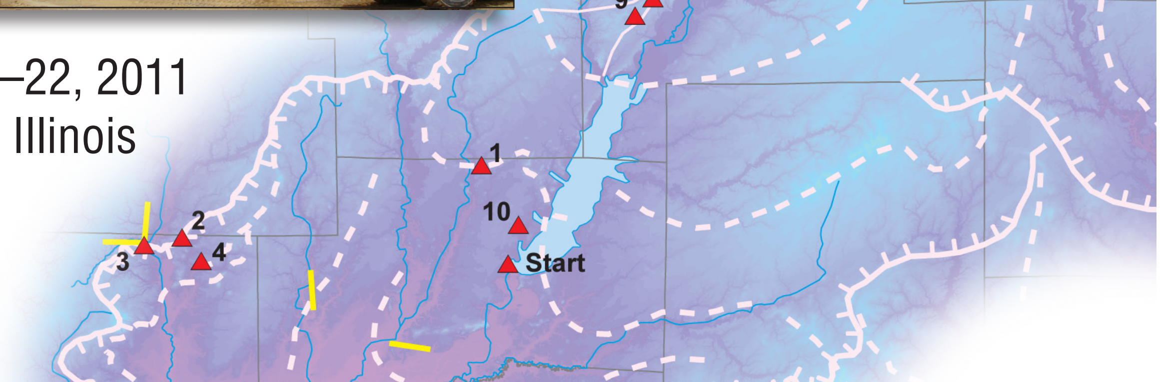
Ridges, Mounds, and Valleys: Glacial-Interglacial History of the Kaskaskia Basin, Southwestern Illinois

55th Midwest Friends of the Pleistocene Field Conference

David A. Grimley and Andrew C. Phillips, Editors



May 20–22, 2011
Carlyle, Illinois

Open File Series 2011-1

ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

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David A. Grimley[1] and Andrew C. Phillips[1], Editors

with contributions from B. Blackwell[2], B.Brandon Curry[1], Jeffrey Dorale[3], Elizabeth Geiger[4], Erik Gerhard[5], Samuel Indorante[5], Samantha Kaplan[6], Brad Koldehoff[7], Michael Konen[8], Timothy H. Larson[1], Craig Lundstrum[9], Rebecca Teed[10], Hong Wang[1], and Nathan D. Webb[1]

[1]Illinois State Geological Survey, Prairie Research Institute, University of Illinois, Champaign, IL.
[2]RFK Science Research Institute, Williams College, Williamstown, MA.
[3]Department of Geosciences, University of Iowa, Iowa City, IA.
[4]Formerly Department of Geology, Southern Illinois University, Carbondale, IL.
[5]U. S. Department of Agriculture-Natural Resources Conservation Service, Carbondale, IL.
[6]Department of Geography and Geology, University of Wisconsin–Stevens Point, WI.
[7]Illinois State Archeological Survey, Prairie Research Institute, University of Illinois, Champaign, IL.
[8]Department of Geography, Northern Illinois University, DeKalb, IL.
[9]Department of Geology, University of Illinois, Champaign, IL.
[10]Department of Earth and Environmental Sciences, Wright State University, Dayton, OH.

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Illinois State Geological Survey
Prairie Research Institute
University of Illinois at Urbana-Champaign
615 E. Peabody Drive
Champaign, IL 61820-6964
http://www.isgs.illinois.edu

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Meetings of the Midwest Friends of the Pleistocene*

1	1950 Eastern Wisconsin	Sheldon Judson
2	1951 Southeastern Minnesota	H.E. Wright Jr., R.V. Ruhe, and L. Gould
3	1952 Western Illinois and eastern Iowa	P.R. Shaffer and W.H. Scholtes
4	1953 Northeastern Wisconsin	F.T. Thwaites
5	1954 Central Minnesota	H.E. Wright, Jr., and A.F. Schneider
6	1955 Southwestern Iowa	R.V. Ruhe
7	1956 Northwestern lower Michigan	J.H. Zumberge and W.N. Melhorn
8	1957 South-central Indiana	W.D. Thornbury and W.J. Wayne
9	1958 Eastern North Dakota	W.M. Laird and others
10	1959 Western Wisconsin	R.F. Black
11	1960 Eastern South Dakota	A.G. Agnew and others
12	1961 Eastern Alberta	C.P. Gravenor and others
13	1962 Eastern Ohio	R.P. Goldthwait
14	1963 Western Illinois	J.C. Frye and H.B. Willman
15	1964 Eastern Minnesota	H.E. Wright, Jr. and E.J. Cushing
16	1965 Northeastern Iowa	R.V. Ruhe and others
17	1966 Eastern Nebraska	E.C. Reed and others
18	1967 South-central North Dakota	L. Clayton and T.F. Freers
19	1969 Cyprus Hills, Saskatchewan and Alberta	W.O. Kupsch
20	1971 Kansas and Missouri Border	C.K. Bayne and others
21	1972 East-central Illinois	W.H. Johnson, L.R. Follmer and others
22	1973 West-central Michigan/ east-central Wisconsin	E.B. Evenson and others
23	1975 Western Missouri	W.H. Allen and others
24	1976 Meade County, Kansas	C.K. Bayne and others
25	1978 Southwestern Indiana	R.V. Ruhe and C.G. Olson
26	1979 Central Illinois	L.R. Follmer, E.D. McKay III and others
27	1980 Yarmouth, Iowa	G.R. Hallberg and others
28	1981 Northeastern lower Michigan	W.A. Burgis and D.F. Eschman
29	1982 Driftless Area, Wisconsin	J.C. Knox and others
30	1983 Wabash Valley, Indiana	N.K. Bleuer and others
31	1984 West-central Wisconsin	R.W. Baker
32	1985 North-central Illinois	R.C. Berg and others
33	1986 Northeastern Kansas	W.C. Johnson and others
34	1987 North-central Ohio	S.M. Totten and J.P. Szabo
35	1988 Southwestern Michigan	G.J. Larson and G.W. Monaghan
36	1989 Northeastern South Dakota	J.P. Gilbertson
37	1990 Southwestern Iowa	E.A. Bettis III and others
38	1991 Mississippi Valley, Missouri and Illinois	E.R. Hajic, W.H. Johnson and others
39	1992 Northeastern Minnesota	J.D. Lehr and H.C. Hobbs
40	1993 Door Peninsula, Wisconsin	A.F. Schneider and others
41	1994 Eastern Ohio and western Indiana	T.V. Lowell and C.S. Brockman
42	1995 Southern Illinois and SE Missouri	S.P. Esling and M.D. Blum
43	1996 Eastern North Dakota & NW Minnesota	K.I. Harris and others
44	1998 North-central Wisconsin	J.W. Attig and others
45	1999 North-central Indiana & south-central Michigan	S.E. Brown, T.G. Fisher and others
46	2000 Southeast Nebraska and NE Kansas	R.D. Mandel and E.A. Bettis III
47	2001 NW Ontario and NE Minnesota	B.A.M. Phillips and others
48	2002 East-central Upper Michigan	W.L. Loope and J.B. Anderton
49	2003 Southwestern Michigan	B.D. Stone, K.A. Kincare and others
50	2004 Central Minnesota	A.R. Knaeble, G.N. Meyer and others
51	2005 North-central Illinois	E.D. McKay III, R.C. Berg and others
52	2006 Northwest-central North Dakota	L.A. Manz
53	2007 East-central Wisconsin	T S. Hooyer
54	2008 Northeastern Illinois	B.B. Curry and others
55	2011 Southwestern Illinois	D.A. Grimley and A.C. Phillips

* Field conferences were not held in 1968, 1970, 1974, 1977, 1997, 2009, or 2010.

A Brief History of the Kaskaskia Basin

The glaciers came and the glaciers went; the rivers rose and lakes formed. The wind blew and the dust covered all. Life rejoiced when the ice was no more.

The snails and the trees thought they were so free. The basins were filled and the rivers had glee.

But once again the ice advanced; covering all with relentless power. Lakes and rivers were filled to the brim; only to drain when the game was over. Hills and plains were left to see, by mammoths and mastodons that still ran free.

Ostracodes and mollusks were left to ponder; when will the ice come from over yonder ?

And once again, the glaciers advanced, but this time they had no chance. The ice could only view the Kask without much affect to its inner core. Yet the powerful Miss ran its course and bumped its neighbor to its place. The wind blew and the dust covered all. Life rejoiced when the ice was no more.

Addendum: Native peoples entered the basin, trading materials from here to there. How did they live and where did they go ? The evidence is now gone, under 20 feet H_20.

An Anonymous Kaskaskian

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- climatic records during the middle to late Pleistocene and Holocene
- archeological history
- sodium affected surface soils
- integration of geophysical studies with research and mapping

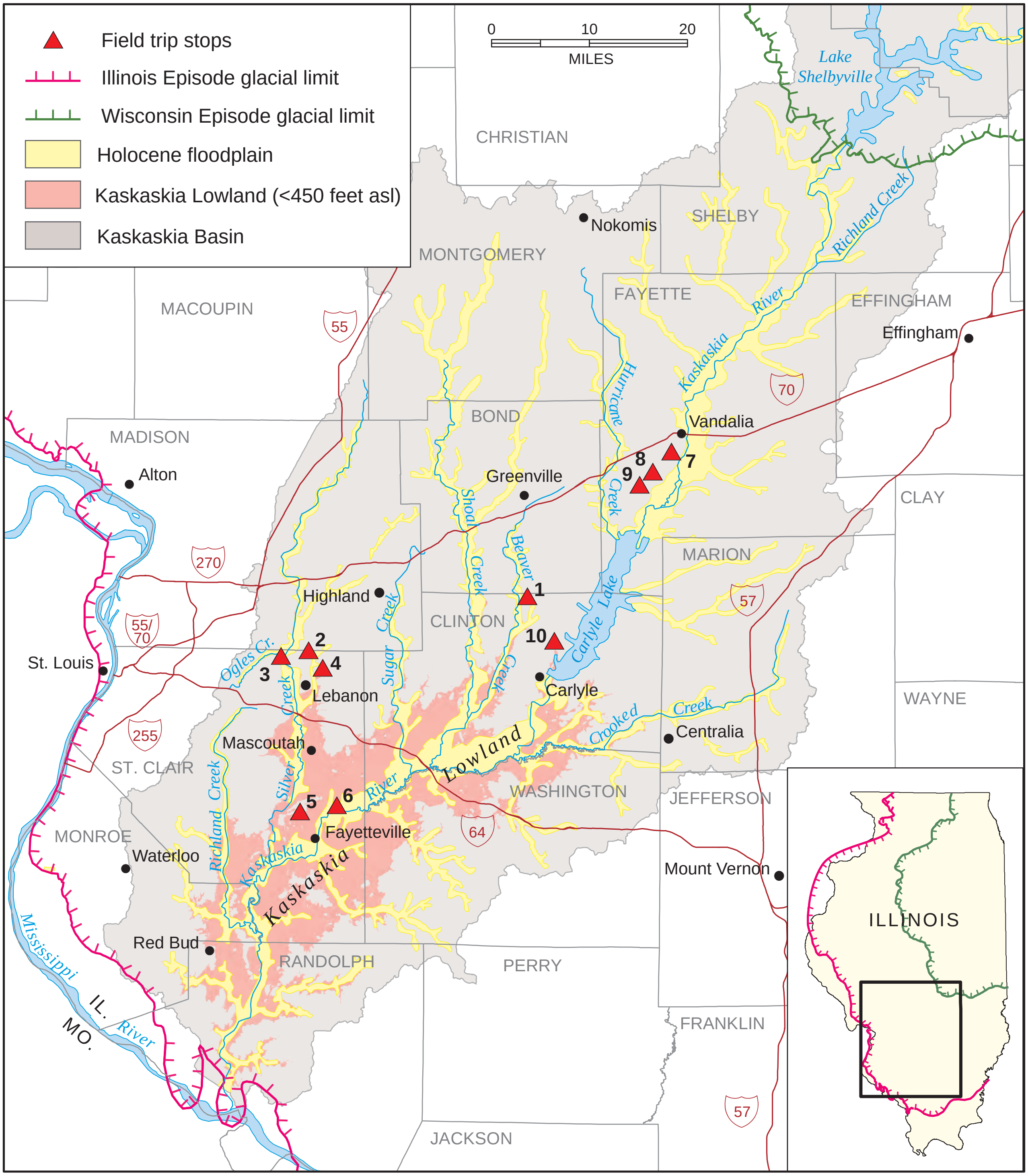


Figure Q0. Overall location map of the Kaskaskia Basin and Kaskaskia Lowland in southwestern Illinois.

