. With time, stream and sediment discharge dropped, and trough cross-bedded pebble gravels were deposited from dunes migrating over the former channels. High-energy flood deposits occur at the top of outwash sequences beneath other terraces in the upper Middle Illinois River valley as well, including those up-valley associated with the high and intermediate terraces at Hennepin (Figs. 33 and 34). A sample of Unit z was collected for OSL analysis and yielded an age of 19,450 ± 1,450 cal yr B.P. (Sample UNL-1205), which equates to approximately 16,000 ^{14}C yr B.P. (Table 1). This result reduces uncer-

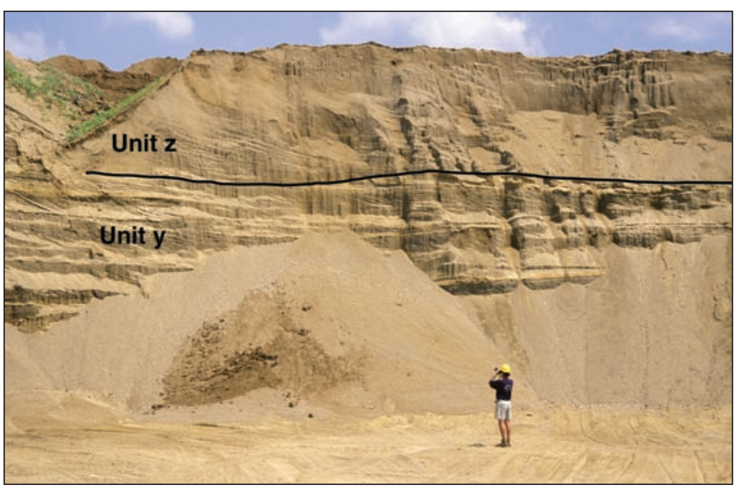


Figure 32 Large, coarse-grained channel fills constitute the lower part of Unit z.

tainty regarding the age of Unit z but needs to be confirmed with additional age determinations. If correct, the result would indicate that Unit z postdates the deposition of the Tiskilwa Formation and the later Batestown and Yorkville Members of the Lemont Formation in the field trip area and confirms that Unit z is inset into the till succession rather than exhumed from beneath the tills. Units x and y have not been dated.

As the Unit z flood waned here at Lacon, the Illinois River downcut west of what is now the high terrace, leaving the top of the succession well over 20 m (65 ft) above the modern river level. Eolian deposits, including loess (Peoria Silt) and eolian sand (Parkland facies of either the Peoria Silt or Henry Formation), were deposited on the terrace surface.

Discussion From the terrace outwash succession, these interpretations can be made:

1. For the outwash succession underlying the terrace surface, distinct sedimentation events for the upper two units are marked by bounding surfaces that signify initial scour and development of an unconformity on the underlying deposits (e.g., Figs. 30 and 31).
2. The coarsest (highest energy) sediments of each unit sedimentation event occur at the base of the units just above the unconformity.

Figure 33 The high terrace succession at the head of the Middle Illinois River valley at Hennepin. Just as at Lacon, the succession here is from multiple depositional events (separated by unconformities), and the uppermost part of the succession has the coarsest, highest-energy deposits.

Figure 34 The intermediate terrace succession of the Middle Illinois Valley at Hennepin. Again, the record consists of a sand-and-gravel succession from multiple depositional events with the coarsest, highest-energy deposits at the top of the terrace succession. Both the high and intermediate terrace deposits are up-valley and coarser than at Lacon, and the intermediate terrace deposits at Hennepin are noticeably coarser than the high terrace deposits. Illinois River valley terraces were each deposited by multiple depositional events, and the highest-energy events of each terrace level are associated with the unit at the top of the sequence.

3. During each sedimentation event, generally lower energy deposition took place with time, the finest-grained beds tending to occur at or near the top of the preserved sequence.
4. The coarsest (highest energy) unit underlying the terrace is the uppermost unit, Unit z.
5. For aggregate resource evaluation, the distinct stratigraphy of the sand-and-gravel succession and the differences in grain size within the stratigraphic units can be extremely helpful for accurately assessing the volumes of different grain-size material at a site.

The Timing and Depth of Outwash Incision and Backfilling Events Detailed examination of the outwash succession here and at other places in the upper Middle Illinois River valley provide insight into the complexity of the outwash sequence, but several questions remain unanswered.

There are several alternative interpretations for the Lacon sequence, and they involve determination of the depth of incision and the age and number of events that backfilled the terrace area with outwash sand and gravel.

One possible interpretation is that late Wisconsin Episode floodwaters deeply carved the present Illinois River valley below any existing Ancient Mississippi River units of sand and gravel and backfilled to what is now the high terrace level during several successive Wisconsin Episode events (at least those related to the exposed Units x, y, and z). Alternative interpretations involve Wisconsin Episode meltwaters carving the present Illinois River valley down only into the top of Ancient Mississippi River sands and gravels and then backfilling with Wisconsin Episode sand and gravel. In the simplest of these cases, incision would occur only to the base of the uppermost unit, Unit z. This case would require only a single large magnitude flood event to incise the valley and form the high terrace, and the units underlying Unit z would be exhumed proglacial Wisconsin Episode or pre-Wisconsin Episode Ancient Mississippi River deposits similar to those we will examine tomorrow at Stop 2-4, the Sandy Creek Section. Other alternatives involve deeper incision, such as to the base of Unit y or Unit x and subsequent deposition by multiple Wisconsin Episode events.

More research is needed to determine which of the alternatives might be correct. Such research could include (1) physical correlation to determine whether the Ancient Mississippi River sands and gravels underlying the uplands east of the high terrace area occur at elevations similar to those at this outcrop, making the exhumation of Ancient Mississippi River sands plausible, (2) mineralogical studies to determine whether mineralogy can be used to correlate sand-and-gravel units, and (3) absolute dating via OSL or other methods to provide direct age correlation of the units.

Seismic reflection profiling was done across the high terrace in an effort to determine the geometry of subsurface units and contacts. This technique might also be helpful in determining whether the contacts and larger sedimentary structures in the Ancient Mississippi River sand and gravel underlying the upland to the east of the site are comparable with those in the sand and gravel at depth beneath the terrace. A shear-wave (S-wave) seismic reflection traverse 650 m (2,130 ft) long was completed across the eastern part of the high terrace beginning 400 m (1,320 ft) east of Stop 1-7 and extending east onto the adjacent upland about 20 m (65 ft) higher in elevation (Fig. 35). Although both S-wave and compressional-wave (P-wave) seismic reflection gave good results, the low water table rendered processing and interpretation of the P-wave section difficult.

Time-to-depth conversion was possible using available regional borehole data. The present upland on the eastern part of the section is underlain by 35 m (115 ft) of Wisconsin Episode diamictons overlying a sand layer 15 m (50 ft) thick that in turn overlies bedrock. An erosion surface

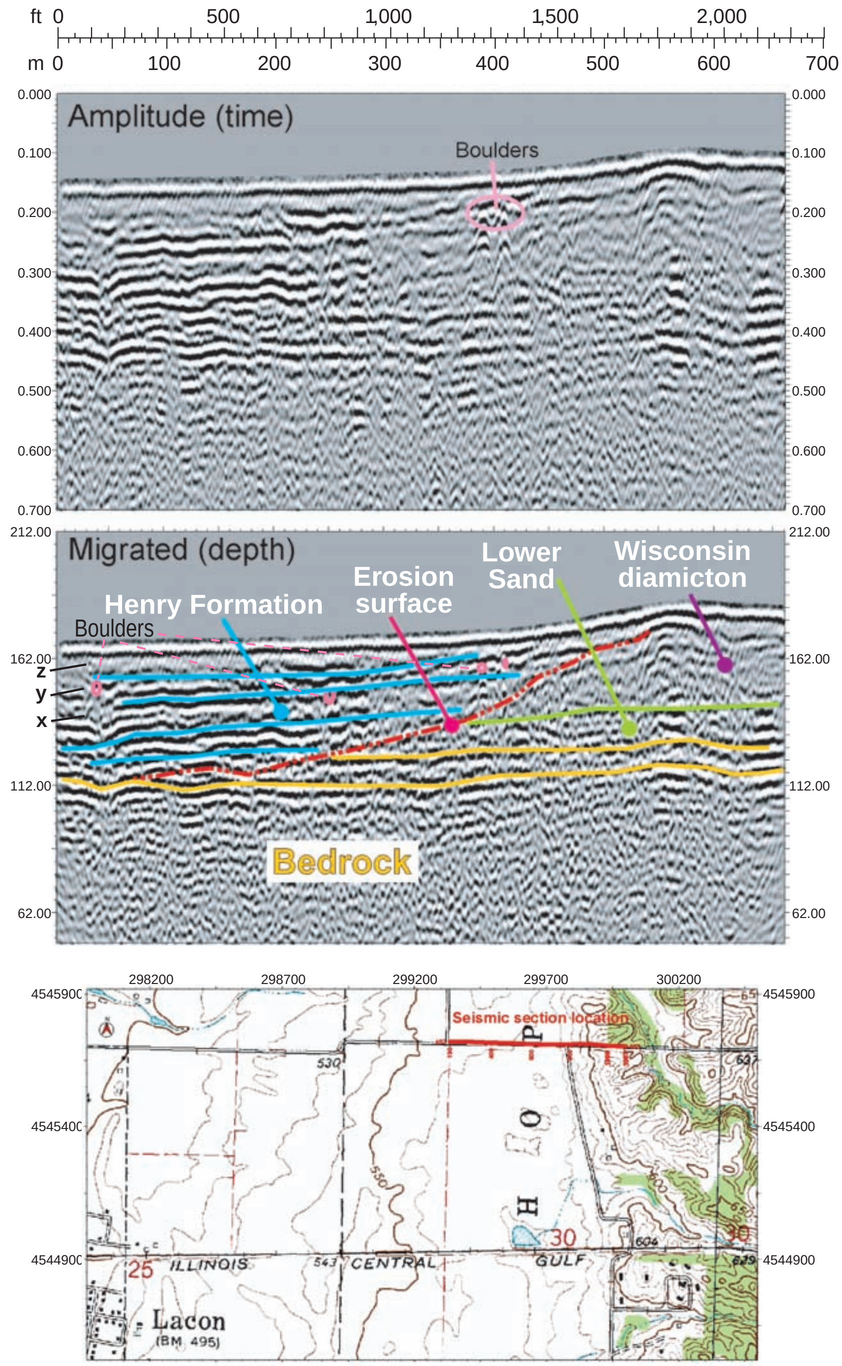


Figure 35 Shear-wave seismic transverse and interpreted stratigraphy across the Illinois River high terrace and adjacent upland east of Stop 1-7 on the Lacon 7.5-minute Quadrangle, Marshall County, Illinois. Colored lines in the middle image show reflection surfaces within color-coded units. The upper yellow line is the bedrock surface. The lower yellow line is reflector within bedrock. Green is the contact of Wisconsin till upon Ancient Mississippi River valley sand and gravel of unknown age. Blue lines are reflectors within the Henry Formation. The uppermost blue and next lower blue reflectors may correlate to the z-y and y-x contacts, respectively. The dashed red line is the interpreted unconformity.

is interpreted to extend downward from the valley wall (terrace-upland boundary), truncating the entire upland till and underlying sand succession as well as the bedrock surface to a level about 10 m (over 30 ft) lower than that beneath the uplands. Sediment of sand and gravel on the western part of the transect (presumably including the Units x, y, and z exposed in the Midwest Materials pit) underlie the terrace, onlap the erosion surface, and, thus, could be interpreted to postdate the Wisconsin Episode diamictons.

This interpretation of the S-wave seismic reflection traverse suggests that late Wisconsin Episode floods formed the present Illinois River valley, cutting the erosion surface into the bedrock underlying the high terrace and depositing the successive sand-and-gravel units.

Geomorphic evidence, such as the configuration of major bars, taken collectively as diagnostic of catastrophic flooding (Kehew and Lord 1987), has been identified down the Illinois Valley and attributed to the Kankakee Torrent (Hajic 1990). This evidence can be interpreted to account for valley incision to the base of the uppermost terrace unit, Unit z, deposition of Unit z, and formation of high terrace remnants of the upper Middle Illinois River valley.

Based on the geomorphic interpretations, the Illinois River valley was carved as an inner flood channel in the Upper Illinois River valley. Streamlined bedrock erosional residuals rise above the valley floor. Behind the Marseilles Moraine, the Illinois River valley heads in the Morris Basin where it represents an incised lake basin outlet. Scoured and channeled upland surfaces between moraines on either side of the Illinois River valley there represent the outer erosional zone formed during the earliest stages of flood flow.

In the upper Middle Illinois River valley, most high terrace remnants that accord with the high terrace at Lacon are preserved on alternating sides of the valley and are interpreted as alcove bars. Most exhibit a marginal channel at the foot of the uplands, although that is not the case at Lacon. The aforementioned high terrace at the bend near Hennepin represents a pendant bar that formed in the relatively sheltered lee of the uplands on the south side of the valley. The catastrophic flood inner channel is represented by the valley area that lies below the high terraces. In this reach, the inner channel exhibits a meandering form.

Farther down valley, the towns of Pekin and South Pekin are situated atop two streamlined high terraces that represent expansion bars immediately downstream of Peoria where the Illinois River passes through the Bloomington Moraine (which here is the terminus of the Lake Michigan Lobe) at the head of the lower Middle Illinois River valley. These bars were deposited upon a broad, biconcave, scoured surface cut into the Bloomington outwash fan; bar tops accord with the high terrace upstream.

Geomorphic evidence for later events related to drainage of Glacial Lake Chicago are uncertain and are not included in the geomorphic interpretation.

Exactly when the Marseilles Moraine was breached and the spillover of floodwaters coursed through other sluiceways and outlets is uncertain. Willman and Frye (1970) estimated the Kankakee Torrent occurred between 14,000 and 15,000 ^{14}C yr B.P. Hajic (1990) estimated that the flood occurred between about 15,500 and 16,000 ^{14}C yr B.P. Incision of the inner flood channel definitely predates 15,000 ^{14}C yr B.P., an age obtained from organic debris recovered from laminated silts within the flood channel. Our OSL ages of 19,450 ± 1,450 cal yr B.P. (UNL-1205) for Unit z and 22,100 ± 1,420 cal yr B.P. (UNL-1204) equate approximately to 16,000 ^{14}C yr B.P. and 18,500 ^{14}C yr B.P., respectively (Table 1). The 16,000 ^{14}C yr B.P. Unit z date from Lacon is consistent with Hajic's (1990) suggested timing. The 18,500 ^{14}C yr B.P. age from Hennepin, also from outwash in a high terrace, however, is older than shown by the Hajic model. No dates are available for other units underlying the terrace surfaces, such as Units x and y at the Lacon exposure. Additional research is necessary to definitively correlate units and determine the age of late Wisconsin Episode incision and backfilling events in the Illinois River valley.

We do not know why did the Middle Illinois River valley reoccupied the Ancient Mississippi River valley during the Wisconsin Episode after retreat of the glacier or, for that matter, why it did during earlier episodes. The valley features preserved today are young, dating to truncation of glacial uplands down-valley from the Marseilles Morainic System. Hence, the record of initial valley development during the Wisconsin Episode has been eroded away by later flood events. Reoccupation of the western edge of the Ancient Mississippi River valley by the Illinois River may have been initiated from subglacial drainage using the Ancient Mississippi River valley or from proglacial drainage along the ice front as the glacier retreated and the stream occupied lowlands on the surface of the freshly exposed Wisconsin Episode glacial succession or from events along the Fox River valley that predated breaching of the Marseilles Morainic System.

Summary Deciphering outwash deposition and understanding outwash successions is just like deciphering the record of any other sedimentary deposit. Understanding involves systematic description of the deposits, in this case description that can be related to streamflow conditions and the geometry of the deposits, including identification of different order bounding surfaces in the successions. This information, coupled with knowledge of the broader geomorphic, stratigraphic, and event contexts, allows the formulation of testable hypotheses to better interpret, understand, and date outwash successions.

Of particular significance to this site is that the sand and gravel underlying the terrace is not a single unit, but several units, each separated by a major unconformity. Stratigraphic units between the unconformities have a distinct stratigraphy, and, in each unit, stream energy decreased as the succession for that unit was deposited.

Once depositional conditions are deciphered, how do we correlate sand-and-gravel units and date stream incision and backfilling? The following questions remain to be answered:

1. How deeply did Wisconsin Episode meltwaters incise the Middle Illinois River valley?
2. How many Wisconsin Episode sedimentary events are discernible? Only one, the flood event that deposited Unit z at this stop? Or were there more, causing deep incision and subsequent deposition of other units, such as Units x, y, and any underlying units not exposed?
3. If there were several closely related periods of late Wisconsin Episode outwash deposition in the upper Middle Illinois River valley, what up-valley glacial events were they related to?
4. Do the different sand-and-gravel units differ mineralogically, and can that aid in correlation? Does the mineralogy of the units differ enough to affect resource use such as differences in groundwater quality and construction aggregate quality?

FIELD TRIP STOP DESCRIPTIONS: DAY 2

Stops 2-1, 2-2, and 2-3: Illinois Route 18 Sections

Henry 7.5-minute Quadrangle
S½ Sec. 35, T31N, R2W, Putnam County
Wisconsin and Illinois Episode Successions in Uplands East of the Illinois River over the Center of the Ancient Mississippi Bedrock Valley

E. Donald McKay III and Richard C. Berg

Introduction Several important and interesting outcrops of Quaternary deposits occur along the south side of Illinois Route 18 east of Henry, Illinois. There the highway descends westward from the uplands into the valley of a westward-flowing, unnamed tributary to the Illinois River for a distance of about 3 km (1.9 mi). Erosion along the south bank of the stream has exposed glacial and fluvial deposits between 1.6 and 2.4 km (1 and 1.5 mi) upstream (east) of the confluence of the tributary and the Illinois River. These exposures lie above the center of the bedrock valley (Fig. 5), the eastern margin of which is another 6 km (3.7 mi) to the east of the stop (Stop 2-1).

Deposits in this area record events that occurred as the Ancient Mississippi River was overridden by Illinois Episode and Wisconsin Episode glaciers from the east. The day's route begins high in the stratigraphic section in the headwaters of the tributary and works westward, down elevation, and down section toward the Illinois River (Fig. 36).

At Stop 2-1, we will examine the outcrop as well as data and results from a 78-m (256-ft) core (I-1081 Nauman No. 1), sampled by the ISGS in 2003 from a site about 400 m (1,300 ft) northeast of Stop 2-1. The core penetrated bedrock in the bottom of the Ancient Mississippi River valley at an elevation of 115.5 m (379 ft), which is about 54 m (177 ft) lower than the base of the outcrop exposure at Stop 2-1 and only a few meters above the lowest known part of the bedrock valley floor.

Despite being located above the bedrock valley, the easternmost stops, Stops 2-1 and 2-2, expose a succession of deposits and paleosols typical of the upland landscape east of the Ancient Mississippi River valley (i.e., Wisconsin till and loess over Sangamon paleosol developed in late Illinois Episode till). These sections show that, by the middle to late Illinois Episode, this part of the Ancient Mississippi River valley had been filled with sediment and that the river had been permanently displaced elsewhere in the bedrock valley. At Stop 2-3, valley-fill sand and gravel intertongues with middle and late Illinois Episode diamictons along a boundary between the Illinoian upland and valley successions. Deformation, faults, and tilting suggest that the sediment at the Stop 2-3 site was deposited atop or adjacent to ice in a setting near the eastern wall of the Ancient Mississippi River valley in middle Illinois time. Stop 2-4, the last stop of the trip, reveals the thickest Illinois Episode fluvial sediment exposed in the Middle Illinois River valley and, together with a core taken at its base, contains a record of deposition in the channel belt of the Ancient Mississippi River valley from perhaps as early as pre-Illinois Episode time through the late Illinois Episode.

Objectives

1. To examine Wisconsin and Illinois Episode glacial and fluvial deposits at a location overlying the axis of the Middle Illinois Bedrock Valley,

2. To study a well-expressed profile of the Sangamon Geosol and discuss evidence for its landscape position and history,
3. To examine a relatively complete succession of middle and late Wisconsin Episode loess buried by Wisconsin Episode tills,
4. To consider the origin of collapsed diamictons and fluvial sediments forming part of the middle to late Illinois Episode fill in the Ancient Mississippi River valley,
5. To study a unique exposure of thick Illinois Episode Ancient Mississippi River sand-and-gravel deposits, and
6. To examine core samples of the deposits from the bottom of the Ancient Mississippi River valley.

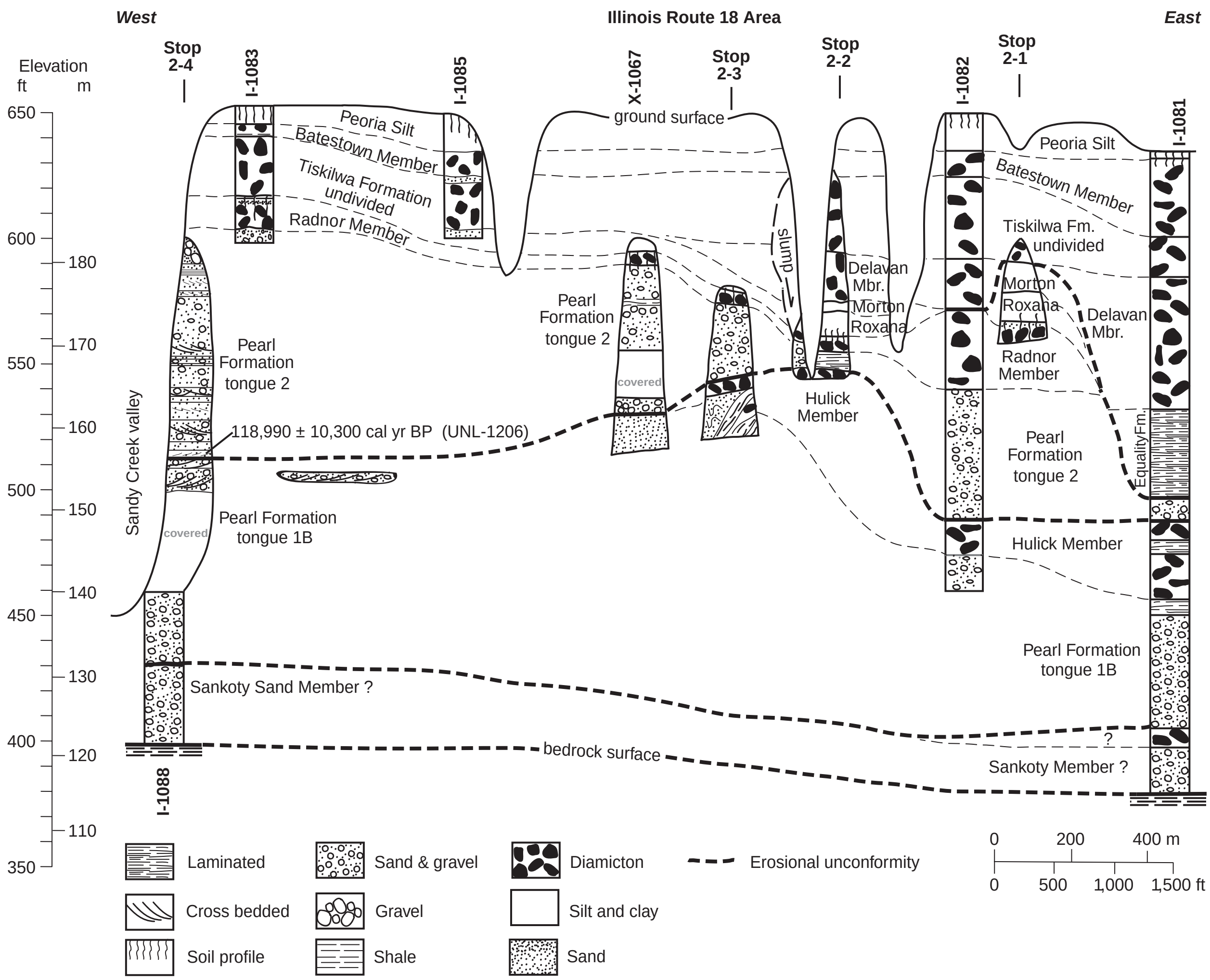


Figure 36 Cross section along Illinois Route 18 providing an overview of lithofacies and lithostratigraphic correlations between field trip Stops 2-1, 2-2, 2-3, and 2-4 east of the Illinois River in Putnam and Marshall Counties. Core I-1082 is 0.4 km (0.25 mi) north of the line of cross section.

Stop 2-1: Sister's Section and Core I-1081

NE¼ SW¼ SE¼, Sec. 35, T31N, R2W, Putnam County (section)
NW¼ NE¼ SE¼, Sec. 35, T31N, R2W, Putnam County (borehole)

Setting Stop 2-1 (Figs. 37 and 38) lies near the headwaters of the Illinois Route 18 tributary valley. The base of the section is approximately 30 m (100 ft) below the surface of the Wisconsin till plain and 54 m (177 ft) above bedrock. Core I-1081 (Nauman No. 1) was taken about 400 m (1,300 ft) northeast of the outcrop.

Description At the base of the Sister's Section is 0.6 m (2 ft) of weathered, silt loam-textured, weakly stratified diamicton containing common coal and shale clasts. The unit is correlated to late Illinois Episode diamicton (Radnor Member of the Glasford Formation; Figs. 37 and 38). Two oxidized samples of the diamicton average 27% sand, 45% silt, and 28% clay. The mean clay mineral composition is 10% expandables, 66% illite, and 24% kaolinite plus chlorite. Analytical data for samples from this outcrop and Core I-1081 are given in Table 1 and in Appendix B, Table B-7.

A well-expressed paleosol profile (Sangamon Geosol) occurs in the lower part of the section (Fig. 38). Its dark A horizon overlies a well-expressed E horizon, and a thick, well-expressed clay-rich Btg horizon. Weathering extends into the stratified sand, gravel, and diamicton that overlie the Radnor Member. The paleosol at this site has a silty, overthickened, upper solum typical of the Sangamon Geosol in this area.

Reddish brown to dark brown silt, 3.7 m (12 ft) thick in the middle of the section, is the Roxana Silt (Wisconsin Episode loess), which conformably overlies the Sangamon Geosol across a gradual contact. The lower part of the loess is leached. The middle 2 m (6.5 ft) contains up to 13% dolomite and less than 2% calcite, and the upper 0.6 m (2 ft) is leached, contains dispersed charcoal, and is a very weakly expressed Farmdale Geosol. Distinctive color zones are present that are characteristic of the Roxana Silt and traceable as far south as Arkansas, suggesting that the unit is completely preserved.

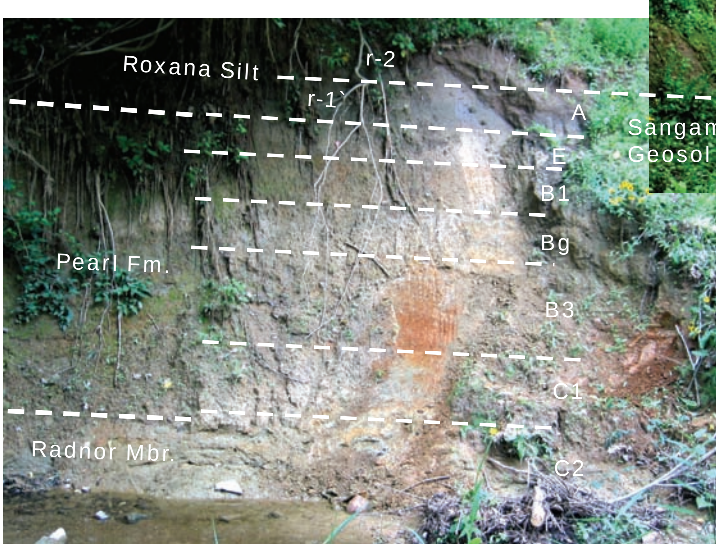


Figure 37 Wisconsin and Illinois Episode deposits and the Sangamon Geosol at Stop 2-1. Lithostratigraphic units, loess zones, paleosol horizons, and contacts are shown.

Above the Roxana loess is 2.67 m (8.25 ft) of light gray to yellowish brown, dolomitic silt, interpreted to be loess of the Morton Tongue (Peoria Silt). It contains up to 20 to 33% dolomite and less than 1% calcite. At the top of the section is 4.3 m (14 ft) of reddish brown, pebbly loam-textured, calcareous diamicton (Tiskilwa Formation).

Discussion The thin weathered diamicton at the base of the exposure is correlated to the late Illinois Episode Radnor Member. At this site, the diamicton is somewhat sandier and less clayey than at Stop 2-2.

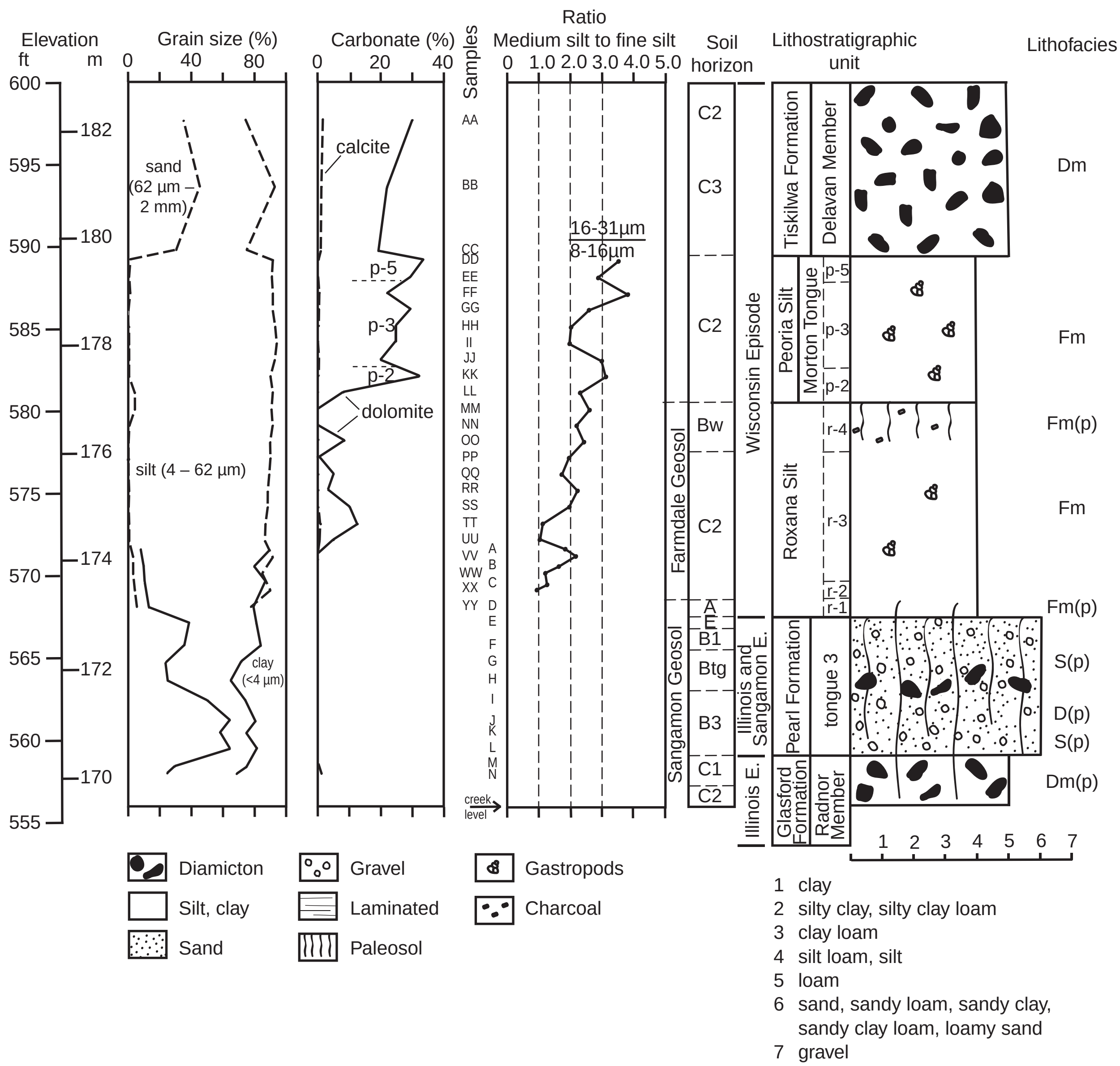


Figure 38 Lithostratigraphic and lithofacies interpretations, grain size, and carbonate mineralogy for deposits exposed at Stop 2-1. Dolomite mineral zones (p-2, p-3, and p-5) in the Morton Tongue of the Peoria Silt and color zones (r-1, r-2, r-3, and r-4) in the Roxana Silt are used as defined by McKay (1977).

As already seen in Rattlesnake Hollow, Sangamon Geosol profiles in the area exhibit a wide range of drainage classes and are developed in a variety of glacial and non-glacial sediments. The paleosol in the lower part of the Stop 2-1 exposure exhibits distinctive horizonation and is developed in alluvium and colluvium overlying late Illinois Episode diamicton (Radnor Member). Comparison of Core I-1081 and Stop 2-1 (Fig. 36) shows considerable relief on the Sangamon surface locally.

Higher in the section, the dark, silt loam A horizon of the Sangamon contrasts sharply in color and texture with the underlying light-colored, loamy E horizon. The A horizon includes a significant proportion of silt, which is interpreted as the first Wisconsin Episode loess increment that was partially incorporated into the soil profile. Studies elsewhere have shown that the silt fraction of that zone contains weathered and unweathered mineral grains, unlike the underlying E and B horizons, which are uniformly highly weathered (Frye et al. 1974). Therefore, these silty A horizons are interpreted to include an increment of unweathered sediment (i.e., early Wisconsin Episode loess).

The Wisconsin Episode loess succession (Roxana Silt and Morton Tongue) at Stop 2-1 is thicker and more completely preserved than in Rattlesnake Hollow (Stops 1-3 through 1-6) where the Morton was absent. The greater thickness of the Roxana Silt at Stop 2-1 may indicate it was nearer its Ancient Mississippi River valley source area than the Rattlesnake Hollow sites and/or that it was downwind of the loess source.

Age determinations on the Roxana Silt and equivalent sediments elsewhere indicate the bulk of the unit was deposited between about 55,000 ^{14}C yr B.P. and about 28,000 ^{14}C yr B.P. (McKay 1979, Curry and Follmer 1992, Grimley et al. 1998), although older ages have been suggested for the lowermost increment (Frye et al. 1974). At Stop 2-1, the lowermost increments of the Roxana loess show considerable pedogenic alteration. Given that this site was adjacent to the Ancient Mississippi River valley where thin increments might be preserved, questions remain, presenting avenues for continued research locally.

Color zones in the Roxana Silt have been related to differences in the color and mineralogy of sediment derived from several sediment source areas in the upper Ancient Mississippi River watershed (Frye et al. 1960, McKay 1977, Follmer et al. 1979, Leigh and Knox 1994). Some color is syndepositional and/or postdepositional pedogenic alteration (McKay 1977). Red hues are thought to indicate sediment from sources in the Ancient Mississippi River headwaters areas of Minnesota and northern Wisconsin (McKay 1977, Leigh 1994, Grimley et al. 1998). Mineralogy of the loess suggests that the brownish gray zone in the middle of the Roxana was derived from outwash that was somewhat richer in illite and dolomite than the reddish zone sources (McKay 1977). This result perhaps indicates a source from the Green Bay and/or Lake Michigan Lobes, which overrode Paleozoic carbonate and shale. Alternatively, this gray sediment may have come in part from an early Des Moines Lobe (Leigh 1994). The upper 1.0 m (3.3 ft) of reddish Roxana Silt (r-4) is leached of carbonate and contains dispersed charcoal fragments. The reddish color has been suggested as being partly due to a northern source and partly due to weathering. The charcoal has not been dated at this section.

The Morton Tongue (lower part of the Peoria Silt) was overridden by the Lake Michigan Lobe. The base of the tongue along the Ancient Mississippi River valley dates to about 25,000 ^{14}C yr B.P. (McKay 1979, Leigh and Knox 1994), and it was buried in this area by the glacier that deposited the Wisconsin Episode till (Delavan Member) shortly after 20,780 ^{14}C yr B.P. (this report). The carbonate zones present within the Morton Tongue (Fig. 38) suggest that the deposit at Stop 2-1 is not truncated significantly. Above a transition zone at the base are three zones, p-2, p-3, and p-5, defined elsewhere and widely traced in Mississippi River Valley loess (McKay 1977). Zone p-2 is an early dolomite-rich zone derived from late Wisconsin outwash carried into the Ancient Mississippi River valley beginning 25,000 to 24,500 ^{14}C yr B.P. from headwaters near Lake Michigan where Niagaran dolomite crops out and local drift is rich in dolomite (McKay 1977, Follmer et al. 1979, Grimley et al. 1998). Zones p-3 and p-5 record combined outwash sources from the upper Mississippi and northeastern Illinois. The upward trend toward higher dolomite indicates the predominance of outwash from the Lake Michigan Lobe as it approached central Illinois.

Both the Roxana Silt and Morton Tongue contain gastropod shells, which have potential significance for ^{14}C age determinations and paleoenvironmental reconstructions. A detailed analysis of the clay and silt mineralogy and geochemistry of this section might be useful for comparison with loess and related sediments elsewhere.

Because the location of the early to middle Wisconsin Ancient Mississippi River valley is uncertain, we used trends in the grain size of loess deposits to help determine the direction of the local loess source. Loess deposits derived from glacial valley trains in the Midwest have well-documented grain-size trends (Smith 1942, Frazee et al. 1970). The deposits become finer grained with increasing distance from the source valley. Samples of the Morton Tongue were collected from Stop 2-1 and several outcrops in the local area. Grain-size analyses of the loess at Stop 2-1 (Fig. 38) show that later increments of the loess were coarser than earlier increments.

Several factors might have influenced the trend in grain size. Perhaps the near-valley margin was progressively eroded, decreasing the distance between the source valley and the Stop 2-1 site during the 30,000 years or so that loess accumulated. Perhaps aggradation of the fluvial surface raised the elevation of the source and thereby effectively decreased bluff height, allowing transport of coarser silt to the site. Perhaps long-term changes in grain size of material transported in the valley occurred as the Wisconsin glacier advanced further south into the Ancient Mississippi River watershed.

The direction to the source valley from the three sampling sites is indicated by Figure 39, which shows ratios of silt fractions of the loess samples from Stop 2-1 and two other sites. These data indicate loess grain-size has a coarsening trend to the north-northeast, which is consistent with regional observations from drilling that have not found evidence of the early to middle Wisconsin Episode valley to the east of the Route 18 sites. Also, outcrop evidence from Clear Creek (Stop 1-1) suggests the main stem of the Ancient Mississippi River was there during the Wisconsin Episode. Thus, the valley could have been about 2 to 3 km (1.25 to 2 mi) to the north of Stop 2-1 when the Morton Tongue was deposited.