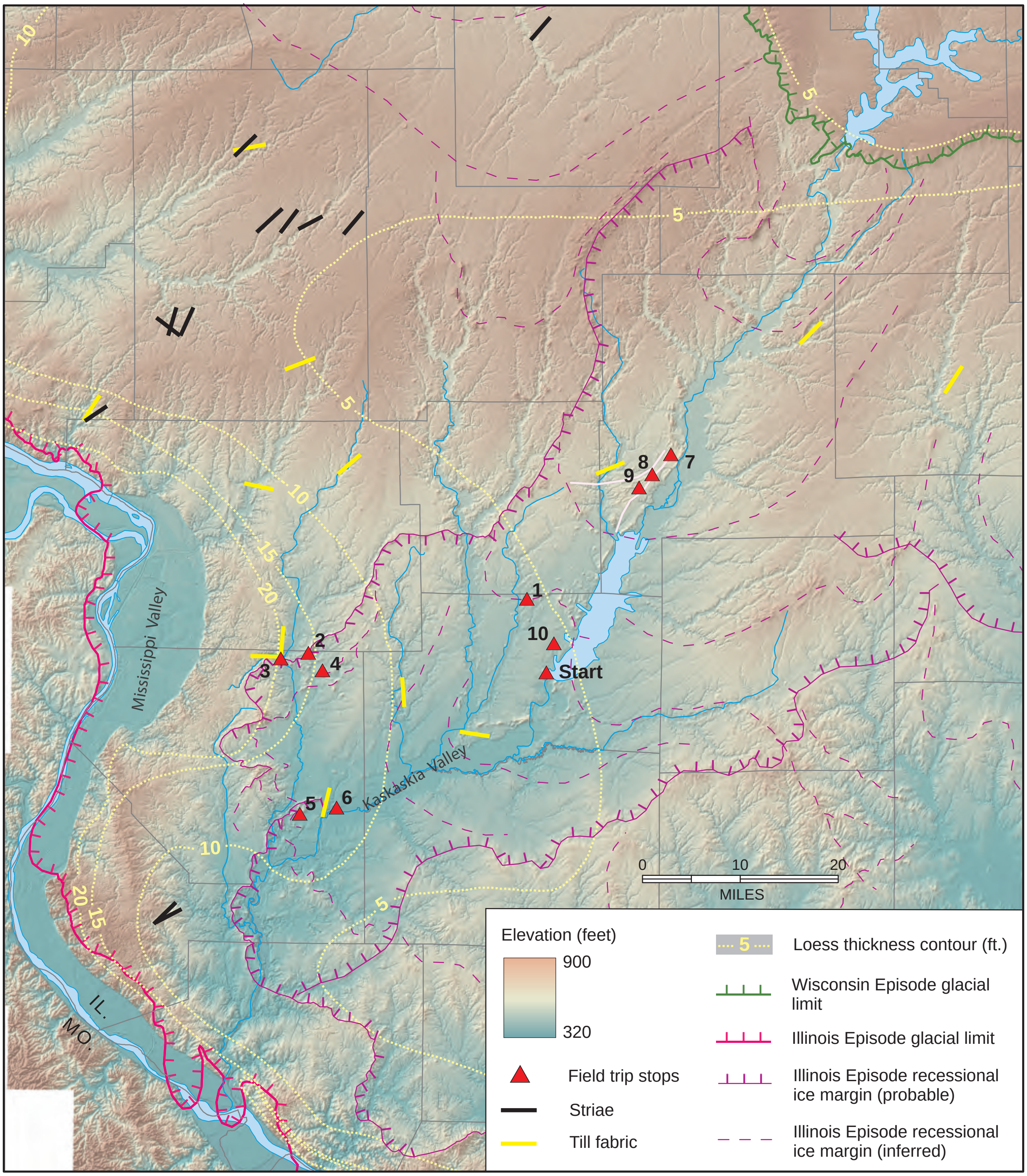


Figure Q1. Inferred ice margin positions in the Kaskaskia Basin region of southwestern Illinois. Striation directions are from Leighton and Brophy (1961), E.D. McKay III, and others. Till fabric directions are from Lineback (1971) and Webb (2009).

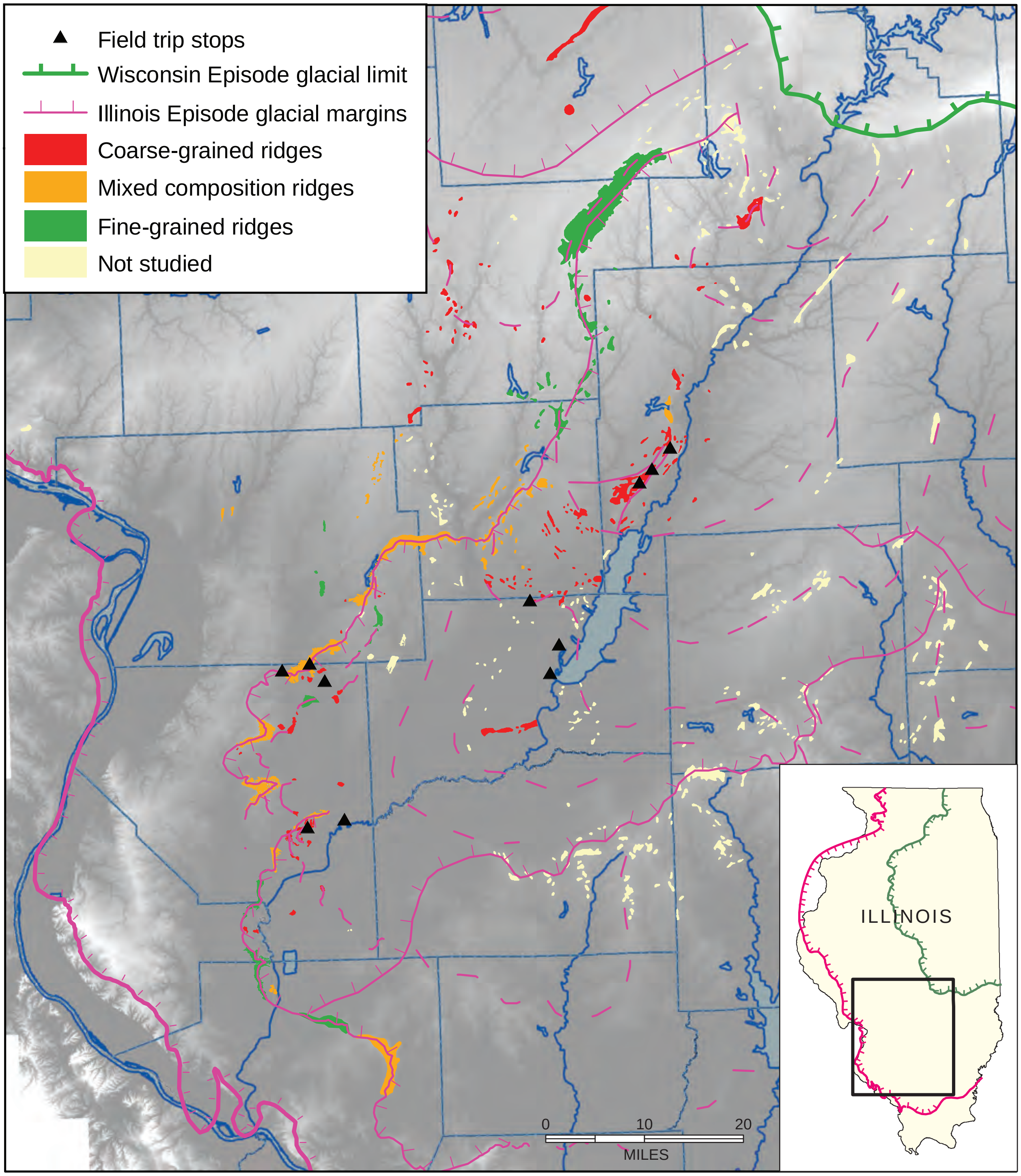


Figure Q2. Generalized lithologic composition of contructional glacial ridges in southwestern Illinois. Modified from Webb (2009), and based on various studies by Leighton and Brophy (1961), Lineback and Jacobs (1969), Stiff (1996), Grimley and Phillips (2011) and others.

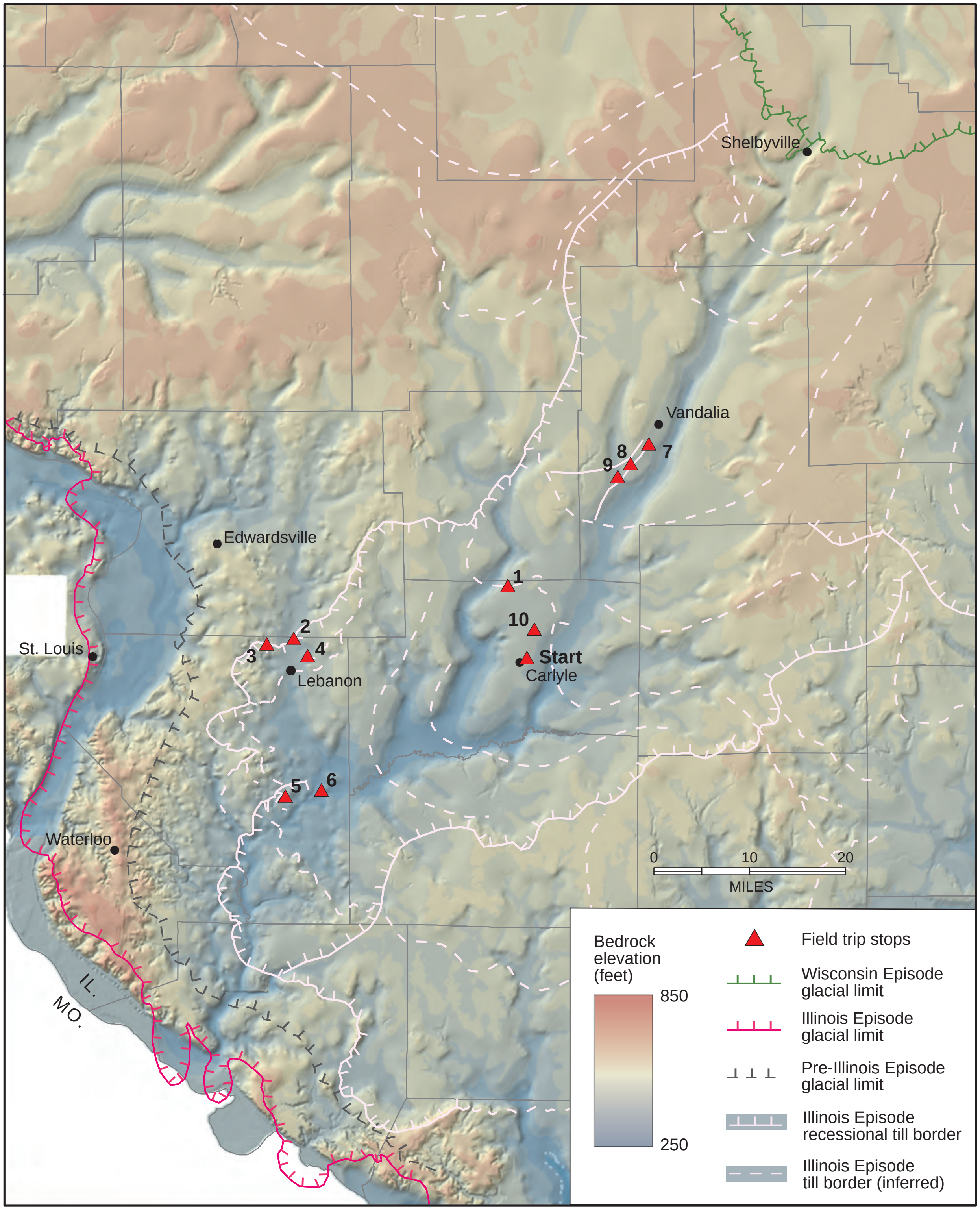


Figure Q3. Bedrock topography map of southwestern Illinois. Based on Grimley and Phillips (2011) and unpublished data in Madison, St. Clair, and Monroe Counties. Based on Herzog et al. (1994) for all other areas.