ISGS Core I-1081(Figs. 40 and 41) contributes further to the understanding of the local paleogeography and Wisconsin history during the period before the Ancient Mississippi River valley was overridden by the Wisconsin glacier about 20,500 ^{14}C yr B.P. Drilled in 2003 at a site about 400 m (1,300 ft) northeast of Stop 2-1, the borehole penetrated Wisconsin diamictons over Wisconsin lacustrine and fluvial sediments over Illinois Episode deposits to bedrock. The lacustrine deposits (Equality Formation) are of particular importance. They are thick and organic-rich and fill a lake of unknown size that likely occupied a tributary to the Ancient Mississippi River valley during the Wisconsin Episode. The core shows that the tributary was incised into middle Illinois Episode deposits, was drowned and filled with lake sediment, and was buried by the late Wisconsin Episode glacier. Missing from the core are units seen at the Stop 2-1 outcrop, including the Wisconsin loesses, last interglacial soil, and late Illinois glacial and proglacial sediments (Morton Tongue, Roxana Silt, Sangamon Geosol, Radnor Member, and the upper part of the

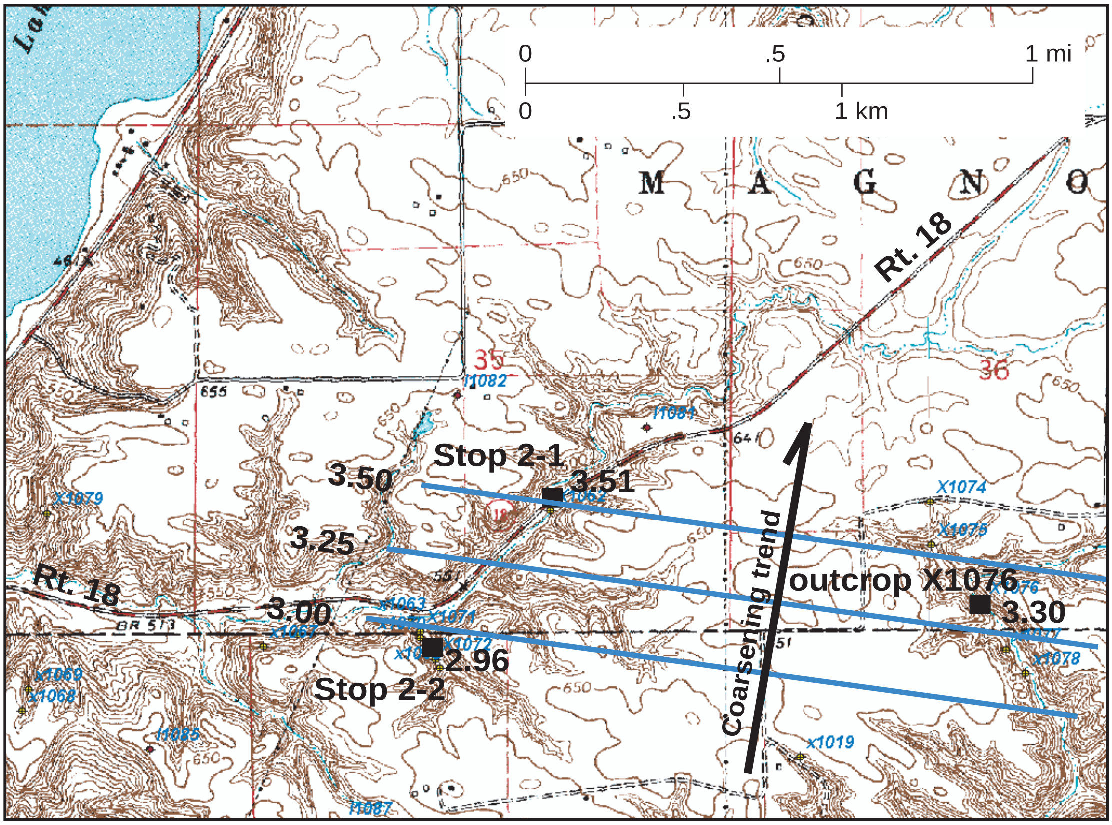


Figure 39 Contoured average values of the ratio of medium silt (16 to 31 µm) to fine silt (8 to 16 µm) for samples of late Wisconsin Episode loess (Morton Tongue) at three sites east of the Illinois River, Henry 7.5-minute Quadrangle.

Pearl Formation). Sediments infilling the tributary include gravel (Henry Formation) at the base and 9.5 m (31 ft) of organic lacustrine silt. Plant remains from six samples range in age from 24,260 ± 760 ^{14}C yr B.P. (29,160 ± 820 cal yr B.P.) near the base to 20,780 ± 140 ^{14}C yr B.P. (24,800 ± 360 cal yr B.P.) at the top (Fig. 39).

Evidence elsewhere provides a chronological context for these deposits and indicates that deposition of late Wisconsin loess (Peoria Silt) began along the Ancient Mississippi River valley about 25,000 ^{14}C yr B.P. (McKay 1979) and that the Ancient Mississippi River was diverted to its modern channel by the Lake Michigan Lobe glacier at 20,350 ± 85 ^{14}C yr B.P. (Curry 1998). These ages and the record in Core I-1081 and the Stop 2-1 outcrop suggest the following events. Some time after deposition of the late Illinois Episode diamicton (Radnor Member), the late Illinois Episode upland was incised, probably by a tributary to the Ancient Mississippi River valley. Incision began as early as the late Illinois Episode and may have continued into the Wisconsin Episode. Absence of the Roxana Silt in Core I-1081 indicates that erosion postdates the early to middle Wisconsin Episode deposit. Lacustrine sediment in Core I-1081 records the creation and infilling of a lake beginning about 24,260 ± 760 ^{14}C yr B.P., suggesting that aggradation and high water in the main stem Ancient Mississippi River valley had blocked the mouth and ponded the local tributary at that time. This age corresponds approximately to the beginning of formation of the Marengo Moraine (comprising Tiskilwa Formation) in the Harvard Sublobe in northeastern Illinois (Hansel and Johnson 1996). A significant source of the outwash in the Ancient Mississippi River valley at this time was the glacier margin in Illinois. Loess deposition at Stop 2-1 during this same period indicates that fluvial surfaces on the Ancient Mississippi River valley floor were periodically exposed, dried, and deflated, continuing to serve as a loess source. Lake infilling in the tributary continued as the Wisconsin Episode glacier approached central Illinois but ceased when the glacier overrode the lake and deposited diamicton (Delavan Member) shortly after 20,780 ± 140 ^{14}C yr B.P. This youngest age for lake sediment from Core I-1081 predates the age of Ancient Mississippi River diversion by a few hundred years.

The slackwater lake site at the Core I-1081 site is located near the easternmost reach of the mainstem of the Ancient Mississippi River valley in central Illinois during the early to middle Wisconsin Episode. It was at least a kilometer and perhaps several kilometers east of the eastern bluff of the river in an area that was near the location of first encounter between the advancing

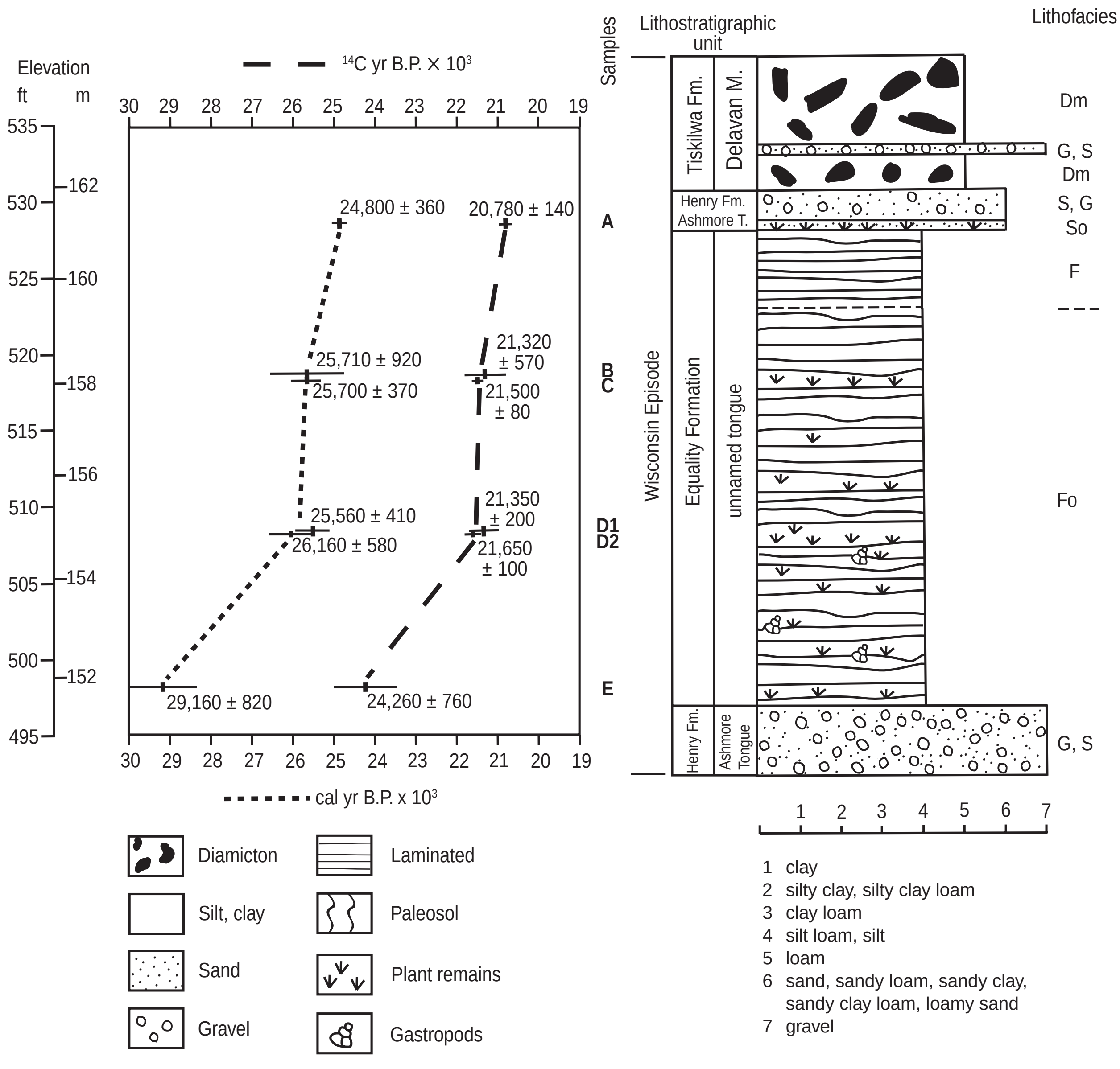


Figure 40 Lithostratigraphy and lithofacies interpretations and radiocarbon ages (14C yr B.P. and cal yr B.P.) of deposits sampled in Core I-1081, located 600 m (1,968.5 ft) northeast of the outcrop at Stop 2-1. Lithofacies code is given in Figure 11.

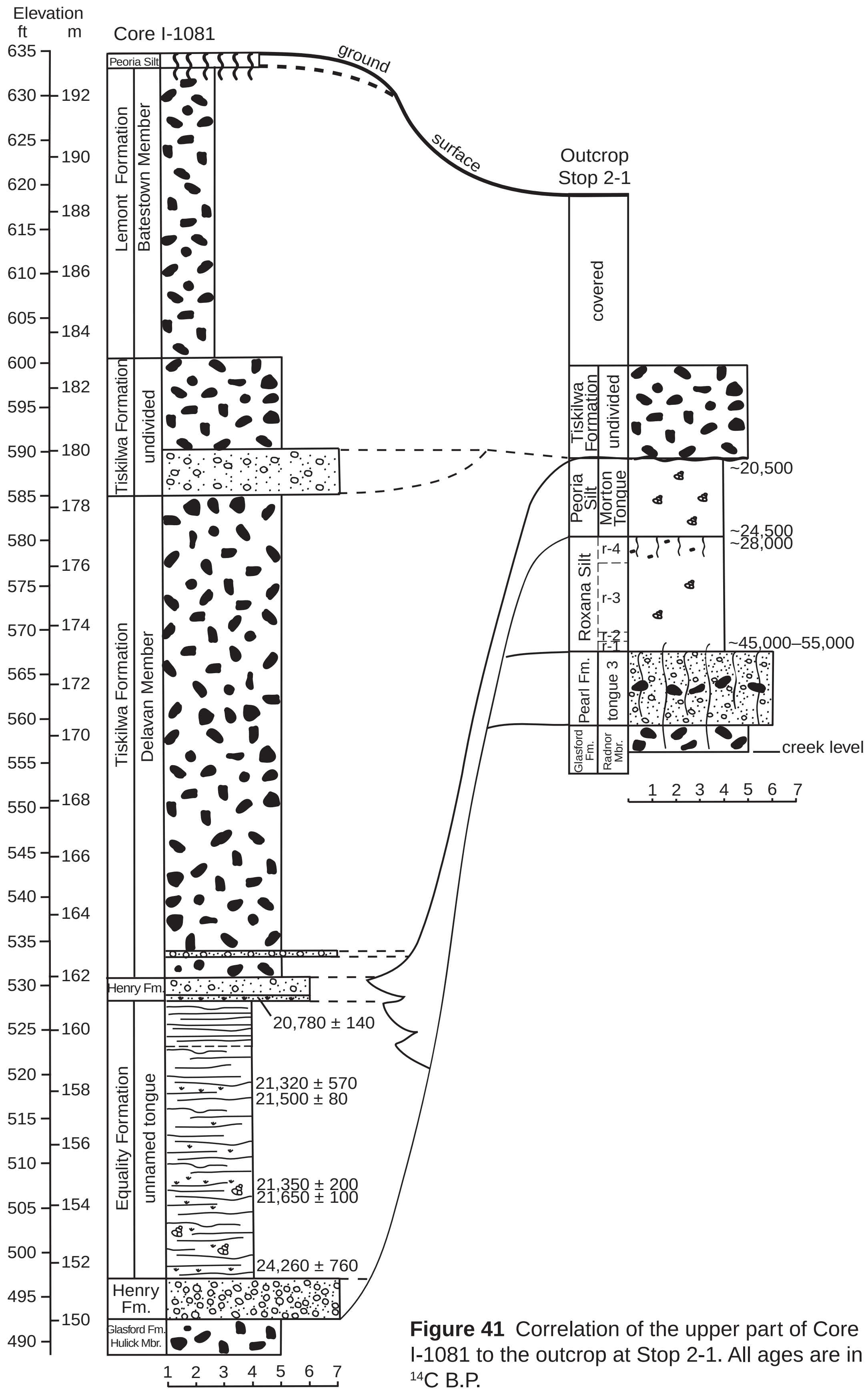


Figure 41 Correlation of the upper part of Core I-1081 to the outcrop at Stop 2-1. All ages are in ^{14}C B.P.

Lake Michigan glacier and the Ancient Mississippi River. The age of the uppermost lacustrine sediment in the lake approximates its burial by the glacier. Blockage of the Ancient Mississippi River would have occurred after the Core I-1081 site was overridden. Blockage may have been a gradual process if the Ancient Mississippi River maintained its course along the glacier margin for a time as it was pushed westward. Eventually constricted between the ice sheet and the bedrock-defended western bluff, the river was blocked, forming Lake Milan to the north. The lake filled and eventually spilled over a divide at Rock Island. Diversion of the Ancient Mississippi River to the modern Mississippi River channel was complete.

Deposits interpreted to be a sedimentary record of the diversion are preserved at Lomax in western Illinois along the postdiversion river valley about 120 km (75 mi) south of Rock Island. There the age of the diversion is estimated from several samples to be 20,350 ± 85 ^{14}C yr B.P. (Curry 1998). That result is several hundred years younger than our uppermost sample (20,780 ± 140 ^{14}C yr B.P.) from I-1081, but the exact age difference between the sites is difficult to know given the significant error ranges on the ^{14}C determinations. The relatively small difference does suggest the diversion took place shortly after the I-1081 site along the Ancient Mississippi River valley was overridden glacially. Because of measurement uncertainty, however, the age difference is an imprecise estimate of the time required for the glacial blockage of the Ancient Mississippi River valley in central Illinois to flood Lake Milan, spillover at Rock Island, and impact the western valley at Lomax.

Stop 2-2: December Section

SW ¼ SE ¼ SW ¼ Sec. 35, T31N, R2W, Putnam County

Setting Stop 2-2 is about 500 m (1,600 ft) downstream of Stop 2-1 on the south side of the highway. It includes two stream cut exposures. The exposure nearest Illinois Route 18 is a stream bank that exposes the toe of a landslide. Upstream in the lower end of a northward flowing gully is an intact succession of deposits.

Description The first exposure shows 1.5 m (5 ft) of loam-textured, calcareous diamicton at the base overlain by 2.1 m (7 ft) of sand and gravel, which is overlain by 1.5 m (5 ft) of reddish brown, calcareous, loam-textured diamicton on a shear-plane contact that shows evidence of lateral sliding and small-scale infolding.

The second exposure (Fig. 42) occurs a short distance upstream in a gully that enters the main stream from the south. It shows 0.5 m (1.6 ft) of calcareous, coal-rich, loamy and texturally variable diamicton (Hulick Member), overlain by 1.5 m (5 ft) of bedded sandy silt, overlain by 4 m (13 ft) of silty clay diamicton (Radnor Member) with a paleosol (Sangamon Geosol) in its upper part. Above the Radnor Member are 2.1 m (7 ft) of reddish brown loess (Roxana Silt) and 1 m (3 ft) of yellowish brown loess (Morton Tongue), the upper part of which is covered by slump debris.

Discussion At the first exposure (near the road), a landslide of unknown age (probably historical) has carried Wisconsin Episode diamicton (Tiskilwa Formation) down slope atop Illinois Episode sand and gravel and diamicton (Pearl Formation over Hulick Member). Missing from the section are units probably totaling more than 7 m (23 ft) thick, including the late Illinois Episode diamicton, last interglacial soil, Wisconsin loesses, and the lowermost Wisconsin Episode till.

This landslide site is an example of a common challenge in the mapping of surficial deposits in the area. Much of the slope area in the major tributaries of the Illinois River has undergone mass movement. Many and perhaps most of the Quaternary exposures are significantly disturbed by slumping, which necessitates extra effort early in the mapping project to identify sites from which the stratigraphic framework can be reliably established.

The second exposure (in the north-flowing tributary) shows the intact succession from the middle Illinois Episode diamicton (Hulick Member) upward through the younger Wisconsin loess (Morton Tongue). This is the only exposure we will see on the trip of relatively unweathered late Illinois Episode diamicton (Radnor Member), which at this site is a silty clay loam to silty clay texture and is significantly more illitic (81% illite) than the other Illinois Episode diamictons.