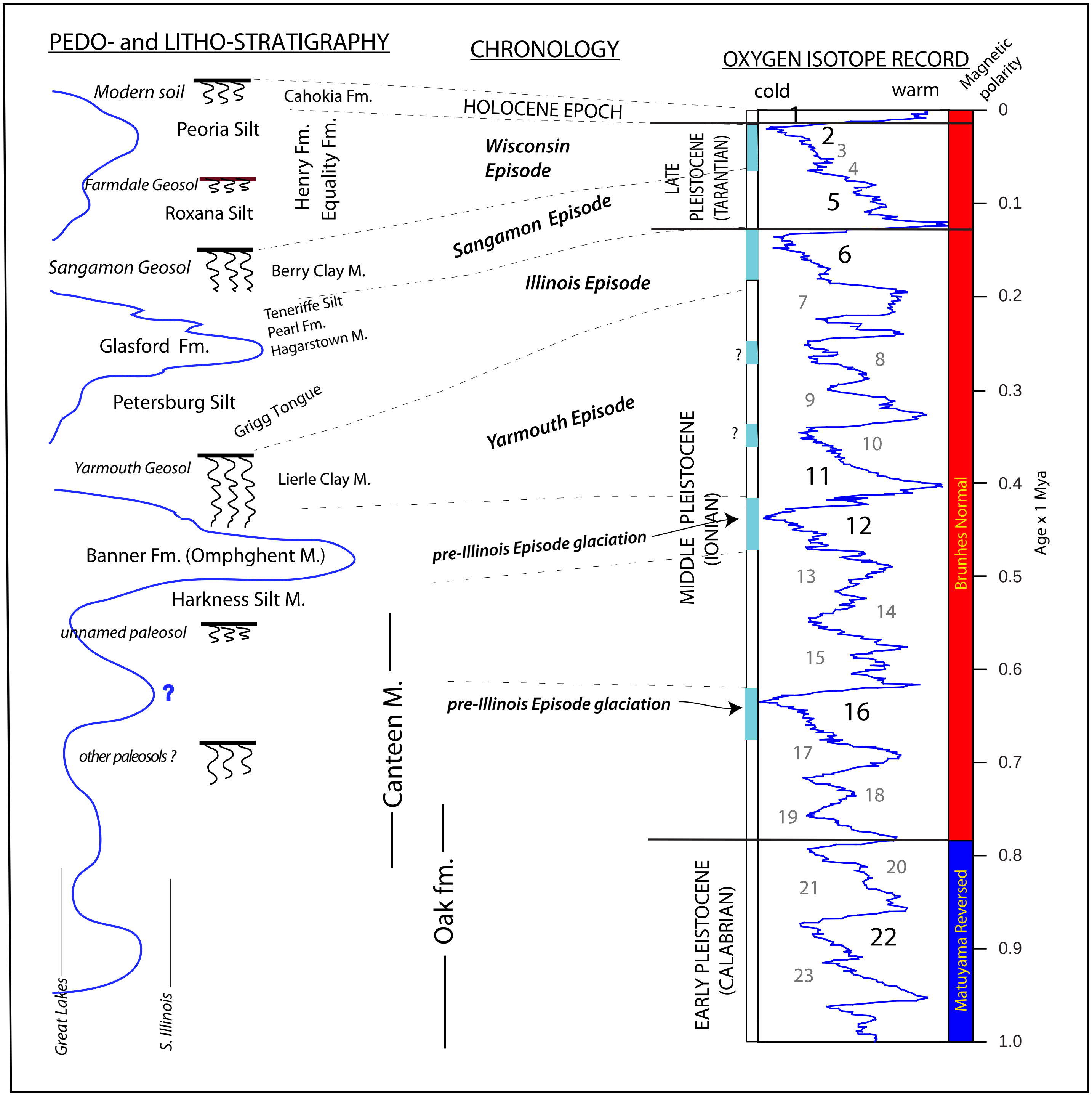
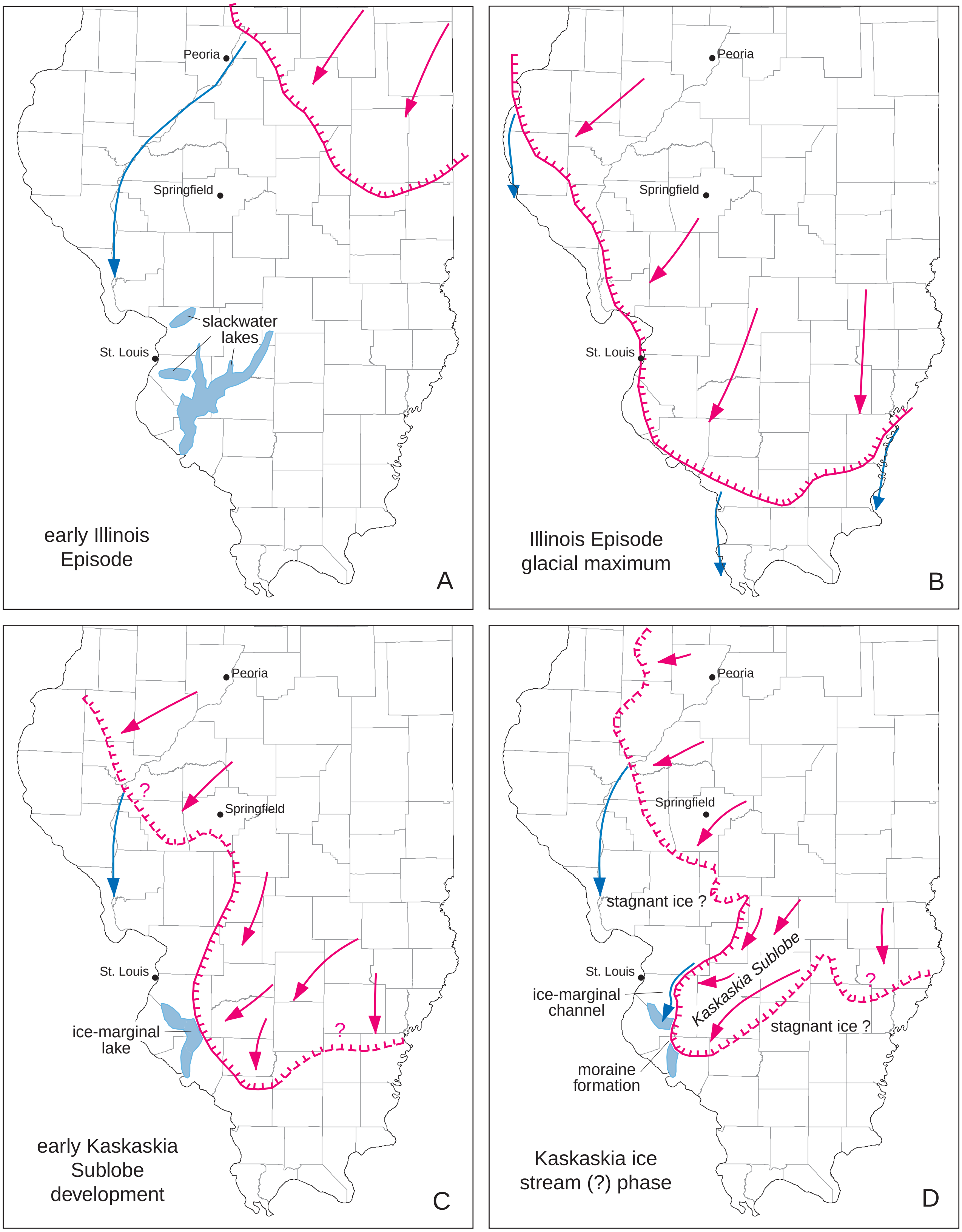


Figure Q4. Stratigraphic framework and age of Quaternary deposits in the Kaskaskia Basin region.



Scale ~1:4,000,000

Figure Q5. Cartoon diagrams of ice advances and geologic events in southern Illinois (Kaskaskia Basin) during the middle to late Quaternary.

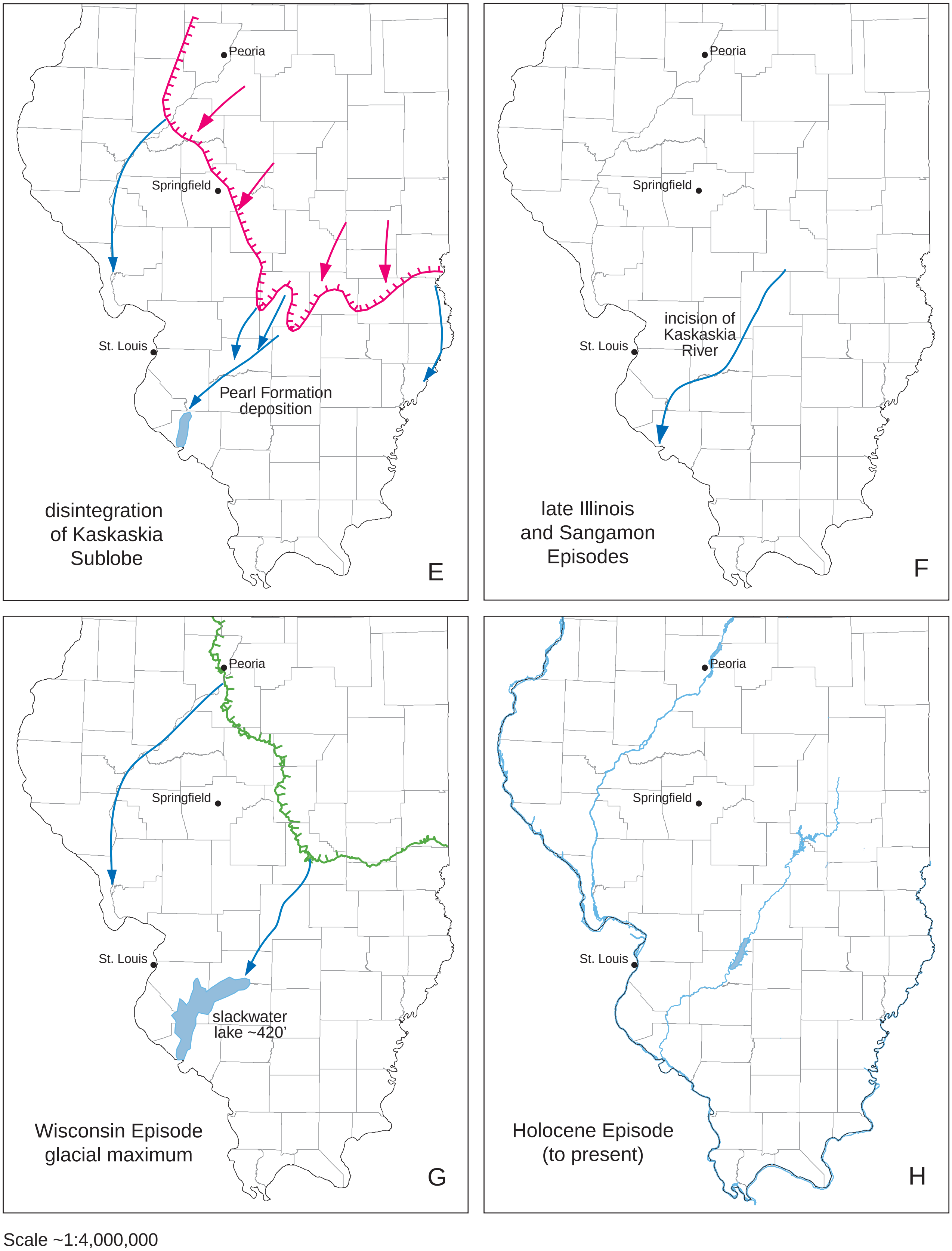


Figure Q5. Cartoon diagrams of ice advances and geologic events in southern Illinois (Kaskaskia Basin) during the middle to late Quaternary.

PART I: QUATERNARY GEOLOGIC OVERVIEW OF THE LOWER KASKASKIA BASIN

Introduction

The intention of this field trip is to provide a tour of Quaternary deposits and history of the Kaskaskia Basin region of southwestern Illinois. As far as we know, a Friends of the Pleistocene or Geological Society of America field trip related to the Quaternary or Pleistocene history has never been run in the Kaskaskia region. This area was glaciated during both the pre-Illinoian and Illinoian Stages and includes the controversial Ridged-Drift area (Leverett, 1899; Jacobs and Lineback, 1969) that contains constructional hills of various forms which protrude from the dissected Illinoian till plain. During this trip, we will offer our current hypothesis which envisions a Kaskaskia Basin Sublobe, at times possibly involving an ice stream, within an overall glacial advance from the Lake Michigan Basin during oxygen isotope stage 6. We believe that such a sublobe may explain the presence and general distribution of morainal ridges, esker forms, and other ice-contact landforms in southwestern Illinois.

This guidebook includes a traditional road log, a general introduction of our latest thoughts on the regional Quaternary history, and a description for each stop. The field trip stops include sand and gravel pits, natural exposures, archeological sites, soil pits, and core samples of ridge deposits. The principal theme of the trip is the origin of the Ridged-Drift and the former existence of a possible sublobe; however, secondary themes is the occurrence of a slackwater lake, with fluctuating water levels, in the lower reaches of the Kaskaskia Basin during each major glaciation. The following general discussion of the Quaternary history in southwestern Illinois is based in part on detailed 1:24,000-scale mapping and research that has been conducted primarily in the western portion of the field trip area (Madison, Monroe, and St. Clair counties) over the past decade.