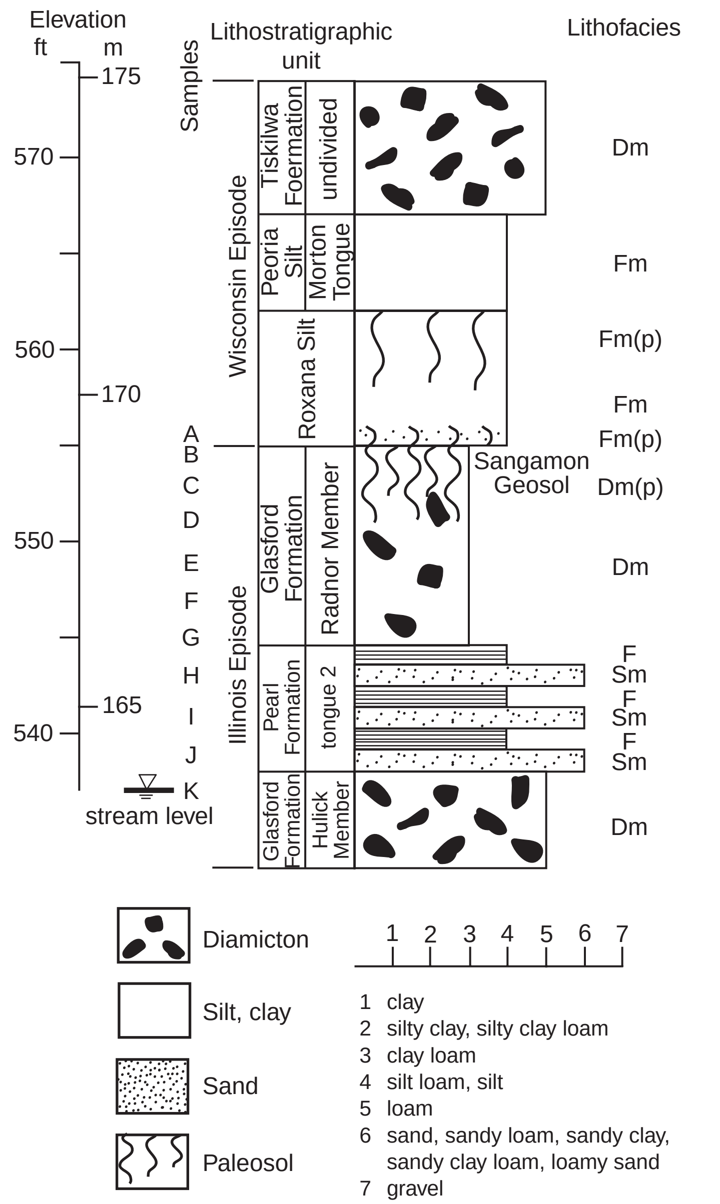


Figure 42 Lithostratigraphy and lithofacies interpretations of deposits exposed at Stop 2-2. Lithofacies code is given in Figure 11.

Stop 2-3: Kettle Section

SW¼ SW¼ SE¼ Sec. 35, T31N, R2W, Putnam County

Setting Like the other stops along Illinois Route 18, Stop 2-3 overlies the approximate center of the bedrock valley. But, unlike Stops 2-1 and 2-2, Stop 2-3 exposes thick, coarse-grained glaciofluvial deposits (Figs. 43, 44, and 45). The exposure occurs on a high cutbank on the south side of the stream. Recent slumping has exposed a thick upper section of deposits. The base of the section lies at an elevation of 158 m (520 ft), about 43 m (140 ft) above the bedrock surface. Less than 100 m (300 ft) downstream of Stop 2-3 is another exposure that we will not visit, but that is important and is discussed because it has exposed a succession of deposits similar to those in the upper part of Stops 2-3 and 2-4. That site, the Little Sandy Section, has allowed tracing of the thick Illinois Episode fluvial succession of Stop 2-4 to be traced to within 100 m of Stop 2-3.

Description Exposed at the base in the lower left (east) part of the section are interbedded sand, sandy silt, sandy gravel, and diamicton, more than 13 m (42 ft) thick (Fig. 43). These deposits dip 20 to 25 degrees to the right (west) across the face of the exposure. The lower part of this succession is predominantly sand, silt, and silty sand (Fig. 45). Up-section these deposits are mainly bedded, loam-textured diamicton. This tilted lower succession is cut by numerous small offset faults at high-angle to the attitude of the beds. Along the upper part of this face of

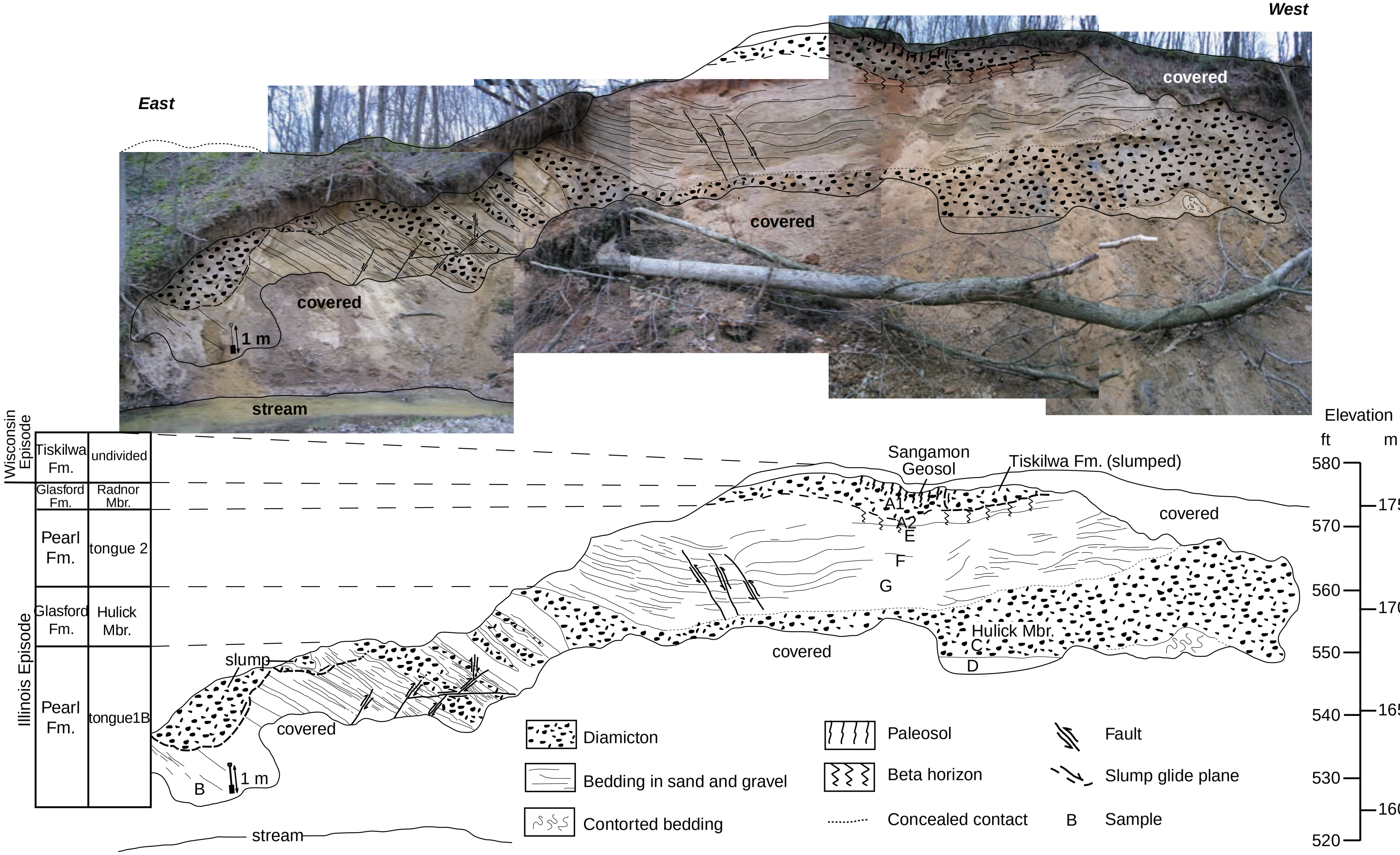


Figure 43 Photomosaic and sketch of Kettle Section (Stop 2-3), showing bedding, contacts, structures, lithofacies, and lithostratigraphic correlations. Photogaphs and mosaic by E. Donald McKay III.

the exposure, slump debris of reddish diamicton derived from up-slope and up-section, covers the underlying deposits. These resemble the shallow slump deposits at Stop 2-2.

At the top of the rotated deposits is 2 to 3 m (6.6 to 10 ft) of unoxidized to oxidized, loam-textured diamicton (Fig. 43) that is present across the entire exposure. Samples of the unoxidized diamicton have an average clay mineral composition of 4% expandables, 67% illite, and 29% kaolinite plus chlorite (Appendix B, Table B-9). Near the west end of the exposure, stratified silty clay and silty sand with strongly contorted bedding underlie the diamicton. The loam diamicton is overlain by about 5 m (16 ft) of generally flat-lying, matrix-supported, calcareous, pebble gravel containing cobbles up to about 15 cm (6 inches). This unit is cut by several high-angle reverse faults with associated drag folds and overlain by 1 to 2 m (3 to 6 ft) of red, weathered sand and gravel.

Unconformably overlying the red weathered zone are complexly deformed diamictons, silt, paleosol, and sand and gravel. An accurate interpretation of the age of these complex upper deposits and soils is important to understanding the age and history of the underlying deposits. Oxidized, calcareous, silty clay-loam diamicton from beneath

Figure 44 High-angle reverse fault (black dashed line) offsets beds (red dashed lines) in the upper gravel (Pearl Formation tongue 2) exposed in the Kettle Section (Stop 2-3), Marshall County, Illinois. Shovel is 1 m (3.3 ft) long.

Figure 45 Tilted thin interbeds of silt, sandy silt, and loam diamicton exposed in the Kettle Section (Stop 2-3), Marshall County, Illinois. Beds are cut by very small offset normal and reverse faults (not visible) at high-angle to the bedding. Shovel is 1 m (3.3 ft) long.

the paleosol in this upper zone has a clay mineral composition of 7% expandables, 82% illite, and 11% kaolinite plus chlorite.

Discussion High-angle reverse folds and steeply tilted beds of the lower part of the section suggest letdown over a buried, melting ice block (McDonald and Shilts 1975). Although faulted, the dipping bedded sediments are largely intact, suggesting that they were frozen or let down slowly. Multiple thin diamicton interbeds were likely deposited as debris flows. Thick gray, loam diamicton in the middle of the section is also interpreted as a flow and has a clay mineral composition most like that of the middle Illinois Episode diamicton (Hulick Member).

Gravel that overlies the Hulick Member and underlies the late Illinois Episode diamicton (Radnor Member) is correlated to tongue Pe-2 of the Pearl Formation. This unit at Stop 2-3 is generally flat-lying, but sags gently toward the center of the section and is cut by reverse faults with offset of about 0.5 m (1.5 ft). The unit contrasts markedly with the underlying tilted and faulted deposits (Fig. 44). Unit Pe-2 is interpreted as a proglacial channel-belt deposit of the Ancient Mississippi River emplaced when the river returned to the area following retreat of the margin of the middle Illinois (Hulick) glacier. The fact that this post-Hulick, pre-Radnor gravel is deformed suggests that the succession was emplaced on stagnant glacial ice.

The paleosol near the top of the section is interpreted as the Sangamon Geosol developed in thin silty parent material overlying late Illinois Episode diamicton (Radnor Member). Although incompletely exposed, the paleosol clearly underlies Wisconsin Episode sediments and is not cut by the faults present in the lower part of the section. The illitic, silty clay loam diamicton is like that exposed at Stop 2-2 as well as at X-1067 (Fig. 36) 100 m (330 ft) to the west. At X-1067, Radnor till overlies sandy gravel (tongue Pe-2), as it does here at the Kettle Section. The reddish soil zone most visible near the top of the Kettle exposure is a beta horizon, which formed under Sangamon Episode weathering. A beta horizon is a particular type of Bt horizon that forms at the contact between finer-textured materials (above) and coarser-textured materials and may be separated from the main Bt horizon by relatively unweathered material, which is the case at this site.

Although a slump complicates the upper part of the Kettle Section, the presence of a Sangamon Geosol confirms the assignment of the underlying deposits to the Illinois Episode. About 100 m west of the Kettle site, the middle Illinois Episode till (Hulick Member) has been cut out and is replaced by the upper gravel (tongue Pe-2) at Kettle.

Stop 2-4: Sandy Creek Section and Cores I-1083 and I-1088

Henry 7.5-minute Quadrangle

NW¼ Sec. 3, T30N, R2W, Marshall County

Late Wisconsin Episode Diamictons over Illinois and pre-Illinois Episode Valley Fill in the Ancient Mississippi River Valley

E. Donald McKay III, Richard C. Berg, and Timothy J. Kemmis

Objectives

1. To examine fluvial deposits that fill the Ancient Mississippi River valley in the upland east of the Illinois River valley.
2. To view more than 40 m (130 ft) of Ancient Mississippi River valley sand and gravel, the thickest exposure of pre-Wisconsin fluvial deposits in the area.

3. To discuss evidence from a core of Wisconsin and Illinois deposits in the upland above the section.
4. To discuss sedimentologic and lithostratigraphic interpretations of the exposed Ancient Mississippi River deposits.
5. To examine samples of reddish sand (Sankoty Member?) sampled in a core drilled below the section.

Setting Sandy Creek is one of the largest tributaries of the Middle Illinois River. Its 1.2-km (0.75-mi)-wide valley is incised 60 m (200 ft) below the adjacent uplands. Its headwaters, 40 km (25 mi) east of the field trip area, originate in a temporary outlet where glacial Lake Pontiac (late Wisconsin Episode) spilled through the Minonk Moraine (Fig. 2) and on to the Illinois River during the retreat of the Lake Michigan Lobe (Willman and Frye 1970). The exposure was described previously by students and faculty from Illinois State University (Nelson et al. 2002). Two cores drilled at the site in 2003 are the basis for our revised stratigraphic interpretation.

Description The total thickness of Ancient Mississippi River fill at this location, determined from a core drilled in the upland above the outcrop, the outcrop, and a core drilled at the base of the outcrop is about 77 m (251 ft) (Figs. 46 and 47). Analytical data for samples from the cores and outcrop are given in Appendix B, Tables B-10 and B-11.

Core I-1083 was taken on the upland immediately upslope of the outcrop at a surface elevation of 199 m (654 ft). The core penetrated 11.3 m (37 ft) of silt and diamictons over a truncated paleosol in diamicton, ending in gravel correlated to the gravel about 1 m (3 ft) below the top of the outcrop.

Core I-1088 was drilled on the debris apron at the base of the outcrop slope to determine the succession of deposits below the outcrop. The core penetrated 19.5 m (64 ft) of sand and gravel before refusal at an elevation of 122 m (399 ft), which is interpreted as bedrock. The succession includes 5.2 m (17 ft) of yellowish brown sand and matrix-supported pebble gravel, overlying 5.2 m (17 ft) of pinkish yellowish brown interbedded sands and pebble gravels, overlying 9 m (30 ft) of red sands and pebble gravels, which extend to bedrock at elevation 130 m (428 ft). Fragments of pelecypod shells were recovered just above bedrock.

The outcrop exposes a succession of four thick sand-and-gravel units deposited by the Ancient Mississippi River. The combined thickness of the four units is about 27 m (90 ft). Unconformities separate the units, and the thickest, coarsest beds for each unit, representing the highest energy conditions, occur at or near the base of each unit. A detailed description is given in Appendix F. A brief description follows.

The lowest 6 m (20 ft) of sands and gravels exposed at the base of the section is designated as Unit I (Figs. 47 and 48). Unit I differs distinctly from the overlying units in being slightly pink, rather than yellowish brown, and flow directions are to the east-southeast, rather than to the west-southwest as in overlying units. At the base of the exposed section is a very thick, only partially exposed bed. Because of the limited exposure, it is uncertain whether the exposed 2.7-m- (9-ft-) thick foresets of this bed are cross-beds, representing migration of a large dune during flood conditions, or if the foresets are lateral accretion beds of a transverse channel fill. The succession overlying this bed changes upward from trough cross-bedded pebble gravels and sand, in which Illinois State University geologists have noted flute casts (Nelson et al. 2002), to ripple-drift cross-laminated sand to thinly bedded and laminated sand, indicating decreasing flow strength as this unit was deposited.

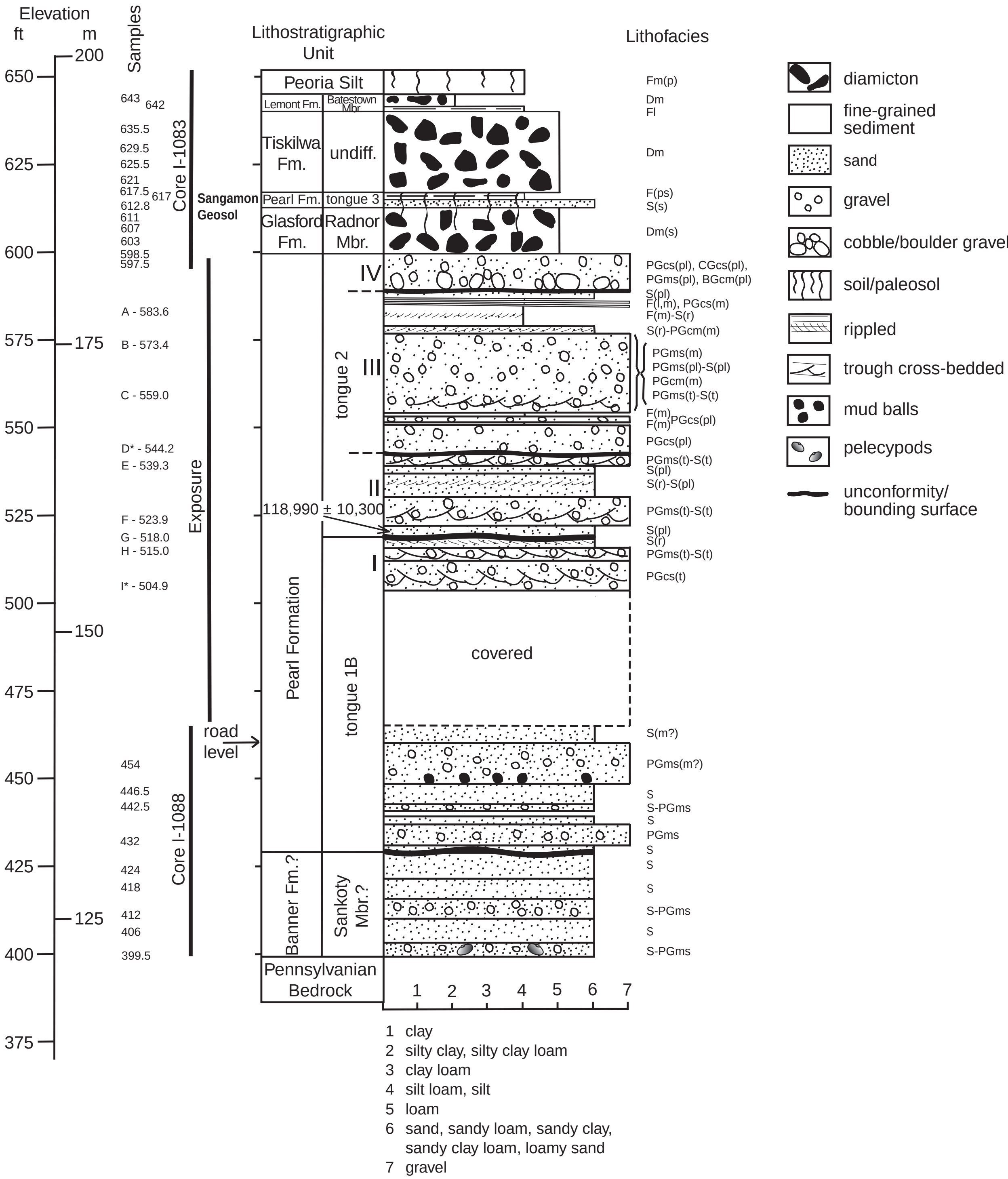


Figure 46 Lithostratigraphy and lithofacies interpretations of deposits exposed at the Sandy Creek Section (Stop 2-4) and sampled in Cores I-1083 and I-1088. Lithofacies code is given in figure 11 for fine-grained deposits and diamicton and in Appendix C, Table C-1 for coarse deposits.