Quaternary History and Stratigraphy, Lower Kaskaskia Basin, SW Illinois

The Quaternary and Pleistocene recently have been redefined to include time back to about 2.6 Mya (Head et al, 2008); however, little is known about Early Pleistocene deposits (Galasian and Calabrian Stages) in the region. The Kaskaskia Basin (Fig. Q0) was overrun by continental glaciers twice during the Middle Pleistocene (Ionian Stage; Head et al., 2008); first, during a pre-Illinois Episode glaciation (sometime between ~ 700 and 420 thousand years ago) and second, during the Illinois Episode glaciation (~ 180 to 130 thousand years ago). Deposits of both glaciations were documented in southern Illinois by MacClintock (1929), and have been repeatedly confirmed by observations in outcrops and cores (McKay, 1979; Phillips, 2004; Grimley and Phillips, 2011). During both glacial episodes, glaciers generally advanced from the northeast, with Illinois Episode glaciers emanating from the Lake Michigan Basin (Willman and Frye 1970; McKay, 1979; Grimley et al. 2001) and pre-Illinois episode glaciers probably emanating from the eastern Great Lakes basins (Michigan, Huron, Erie and/or Saginaw). During both episodes, glacial meltwater in southwestern Illinois appears to have been focused towards an ancestral valley in the Kaskaskia Lowland (Fig. Q0), documented by sandy outwash in the subsurface (Phillips 2009; Grimley and Phillips, 2011). The ancestral location of the Kaskaskia Valley somewhat coincides with the current valley and provided a southwestern passage of meltwater towards the Mississippi River valley or into ancient slackwater lakes. During the last glaciation, the Wisconsin Episode (~ 60 to 12 thousand years ago), glacial ice reached northeastern Illinois, northern Iowa, Wisconsin and Minnesota, but did not reach southern Illinois (Hansel and Johnson, 1996). Yet the effects of this glaciation were left throughout southwestern Illinois as torrents of glacial meltwaters deposited sand and gravel outwash in the Mississippi River valley (Grimley et al., 2007) and to a lesser extent (and with finer texture) in the Kaskaskia River valley (Grimley and Webb, 2010; Grimley and Phillips, 2011). Finer silty sediment in the outwash valleys, especially the Mississippi Valley, was deflated by wind and incrementally draped over the uplands, providing a record of thick loess deposits (McKay, 1979; Wang et al., 2003; Grimley and McKay, 2004). Reflecting this source area, loess thickness on uneroded uplands decreases exponentially away from the Mississippi Valley (McKay, 1979; Hansel and Johnson, 1996; Grimley and Phillips, 2011). Concurrent with loess and outwash deposition, widespread lake deposits formed in a large slackwater lake in the lower Kaskaskia Valley (Shaw, 1921; Phillips, 2008; Grimley and Webb, 2009). This lake, known as glacial Lake Kaskaskia (Willman and Frye, 1970), is expressed geomorphically today by multiple terrace levels. Postglacial deposits occur in modern valleys, with deposits of fine sand, silt, and clay (30 feet thick) in the formerly active meander belts of the Kaskaskia Valley. Channelization, straightening, and confinement by levees of these rivers and of some smaller creeks has altered the natural sedimentary regimes and processes in the past century and a half.

Surficial deposits in the middle to lower Kaskaskia drainage region of southwestern Illinois (Fig. Q0, Q1) vary widely from thick glacial and postglacial alluvium (combined > 100 feet) in the broad Kaskaskia Valley, to thin glacial sediment (<25 feet) on bedrock topographic highs, to areas of thick loess (>25 feet thick), to ice-contact deposits (up to 150 feet thick) in a train of ridges sub-parallel to the Silver Creek and Kaskaskia River valleys (Fig. Q2; Grimley and Phillips, 2011).

Exposures of bedrock, predominantly Pennsylvanian rocks, occur where creeks have incised into bedrock topographic highs. The trend of preglacial ridges and valleys on the bedrock topographic surface follow the strike of Paleozoic rocks of the west side of the Illinois Basin (Fig Q3). For instance, N-S and NW-SE trending buried bedrock valleys occur in eastern St. Clair County (Fig. Q3) and likely developed adjacent to preglacial cuestas with shales in lowlands and sandstone or limestones forming the highlands. The lower reaches of the Kaskaskia River flow into an area of more competent Mississippian bedrock (Kolb, 2010), causing the valley to be more constricted in this area. Highlands underlain by Mississippian rocks in far southwestern Illinois, containing karstic limestone, also helped to impede the flow of glacial ice and prevented significant advances into Missouri from northeastern source glaciers during the middle Pleistocene. The limit of glaciation during both the Illinois and pre-Illinois episodes appears to have been in the Mississippian highlands of southwestern Illinois (Grimley and Shofner, 2008; Kolb, 2010).

Early to Early-Middle Pleistocene preglacial history (~ 2.6 Mya - 500 ka):

The early Quaternary history, prior to invasion of the first glaciers, has a limited geologic record that includes weathering and alluvial deposition. Deposits are mainly limited to bedrock residuum, colluvium, and alluvium, not unlike present-day surficial deposits in unglaciated regions of Missouri and Kentucky that are far from loess sources. A hillier terrain during this preglacial time probably resulted in more active gravity-slope processes, including creep and slumping along the margins of valleys. Alluvial deposits from preglacial Quaternary time tend to be relatively sandy or clayey in texture, and lack the dominantly loessal influence that caused a preponderance of silty-textured upland, lacustrine, and alluvial deposits of middle to late Quaternary age.

Canteen Member [preglacial alluvium and colluvium]

Fine-grained alluvial and colluvial deposits, typically faintly stratified, have been informally classified as the **Canteen member**, a basal unit of the **Banner Formation** (Fig. Q4; Phillips, 2004). This unit has now been documented by numerous subsurface observations, and is preferentially found in buried bedrock valleys tributary to the ancestral Kaskaskia and Mississippi Valleys (Phillips and Grimley, 2004; Grimley and Phillips, 2011). A preglacial interpretation for deposition of the Canteen member is substantiated by the lack of glacial erratics, low magnetic susceptibility, low or negligible carbonate content, and high kaolinite/chlorite content. All of the above reflect a domination of local bedrock influences, predominantly Pennsylvanian shale. In many areas it may have a slight greenish-gray cast, not unlike the color of some local shales or may reflect poorly drained soil conditions. Beds of sand occur locally near the unit base. In some areas of southwestern Illinois, weak to moderate soil structure indicative of a paleosol has been observed in upper portions of the Canteen member. Most of the Canteen member was probably deposited during the early-middle Pleistocene based on amino acid geochronology of one core (Oches et al., 2002). The lower foot or so of the Canteen member, above Pennsylvanian bedrock, may include residuum or subangular sandy gravel. In a few areas, a few inches to a few feet thick of rounded chert gravel in deep bedrock valleys at the basal contact with bedrock may be correlative with the **Grover Gravel**, a Pliocene or early Quaternary fluvial deposit (Willman and Frye, 1970). Thick residuum, formed in-situ from weathered limestone or shale, has been classified as the **Oak formation** (Fig. Q4; Nelson et al., 1996) and is probably Pliocene to early Pleistocene in age. The Oak formation may underlie the Canteen member or may be included within the Canteen member if the residuum is thin and similar in lithology.

pre-Yarmouth (or pre-Illinois) Episode glaciation, Middle Pleistocene (~ 650 - 430 ka):

Overall, evidence from Quaternary mapping and glacial studies in southwestern Illinois indicates that there was principally one glacial advance that physically reached this area during pre-Yarmouth (or pre-Illinois) Episode time (Grimley and Phillips, 2011). General correlations to the marine oxygen isotope record suggest that this regional glacial advance may have been synchronous with either OIS 12 or OIS 16 (Fig. Q4), both periods of significantly large global ice volume and extreme cold (Shackleton, 1987; Hansel and McKay, 2010). Amino acid geochronology using pre-Illinois episode fossil gastropods also suggest an age between about 650 and 400 ka (Grimley et al., 2010). An age of ~ 450 ka (OIS 12) may be more likely based on compositional weathering indices for Yarmouth Geosol development duration in comparison with Sangamon Geosol development duration (Grimley et al., 2003).

Banner Formation till deposits

The limit of pre-Illinois Episode till observations in southwestern Illinois appears to be close to, and just within, the border of the Illinois Episode glaciation (MacClintock, 1929; Willman and Frye, 1970; Grimley and Shofner, 2008; Kolb, 2009) which locally parallels the strike of the Mississippian bedrock escarpment that rims the Illinois Basin. Within the interior of the Kaskaskia Basin, where Illinois Episode glaciers had been largely erosive, the Banner till deposits are generally sporadic or absent from bedrock topographic highlands due to later glacial erosion. Banner till deposits were also significantly scoured by later fluvial or glacial events in the main meltwater sluiceways such as the Kaskaskia Valley. Correlations are of course difficult where key paleosol maker horizons have been removed by erosion.

Pre-Illinois Episode till (and related debris flow diamicton) in the western part of the St. Louis Metro East region has been informally classified as the **Omphghent member** (pronounced Om-jent) of the **Banner Formation** (Fig. Q4; McKay 1979, 1986). The Omphghent member only rarely occurs near-surface (McKay, 1979; Grimley and Phillips, 2010), being found mainly in preglacial tributary bedrock valleys or lowlands where it has been protected from erosion during later geologic events. In its type area of central Madison County, the Omphghent member is a calcareous, grayish brown to yellowish brown (oxidized), pebbly silty clay loam to silty clay diamicton. The unit is interpreted primarily as till or debris flows, and can include small lenses of glacifluvial sand and gravel. The diamicton includes usually < 5 % (by volume) pebbles of sandstone, chert, shale, siltstone, and rare crystalline erratics. The upper part of the till (or all of it if thin) is oxidized by Yarmouth Geosol interglacial soil development and may include the strongly developed soil solum; however, the solum is more commonly contained within the overlying Lierle Clay Member (see Yarmouth Episode section). Till of the Omphghent member is thinner and more clayey in the southern and western areas of the Kaskaskia Basin (Grimley and Webb, 2010) compared to farther north (Phillips and Grimley, 2004) due to more local incorporation of soft Pennsylvanian shales, proglacial pre-Illinois Episode lake sediment, and bedrock residuum.

Where defined in central Madison County, the Omphghent till has a higher clay content, less illite, less dolomite and more shale fragments than the overlying Glasford Formation till, reflecting more input from the local substrate. Outside of central Madison County, lithological distinction between the pre-Illinois and Illinois Episode tills in southwestern Illinois is less apparent, but is possible with detailed analyses and correlations to key localities. Near the glacial termini, local shale-rich deposits, residuum, and loess were incorporated into glacier beds during both glaciations (Grimley and Webb, 2010), and so the Banner and Glasford tills may have a similar field appearance in some areas (*i.e.*, Monroe, western St. Clair and Randolph Counties). In the up-ice direction to the east, the pre-Illinoian till is less clayey than to the southwest, and can have a similar texture to the loamy or silty Glasford Formation (Jacobs and Lineback, 1969) and so is often referred to as Banner till or Banner diamicton (rather than Omphghent member). The most useful analytical parameter for distinguishing tills from the 2 glaciations (in the absence of paleosols and stratigraphic control) seems to be carbonate content or calcite-dolomite ratios (Jacobs and Lineback, 1969; McKay, 1979; Phillips and Grimley, 2010), with less dolomite and less total carbonate typically for the Banner Formation. Due to a possibly different distal source area (perhaps Lake Huron or Saginaw region ?), there may be other geochemical or mineralogical signatures or ratios that could further help with unit delineation.

Banner Formation lake sediments, loess, and outwash

Pre-Illinois Episode till deposits in the Kaskaskia Basin may be intercalated with lake sediments, fine-grained alluvium, sand and gravel outwash, or loess deposits. The most common of these sediments in the lower Kaskaskia region is massive to laminated, and sometimes fossiliferous, silt to silty clay (**Harkness Silt Member** of the **Banner Formation;** Fig. Q4**;** Willman and Frye, 1970). This unit may include lake sediments, fine-grained alluvium and loess deposits, with thickest occurrences consisting of laminated lake deposits. The lakes were mostly likely of slackwater origin, dammed in the Kaskaskia Valley by high sediment accumulations in the Mississippi Valley. Pre-Illinois Episode sand and gravel in the Kaskaskia Valley have not been given a formal member name and so are referred to as Banner sand or Banner outwash. Both the Harkness Silt and Banner sand are subsurface units, and occur predominantly in preglacial bedrock valleys where they are preserved below pre-Illinois or Illinois Episode till deposits.

The thickest known succession of the Harkness Silt Member was observed below Omphghent diamicton in a buried bedrock valley a few miles west of the modern Kaskaskia Valley in northern Randolph County (Grimley and Webb, 2010). At this site, 55 feet of calcareous, laminated, greyish brown to slightly pinkish, silty clay to silty clay loam fills the preglacial valley. A slackwater lacustrine environment is interpreted based on the presences of several gastropod and bivalve (*Pisidium* sp.) shells (~2 - 10 mm in size), ostracodes, aquatic vegetation, and small bits of conifer wood fragments and needles (probably *Picea* sp.) that likely washed into a generally shallowing lake. Aquatic gastropods include *Fossaria* sp., *Gyraulus* sp., *Valvata tricarinata,* and *Probythinella lacustris*. Distinctive ostracodes in the basal, more pinkish-brown portion of the Harkness Silt may indicate a relatively deep and low turbidity lake, perhaps when loess deposition was minimal. The pinkish color may reflect a time when pre-Illinois Episode ice began to advance across the Lake Superior region, an area that could have provided an abundant source of pinkish sediment.