The overlying Unit II is more than 6 m (20 ft) thick and is oxidized yellowish brown. Cross-bed dip directions in this unit, like that in the overlying unit, are to the west-southwest. Interbedded trough cross-bedded pebble gravel and sand occur at the base of the unit, which is overlain by low-energy ripple drift and thinly bedded to laminated sand. Trough cross-bedded sand and pebbly sand occur at the top of the unit. A single sample from the base of Unit II yielded an OSL age of 118,990 ± 10,300 cal yr B.P. (Sample UNL-1206; Figure 46 and Table 1).

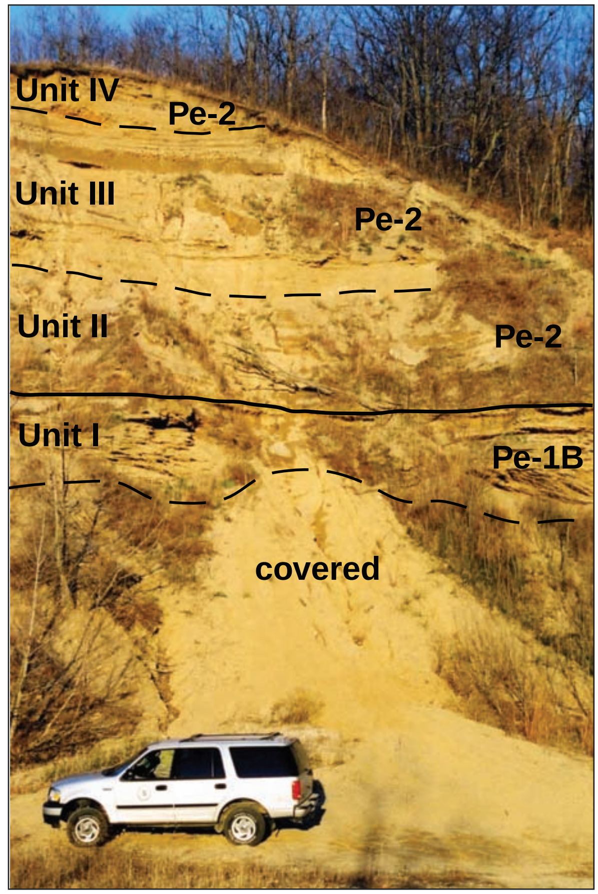


Figure 47 Sandy Creek Section (Stop 2-4) showing Illinois Episode fluvial gravel and sand of the Pearl Formation, described field Units I through IV, and Pearl Formation tongues (Pe-1B and Pe-2). Refer also to Figure 46.

The overlying Unit III (Fig. 48) is more than 14 m (47 ft) thick, and it is also oxidized yellowish brown. Cross-bed dip directions indicate flow to the west-southwest for this unit. Stream flow strength fluctuated during aggradation of this unit. The coarsest deposits occur at the base and include well-sorted, planar-bedded, clast-supported pebble gravels (facies PGcs(pl)). Shallow troughs or channels cut in the tops of the gravels are filled with massive silts and very fine sands (facies F(m)), deposited during periods of waning flow in the course of episodic sedimentation of the pebble gravels. Overlying the gravels is a thick sequence of trough cross-bedded sandy pebble gravel and sand, deposited as dunes migrated over the channel floor. The trough cross-bedded sands and gravels are overlain by massive to planar-bedded sands, pebbly sands, and ripple-drift cross-laminated sands. Low-energy, massive, laminated, and ripple-drift cross-laminated silts and sands occur near the top of the unit.

The uppermost exposed unit, Unit IV (Fig. 48), is 3.2 m (10.5 ft) thick and oxidized yellowish brown. This unit is the coarsest sand-and-gravel unit at this location and consists of planar-bedded boulder, cobble, and pebble gravel in the lower half of the unit and planar-bedded pebble gravel in the upper half. The paleoflow direction is difficult to determine from these deposits.

Discussion Taken upslope of the outcrop, Core I-1083 penetrated a succession of Wisconsin and Illinois Episode deposits overlying those exposed. From the top, the core included 2.7 m (9 ft) of loess (Peoria Silt), 1.2 m (4 ft) of gray loam diamicton (Batestown Member), 7 m (23 ft) of reddish brown loam diamicton (Tiskilwa Formation, undivided), and 4.3 m (14 ft) of gray loam Illinois Episode diamicton (Radnor Member). The Radnor till is weathered in its upper part (Sangamon Geosol) and overlies 1.2 m (4 ft) of Illinois Episode sand and gravel (Pearl Formation).

Prior to collection of Core I-1083, the outcrop had been interpreted as late Wisconsin Episode Henry Formation deposited by the Illinois River and Sandy Creek (Nelson et al. 2002). Discovery of Wisconsin Episode tills (Batestown Member and Tiskilwa Formation), an interglacial soil

(Sangamon Geosol), and an Illinois Episode till (Radnor Member) overlying the thick sand and gravel indicates that the thick sorted sediments at Stop 2-4 are Illinois Episode or older. The OSL age of 118,990 ± 10,300 cal yr B.P. (Sample UNL-1206; Table 1) generally supports this interpretation and falls during a time considered to be part of the Sangamon Episode. Nevertheless, the Sandy Creek Section is thought to be the thickest outcrop of Illinois Episode Ancient Mississippi River sand and gravel (Pearl Formation) in the area.

The absence of early and middle Illinois Episode diamictons (Kellerville and Hulick Members) indicates that both were eroded at this site during one or more periods of Ancient Mississippi River incision during the Illinois Episode. A single post-Hulick incision event may have eroded both. If so, much of the exposed sand and gravel dates to the middle Illinois Episode or later. Alternatively, the marked change in paleoflow direction in the sequence between Units I and II could mark a significant unconformity that separates two episodes of valley fill. This unconformity is the most significant in the Stop 2-4 outcrop. Thus, sand-and-gravel units above the change in paleoflow direction (Units II through IV) are tentatively correlated to the younger tongue of the Pearl Formation (tongue Pe-2), which underlies the late Illinois till (Radnor Member), and Unit I is tentatively correlated to the older tongue of the Pearl Formation (tongue 1B) that elsewhere underlies the middle Illinois Episode till (Hulick Member). Tongue Pe-2 is also present at Stop 2-3 (Kettle), where it occurs between the Radnor and Hulick Members. Tongue Pe-2 records similar paleoflow directions at both Stops 2-3 and 2-4.

In Core I-1088, drilled downward from the base of the Stop 2-4 outcrop, red sand at the base is significantly different in composition from overlying deposits. The red sand has a uniquely low content of calcite and dolomite (Appendix B, Table B-11) and contains large bivalve clam shells in the lower 0.6 m (2 ft) of the deposit, which rests on Pennsylvanian bedrock 20 m (64 ft) below the base of the exposure. This reddish sand unit is tentatively correlated to the Sankoty Sand

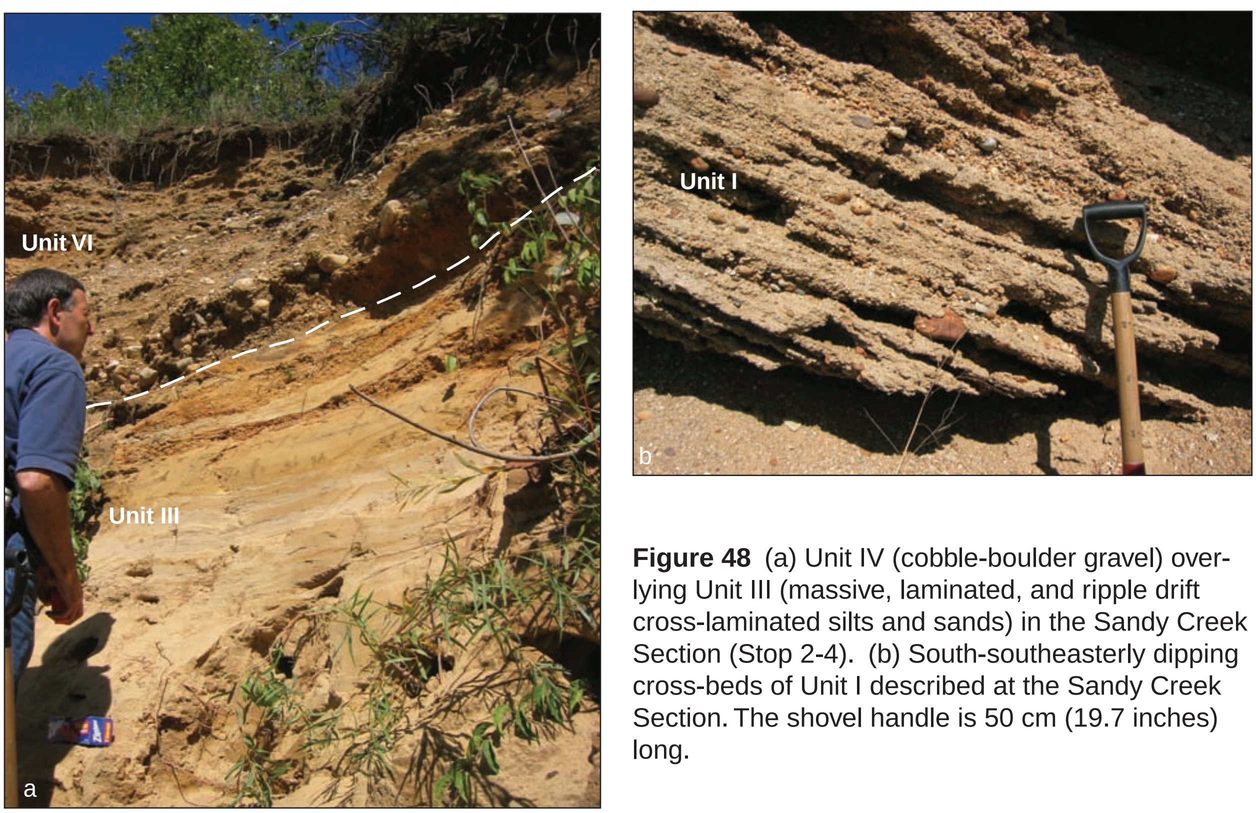


Figure 48 (a) Unit IV (cobble-boulder gravel) overlying Unit III (massive, laminated, and ripple drift cross-laminated silts and sands) in the Sandy Creek Section (Stop 2-4). (b) South-southeasterly dipping cross-beds of Unit I described at the Sandy Creek Section. The shovel handle is 50 cm (19.7 inches) long.

Member of the Banner Formation based on its similarity to the original definition of the Sankoty (Horberg 1950) and to sand that occurs in our Schoepke No. 1 core, where red sand underlies oldest Illinois Episode diamicton (Kellerville Member). If these Pearl Formation and Sankoty Sand Member correlations at Sandy Creek are correct, then the oldest tongue of the Pearl Formation (Pe-1A), which predates the early Illinois Episode diamicton (Kellerville Member), is absent at Sandy Creek.

Although these interpretations are consistent with the single available OSL determination for tongue Pe-2, clearly, more age determinations are needed to assess our correlations and measure the relative ages of the several Pearl tongues. Should the OSL method prove reliable, further dating of the Pearl Formation sands where they are interbedded with tills in the Ancient Mississippi River valley area might for the first time answer questions about the timing and duration Illinois Episode events, including (1) deposition of the four major fluvial units, (2) deposition of the three principal till sheets, including the most widespread till in Illinois, and (3) impacts of Lake Michigan Lobe on the Ancient Mississippi River, therefore providing important information about (4) the principal events of the Illinois Episode in its type area.

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APPENDIX A: QUATERNARY STRATIGRAPHY

Lithostratigraphic classifications and terminology used herein follow those of Hansel and Johnson (1996) for the Wisconsin Episode and Willman and Frye (1970) for older deposits. Stratigraphic units that occur in the Ancient Mississippi River valley in central Illinois are discussed in order from oldest to youngest. Refer also to Figures 5 and 6.

Pre-Illinois Episode

Banner Formation, Sankoty Sand Member The oldest Quaternary deposit in the area, the Sankoty Sand Member (Figs. 5 and 6), was defined by Horberg (1950) and interpreted as a fluvial deposit of early Pleistocene or preglacial age. Willman and Frye (1970) included the Sankoty Sand as a member of the Kansan age Banner Formation and noted that the Sankoty Sand Member "is not known to have a soil on it where it is overlain by Kansan age till." They also indicated "it is more likely pro-Kansan outwash." The Sankoty Sand has been widely mapped along the Ancient Mississippi River valley (Horberg et al. 1950, McComas 1968).

The Sankoty Sand Member, as defined, has a distinctive pinkish color and ranges in texture from medium- to coarse-grained sand but locally ranges from silty fine sand to very coarse sand and granule gravel. The unit is more than 75% quartz, of which 10 to 20% is pink, clear, polished, and rounded (Horberg et al. 1950, Walker et al. 1965). The remaining 25% of the sand grains is nearly equal proportions of feldspar and crystalline and sedimentary rocks. The pinkish color is attributed to reddish (hematite) stain on sand-grain surfaces. Coarser fractions of the unit (gravel >4 mm [0.16 inch]) are composed predominantly of dolomite (Walker et al. 1965). Horberg (1953) reported that the Sankoty Sand averages 30 m (100 ft) thick and can be as much as 90 m (300 ft) where deep bedrock valleys underlie the uplands.

A preglacial age for the oldest valley-fill sand and gravel in the Ancient Mississippi River valley in the central Illinois area we studied is not confirmed by available evidence. In Illinois, feldspar and crystalline rock fragments, such as occur ubiquitously in these deposits, are generally attributed correctly to glacial sources. Alternatively, igneous and metamorphic minerals and rock fragments in fluvial deposits in the Ancient Mississippi River valley watershed might conceivably have been transported by a preglacial river from exposed igneous and metamorphic bedrock in the upper reaches of the Mississippi watershed if the river reached those rock outcrops at that time.

A pre-Illinois Episode age for these deposits (e.g., Horberg 1953, McComas 1968) has not been confirmed by our work. Tills thought to be pre-Illinois Episode in age lie close to bedrock and overlie thin sand, most of it not pinkish. Neither we nor previous workers have identified a Yarmouth Geosol in the study area, so the age of pinkish sands above the pre-Illinois Episode tills cannot yet be definitively determined. No quantitative age determinations have been done on the sand units or the adjacent units.

Although our observations are limited to a fraction of the area of occurrence of the Sankoty Sand Member mapped by Horberg et al. (1950) and McComas (1968), we have confirmed the observation of Horberg et al. (1950) that the Ancient Mississippi River valley fill is a complex of several fluvial successions interrupted by glacial deposits. Our work shows that those successions can be identified and distinguished with detailed drilling and quantitative data. Our recent drilling and mapping in the Ancient Mississippi River valley between Hennepin and Chillicothe suggest that the Sankoty Sand Member, as previously mapped in that area, includes inset coarse fluvial valley-fill deposits interfingered with tills composed of significant thicknesses of sediment, all mainly of Illinois Episode age.

We interpret the pink-colored sands in the succession as not being as age-restricted indicators of an old unit, as once thought, but as being repetitive lithologies that interfinger with Illinois Episode diamictons. The color and mineralogy of the “Sankoty-type” sands are attributable more to a particular provenance than to a particular age deposit. Therefore, we attribute the red hue and “distinct” composition of the Sankoty-type sand to source areas in the upper Mississippi watershed primarily north of the limit of Paleozoic rocks. We attribute the more dolomitic outwash facies to meltwater sources from glaciers in the Lake Michigan or Green Bay basins that entrained large amounts of dolomite.

These questions of complexity, composition, and correlation have practical importance, because they begin to explain why the “Sankoty aquifer,” which is a prolific water supply in some areas, is much less productive in others. Far from being homogenous and regionally predictable as previously mapped, the Sankoty aquifer is, rather, a succession of complex fluvial deposits compartmentalized by their interbedding with low-conductivity glacial diamictons and lacustrine deposits, which accounts in large part for the highly variable water yields and water quality from the so-called Sankoty aquifer.

Illinois Episode

Pearl Formation Outwash sand and gravel related to Illinois Episode glaciation is thick and widespread in the Ancient Mississippi River valley of central Illinois. These deposits are included in the Pearl Formation, which is subdivided here into tongues where the unit interfingers with the Illinois Episode tills (Figs. 5 and 6). Willman and Frye (1970) defined the Pearl Formation as deposits that overlie or extend beyond Illinoian till. Glaciofluvial deposits that underlie and interfinger with the Illinois Episode diamictons were recognized as being continuous with the Pearl Formation but in nomenclature were separated from it by a stratigraphic convention, the vertical cutoff. Such deposits were included as part of the till and intratill members of the Glasford Formation (Willman and Frye 1970). For this report, we depart from that usage by recognizing the major sand and gravel deposits beneath and between Illinois Episode diamictons of the Glasford Formation as continuous with the Pearl Formation beyond the glacial margin. We treat them in the nomenclature as informal tongues of the Pearl Formation. From the base upward, they are tongues, Pe-1A, Pe-1B, and Pe-2. The surficial Illinois Episode outwash sand and gravel (herein referred to as Pe-3 to distinguish it from the three tongues) is entirely a subsurface unit in the field trip area. These units range from fine sand to boulder gravel and include sedimentary clasts of local origin as well as abundant erratic lithologies. Pearl Formation sand and gravel may be indistinguishable from the older Sankoty Sand Member or younger, Wisconsin Episode sands and gravels where Illinois Episode diamictons are absent. Some beds in the Pearl Formation have lithologies similar to those previously ascribed to the Sankoty Sand Member. The particular Pearl tongue present in a succession is defined by the diamicton that overlies it; the Kellerville Member overlies Pe-1A, Hulick Member overlies Pe-1B, and Radnor Member overlies Pe-2. Mineralogical variation within the tongues, although noted, has not yet allowed identification of tongues where the diamictons are absent. Relationships of the Pearl Formation and its tongues to the Illinois Episode diamictons are shown in Figures 5 and 6.

Pearl Formation, tongue Pe-1A Tongue Pe-1A overlies the Sankoty Sand Member or older deposits and is overlain by diamicton of the Kellerville Member of the Glasford Formation. In parts of the Ancient Mississippi River valley, the Pearl Formation is the principal sand-and-gravel deposit. In these areas, the underlying Sankoty Member has been largely reworked during deposition of the Pearl sand.

Glasford Formation, Kellerville Member The oldest glacial diamicton identified in the study area, the Kellerville Member of the Glasford Formation (Figs. 5 and 6), occurs only in the subsurface. This unit is a grayish brown to gray, silty clay loam diamicton that is dolomitic and contains a higher percentage of expandable clay minerals than do other Illinois Episode diamictons. The proportion of expandable clay minerals in this diamicton has been found to increase westward toward the ice margin in eastern Iowa (Willman and Frye 1970; Glass and Killey 1988). The Kellerville Member has limited extent within the Middle Illinois Bedrock Valley, having been incised during later Illinois and Wisconsin Episode fluvial events that deepened and widened the valley. The Kellerville Member was deposited by glaciers from the Lake Michigan Basin. The diamicton overlies the Sankoty Sand Member or Illinois Episode outwash, correlated here to tongue Pe-1A of the Pearl Formation. A paleosol developed in the Kellerville Member, the Pike Geosol, has not been observed in the Middle Illinois River valley.