Some pre-Illinois Episode sand deposits do occur in the lower Kaskaskia region (Grimley, 2010) although delineation of these deposits from younger sand units is sometimes difficult using descriptions of water-well logs. On uplands, pre-Illinois Episode loess deposits that occur above the till are generally encapsulated by the Yarmouth Geosol weathering horizons. Proglacial loess that occurs below Banner till is included within the Harkness Silt unit, but is a few feet in thickness or less. However, much of the silt-rich sediment within Harkness Silt lacustrine deposits are likely derived from loess on adjacent uplands. A pre-Illinoian loess deposit with a pre-Yarmouth weathering profile, informally classified as the Burdick loess by McKay (1979) in Madison County, Illinois, is perhaps one glacial stage older than the Omphghent till. Although this unit has not been found as yet in the Kaskaskia Basin, possibly correlative loesses have been found in unglaciated southern Illinois (Wang et al., 2009).

Yarmouth Episode (interglacial), Middle Pleistocene (~ 430 to 190 ka):

The Yarmouth Episode, as here used, includes the time of development of the Yarmouth Geosol, a widely recognized interglacial paleosol. The presence of the Yarmouth Geosol, preserved within the uppermost pre-Illinois Episode deposits, allows for delineation of these units from younger Illinois Episode deposits (Leverett 1898; Willman and Frye 1970). In addition to weathering and soil development processes, the Yarmouth Episode also was a time for deposition of accretionary and alluvial deposits (**Lierle Clay Member, Banner Formation**; Fig. Q4) in lowlands, and was a time of overall landscape dissection and erosion.

The wetland or poorly-drained facies of the Yarmouth Geosol is typically preserved within the Lierle Clay Member (described below) and is found above Banner till deposits, though partially eroded in many places (Grimley and Phillips, 2010). The well- to moderately-drained facies of the Yarmouth Geosol, formed on highlands and prominent uplands, were mainly scoured by glacial erosion during the succeeding Illinois Episode glaciation. Thus, these facies of the geosol are rarely observed within glaciated portions of the Kaskaskia Basin. However, oxidized, well-drained, reddish-brown Yarmouth Geosol profiles are found in unglaciated areas of southern Illinois (Grimley et al., 2003; Wang et al. 2009). Mineralogical and magnetic properties, representative of soil development duration, suggest that Yarmouth Geosol alteration and soil development was about triple that for the Sangamon Geosol (Grimley et al., 2003). Considering the degree of interglacial soil alteration and thickness, and the relatively deep dissection of pre-Illinois Episode till plains (Willman and Frye, 1970), the time of the Yarmouth Episode may best correlate to oxygen isotope stages 11 through 7 (~ 425 to 180 ka), compared to oxygen isotope stage 5 (~ 125 to 75 ka) for the Sangamon Episode (Hansel and McKay, 2010).

Stream dissection and erosion occurred for a considerable time during the possibly 200 ka or more length of the Yarmouth Episode. This likely resulted in scouring of valleys and lowering of stream base levels during the late Yarmouth Episode or possibly early Illinois Episode (Willman and Frye, 1970). Following this period of dissection, Illinois Episode deposits served to preferentially fill in these low areas with lake sediments, outwash, redeposited loess, till, debris flows, etc. (Grimley and Phillips, 2011).

Lierle Clay Member, Banner Formation [accretionary deposits]

Only one deposit of the Yarmouth Episode is formally recognized as a lithostratigraphic unit. The Lierle Clay Member of the Banner Formation is an accretionary deposit that occurs in paleo-lowlands or depressions and may be up to 15 feet thick. This unit is clay-rich, leached of carbonates, and high in expandable clay minerals (Willman and Frye 1970). Pedogenic alteration including clay skins, iron staining, soil structure, and mottled colors (greenish gray), along with some faint laminations within this unit records the interglacial soil development of the Yarmouth Geosol in a lowland or wetland environment. Iron and manganese concretions are sometimes abundant and < 5 % small pebbles of angular chert are typical.

Illinois Episode, late Middle Pleistocene (~190 to 130 ka):

During the maximum glaciation of the Illinois Episode, glaciers advanced southwest as far as downtown St. Louis (Goodfield, 1965) and to near the confluence of the Kaskaskia Valley with the Mississippi Valley (Kolb, 2009). Illinois Episode glaciers thus completely covered pre-Illinois Episode deposits in the Kaskaskia Basin (Fig. Q5), leaving behind a record of glacial diamicton, glacifluvial, and other ice-marginal sediments. On some bedrock highlands, the already thin and weathered pre-Illinois Episode deposits were removed by direct glacial or glacifluvial erosion. In other areas, typically lowlands or tributary valleys, a full sequence of pre-Illinois Episode deposits containing a strongly developed Yarmouth paleosol was preserved and buried by the younger sequences. As the Illinois Episode glacial margin receded from its maximum extent, and ice stagnated and thinned, a series of recessional morainic margins developed in the Kaskaskia Basin that are envisioned to be part of a regional sublobe (Webb, 2009; Grimley and Webb, 2010; Grimley and Phillips, 2011), referred to here as the Kaskaskia Sublobe (Fig Q5 D). Thinning glacial ice would have allowed for increasing influence of the local bedrock topography on glacial flow, resulting in small lobate forms, up to a few miles across, that protruded from the overall margin. In this model, glacial sedimentation was enhanced in reentrants between the sublobes, where convergent ice flow would have concentrated direct glacial, glaciocolluvial (debris flows) and glacifluvial sedimentation (subglacial and supraglacial stream outflow). Many prominent glacial ridges today (*i.e.*, Shiloh Ridge, Turkey Hill in St. Clair County) that formed in these convex ice marginal areas are comprised of the **mixed facies of the Hagarstown Member, Pearl Formation (**Fig. Q4; Grimley and Webb, 2010; Grimley and Phillips, 2011). Divergent glacial ice in the concave areas of the ice margin were more sediment starved, more typically morainal in character, and tend to be composed mainly of fine-grained material with fewer sand bodies. These deposits, are predominantly fine-grained with many sheared inclusions of Yarmouth paleosol and older materials and are classified as a morainal facies of the **Glasford Formation.** Other types of ridges, more abundant within the interior of the Kaskaskia Basin, contain sandy or locally gravelly glacifluvial deposits (**sandy facies of the Hagarstown Member, Pearl Formation)**. Landforms containing such deposits include ice-walled channels (tunnel eskers or subaerial) and kames, and tend to be most abundant on the northwest side of the present-day Kaskaskia Valley. The occurrence of the three lithologic end members (Glasford morainal, Hagarstown mixed facies, and Hagarstown sandy facies) within constructional, Illinois Episode, glacial ridges in southwestern Illinois, and their related origin, will be a primary focus of this field trip.

Ice-blocked proglacial lakes, likely coalescing with preexisting slackwater lakes, developed and inundated tributary valleys to the lower Kaskaskia Valley; resulting in lacustrine sediment deposition before (**Petersburg Silt**) and after (**Teneriffe Silt**) Illinois Episode glacial advances. Ice-dammed or moraine-dammed lakes may have caused rising levels in the preexisting lakes, which may have been as extensive as the Wisconsin Episode version of glacial Lake Kaskaskia (Willman and Frye, 1970). Consequently, slackwater lake deposits were extensively sedimented in the lower Kaskaskia drainage basin as a result of Mississippi River aggradation (see section on glacial Lake Kaskaskia).

During and following the stagnation and final melting of Illinois Episode glaciers, proglacial outwash (**Mascoutah facies, Pearl Formation**) was deposited in the middle and lower Kaskaskia drainage basin and probably fed into the proglacial or slackwater lake system. Ice marginal fans (STOP #2) and overflow channels with sand and gravel outwash contributed to the network of glacifluvial deposits that fed into the Kaskaskia Basin, one of the prominent areas of discharge for glacial meltwater for the Illinois Episode ice sheet in Illinois. Ogles Creek and Richland Creek in St. Clair County appear to have developed as ice-marginal outwash channels on the west side of a prominent recessional morainic border (Grimley and Phillips, 2011). As the Kaskaskia Sublobe receded further from a temporary margin (Fig. Q5), other ice marginal or proglacial meltwater streams flowed through south and southwest-flowing tributary valleys such as those of Silver Creek, Sugar Creek, Shoal Creek, Beaver Creek, and Hurricane Creek, all feeding into the Kaskaskia Lowland and depositing Pearl Formation outwash (Figs. Q0, Q1, Day1, Day2).

Petersburg Silt [sub-Glasford lake deposits and loess]

Fine-grained, massive to stratified, and sometimes fossiliferous sediments preserved below Illinois Episode till deposits are classified as the Petersburg Silt (Willman and Frye, 1970). This deposit of silt to silty clay with some fine sand beds is genetically and predominantly lake sediment, but also includes fine-grained alluvium and loess. Stratigraphically, the Petersburg Silt occurs below the Glasford Formation and above pre-Illinois Episode deposits (Willman and Frye 1970). However, the vast majority of this unit in the Kaskaskia region was deposited in proglacial lakes that formed as a result of ice-blockage or slackwater conditions. The Petersburg Silt is thus generally found in small lowlands and valleys on the pre-Illinois Episode paleo-landscape. In the lower valley region, this unit is mainly interpreted as slackwater lake sediment resulting from the impoundment of the Kaskaskia Valley and its tributaries in response to Mississippi River valley aggradation during the advance of the Illinois Episode ice sheet (Grimley and Phillips, 2011). The lake would have been present before burial by glacial ice and deposition of Glasford till and ice marginal sediment. Fossil gastropods in the Petersburg Silt, indicative of shallow lacustrine conditions and fluctuating water levels, have been noted across the lower Kaskaskia Basin (Geiger, 2008; Grimley and Webb, 2009). Numerous species of terrestrial and aquatic gastropods have been observed (Geiger, 2008), such as those at the Ogles Creek Section (STOP # 3).

Glasford Formation [till and ice-marginal sediment]

In southwestern Illinois, glacial diamicton, including till and debris flow deposits, are classified as the Glasford Formation (Willman and Frye, 1970; Grimley and Phillips, 2011). Although members of the Glasford Formation (Smithboro and Vandalia Members) have been differentiated in the Vandalia area by Jacobs and Lineback (1969), these units have not proven to be lithologically traceable to the west as the tills become gradually siltier and less illitic. The Fort Russell till member was differentiated informally in Madison and St. Clair Counties (McKay, 1979), but this unit appears to be gradational with till units to the east, perhaps in facies, and so cannot be clearly differentiated. We have thus chosen to use only the term Glasford Formation or Glasford till, rather than member names, until more data and research has been conducted in the middle Kaskaskia Basin (Bond, Clinton and Fayette Counties). Our model also now envisions a series of recessional ice margins that all originate generally from a Lake Michigan Lobe source. Thus, the lithological variations in Illinois Episode tills of the Kaskaskia Basin are probably local in origin, reflecting the composition of overridden Pennsylvanian bedrock, pre-Illinois Episode deposits, or proglacial Illinois Episode waterlain deposits in central and southern Illinois.

mixed and sandy facies, Hagarstown Member, Pearl Formation [ice-contact deposits]

The Hagarstown Member, originally defined by Jacobs and Lineback (1969) and Willman and Frye (1970) within the Glasford Formation, included poorly to well sorted gravel, and sand, interbedded with gravelly diamicton. The unit's depositional environment was suggested as an ice-walled channel deposit or other glacifluvial origins. This use of this unit appears to have evolved such that some Illinois Episode glacial ridges in the Kaskaskia Basin that were not known to be coarse-grained became mapped by Lineback (1979) as Hagarstown Member, probably by geomorphic inference. Later, Killey and Lineback (1983) reclassified the Hagarstown Member within the Pearl Formation, rather than the Glasford Formation, so that it is more analogous to the Wasco facies of the Henry Formation, ice-contact deposits of the Wisconsin Episode. However, in the course of detailed mapping, it became clear that the constructional glacial ridges have varying lithologic character. Deposits in ridges with mixed or alternating layers of coarse sand and gravel, fine sand, diamicton, silt, and/or silty clay are here classified informally as the Hagarstown Member mixed facies. If the material is dominantly diamicton (> 75%), then the material is classified as the Glasford Formation. If the material is dominantly sand or coarser (> 75%), then it is classified as the Hagarstown Member sandy facies. The sandy facies may include coarse-grained ice-contact sediments in areas of eskers, ice-walled channels, kames or ice-marginal fans.

Mascoutah facies, Pearl Formation [outwash]

Of considerable significance in the Kaskaskia Valley are thick Pearl Formation sand deposits (up to 55 feet thick), with some gravel, that occur in loess-covered terraces or in lowlands below younger Cahokia, Henry and Equality Formation sediments (Grimley and Phillips, 2011; units described below). Pearl Formation outwash, defined by Willman and Frye (1970), is predominantly Illinois Episode in age, but basal portions may include undifferentiated pre-Illinois

Episode fluvial deposits. The Mascoutah facies was informally defined by Grimley and Webb (2010) in order to more clearly distinguish Pearl Formation proglacial outwash deposits from more lithologically variable ice-contact facies sandy deposits (Hagarstown Member, Pearl Formation). Deposits classified as the Mascoutah facies, consists of mostly fine to coarse sand and are typically horizontally stratified (Grimley, 2010; Grimley and Webb, 2010). The unit contains Sangamon Geosol weathering in generally fine-grained upper portions if not eroded. The Mascoutah facies can be traced lithologically in the subsurface for several miles from eastern St. Clair to northern Randolph counties (Grimley, 2010; Phillips, 2009; Grimley and Webb, 2009) and likely extends beneath much of the middle and lower Kaskaskia Valley. It also occurs in feeder tributary valleys (particularly those with south or southwest draining orientations) such as the Silver Creek and Shoal Creek valleys.

Grigg tongue, Pearl Fm. [sub-Glasford outwash]

The Grigg tongue was recently used to map a basal tongue of sand and gravel that occurs below the Glasford Fm. in some areas of the lower Kaskaskia Basin, typically within a few miles of the present day valley (Grimley and Webb, 2010; Grimley, 2010). The presence of this unit is based primarily on water well and engineering boring logs, but data convincingly indicates its occurrence in the lower Kaskaskia Valley and many private water wells tap into this aquifer material locally (Grimley and Webb, 2010). The origin of this unit is likely proglacial sand and gravel deposited in front of an advancing Illinois Episode ice sheet. Sedimentologically and lithologically, it appears similar in character to the Mascoutah facies of the Pearl Formation, but lies stratigraphically below the Glasford Formation. Because it conceptually connects to the Mascoutah facies beyond the limit of glaciation, this unit has been defined as a tongue of the Pearl Formation (analogous to the Ashmore tongue of the Henry Formation for Wisconsin Episode deposits; Hansel and Johnson, 1996).

Teneriffe Silt [late-glacial lake sediment and loess]

The Teneriffe Silt is a massive to stratified silt deposit, that may include some clayey or sandy beds; it overlies other Illinois Episode deposits and contains the Sangamon Geosol in its top (Willman and Frye, 1970). This is typically a lake deposit, but may also include late Illinois Episode loess and beds of fine-grained outwash. Although it was originally defined as only within the limit of Illinois Episode glacial deposits, it has since been extended to Illinois Episode lake deposits beyond the glacial border (Lineback, 1979; Heinrich, 1982; Grimley et al., 2009). The Teneriffe Silt has been observed and mapped as the surficial deposit (below Wisconsin Episode loess) in several isolated areas in southwestern Illinois. Areas of deposition may include proglacial lakes where meltwater was trapped between the receding ice and a recessional moraine such as in northern Randolph County (Ostendorf, 2009; Grimley and Webb, 2010) and St. Clair County (Phillips, 2004). Other areas of Teneriffe Silt include proglacial lakes formed between glacial ice and areas of high topography in the Mississippian bedrock uplands of Monroe and southern St. Clair Counties (Phillips, 2010; Grimley and Phillips, 2011) or locally in ice-marginal waterlain deposits (STOP #2, this guidebook).

Sangamon Episode, Late Pleistocene (~ 130 to 60 ka):

The Sangamon Episode is the time represented by development of the Sangamon Geosol into Illinois Episode deposits (Fig. Q4). The original Sangamonian Stage was defined by this weathering zone (Leverett, 1899; Follmer et al., 1979). In the Kaskaskia Basin of southwestern Illinois, the Sangamon Geosol is ubiquitous in upland areas (Jacobs and Lineback, 1969; Grimley et al., 2001). Though sometimes partially truncated or eroded, the Sangamon profile is typically well preserved in upper portions of Illinois Episode deposits and separated from the modern soil profile by a 5- to 30-foot thick protective blanket of Wisconsin Episode loess deposits.

The Sangamon Episode (mainly correlative with OIS 5) was a time of generally warm interglacial climate, probably similar to today's climate on average or perhaps slightly warmer and more humid at times (Ruhe et al., 1974; Eyles and Clark, 1988; Curry and Baker, 2000). Climatic fluctuations within the time of the Sangamon Episode are known globally (Martinson et al., 1987) and have been recorded by variations in pollen and ostracode taxa assemblages in south-central Illinois (Teed, 2000; Curry and Baker, 2000; Curry et al. 2010). The best known record of Sangamon Episode deposits in the Midwestern USA comes from lake deposits in kettle basins in south-central Illinois. One of these sites, Pittsburg Basin (STOP #9), will be visited on this field trip and has been extensively studied for paleoecological records (Grüger, 1972b; Curry, 1995; Teed 2000). Based on such studies, as well as the Alfisol expression of Sangamon Geosol profiles in southern Illinois and Indiana (Ruhe et al., 1974; Follmer, 1983; Grimley et al., 2003), woodlands are envisioned to have been extensive during the last interglacial. The occurrences of species of more southern or eastern affinity (such as Sweetgum and American Beech, respectively), in addition to the typical Oak-Hickory biota, is evidence that the forest diversity was slightly greater during the Sangamon Episode than during the Holocene (Teed, 2000).

Berry Clay Member, Glasford Formation (or Pearl Formation) [accretionary deposit]

The **Berry Clay Member** (Fig. Q4) is a deposit of clay, silt, and sparse pebbles that was deposited as accretionary sediment in depressions and lowlands during the Sangamon Episode (Willman and Frye, 1970). This deposit also includes syndepositional weathering of the Sangamon Geosol so that the sediment package is simultaneously a lithologic unit and an accretionary soil. In most areas, the Berry Clay Member contains characteristics of a wetland soil with iron mottling and gleying. It has been called an accretion-gley (Willman and Frye, 1970); however, in some areas the unit has a more oxidized character where drainage conditions were later improved with gradual stream dissection of the surrounding terrain. Sediment sources for the Berry Clay Member include redeposited late Illinois Episode loess and the uppermost till from surrounding areas on the till plain. The Berry Clay Member is typically found in isolated, closed depressions on till plains, but may include broad areas as much as a mile or so in diameter. The use of the Berry Clay Member in the Kaskaskia Valley has been extended to being an upper member of the Pearl Formation in areas where clay loam or sandy clay loam deposits containing the Sangamon Geosol occur above the Pearl Formation (Grimley, 2010). In these areas, the sediment source for the Berry Clay Member is, again, mainly eroded loess that was redeposited into lowland areas. On shallow lake plains and floodplains, material similar to the Berry Clay Member is difficult to distinguish from the Teneriffe Silt and so these units have been mapped as a complex (Grimley and Phillips, 2011). The sediment deposited in Pittsburg Basin (STOP #9), and similar kettle basins, during the Sangamon Episode could be classified as a Berry Clay Member - Teneriffe Silt complex.

Wisconsin Episode, Late Pleistocene (~ 60 to 12 ka):

During the last period of continental glaciation, the Wisconsin Episode, glacial ice did not reach the area, but glacial meltwater, emanating from glacier margins in the upper Midwest, deposited silt, sand, and gravel (outwash of the **Henry Formation**) in the Mississippi Valley and, to a lesser extent, in the Kaskaskia Valley. Silty waterlain deposits in the Mississippi Valley were repeatedly entrained by prevailing westerly winds into intense dust clouds and, with subsequent settling of silt particles, deposited as a cover of loess (**Peoria and Roxana Silts**; Fig. Q4) up to 90 feet thick on the Mississippi River valley bluffs but thinning southeastward to ~7 feet thick on uplands adjacent to the Kaskaskia Valley (Fig. Q1). Concurrent with loess deposition on uplands and outwash deposition in major valleys, a large slackwater lake called glacial Lake Kaskaskia formed in the Kaskaskia drainage basin up to about 425 feet asl, probably the result of high aggradation of outwash sediment in the Mississippi Valley. Radiocarbon dating of fossil gastropod shells and conifer wood in lake deposits (**Equality Formation**; Fig. Q4) preserved in terraces and valley fill sequences, indicates the lake was at its maximum extent between about 25,000 and 15,000 calendar years ago (Grimley and Webb, 2009; Grimley and Webb, 2010).

Henry Formation [outwash]

Fine to medium sand deposits found immediately below the Cahokia and/or Equality Formations in the Kaskaskia Valley are in places interpreted as the Henry Formation, as at the Highbanks Road Section (STOP #6). The distinction between older and younger alluvial units can be subtle and difficult to differentiate in mapping (Grimley, 2010). Overall, the Henry Formation (in the Kaskaskia Valley area) tends to be a bit coarser than the Cahokia Formation sand but has less coarse sand and gravel than the Pearl Formation, probably due to closer proximity to the ice margin. However, there may be considerable overlap in the grain size of these units. Sand in the Henry Formation can be noncalcareous or calcareous and may be intercalated with, overlain, or underlain by calcareous silt loam beds of the Equality Formation.

Peoria and Roxana Silts [loess]

Wisconsin Episode loess deposits in the Kaskaskia Basin (Fig. Q1) range from about 30 feet thick on the western edge of the basin (Grimley and Phillips, 2011) to less than 5 feet thick in the northeastern part of the basin (Fehrenbacher et al., 1986). The loess deposits consist of two units, the Peoria Silt and the Roxana Silt (Hansel and Johnson, 1996). The Peoria Silt, ubiquitous across central USA uplands (Follmer, 1996), is a tan to grayish brown silt loam containing modern soil development in its top. Less altered zones of the Peoria Silt, several feet or more below the surface, may be calcareous (mainly dolomitic) and locally contain fossil terrestrial gastropods. The Roxana Silt is a more pinkish-brown to grey brown colored silt loam. It directly underlies the Peoria Silt and is thinner, with a thickness about 20% to 60 % that of the Peoria Silt. The Peoria and Roxana Silts are differentiated in part by the occurrence of the Farmdale Geosol (a weakly developed interstadial soil) in the top of the Roxana Silt, although this paleosol may be difficult to recognize where the total loess thickness is less than 10 feet. In the Kaskaskia Basin, the Roxana Silt is nearly always leached of carbonates. Due to their eolian origin, the Peoria and Roxana Silts drape older Illinois Episode units across the landscape with a relatively uniform thickness locally (except where eroded). The Sangamon Geosol normally underlies the Roxana Silt and separates these Wisconsin Episode loesses from Illinois Episode deposits. Peoria Silt deposition was concurrent with portions of the Equality Formation lake deposits (see below) and locally interfingers with, as well as partially overlies, such deposits on terraces. Intact loess deposits are not found on the younger Holocene surfaces and so the presence of a loess cover can help delineate ages of geomorphic surfaces.

Equality Formation [lake sediment]

The Equality Formation includes generally fine-grained sediment (silt and clay), typically faintly laminated, that was deposited as lake sediment (Willman and Frye, 1970; Hansel and Johnson, 1996). The environment of deposition in the Kaskaskia Basin was primarily as a slackwater deposit, as the Mississippi River aggraded significantly in its valley during the last glacial maximum (*more details in later section on glacial Lake Kaskaskia history*). Other tributary valleys of the Mississippi Valley, such as the Big Muddy Valley (Trent and Esling, 1995), were similarly backflooded and infilled. In calcareous, unoxidized zones (at depth) of the Equality Fm. in the Kaskaskia Basin, it is common to find organic debris, fossil conifer wood, and mollusk and ostracode shells preserved that are representative of fluctuating lake levels in a shallow, freshwater lake (Geiger, 2008; Grimley and Webb, 2009). A site with thick deposits of fossiliferous Equality Fm. will be seen on STOP #6 of this field trip (Highbanks Road Section).

Holocene (12 ka to the present):

Near-surface Holocene deposits (from last 11,700 years; Walker et al., 2009) are up to 30 feet thick in the Kaskaskia Valley and include various alluvial facies of the Cahokia Formation, from fine sandy point bar and channel deposits to fine-grained overbank deposits and silt clay abandoned meander fills. Many of the tributary streams are dominated by silty sediment consisting of mainly redeposited loess. A early- to mid-Holocene terrace (~ 395 feet asl) is present in the lower Kaskaskia Valley and nearby tributaries. This terrace contains probable early or middle Holocene postglacial deposits (*high level clayey facies*), which may have resulted from slackwater conditions or extensive overbank flooding. The lower Kaskaskia River was significantly straightened and channelized from Fayetteville southward by the removal of several natural river meanders for a navigation project in 1974. In advance of the project, archeological studies were conducted and numerous sites with projectile points, tools, and fire-cracked rocks were noted in the floodplain, terraces, and adjacent lands (Conrad 1966). From human activity during the past 150 years, the landscape of the Kaskaskia Basin contains significant areas of anthropogenic fill in urban areas, landfills, dams, artificial levees, former strip mines for coal, limestone quarries, aggregate mines, and interstate interchanges.