Pearl Formation, tongue Pe-1B Sand and gravel of tongue Pe-1B (Figs. 5 and 6) overlies the Kellerville Member of the Glasford Formation or older deposits and is overlain by diamicton of the Hulick Member of the Glasford Formation.

Glasford Formation, Hulick Member A grayish brown to gray, loam-textured diamicton, the Hulick Member (Figs. 5 and 6) is exposed at the surface along Rattlesnake Hollow in southern Marshall County and in several locations along Illinois Route 18 east of the town of Henry in Putnam County. This diamicton contains more dolomite and illite and a lower proportion of expandable clay minerals than does the underlying Kellerville Member. The diamicton has a coarser texture and lower illite content than the overlying Radnor Member. The Hulick Member in the Middle Illinois River valley contains abundant clasts of the local bedrock, particularly coal. The diamicton is the lateral equivalent of the Vandalia Member in south-central Illinois and, in the Ancient Mississippi River valley, forms a thick, widespread deposit. The Hulick Member is particularly thick near the margins of the Middle Illinois Bedrock Valley, but the unit is less continuous near the axis of the valley, where it was eroded during later Illinois and Wisconsin Episode fluvial events. An exception is a remnant of the Illinois Episode upland preserved east of Henry along Illinois Route 18, which was visited on Day 2 of the field trip. Here the diamicton contains evidence of ice collapse. The Hulick Member overlies Illinois Episode outwash (correlated here to the informal tongue Pe-1B of the Pearl Formation), older sediments, or bedrock.

Pearl Formation, tongue Pe-2 Sand and gravel of tongue Pe-2 overlies the Hulick Member of the Glasford Formation or older deposits and is overlain by diamicton of the Radnor Member of the Glasford Formation (Figs. 5 and 6). An OSL determination on the lowermost beds in Pe-2 from the Sandy Creek Section (this report) has an age of 118,990 ± 10,300 cal yr B.P. (Sample UNL-1206; Table 1).

Glasford Formation, Radnor Member The Radnor Member is the youngest Illinois Episode diamicton in central Illinois. The Radnor is a gray silty clay loam to loam diamicton; the Sangamon Geosol commonly is developed in its upper part (Figs. 5 and 6). The diamicton is texturally finer grained and contains more illite than do other Illinois Episode diamictons. The Radnor contains interbedded sand, gravel, and silt, particularly in its upper part. It commonly contains clasts of the local bedrock. The unit is continuous in the subsurface beneath the upland along the Ancient Mississippi River valley, but is typically not present in the central part of the Middle Illinois Bedrock Valley where it has been eroded by later fluvial and glacial events. The Radnor Member overlies Illinois Episode outwash, correlated here to the informal tongue Pe-2 of the Pearl Formation or older sediment, and is overlain by tongue Pe-3 of the Pearl Formation or younger deposits.

Pearl Formation, Pe-3 Pe-3 (Figs. 5 and 6) is the uppermost subdivision of the deposit, and its stratigraphic position is that of the Pearl Formation as defined by Willman and Frye (1970). The separate designation is given to distinguish it from the three Pearl Formation tongues. Pe-3 overlies the Radnor Member or older deposits and has the Sangamon Geosol in its upper part.

Sangamon Geosol The Sangamon Geosol (Fig. 4) formed on the glacial and fluvial deposits left by retreating Illinois Episode glaciers and in colluvial and alluvial sediments deposited thereafter. The Sangamon Geosol displays a wide range of soil characteristics that are dependent upon its parent material and the prevailing drainage, vegetation, and slope conditions during soil development. The Sangamon profile is commonly leached of carbonates to a depth of 1.5 to 2 m (4.9 to 6.6 ft) or more. The solum has a well-developed Bt horizon and has A or A and E horizons in many locations. The Sangamon Geosol is typically developed in the upper part of the youngest Illinois Episode deposits (i.e., the diamicton [Radnor Member]), colluvial deposits (Berry Clay Member), or sand and gravel (Pearl Formation) across wide areas of upland central Illinois. Near the Ancient Mississippi River valley, where the soil developed in eroded uplands, the parent material type can change over short distances. In most locations, the upper horizons (A or A/E) of the soil profile extend into the lower part of the Roxana Silt.

Roxana Silt The Roxana Silt (Figs. 4, 5, and 6) is a middle Wisconsin Episode deposit present along the Ancient Mississippi River valley in central Illinois and along the Mississippi River as far south as southeastern Arkansas. Studies of the Roxana Silt elsewhere have demonstrated that the Roxana Silt is loess, traceable as a distinct unit along the Ancient Mississippi River valley from Minnesota to Mississippi (Leigh 1994, Follmer 1996). The main body of the unit was deposited between about 55,000 and 28,000 ^{14}C yr B.P. (McKay 1979, Curry and Follmer 1992, Leigh 1994, Leigh and Knox 1994, Hansel and Johnson 1996). In the Middle Illinois River valley area, the Roxana Silt is a thin deposit, less than 3 m (10 ft), deposit of reddish brown to gray, slightly calcareous silt loam, usually leached in its upper and lower parts. At its base, the Roxanna conformably merges with and overlies the Sangamon Geosol. Several weathered zones and silt deposits in the lower Roxana have been distinguished from the main body of the unit (Willman and Frye 1970, Curry and Follmer 1992). Color zones within the unit reflect a combination of provenance and weathering. Red color in the lower part is related to reddish sediment carried by the Ancient Mississippi River from its headwaters in Minnesota and Wisconsin (Grimley et al. 1998). The grayer, more illitic, and more dolomitic, middle interval of the unit is composed of debris eroded by glaciers flowing over Paleozoic age shales and dolomites mapped further south in the watershed. A brief hiatus in loess deposition likely caused by a relatively moist climate from about 28,000 to 25,000 ^{14}C yr B.P. is marked by the weakly developed Farmdale Geosol.

The Robein Silt Member of the Roxana Silt is an organic silt or peat, typically leached of carbonate minerals, that includes the profile of the Farmdale Geosol. The Robein Silt is a regional stratigraphic marker unit, which was the source for the majority of woody debris that was eroded and incorporated into the Wisconsin Episode glaciers. Organic radiocarbon age determinations on the Robein and Roxana range from more than 45,000 ^{14}C yr B.P. (Stop 1-1) to about 20,000 ^{14}C yr B.P. in the Middle Illinois River valley. Because a significant amount of organic material from the Robein Silt and perhaps other source beds was entrained into the Wisconsin Episode ice, several ages obtained at Stop 1-2, for example, are considerably older than the diamicton from which they were sampled.

Farmdale Geosol The Farmdale Geosol, as just noted, is a weakly expressed paleosol formed in the Roxana Silt along the Ancient Mississippi River valley during a period when loess deposition slowed or ceased briefly (Fig. 4). In near-valley locations where loess is thick, the Farmdale Geosol is separated from the upper solum of the Sangamon Geosol by up to several meters of calcareous loess (Roxana Silt). Farther from the valley, where loess deposits are thinner, the Farmdale and upper Sangamon profiles merge.

Peoria Silt, Morton Tongue The Morton Tongue is a silt (loess) deposit of up to 3 m (10 ft) thick that is locally exposed. The dolomitic silt is gray, brownish gray, or yellowish brown and has a silt to silt loam texture. The Morton Tongue is equivalent to the lowermost part of the Peoria Silt beyond the margin of the Wisconsin Episode glacial deposits (Hansel and Johnson 1996). The base of this unit has been consistently dated at about 24,500 ^{14}C yr B.P. to 25,000 ^{14}C yr B.P. along the Ancient Mississippi River valley. The silt accumulated adjacent to the valley until the glacier from the Lake Michigan basin reached the area about 20,350 ± 85 ^{14}C yr B.P. Beyond the Wisconsin margin, a distinct upward change in clay mineralogy from high to low expandable clay content in the lower part of the Peoria Silt, first identified by Glass et al. (1964, 1968), marks the diversion of the Ancient Mississippi River in the stratigraphic record.

Where present, the Roxana Silt, the Robein Silt Member, the Morton Tongue, and the Sangamon Geosol are marker beds that are particularly useful for interpreting the complex stratigraphic succession of the area. Peat and organic silt are commonly noted in drillers' logs.

Henry Formation, Ashmore Tongue Sand and gravel deposits of the Ashmore Tongue (Figs. 5 and 6) fill much of the Ancient Mississippi River valley in some areas. The unit includes sand and gravel in the main channels of the Ancient Mississippi River that were deposited during the Wisconsin Episode (Hansel and Johnson 1996) and overridden by the glacier depositing the Tiskilwa Formation. These deposits have been previously interpreted as part of the Sankoty Sand Member (Horberg et al. 1950, Horberg 1953, McComas 1968). Where it can be demonstrated that the Ancient Mississippi River reworked and eroded much of the older valley-fill sediment during the Wisconsin Episode, we classify its deposits as Ashmore Member rather than Sankoty Sand Member or Pearl Formation. In these areas, the Tiskilwa Formation lies directly above this unit with no intervening Illinois Episode diamictons. More field study and laboratory analyses are needed to consistently distinguish the Ashmore Tongue from the Pearl Formation and Sankoty Sand Member. The Ashmore Tongue is a significant component of the regional aquifer that occupies the Middle Illinois Bedrock Valley. An OSL age determination for a sample collected near the base of the exposure in the upper part of the Ashmore Tongue from the Clear Creek Section (this report) yielded an age of 96,070 ± 6,060 cal yr B.P. (Sample UNL-1203; Table 1). That result, however, is older than expected and will prompt additional age determinations using the OSL method.

Tiskilwa Formation The widespread Tiskilwa Formation is distinctive reddish brown to gray loam diamicton lying at the surface and in the subsurface in the Middle Illinois River valley (Figs. 5 and 6). The diamicton is thick, exceeding 45 m (150 ft) in the field trip area. To the south in the uplands along the Middle Illinois River valley, the Tiskilwa Formation has a maximum thickness of approximately 100 m (330 ft). Throughout the Tiskilwa diamicton, thin beds of sand and gravel or silt are common. Locally, beds of bouldery diamicton occur. The Oakland facies (Hansel and Johnson 1996) is differentiated where the lowermost part of the Tiskilwa diamicton is silty and organic-rich. The lower part (1.5 to 15 m [5 to 50 ft]) of the Tiskilwa, where it is gray to greenish gray, is correlated with the Delavan Member. The upper 1.5 to 4.6 m (5 to 15 ft) of the Tiskilwa Formation, where it is grayish brown to gray, loam-textured diamicton, is referred to as the Piatt Member. In exposures the Delavan diamicton can be misinterpreted as older (Illinois Episode) Radnor or Hulick diamictons, which resemble it in color, although the Hulick and Radnor Members contain more coal fragments and the Radnor Member has a finer texture. The Delavan Member and both Illinois Episode diamictons do not contain abundant wood fragments characteristic of the Oakland facies.

In the Middle Illinois River valley, the Tiskilwa Formation forms part of an end moraine complex including the Bloomington Morainic System (Figs. 1 and 2). Its significant thickness and the presence of outwash and colluvial interbeds are characteristics of a moraine developed during multiple readvances, causing debris stacking, interrupted by periodic standstills and ice retreats. The Middle Illinois River valley lies approximately 16 km (10 mi) from the maximum extent of Wisconsin Episode ice, and therefore it is possible that the glacier margin melted back to a position east of the valley before readvancing. Evidence for readvances were observed at the Clear Creek (Stop 1-1) and Rattlesnake Hollow (Stops 1-3, 1-5, and 1-6) sections.

Henry Formation, Dry Creek tongue Sand and gravel deposits between the Tiskilwa Formation and the overlying Batestown Member are referred to informally as the Dry Creek tongue of the Henry Formation (Figs. 5 and 6) for exposures in a large borrow pit along Dry Creek, SW NW Sec. 11, T29N, R2W, Woodford County, where the unit consists of up to 3.7 m (12 ft) of pebble gravel and coarse sand. The unit is widespread and sheet-like in the shallow subsurface beneath upland areas adjacent to the Middle Illinois River valley where it is locally tapped for household water supply. The deposit does not appear to fill a former channel of the Ancient Mississippi River.

Lemont Formation, Batestown Member An olive-brown to gray, loam diamicton, the Batestown Member (Figs. 5 and 6), overlies the Tiskilwa Formation or the Dry Creek tongue of the Henry Formation beneath most upland areas. Its western limit is approximately delineated by the Eureka Moraine (Figs. 1 and 2), but Batestown diamicton has been mapped to the west of the Eureka Moraine in places.

Lemont Formation, Yorkville Member The Yorkville Member comprises an olive-brown to gray, silty clay loam diamicton that overlies the Batestown Member east of the Middle Illinois River valley. Regionally, tongues of sand and gravel and/or silt and clay separate the two members. The westward limit of the diamicton coincides approximately with the north-south–trending Varna Moraine (Figs. 2 and 3).

Peoria Silt Silt (loess) blankets most of the upland areas to a depth of 1.5 to 4.6 m (5 to 15 ft), overlying the Lemont or Tiskilwa Formations. It is thickest on uplands near the loess source area, the Illinois River valley, and generally absent from alluvial surfaces. Thin, discontinuous loess deposits, however, have been noted on the upper surfaces of some high terraces in the Middle Illinois River valley.

Henry Formation, Mackinaw facies These sand and gravel deposits compose large terraces in the Middle Illinois River valley and small terraces in tributary valleys to the Illinois. These valley train sediments were deposited by meltwater from the Lake Michigan Lobe when it stood in the upper Illinois River watershed. Thin outwash deposits also occur on the uplands and represent local fluvial deposition from a former glacier margin.

Equality Formation These laminated silt and silty clay deposits occur in areas where lakes formerly occupied tributary valleys to the Illinois River or Ancient Missisippi River. These deposits overlie the Sangamon Geosol or Sangamon or Illinois Episode deposits (e.g., Core I-1088) and in places interfinger with or overlie Wisconsin Episode glacial deposits of the Tiskilwa and Lemont Formations along the Ancient Mississippi River valley.

APPENDIX B: ANALYTICAL DATA

Table B-1 Clay mineral and particle size data by lithostratigraphic unit for Stop 1-1, the Clear Creek Section.

Sample[1]	Calcite (% bulk sample)	Dolomite (% bulk sample)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Lemont Formation, Batestown Member									
cd-17-1	5	29	10	74	16	44	48	8	diamicton, stratified
cd-17-2	3	31	2	74	24	44	41	15	diamicton
cd-17-3	3	30	2	74	24	41	42	17	diamicton
cd-17-4	4	32	1	75	24	47	39	14	diamicton
cd-17-5	2	34	1	71	28	56	36	8	diamicton
hg-59-4	--	--	3	79	18	--	--	--	diamicton
mean	3	32	2	75	24	47	40	13	
SD	1	1	1	3	3	6	2	3	
Tiskilwa Formation, Piatt Member									
cd-17-6	3	35	5	67	28	50	39	11	diamicton
cd-17-7	5	35	3	68	28	50	38	12	diamicton
cd-17-8	4	28	4	69	27	54	33	13	diamicton
cd-17-9	2	43	3	71	26	45	42	13	diamicton
cd-17-10	4	39	4	69	27	50	38	12	diamicton
cd-18-2	5	46	3	70	27	56	32	12	diamicton
cd-18-3	15	33	4	69	27	51	36	13	diamicton
cd-18-4	2	35	3	70	27	43	44	13	diamicton
hg-59-5	3	--	4	74	22	--	--	--	diamicton
mean	5	37	4	70	27	50	38	12	
SD	4	5	1	2	2	4	4	1	
Tiskilwa Formation									
cd-17-11	4	37	8	64	28	43	37	20	diamicton
cd-17-12	4	26	13	60	27	45	40	15	diamicton
cd-18-5	4	27	14	61	25	45	41	14	diamicton
cd-18-6	5	30	10	63	27	42	37	21	diamicton
cd-18-7	6	24	14	58	28	40	42	18	diamicton
cd-18-8	4	22	13	60	27	41	38	21	diamicton
cd-18-9	7	27	13	62	25	39	39	20	diamicton
cd-18-10	5	31	13	62	25	39	35	26	diamicton
cd-18-11	6	22	12	64	24	40	39	21	diamicton
cd-18-12	4	26	18	57	25	38	45	17	diamicton
hg-59-6	--	--	22	59	19	--	--	--	diamicton
hg-59-7	--	--	14	61	25	--	--	--	diamicton
hg-59-10	--	--	19	58	23	--	--	--	diamicton
dv-34	--	--	12	55	33	38	45	16	diamicton
dv-33	--	--	9	53	38	33	48	20	diamicton
dv-32	--	--	8	57	36	32	47	21	diamicton
dv-31	--	--	8	53	39	38	48	14	diamicton
dv-42	--	--	7	56	37	38	41	21	diamicton
dv-41	--	--	6	56	38	38	42	19	diamicton
dv-40	--	--	4	55	40	41	41	18	diamicton
mean	5	27	12	59	29	39	42	19	
SD	1	4	4	3	6	3	4	3	

Sample[1]	Calcite (% bulk sample)	Dolomite (% bulk sample)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Tiskilwa Formation, Delavan Member									
dv-39	--	--	24	41	35	25	54	21	diamicton
dv-38	--	--	20	43	37	26	52	22	diamicton
dv-37	--	--	20	44	37	26	53	21	diamicton
mean	--	--	21	43	36	26	53	21	
SD	--	--	2	1	1	1	1	1	
Tiskilwa Formation, Oakland facies									
cd-17-13	0	32	17	58	25	39	31	30	diamicton
cd-17-14	0	18	18	57	25	33	37	30	diamicton
cd-17-15	0	13	24	52	24	18	66	16	diamicton with organic lens
cd-18-1	2	12	28	49	23	28	49	23	diamicton
cd-18-13	2	15	33	47	20	24	67	9	diamicton
cd-18-14	18	16	10	52	38	23	56	21	diamicton lens, green
cd-18-15	1	9	24	54	22	20	70	10	diamicton
hg-59-9	--	--	36	42	22	--	--	--	diamicton, woody
hg-59-11	--	--	28	49	23	--	--	--	diamicton lens, greenish gray
hg-59-12	--	--	46	40	14	--	--	--	diamicton lens, clayey, red
dv-18	3	--	39	28	33	9	84	8	diamicton
dv-50	4	--	21	40	39	23	62	15	diamicton lens, gray
dv-47	2	--	0	38	62	19	55	26	diamicton lens, green
dv-51	--	--	0	45	54	18	43	38	diamicton lens, red clay
mean	5	16	23	47	30	23	56	21	
SD	6	7	13	8	13	8	15	9	

[1]cd, particle size by Christine Dellaria, clay minerals by Adam Ianno; hg, clay minerals by Herbert Glass; dv, particle size and clay minerals by David Voorhees.

Table B-2 Clay mineral and particle size data by lithostratigraphic unit for Stop 1-2, the Friday3 Section.

Sample	Elevation of sample top (ft)	Calcite (% bulk sample)	Dolomite (% bulk sample)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology	Color
Unnamed tongue, Equality Formation											
A	555	7	34	11	66	23	11	80	9	silt	tan
B	552	9	48	6	63	31	16	72	12	silt and fine sand	tan
Tiskilwa Formation, Piatt Member											
C	551	5	25	13	59	27	40	42	18	sandy diamicton	beige
D	549	5	22	11	61	28	39	40	21	diamicton	tan
E	545	4	36	12	62	26	39	40	21	diamicton	tan

Table B-3 Mollusca and ostracode species sampled from the upper facies, unnamed tongue of the Equality Formation, at Stop 1-2, the Friday3 Section.

Species	Samples (no.)	(% of total)
Mollusca		
Valvata sincera (Say, 1824)	6	0.5
Valvata tricarinata (Say, 1817)	345	29.7
Fossaria spp.	4	0.4
Gyraulus circumscriptus (Tryon, 1866)	14	1.2
Gyraulus deflectus (Say, 1824)	103	8.9
Gyraulus crista (Linne, 1758)	1	0.1
Gyraulus spp.	259	22.3
Musculium spp.	5	0.4
Pisidium casertanum (Poli, 1795)	3	0.3
Pisidium compressum (Prime, 1852)	173	14.9
Pisidium lilljeborgi (Clessin, 1886)	19	1.6
Pisidium milium (Held, 1836)	18	1.5
Pisidium nitidum (Jenyns, 1836)	23	2.0
Pisidium subtruncatum (Malm, 1855)	26	2.2
Pisidium ventricosum (Prime, 1851)	13	1.1
Pisidium spp.	150	12.9
Total (19 freshwater, 1 land species)	1,162	100
Ostracode		
Cyclocypris sharpei	261	57.5
Cyclocypris ampla	81	17.8
Fabaeformis candona rawsoni	38	8.4
Cypridopsis vidua	24	5.3
Potamocypris smaragdina	20	4.4
Limnocythere friabilis	15	3.3
Candona paraohioensis	5	1.1
Candona candida	6	1.3
Cypricerus tuberculatus	2	0.4
Limnocythere herricki	1	0.2
Ilyocypris gibba	1	0.2
Total	454	100

Table B-4 X-ray diffraction analyses by lithostratigraphic unit of clay and grain-size (hydrometer) analyses, Stop 1-3, the west section of Rattlesnake Hollow.

Sample	Elevation of sample top (ft)	Calcite (cps)[1]	Dolomite (cps)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Tiskilwa Formation, undivided										
A	593.0	22	35	19	67	14	33	35	32	diamicton
B	590.0	15	28	23	60	17	37	37	26	diamicton
C	584.5	--	--	--	--	--	--	--	--	sand and gravel
D	583.0	22	30	12	66	23	42	32	26	diamicton
E	580.5	19	28	12	66	23	43	32	25	diamicton
F	576.0	15	26	14	64	23	44	32	24	diamicton
G	571.0	--	--	--	--	--	--	--	--	diamicton
Henry Formation, Ashmore Member										
H	569.5	--	--	--	--	--	--	--	--	gravel
I	564.0	--	--	--	--	--	--	--	--	sand
J1	562.5	0	0	45	44	12	26	62	12	diamicton
J2	561.5	0	0	55	35	11	0	89	11	lacustrine silt
Roxana Silt										
K	555.0	0	0	65	27	9	3	80	17	silt
L	553.0	0	0	49	30	22	49	31	20	sandy silt
Pearl Formation										
M	551.0	0	0	25	49	27	65	17	18	loamy sand

[1]cps, counts per second.

Table B-5 X-ray diffraction analyses by lithostratigraphic unit of clay and grain size (hydrometer) analyses, Stop 1-5, the middle section of Rattlesnake Hollow.

Sample	Elevation of sample top (ft)	Calcite (cps)[1]	Dolomite (cps)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Tiskilwa Formation, undivided										
X-295-6	568.00	29	36	12	75	13	48	31	21	diamicton
X-295-5	563.00	27	32	8	70	22	--	--	--	diamicton
Pearl Formation										
X-295-4	543.25	0	13	32	55	13	15	75	10	silt
Glasford Formation, Kellerville Member										
X-295-7	541.00	10	18	23	52	25	17	45	38	diamicton
X-295-3	541.00	9	11	40	42	18	16	53	31	diamicton
X-295-2	535.00	0	0	40	41	19	20	45	35	diamicton
X-295-8	533.00	11	0	60	24	16	10	46	44	diamicton
X-295-1	532.00	0	0	38	39	23	13	53	34	diamicton

[1]cps, counts per second.

Table B-6 X-ray diffraction analyses by lithostratigraphic unit of clay and grain size (hydrometer), Stop 1-6, the east section of Rattlesnake Hollow.

Sample	Elevation of sample top (ft)	Calcite (cps)[1]	Dolomite (cps)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Tiskilwa Formation, undivided										
B12	577.00	37	40	19	68	13	40	33	27	diamicton
B11	573.00	16	29	20	67	13	44	34	22	diamicton
B10	571.50	37	42	10	67	23	38	35	27	diamicton
Tiskilwa Formation, Delavan Member										
B9	558.25	9	16	13	68	19	26	50	24	diamicton
B8	554.50	10	17	9	69	22	24	51	25	diamicton
B7	552.00	11	18	9	69	22	24	51	25	diamicton
B6	550.50	0	15	9	70	21	26	49	25	diamicton
Tiskilwa Formation, Oakland facies										
B5	549.00	0	10	29	52	19	4	84	12	silt and silty diamicton
B4	548.50	0	16	24	57	19	5	81	14	silt and silty diamicton
B3	545.50	0	12	43	41	16	1	88	11	silt and silty diamicton
B-2B	544.50	8	23	11	67	22	28	47	25	diamicton
B2-A	542.50	7	25	13	65	22	26	52	22	diamicton
Glasford Formation, Hulick Member										
4	519.00	13	17	9	75	16	36	43	21	diamicton
3	518.25	8	24	13	66	21	39	48	13	diamicton
2	516.50	12	24	11	68	21	47	43	10	diamicton
B13	516.25	11	17	11	66	23	32	45	23	diamicton
B2	516.00	15	24	9	64	27	32	44	24	diamicton
B1	514.00	13	20	15	66	19	52	36	12	diamicton
1	513.50	11	15	12	66	22	42	43	15	diamicton

[1]cps, counts per second.

Table B-7 X-ray diffraction analyses by stratigraphic unit of clay and bulk powder and grain size (pipet), Stop 2-1, the Sister's Section.

Sample	Elevation of sample top (ft)	Calcite (% bulk sample)	Dolomite (% bulk sample)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Tiskilwa Formation, undivided										
AA	597.7	4	30	15	71	14	35	40	26	diamicton
BB	593.7	3	22	12	75	13	46	47	7	diamicton
CC	589.7	3	19	16	70	14	31	44	25	diamicton
Peoria Silt, Morton Tongue										
DD	589.2	0	33	26	60	14	2	89	8	silt loam
EE	588.2	0	29	30	56	14	1	90	9	silt loam
FF	587.2	1	22	26	59	15	2	91	8	silt loam
GG	586.2	1	29	27	59	14	0	92	8	silt loam
HH	585.2	0	25	28	55	17	1	92	7	silt loam
II	584.2	0	25	33	52	15	1	93	6	silt loam
JJ	583.2	1	20	28	53	19	1	93	7	silt loam
KK	582.2	0	32	46	41	13	1	89	10	silt loam
LL	581.2	1	8	44	37	19	4	88	8	silt loam
Roxana Silt										
MM	580.2	1	1	39	31	29	4	87	9	silt loam
NN	579.2	0	0	45	25	30	1	91	8	silt loam
OO	578.2	0	8	39	41	20	0	90	10	silt loam
PP	577.2	0	1	34	47	19	0	90	10	silt loam
QQ	576.2	0	5	45	38	17	0	89	11	silt loam
RR	575.2	0	3	47	39	14	1	87	12	silt loam
SS	574.2	0	10	48	39	14	0	88	12	silt loam
TT	573.2	2	12	45	42	13	1	86	13	silt loam
UU	572.2	1	5	40	39	20	1	86	13	silt loam
VV	571.2	0	1	36	38	26	3	89	8	silt loam
WW	570.2	0	0	42	31	26	3	83	15	silt loam
XX	569.2	0	0	49	27	24	4	86	10	silt loam
YY	568.2	0	1	47	27	27	6	72	22	silt loam
A	571.6	0	1	42	30	28	8	81	11	silt loam
B	570.6	0	1	49	23	28	10	69	21	silt loam
C	569.6	0	1	51	23	26	11	76	13	silt loam
D	568.2	0	0	55	21	24	13	65	21	silt loam
Pearl Formation, tongue Pe-3										
E	567.2	0	0	15	40	45	38	44	18	loam
F	565.8	0	0	15	41	44	36	48	16	loam
G	564.8	0	0	32	37	31	24	48	28	clay loam
H	563.7	0	1	30	57	13	25	40	35	clay loam
I	562.5	0	0	25	52	23	51	23	26	silty sand
J	561.2	0	1	30	57	14	64	17	19	sandy loam
K	560.5	0	1	50	33	17	58	16	25	sandy loam
L	559.5	0	1	40	46	14	64	18	18	sandy loam
Glasford Formation, Radnor Member										
M	558.5	0	0	7	68	24	29	46	25	diamicton
N	558.0	0	1	13	63	24	25	44	31	diamicton

Table B-8 X-ray diffraction analyses by lithostratigraphic unit of bulk powder and clay, Stop 2-2, the December Section.

Sample	Elevation of sample top (ft)	Calcite (% bulk sample)	Dolomite (% bulk sample)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Roxana Silt										
A	555.5	0.2	0.4	33	39	28	--	--	--	silt
Radnor Member										
B	554.5	0.1	0.3	7	67	26	--	--	--	diamicton
C	553.0	0.3	0.4	5	87	8	--	--	--	diamicton
D	551.0	0.2	0.5	5	91	4	--	--	--	diamicton
E	549.0	0.3	19.7	3	88	9	--	--	--	diamicton
F	547.0	0.1	28.6	3	89	8	--	--	--	diamicton
G	545.0	0.3	19.9	3	91	6	--	--	--	diamicton
Pearl Formation, tongue Pe-2										
H	543.0	0.2	23.0	3	91	6	--	--	--	silty sand
I	541.0	0.5	0.5	9	85	6	--	--	--	silty sand
J	539.0	0.1	0.4	6	88	6	--	--	--	silty sand
Glasford Formation, Hulick Member										
K	537.0	0.7	29.5	1	75	23	--	--	--	diamicton

Table B-9 X-ray diffraction analyses by lithostratigraphic unit of bulk powder and clay, Stop 2-3, the Kettle Section.

Sample	Elevation of sample top (ft)	Calcite (% bulk sample)	Dolomite (% bulk sample)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Glasford Formation, Radnor Member										
A1	566	1.1	18.1	7	82	11	--	--	--	diamicton
Glasford Formation, Hulick Member										
C	538	3.0	26.4	4	65	31	--	--	--	diamicton
D	533	5.6	27.8	4	69	27	--	--	--	diamicton

Table B-10 X-ray diffraction analyses by lithostratigraphic unit of bulk powder and clay, Core I-1083 at Stop 2-4, the Sandy Creek Section.

Sample	Elevation of sample top (ft)	Calcite (% bulk sample)	Dolomite (% bulk sample)	Expandable clay minerals (%)	Illite (%)	Kaolinite + chlorite (%)	Sand, 62 µm to 2 mm (%)	Silt, 4 to 62 µm (%)	Clay, <4 µm (%)	Lithology
Batestown Member										
A	643.0	3.4	27.7	4	85	11	--	--	--	diamicton
B	642.0	2.9	29.4	8	76	16	--	--	--	diamicton
Tiskilwa Formation										
C	635.5	3.3	23.4	6	76	18	--	--	--	diamicton
D	629.5	6.5	16.7	6	66	28	--	--	--	diamicton
E	625.5	3.7	24.7	5	67	28	--	--	--	diamicton
F	621.0	3.5	20.9	4	65	31	--	--	--	diamicton
G	617.5	1.7	34.7	4	67	29	--	--	--	diamicton
Unnamed silt										
H	617.0	2.2	14.2	1	69	30	--	--	--	silt
Radnor Member										
I	612.8	0.4	18.7	1	65	34	--	--	--	diamicton
J	611.0	1.5	18.4	0	69	31	--	--	--	diamicton
K	607.0	3.4	15.6	1	73	26	--	--	--	diamicton
L	603.0	1.7	21.1	1	72	27	--	--	--	diamicton
Pearl Formation										
M	598.5	2.9	36.1	7	85	8	--	--	--	sand and gravel
N	597.5	7.6	31.0	7	85	8	--	--	--	sand and gravel.

Table B-11 X-ray diffraction analyses of bulk powder samples, Stop 2-4, Sandy Creek Section and Core I-1088.

Sample	Elevation of sample top (ft)	Quartz (% bulk sample)	Orthoclase feldspar (% bulk sample)	Plagioclase feldspar (% bulk sample)	Calcite (% bulk sample)	Dolomite (% bulk sample)	Hornblende (% bulk sample)	Lithology
Pearl Formation								
A	583.6	50.7	16.8	6.3	1.7	16.9	0.6	sand
B	573.4	38.7	19.2	6.0	4.3	24.4	0.2	sand
C	559.0	57.7	15.4	3.0	3.3	14.8	0.2	sand
E	539.3	67.2	10.7	2.3	6.0	9.5	0.4	sand
F	523.9	75.0	4.4	6.8	2.1	7.1	0.6	sand
G	518.0	39. 9	15.6	9.7	2.1	25.7	0.2	sand
H	515.0	69.3	7.6	8.7	2.5	6.4	0.6	sand
1088-A	454.0	43.1	3.2	6.8	5.8	36.7	0.1	sand
1088-C	442.5	70.0	6.9	7.7	1.5	9.5	0.1	sand
1088-D	432.0	52.2	14.7	15.4	1.3	8.6	0.3	sand
Banner Formation, Sankoty Member								
1088-F	424.0	61.9	22.7	5.8	0.9	2.6	0.2	sand
1088-G	418.0	79.7	11.8	3.2	0.5	0.7	0.2	sand
1088-H	412.0	85.8	4.2	3.9	1.6	1.2	0.2	sand
1088-I	406.0	69.4	21.8	2.3	0.3	0.4	0.3	sand
1088-J	399.5	75.1	3.4	7.7	1.2	5.8	0.2	sand

APPENDIX C: INTERPRETING OUTWASH SEQUENCES

The Importance of Lithofacies Codes and Bounding Surfaces

Geologists' attempts to make meaningful interpretations of past outwash environments have been hampered by the lack of a systematic means to describe sand and gravel deposits in a way that leads to understanding flow conditions when the sequence was deposited.

Lithofacies Codes A simple and effective lithofacies code combining grain size and sedimentary structure was developed by Miall (1977) for braided-stream deposits. This simple code combined a capital letter for grain size, such as G for gravel, with a lower case letter for sedimentary structure, such as p for planar cross-beds. Thus, sediment designated as Gp constitutes planar cross-bedded gravel. The importance of the lithofacies code, in addition to being a convenient, simple way to describe sand and gravel deposits, is that the sedimentary structures and grain size can be attributed to flow-regime bed forms (Fig. C-1) to gain an understanding of past streamflow conditions.

Kemmis et al. (1988) expanded Miall's code to allow for greater subdivision of gravel size and sorting as well as adding various sedimentary structures observed in Wisconsin Episode outwash sequences (Table C-1). Because a large range in gravel sizes

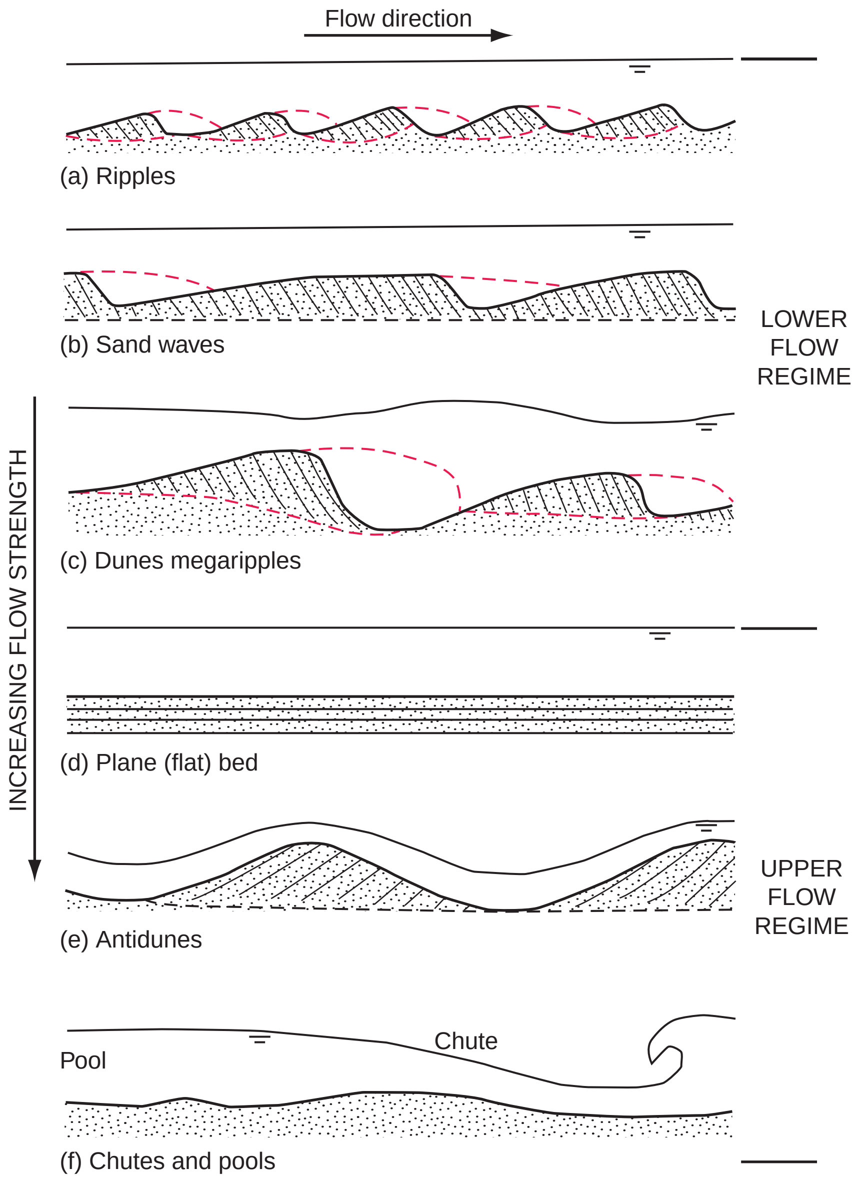

Figure C-1 Fluvial bed forms abruptly change with increasing flow velocity and depth (flow strength) from the lower flow regime through the upper flow regime (Blatt et al. 1980). Relating sedimentary structures determined from lithofacies codes to these past flow-regime bedforms enables reconstruction of past flow conditions during deposition of the sediments. (From H. Blatt, G.V. Middleton, and R.C. Murray, Origin of Sedimentary Rocks, 2nd ed. © 1980. Reprinted by permission of Pearson Education, Inc. Upper Saddle River, New Jersey.)

Table C-1 Lithofacies code for fluvial and glaciofluvial deposits (adapted from Kemmis et al.1988).