Cahokia Formation [alluvium]

Clayey and sandy facies of the Cahokia Formation, at times interstratified, have been differentiated in the large valley meander belts of the postglacial Kaskaskia Valley (Grimley and Phillips, 2011). Near-surface deposits consist of interstratified fine to medium sand with silt loam, silty clay loam, and silty clay. Sandy deposits (up to 25 feet thick) in channels and point bars of the Kaskaskia River are mapped as **sandy facies of the Cahokia Formation**. These deposits are typically fine to medium sand, moderately well sorted, and noncalcareous. They range in age from recent to possibly several thousand years old (mid to early Holocene) at higher elevations and in the subsurface. The **clayey facies of the Cahokia Formation** includes silt loam, silty clay loam and silty clay in overbank deposits, swale fills, and abandoned meander fills on the modern floodplain. This unit is also present as a cap on low terraces in the lower Kaskaskia Valley (Phillips, 2008; Grimley and Webb, 2010).

Origin of Glacial Ridges (Ridged-Drift) in Southwestern Illinois

Historical studies and observations

Glacial ridges in southwestern Illinois, historically known as the Ridged Drift (Leverett, 1899), have now been studied for over a century by various researchers. The conical to elongate hills are relatively abundant and prominent in southwestern Illinois, especially immediately west of the Kaskaskia River where they can be up to a few miles long, a mile wide, and 30 to 150 feet in relief above the Illinois Episode till plain (Figs. Q0, Q2, Day1). Several bands of prominent ridges and hills, varying from continuous to fragmentary and elongate to varying degrees, are found around the margins and within the interior of the Kaskaskia Basin (Figs. Q1, Q2). In many areas, scattered or isolated knolls (low conical hills) are found in the vicinity of the more elongate ridges. Some ridge belts appear to parallel river systems, some appear to align in arcuate or lobate patterns on a regional scale, and some appear to protrude oddly and singly from the surrounding till plain.

Through their history of investigation and mapping, the ridges have been interpreted as dominantly morainal (Leverett, 1899; MacClintock, 1929; Willman, Glass, and Frye, 1963;

Phillips, 2008), as eskers, esker-like, or ice-walled channels (Ball, 1940; Jacobs and Lineback, 1969; Burris et. al., 1981), as crevasse fills (Leighton, 1959; Leighton and Brophy, 1961), or as some combination (Stiff, 1996; Grimley and Webb, 2010). The interpretations of researchers seem to reflect regions or aspects of the Kaskaskia Basin that were studied most intensely (*e.g.*, central axis of basin, marginal ridges of basin). Leverett (1899) hypothesized that the prominent NE-SW trending ridge system, on the western side of the Kaskaskia Basin, marks the western border of a lobe persisting in southern Illinois after ice had retreated from western Illinois. MacClintock (1929) supported this hypothesis, noting the morainic topography in the region with outwash extending westward from the ridge deposits. In subsequent years however, Ball (1940) concluded the ridge system likely had a glacifluvial origin, based on several observations of sorted sediment. Based on observations in sand and gravel pits in the Vandalia area, Jacobs and Lineback (1969) similarly favored a glacifluvial origin, envisioning ice-walled channels with subsequent collapse causing an influx of supraglacial debris. This model could explain the sedimentological complexity of ice-contact deposits in the Vandalia area ridges, which appear to include ice-walled channels or eskers (either subglacial or subaerial). The largely coarse-grained deposits in this area (field trip STOPS #7 and #8) were termed the Hagarstown Member (Jacobs and Lineback, 1969; Willman and Frye, 1970; Killey and Lineback, 1983). The glacifluvial or eskerine origin of another ridge, in the vicinity of Taylorville, was supported by the geophysical data of Burris et al. (1981).

In contrast, Willman, Glass, and Frye (1963), in partial agreement with Leverett (1899) and MacClintock (1929), hypothesized that the ridges constitute an interlobate morainic complex based on slightly different mineral compositions in tills east and west of a prominent ridge belt. Still often cited today, Leighton (1959) and Leighton and Brophy (1961) strongly argued that the ridge system has characteristics of a crevasse fill system with related moulin kames. They concluded that ridge orientations are parallel to ice flow (based on available striation data) and that a local trellis drainage pattern was genetically related to crevasses. More recently, a study of ridge geomorphology and a GIS analysis of water well log descriptions in a portion of the ridge system northwest of Vandalia (Stiff, 1996) highlighted the varying subsurface composition of ridge deposits, ranging from dominantly fine-grained in the Nokomis area to dominantly coarse-grained in the Vandalia area (Fig. Q2). Recent 1:24,000-scale surficial geologic mapping in southwestern Illinois has further documented the spatial variability in texture, composition, and geomorphology of ridges in the southwestern part of the Kaskaskia Basin (Phillips, 2008; Grimley and Webb, 2009; Grimley, 2010).

Ice directional indicators

The direction of glacial ice flow in the Kaskaskia Basin during the Illinois Episode is recorded at several sites with till fabric measurements and rare instances of striations (Fig. Q1). Striations are the most reliable ice directional indicators, but are rarely observed due to limited bedrock exposure. Striations were observed, mainly in limestone quarries, by Leighton (1959), with a few additional observations by Grimley et al. (2001), E.D. McKay (personal communication), and others. Most striations have been observed in bedrock around the margins of the basin where bedrock highlands were scoured. Some degree of caution is needed since some striation directions may possibly reflect pre-Illinois Episode glaciation. Till fabric data from Glasford till in southwestern Illinois consists of data obtained by Lineback (1971), who noted mainly SW flow directions in the upper Kaskaskia Basin, and by Webb (2009), who noted more variable directions in the lower part of the basin (Fig. Q1).

Currently working hypothesis --- Kaskaskia Sublobe or Ice Stream

Our current hypothesis is that a glacial sublobe, here referred to as the Kaskaskia Sublobe, episodically stabilized at successive positions in the Kaskaskia Basin during overall ice-margin retreat during the waning phase of Illinois Episode glaciation (late OIS 6). Consequently, a series of constructional ridges (morainic, eskerine, kamic, etc.) were formed in association with various ice marginal positions as the sublobe progressively retreated (Figs. Q1, Q5). Meltwater stream outlets, overflow channels, and ice-marginal lakes formed during melting phases and added to the complexity of deposits in the Kaskaskia Lowland.

During the glacial maximum of OIS 6 (Illinois Episode), a regional lobe emanated from the Lake Michigan Basin and overwhelmed the Kaskaskia Basin as it flowed southwestward to its terminus at St. Louis, Missouri and Valmeyer, Illinois (Fig. Q5B). Later, as the ice downwasted and thinned, an area of active ice may have become restricted to the Kaskaskia Basin lowlands (Fig. Q5C and Q5D), with perhaps stagnant melting ice along the sides of the basin. If stagnant or slower moving ice was adjacent to the Kaskaskia Sublobe, some of the lateral marginal moraines may be ice stream shear margin moraines (Stokes and Clark, 2002). Taking several observations into consideration (listed below), a case can be made that the Kaskaskia Sublobe was in fact an ice stream during a portion of its history (Webb, 2009). The geographic dimensions of the Kaskaskia Basin and the presence of a preexisting substrate of soft shale, fine-grained till, and lake deposits would have been favorable for development of an ice stream (Stokes and Clark, 2001). A scenario can be envisioned in which a resurgent ice stream flowed into the basin, with thinner, more stagnant ice decaying on the adjacent bedrock-cored highlands (Figs. Q3, Q5D). The complexity of deposits on the northwestern margin of the basin may have similarities to sedimentary processes in the Kettle Moraine region of southeastern Wisconsin during the last glaciation (Carlson et al., 2005). The occurrence and geometry of some Illinois Episode recessional moraines in the Kaskaskia Basin also appear similar in form to some of the last glaciation in central Illinois (Johnson and Hansel, 1999), such as the Cerro Gordo Moraine. Though differences in glacial processes and landforms between the Illinois and Wisconsin Episode glaciations in Illinois are found, they may be less than once thought.

The presence of a sublobe or ice stream in the Kaskaskia Basin can explain a number of glaciological or geomorphic features:

1.) **recessional morainal ridges** -- formed progressively as ice downwasted and receded to the northeast;
2.) **push moraines** at the toe of the sublobe suggest active ice conditions (Grimley and Webb, 2010)
3.) **ice-contact sediment in eskers, kames** -- more prevalent in the interior of the sublobe; evidence of stagnation (Jacobs and Lineback, 1969)
4.) **ice marginal drainage** and overflow channels (Phillips, 2004, 2008)
5.) **proglacial lakes** (depositing Teneriffe Silt) that temporarily formed by ice blockage (Ostendorf, 2009; Grimley and Webb, 2010)
6.) **curved stream valleys** that appear to follow former ice margin positions (Fig. Q0)
7.) **large scale flute**-like features on statewide DEM (Luman et al., 2003) in middle-upper Kaskaskia Basin

More details on this hypothesis are discussed in STOP #'s 1, 2, 5, 7 and 8.

Geologic History of Glacial Lake Kaskaskia

The lower reaches of the Kaskaskia Basin, here referred to as the Kaskaskia Lowland (<450 feet elevation, southwest of Carlyle Lake; Fig. Q0) contain a cyclical Quaternary record of fluvial, lacustrine, and glacial deposits from the past ~ 500 ka, with all deposits overlying Paleozoic bedrock. During this time, the Kaskaskia Lowland (including the modern valley and its ancestors) experienced a succession of cut-and-fill sequences, with overall aggradation during glacial episodes and predominantly incision and removal of deposits during the interglacial times (Fig. Q5), though with some exceptions. During continental glaciations that advanced south of the Great Lakes (pre-Illinois, Illinois, and Wisconsin episodes), widespread backflooding occurred in the Kaskaskia Lowland in response to high aggradation in the Mississippi Valley (as much as 70 feet above the current river level). The backflooding and formation of slackwater lakes in the Kaskaskia Lowland was particularly extensive due to the valley's very low gradient. Today's Kaskaskia River valley only drops about 60 feet in elevation from areas near Carlyle (~ 415 ft. asl) to its confluence with the Mississippi River (~ 355 ft. asl), about 65 miles of straight valley distance downstream. Thus, the average gradient of the modern Kaskaskia Valley is < 1 ft./mile (not considering meanders). The timing of large slackwater lakes forming in the Kaskaskia Valley was concurrent with extensive outwash and loess deposition along the Mississippi Valley. During interglacials (Yarmouth and Sangamon Episodes, Holocene), the Kaskaskia River and its tributaries generally incised the valley fills in response to periods of downcutting of the Mississippi River (Curry and Grimley 2006). Although the term glacial Lake Kaskaskia was originally defined as a slackwater lake that formed during the peak of the Wisconsin Episode glaciation (Willman and Frye, 1970), we have here extended the use of this name to earlier Illinois and pre-Illinois episode occurrences of slackwater lakes in the Kaskaskia Lowland.

The former flooding of the Kaskaskia Lowland by glacial Lake Kaskaskia during the Wisconsin Episode has been well known for decades (Shaw, 1921; Willman and Frye, 1970). The timing of this most recent occurrence of glacial Lake Kaskaskia was coincident with many other slackwater lakes in tributary valleys to the Mississippi, Illinois, Ohio and Wabash River valleys during the last glacial maximum (Willman and Frye, 1970; Frye et al., 1972; Lineback, 1979; Moore et al., 2007; Grimley et al., 2009). Rising base levels in the Mississippi Valley initiated in the mid-Wisconsin Episode at least as early as ~ 45 ka when glacial ice was probably in the Lake Superior region (Curry and Grimley, 2006), and perhaps as early as 55 ka, the estimated basal age for Roxana Silt deposition in the region (McKay, 1979; Leigh, 1994). During initial phases of glacial Lake Kaskaskia, a finger-like slackwater lake was probably restricted to areas in Randolph

County and perhaps southern St. Clair County. Increasingly higher base levels during the last glacial maximum caused further blockage and led to the maximum extent of glacial Lake Kaskaskia, probably extending as far northeast as the Carlyle area (Fig. Q5G). The peak extent of the lake was probably between about 25,000 and 15,000 calendar years ago, based on radiocarbon dating of fossil gastropod shells and conifer wood in the Equality Formation lake deposits (Grimley and Webb, 2009, 2010). This timing is approximately synchronous with Peoria Silt deposition (McKay, 1979, 1986; Wang et al., 2003) and overlaps with the timing of high terrace levels and peak flooding in the St. Louis region at ~ 23 to 19 cal ka (Hajic et al., 1991), in the Ohio-Wabash system (Frye et al., 1972) and the lower Mississippi River valley (Grimley et al., 2009). Typical elevations for the terrace the contains glacial Lake Kaskaskia deposits range between about 410 and 430 feet asl in St. Clair County (Phillips, 2008; Grimley, 2010). Multiple terrace levels do exist (NRCS, 2006; Grimley, 2010), but tracing them regionally is difficult.