Gross particle size: first symbols	
BG	boulder gravel
CG	cobble gravel
PG	pebble gravel
G	gravel
Cm	clast-supported
Cs	matrix-supported
Cm	clast-to-matrix supported
S	sand
F	fines (silt and clay)
Bedding structures: second symbols, in parentheses	
(m)	massive
(pl)	planar-bedded; crudely horizontal; may be slightly undulatory
(h)	horizontally laminated; may be slightly undulatory
(r)	ripple-drift cross-laminated (various types)
(t)	trough cross-bedded; size (scale) and single or multiple sets noted on log
(w)	wedge cross-bedded; size (scale) and single or multiple sets noted on log
(p)	planar cross-bedded; size (scale) and single or multiple sets noted on log
(c)	cross-bedded deposits with complex upper and lower contacts; generally large scale, solitary sets; lower contacts commonly undulatory over irregular channel floor; upper contacts commonly undulatory, truncated by overlying bedding structures
(la)	lateral-accretion deposits
(ccf)	channel cut-and-fill; massive or simple structures mimicking the scoured channel cross section
(ccfc)	channel cut-and-fill structure with complex facies changes within the fill (see Ramos and Sopeña 1983)
(ccft)	channel cut-and-fill structure with transverse fill (see Ramos and Sopeña 1983)
(ccfms)	channel cut-and-fill structure with multistory fill (see Ramos and Sopeña 1983)
(lag)	lag at base of channel or cross-bed set
(g)	normally graded
(ig)	inversely graded
(n-i)	normally to inversely graded
(i-n)	inversely to normally graded
(l)	low-angle (<10°) cross-beds
(e)	erosional scours with intraclasts
(s)	broad shallow scours
(sc)	laminated to massive fines
(-t)	various bedding structures comprising deltaic topset beds
(-f)	various bedding structures comprising deltaic foreset beds
(-b)	various bedding structures comprising deltaic bottomset beds

is recognized in the field, Kemmis et al. (1988) subdivided gravels into pebble gravel (PG), cobble gravel (CG), and boulder gravel (BG). Gravel deposits also differ significantly in sorting, so the expanded lithofacies code provides a simple means to describe this as well: the designation cs standing for well-sorted, clast-supported gravels; ms standing for poorly sorted, matrix-supported gravels; and cm standing for intermediately sorted, clast-to-matrix supported gravels. To make a clearer distinction between the designations for grain size and sedimentary structure, the expanded lithofacies code also puts the sedimentary structure designations in parentheses. Here are examples of lithofacies designations using the expanded code of Table C-1:

PGms(t) trough cross-beds of matrix-supported pebble gravel (i.e., trough cross-beds of sandy pebble gravel)

S(m) massive sand (description should also include designation of texture as either very fine, fine, medium, or coarse)

F(l) laminated fine-grained sediment (fine-grained texture also should be described in greater detail using either U.S. Department of Agriculture textures or the Unified Soil Classification)

Study of the vertical and lateral changes in lithofacies, combined with an understanding of the bounding surfaces within the outwash sequence, can lead to an understanding of past stream behavior as the sequence was deposited, as demonstrated at field trip Stop 1-7.

Bounding Surfaces First-order boundaries are those that occur between individual beds or cross-beds. Some beds or cross-beds occur in groups, and the boundaries between these groups can be designated as second-order bounding surfaces. Channel fills may comprise several groups of beds or cross-beds, and the boundaries of these channel fills constitute a third-order bounding surface. In turn, valley fills may be composed of multiple channel fills, and these fill boundaries constitute fourth-order bounding surfaces for the outwash sequence, and so on.

The key to unraveling complex outwash sequences and understanding past outwash conditions, then, depends on recognizing the different order bounding surfaces in the sequence and describing the deposits in a way that can be related to streamflow conditions, such as flow-regime bed form concepts.

APPENDIX D: REFLECTORLESS TOTAL STATION FOR MEASURING INACCESSIBLE SECTIONS

High, unstable outcrops such as sand and gravel composing the high terrace of the Illinois River at Stop 1-7 in Lacon cannot be accurately measured using conventional techniques because of the danger involved. To date, such sections have been observed, photographed, and given a generalized description, but few measurements have been available for scientists and engineers. However, new, affordable surveying technology, the reflectorless total station (RTS), makes it possible to accurately determine elevations and locations as well as aid in sediment description. Furthermore, this technology allows an individual to survey what once required a three-person crew.

The RTS (Figure D-1) works by sending a pulsed laser to a target, such as a bedding plane. The laser electronic distance measuring (EDM) measures the reflected light from the target. The Stop 1-7 outcrop was measured by surveying control points using high-precision, dual-frequency GPS receivers (Figure D-2) achieving precision of 0.02 m horizontally and 0.03 to 0.09 m vertically. The RTS records the data digitally, which can then be downloaded to a computer and used in any number of different applications. Another advantage of using the RTS instrument for outcrop description is that the RTS eyesight works like a telescope, providing a close-up view of the sediments being described, making it possible to characterize sorting and grain size.

At each profile, the relative elevation or altitude of every bedding plane was surveyed, and the lithofacies were described. Table D-1 gives a partial example of one of the profile descriptions. Because each unit and bed are surveyed in geospatially referenced

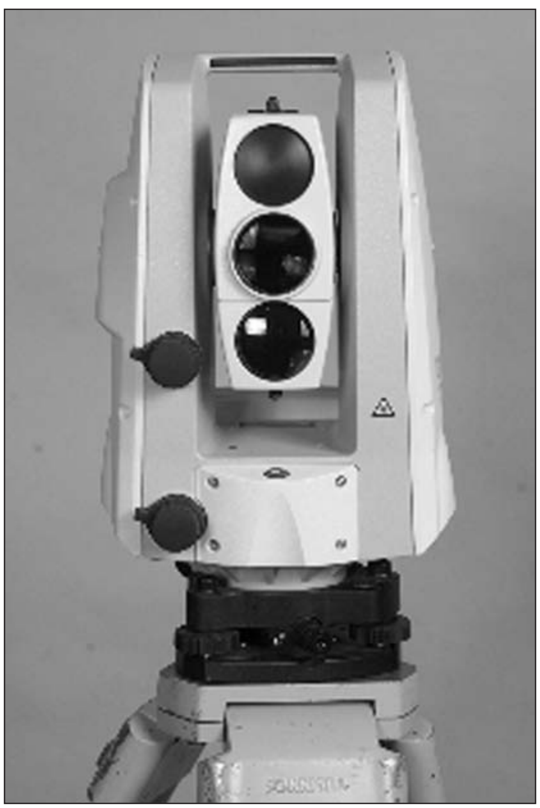

Figure D-1 Trimble TTS500 reflectorless total station.

Figure D-2 Trimble 4000 GPS dual frequency receiver with “pizza dish” antenna and TTS 500 total station.

X, Y, Z coordinates, later surveys at this and nearby pits can be compared with previous surveys to map unit surfaces and to construct profiles and models.

Care must be taken to minimize errors in establishing horizontal and especially vertical control points used to set up and orient the RTS. At this site, the RTS was set up over one control point and backsighted to another. Comparison to a third control point found the setup was correct within 8 mm horizontally and 0.1 m vertically. As for any technical instrument, use of precise, advanced technology improves the convenience and accuracy of surveying but requires a high level of care to achieve useful, accurate results. Since this system does not rely upon prisms and the reflected light from the sediment is reduced, some dark targets are not able to be measured.

Table D-1 Portion of description and survey coordinates observed July 28, 2004, at Midwest Material Company, Lacon, Marshall County, Illinois.

Observation	Easting	Northing	Elevation	Description	Additional notes
P1175	298749.67	4546138.95	156.45	top of section	
P1176	298749.18	4546138.90	155.45	PGms(t)	with occasional cobble
P1177	298748.72	4546137.27	154.23	PGms(t)	
P1178	298742.67	4546137.17	149.75	CGms(ccf) to PGms(ccf)	including clast-supported PC
P1179	298742.60	4546137.19	149.54	S(t)	fine sand
P1180	298742.50	4546137.18	149.38	S(t)	fine sand with few pebbles bedding contact
P1181	298742.35	4546137.20	149.07	PGms(t)	
P1182	298742.23	4546137.21	148.78	PGms(t)	

APPENDIX E: DETAILED DESCRIPTION OF STOP 1-7, PROFILE 1

Table E-1 Description of Profile 1, Stop 1-7, the Midwest Material Company, Lacon Pit.

MIDWEST MATERIAL COMPANY
SW¼, SE¼ Sec. 24, T30N, R3W, Marshall County, Illinois
Described by T. Kemmis, E. Hajic, A. Stumpf, C. Stohr, and R.S. Nelson
July 28, 2004
Elevation of top of stripped section: 156.08 m (512.06 ft)

Elevation of sample top (ft)	Top depth (ft)	Thickness (ft)	Lithofacies	Description
Unit z, total exposed thickness: 21.03 ft				
512.06	0.00	2.17	PGms(t)	trough cross-bedded matrix-supported pebble gravel; some foresets are entirely pebble gravel
509.90	2.20	3.28	PGms(t)	trough cross-bedded matrix-supported pebble gravel; gravel occurrs as individual clasts along foresets
506.62	5.40	3.41	PGms(t)	trough cross-bedded matrix-supported pebble gravel; some foresets are clast-supported very fine pebbles; large gravels occur as isolated clasts within the cross-bed sets
Unit z, total exposed thickness: 21.03 ft				
503.21	8.90	12.17	CGms(ccf)-PGms(ccf)	interbedded planar beds of clast-supported pebble gravel and coarse sand with isolated cobbles, the beds mimicking simple U-shaped channel geometry; some cobble to small boulder size subangular to subrounded diamicton clasts (armored mud balls) in the lower 1.5 m (4.9 ft) of the channels; angular unconformity at the base of this unit; the coarsest exposed unit in the terrace sequence
Unit y, total thickness: 27.82 ft				
491.04	21.00	0.72	PGms(t)	trough cross-bedded matrix-supported pebble gravel composed of approximately 15% fine to medium pebbles
490.32	21.80	0.98	PGms(t)	trough cross-bedded matrix-supported pebble gravel
489.33	22.70	3.58	S(t)-Gms(t)	trough cross-bedded sand with occasional clasts of pebble gravel
485.76	26.30	2.72	S(t)-Gms(t)	trough cross-bedded sand with occasional clasts of pebble gravel
483.03	29.00	1.44	PGms(t)	trough cross-bedded matrix-supported pebble gravel with occasional foresets of clast-supported pebble gravel
481.59	30.50	0.95	S(t)-Gms(t)	trough cross-bedded sand with occasional clasts of pebble gravel
480.64	31.40	0.66	PGms(t)	trough cross-bedded matrix-supported pebble gravel
479.98	32.10	0.89	PGms(t)	trough cross-bedded matrix-supported pebble gravel
479.09	33.00	0.49	S(t)	trough cross-bedded sand; occasional clasts of pebble gravel
478.60	33.50	0.04	S(t)	trough cross-bedded sand; occasional clasts of pebble gravel
478.64	33.40	3.81	S(t)	trough cross-bedded sand; occasional clasts of pebble gravel
474.83	37.20	0.20	Dmm	matrix-supported diamicton, thickens and thins across the outcrop; separates upper and lower cosets of trough cross-bedded sands and pebble gravel
474.63	37.40	2.13	PGms(t)	trough cross-bedded matrix-supported pebble gravel; mostly pebble gravel
472.50	39.60	3.22	S(t)	trough cross-bedded fine sand; few clasts of pebble gravel
469.29	42.80	2.62	PGms(t)	trough cross-bedded matrix-supported pebble gravel; irregular, erosional lower contact
466.17	45.90	1.51	PGms(t)	trough cross-bedded matrix-supported pebble gravel with some foresets composed of clast-supported pebble gravel

(continued)

Table E-1 (continued) Description of Profile 1, Stop 1-7, the Midwest Material Company, Lacon Pit.

Elevation of sample top (ft)	Top depth (ft)	Thickness (ft)	Lithofacies	Description
464.66	47.40	0.26	Dmm	matrix-supported diamicton
464.40	47.70	0.66	PGms(t)-	trough cross-bedded matrix-supported pebble and cobble gravel
463.74	48.30	0.52	CGcs(pl)	planar-bedded clast-supported cobble gravel; angular unconformity at the base of this unit
Unit x, total exposed thickness: 14.07+ ft				
463.22	48.90	0.33	S(m)	massive sand
462.89	49.20	0.69	PGms(t)	trough cross-bedded matrix-supported pebble gravel with finer material at the base of the set
462.20	49.90	1.44	PGms(t)	trough cross-bedded matrix-supported pebble gravel
462.20	49.90	1.44	PGms(t)	trough cross-bedded matrix-supported pebble gravel
460.76	51.30	0.89	PGms(t)	trough cross-bedded matrix-supported pebble gravel with some fine sand foresets
459.87	52.20	0.52	PGms(t)	trough cross-bedded matrix-supported pebble gravel; base not exposed
459.34	52.70	10.20	Slump	
449.14			Base of exposure	

APPENDIX F: DETAILED DESCRIPTION OF STOP 2-4

Table F-1 Description of Stop 2-4, the Sandy Creek Section.[1]

SANDY CREEK SECTION
SW ¼, NE ¼, Sec. 3, T30N, R2W, Marshall County, Illinois
Described by T. Kemmis, D. McKay, and R. Berg
September 16, 2004

Elevation of sample top (ft)	Top depth (ft)	Thickness (ft)	Lithofacies	Description
Described Section A				
Exposed Unit IV, total exposed thickness: 3.2 m (10.5 ft)				
600.0	0.0	5.6	PGcs(pl)	planar-bedded, clast-supported medium pebble gravel
594.4	5.6	1.0	CGcs(pl)	planar-bedded, clast-supported cobble gravel with medium pebble to sand matrix and cobbles up to 20 cm (7.9 inches) in diameter
593.4	6.6	1.9	PGms(pl)	planar-bedded, matrix-supported pebble gravel with occasional cobbles up to 15 cm (5.9 inches) in diameter
591.5	8.5	2.0	BGcm(pl)	planar-bedded, clast- to matrix-supported boulder gravel with cobbles and boulders 15 to 50 cm (65.9 to 19.7 inches) in diameter; coarser textured toward the center of the channel; unconformity at base.
Exposed Unit III, total thickness: 14.3 m (46.9 ft)				
589.5	10.5	2.3	S(pl)	thin- to medium-bedded, planar fine- to medium-grained sand; some fine gravel in lower 30 cm of the bed
587.2	12.8	0.2	F(m)	massive silt, iron-stained, soft sediment deformation along lower boundary
587.0	13.0	1.1	PGcs(m)	massive clast-supported very fine pebble gravel in lenticular bed about 6 m wide
585.9	14.1	0.3	F(l)	laminated silt; some laminae wavy bedded
585.6	14.4	0.3	PGcs(m)	massive clast-supported very fine pebble gravel in lenticular bed
585.3	14.7	4.0	F(m)-S(r)	thin- to medium-bedded massive silt and massive to ripple-drift cross-laminated fine sand; foreset laminae dip to west-southwest; sand beds typically 3 to 7 cm (1.2 to 2.8 inches) thick, silt beds typically 5 to 20 cm (2.0 to 7.9 inches) thick; silt beds occasionally deformed by soft sediment deformation.
581.3	18.7	2.3	F(m)	massive silt, some iron staining at base.
Described Section B (2 m [6.6 ft] west of Section A)				
579.0	21.0	2.0	S(r)-PGcm(m)	thinly bedded ripple-drift cross-laminated fine sand and massive, clast-supported fine pebble gravel; foreset laminae dip to west-southwest.
577.0	23.0	1.9	PGms(m)	massive matrix-supported fine to medium pebble gravel.
575.1	24.9	3.3	PGms(pl)-S(pl)	planar-bedded matrix-supported fine to medium pebble gravel and medium sand.
571.8	28.2	3.3	PGcm(m)	massive clast- to matrix-supported medium to fine pebble gravel.
568.5	31.5	14.4	PGms(t)-S(t)	trough cross-bedded matrix-supported pebble gravel and fine- to medium-grained sand; troughs generally 20 to 40 cm (7.9 to 15.7 inches) thick and 2 to 4 m (6.6 to 13.1 ft) long; foresets dip to west-south-west.
554.1	45.9	0.5	F(m)	massive silt filling in shallow troughs on top of underlying bed.
553.6	46.4	2.8	PGcs(pl)	planar-bedded clast-supported coarse to fine pebble gravel.
550.8	49.2	0.3	F(m)	discontinuous massive coarse silt and very fine sand filling shallow trough 12 to 15 m (39.4 to 49.2 ft) wide on top of underlying bed.
Described Section C (3.5 m [11.5 ft] east of Section B				
550.5	49.5	7.9	PGcs(pl)	planar-bedded clast-supported coarse to medium pebble gravel

(continued)

Table F-1 (Continued) Description of Stop 2-4, the Sandy Creek Section.

Elevation of sample top (ft)	Top depth (ft)	Thickness (ft)	Lithofacies	Description
Exposed Unit II, total thickness: 6.2 m (20.4 ft)				
542.6	57.4	3.6	PGms(t)-S(t)	large-scale trough cross-bedded matrix-supported pebble gravel and find sand; occasional coal fragments; foresets dip to west-southwest.
539.0	61.0	2.0	S(pl)	thinly bedded to laminated planar-bedded fine to very fine sands, individual beds commonly 2 to 5 mm (0.08 to 0.2 inch) thick
Described Section D (5 m [16.4 ft] west of Section C)				
537.0	63.0	6.6	S(r)-S(pl)	ripple-drift cross-laminated very fine- to fine-grained sand with occasional planar beds; undulatory erosional contact at base; foresets dip toward the west-southwest; some discontinuous laminae of sand-sized coal clasts present; Illinois State University geologists note climbing ripples in this interval
530.4	69.6	8.2	Interbedded PGms(t)-S(t)	medium-scale trough cross-bedded matrix-supported pebble gravel and fine- to medium-grained sand, individual sets 20 to 40 cm (7.9 to 15.7 inches) thick, some coal fragments along foresets; foresets dip to west-southwest
Exposed Unit I, total exposed thickness: 5.8+ m (19+ ft)				
522.2	77.8	2.9	S(pl)	thinly bedded planar-bedded to laminated fine- to very fine-grained sand; some secondary iron staining
Described Section E (3 m [9.8 ft] east of Section D)				
519.3	80.7	3.3	S(r)	
516.0	84.0	3.9	PGms(t)-S(t)	ripple-drift cross-laminated fine-grained sand; foresets dip to east-southeast, upper 10 to 20 cm (3.9 to 7.9 inches) cemented with sec ondary carbonate; Illinois State University geologists note flute casts in this interval
Described Section F (10 m [32.8 ft] east of Section E)				
512.1	87.9	8.9	PGcs(t)	set of large-scale trough cross-bedded clast-supported coarse to fine pebble gravel 2.7 m (8.9 ft) thick with occasional cobbles, base not exposed; foresets to southeast (135°) with 30° dip and are commonly 2 to 5 cm (0.8 to 2.0 inches) thick; gravels are primarily subrounded and spherical, resulting in fabric indicators being rare and inconclusive; represents either a mega-dune or transverse channel fill, but exposure too limited to determine
503.2	96.8	29.5	Slump	slump to base of section
473.7	126.3			base of section

[1]Notes:

1. Described by Tim Kemmis, Don McKay, and Dick Berg on September 16, 2004, using lithofacies code adapted from Kemmis et al. (1988).
2. The section exposes Ancient Mississippi River sediments deposited at different times prior to the close of the Illinois Episode.
3. All depths are approximate. Upper 3.2 m (10.5 ft) of section inaccessible and thicknesses estimated visually.
4. The top elevation was used as datum and is estimated from the Henry, Illinois, U.S. Geological Survey 7.5-minute topographic quadrangle map.
5. All sands and gravel beds in this section are oxidized. Many of the finer-grained silt beds are reduced.
6. Ripple-drift cross-lamination and trough cross-bed dip directions are difficult to measure precisely; thus, only generalized dip direction indicated.
7. Exposure limited because of extensive slumping. The geometry of some beds could not be precisely determined.
8. All beds appear to fill broad, very shallow channels.
9. The exposed section records fluctuating flow through time with four groups of sediment related to discrete periods of sedimentation, unconformities separating the different groups.