Early versions of glacial Lake Kaskaskia were formed during the Illinois and pre-Illinois episodes. Though less is known about the earlier lakes, the Wisconsin Episode version of the lake can be used as an analogue to help understand the older lakes (*the recent past is the key to the distant past ?*). Paleontological records have also been very helpful in providing independent evidence for depositional environments. The Illinois Episode version of glacial Lake Kaskaskia was probably initially of slackwater origin based on paleontological and sedimentological records from Petersburg Silt deposits at the Prairie du Pont Section (Grimley et al., 2001), Ogles Creek Section (STOP #3), NAW-2 core (Phillips, 2008), and other localities. Well preserved mollusk and plant macrofossil records at these localities give an indication of fluctuating levels in a generally shallow, alkaline lake (probably 0 to 3 m depth in many areas). Paleoenvironments varied from shoreline to near-shore and deeper lacustrine. During periods of receding lake levels, fluvial or terrestrial conditions (with loess deposition) may have prevailed.

One important distinction in the character of the Illinois Episode glacial Lake Kaskaskia is that the approaching glacier eventually affected conditions in the lake (burying the Petersburg Silt with debris flow and till deposits). In many areas the influence of loess and glacial silt is apparent in upper Petersburg Silt deposits and it can be deduced that silt deposition increased with surrounding loess washing into the lake or the effect of increasing sedimentation and reduced clarity in the lake with influence from the approaching glacier. Small pebbles that could be dropstones are rarely found, in contrast to some pebble to cobble-sized stones in Petersburg Silt deposits west of the Kaskaskia Basin (Grimley et al. 2001; Grimley and McKay 2004). Based on the molluscan record (e.g., more *Fossaria* sp.; less *Valvata tricarinata*), a shoaling of the lake was typical prior to covering by glacial ice and till deposition. As much as 100 feet of Petersburg Silt, much of slackwater origin, were documented in a core in the New Athens West Quadrangle (Phillips, 2008).

The pre-Illinois Episode version of glacial Lake Kaskaskia appears to have existed for a considerable time as well, based on a core in the Red Bud Quadrangle. In this core, 55 feet of fine-grained, fossiliferous Harkness Silt implies that a large slackwater lake existed during the pre-Illinois Episode (Grimley and Webb, 2010) as it did during the later glaciations. Initially, a relatively deep, low turbidity lake is suggested by fossil mollusks in the basal Harkness Silt. During deposition of the basal zone, the pre-Illinois Episode ice had likely not yet advanced significantly into the Mississippi River drainage basin. The molluscan fauna of the upper Harkness Silt is consistent with a shallow freshwater lake with fluctuating water levels. The mapped extent of Harkness Silt (mainly lake deposits) is St. Clair County was shown in Grimley and Phillips (2011, inset figure).

Geophysical Surveys: 2D Resistivity Imaging (Tim Larson)

The Illinois State Geological Survey has been conducting electrical resistivity surveys in central Illinois for over 70 years (e.g., Hubbert, 1934; Bays, 1946; Buhle and Brueckmann, 1964; and Heigold et al., 1985). The method exploits the strong contrast in electrical conductivity between clay (high conductivity/low resistivity) and sand (low conductivity/high resistivity). Historically, most of these surveys were specifically designed to assist in locating shallow groundwater supplies. Typical acquisition strategies concentrated on covering large areas that had relatively sparse information on subsurface geology. The goal was to locate areas of anomalously high resistivity that might correspond to shallow aquifers. Taking advantage of advances in modern electronics, over the past 5 field seasons we used a different approach to acquire detailed resistivity profiles as a tool for mapping Illinois Episode ridges in southwest Illinois. The method, known as 2-D resistivity imaging, uses a computer-controlled acquisition system to obtain nearly continuous resistivity measurements in two dimensions and to produce a simulated cross-section beneath the resistivity profile. The goal of the profiling is to image the sediments across or along the ridges to determine the bulk composition of the various ridges (coarse-grained or fine-grained), the lateral variations in composition, and the approximate geometries of sediment bodies. In addition, the method should be able to map deposits of fine-grained lacustrine and alluvial sediments between ridges. The resistivity profiling method is not as reliable for mapping the buried bedrock surface in the Kaskaskia Basin. The lithology of Pennsylvanian and Mississippian aged bedrock is characterized by extremes in resistivity—shale and coal have low resistivity while sandstone and limestone have high resistivity. Depending on the lithology of the bedrock surface at any particular location, there may or may not be a resistivity contrast with the overlying sediments. Furthermore resolution of the resistivity profiling method decreases with increasing depth. Although the bedrock surface is interpreted in several of the images presented in this report, the location of this surface is only approximate. Electrical resistivity surveys were conducted in areas around STOPS #2, #5, and #7.

PART II: FIELD TRIP ITINERARY, FINDINGS AND DISCUSSION: ROAD LOG AND FIELD STOPS

<u>DAY 1 ROAD LOG (May 21st, 2011):</u>

LEAVE MARINER'S VILLAGE MOTEL (8 AM --- load buses at 7:45 AM)

- turn right on William Rd. [0.5 mi]
- turn right on IL-127 [7.8 mi]
- turn left on Keyesport Rd. [1.0 mi]
- turn left on gravel road into area of sand and gravel pit

STOP # 1: Keyesport Sand and Gravel Pit

- turn right and head east on Keyesport Rd. [1.0 mi]
- turn left on IL-127 North [2.0 mi]
- turn left on IL143 West [12.3 mi]
- turn left on Picatte St. [0.3 mi]

REST STOP: Pierron City Park (PIC Park)

- west on Edward St. [0.1 mi]
- turn right onto Bauman Rd. [0.3 mi]
- turn left on IL-143 West, enter Madison County [1.8 mi]
- at stop sign, turn left on IL-143 W/US-40W [3.1 mi]
- after traffic circle, continue straight onto US-40W [7.4 mi]
- exit right on ramp to IL-4 [0.3 mi]
- turn left on IL-4 South [4.4 mi]
- turn right on Meriwether Rd. to circle at end in Archview Estates

STOP #2: Terrapin Ridge

- turn right on IL-4 South [1.4 mi]
- turn right on Widicus Rd. [0.6 mi]
- continue on Old Lebanon-Troy Rd. [0.4 mi]

- stay right and continue on Old Lebanon-Troy Rd. [0.7 mi]
- take left to stay on Old Lebanon-Troy Rd. [3.0 mi]
- turn left onto Scott Troy Rd. [0.7 mi]
- take first left onto Weil Rd. [1.1 mi]
- continue to end of road at small gate

STOP #3 Ogles Creek Section

- turn around and go west on Weil Rd. [1.1 mi]
- turn right onto Scott Troy Rd. [0.7 mi]
- turn right on Old Lebanon-Troy Rd. [3.0 mi]
- turn right to stay on Old Lebanon-Troy Rd. [0.7 mi]
- bear left on Old Lebanon-Troy Rd. [0.4 mi]
- take first right onto Widicus Rd. [1.1 mi]

LUNCH STOP: Homer Recreation Park

- turn right and head south on Widicus Rd [0.4 mi]
- take second left onto Acorn Way [0.4 mi]
- turn left on IL-4 North [0.5 mi]
- turn right onto Midgley Neiss Rd [1.5 mi]
- turn left onto Emerald Mound Grange Rd [0.3 mi]
- turn left into long driveway

STOP # 4: Emerald Mound

- head south on Emerald Mound Grange Rd [1.9 mi]
- turn right onto US-50 W [1.5 mi] --- enter the historic town of Lebanon
- turn left onto IL-4 S [9.4 mi] ---- pass through the town of Mascoutah
- turn right onto Grodeon Rd [1.2 mi]
- turn left onto Brickyard Rd [0.3 mi]
- turn right into park

REST STOP: Silver Creek Nature Preserve

- head south on Brickyard Rd. [3.0 mi]
- turn right (west) onto Pleasant Ridge School Rd. [0.5 mi]
- follow turn to south on Pleasant Ridge School Rd. [0.5 mi]
- park buses on gravelly area at bend in road

STOP # 5: Pleasant Ridge Area

- head west on Pleasant Ridge School Rd. [1.4 mi]
- turn left onto Karch Rd [2.2 mi]
- turn left onto IL-4 N [3.7 mi]
- turn right onto Town Hall Rd. [2.3 mi]
- turn right onto Highbanks Rd. [2.0 mi]
- turn right onto Slm Rd [0.2 mi]

STOP # 6: Highbanks Road Section

- head southeast on Slm Rd. [0.2 mi]
- turn left onto Highbanks Rd. [4.0 mi]
- turn right onto IL-177 E [3.5 mi]
- turn left onto IL-160 N [9.1 mi]
- turn right to merge onto US-50 E [17.2 mi]
- turn left onto IL-127 N [0.2 mi]
- take the first right onto William Rd. [0.5 mi]

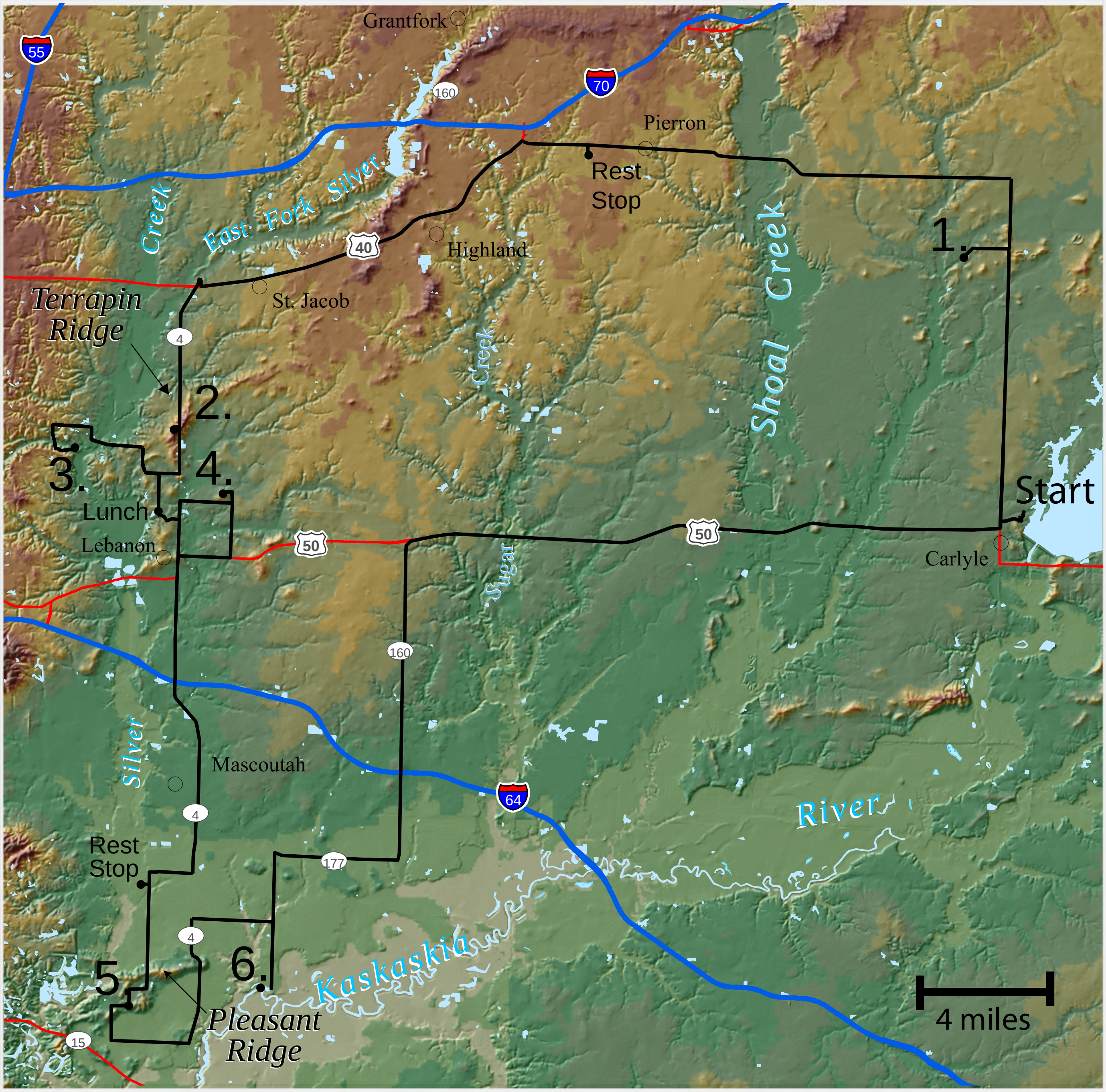


Figure DAY1. Location map of planed trip route for Day One of the field trip. Colors are from 30m statewide digital elevation map. Orange-yellow colors are higher elevations and greenish colors are lower elevations.

STOP 1: Keyesport Sand and Gravel Pit (David Grimley, Andrew Phillips, and Nathan Webb)

PLEASE USE CAUTION AT THIS SITE -- DO NOT WALK OR EXCAVATE BENEATH UNDERCUT, STEEP SLOPES; SAND IS SOFT AND CAVES IN EASILY

Overview

The Keyesport Sand and Gravel Pit is located in an area that contains (or formerly contained) numerous small, conical or irregular-shaped hills dispersed among more streamlined or elongate hills (Figs. Day1, 1.1). Mining has been continuing on a southwestern track for the past several years in order to follow a coarser tract of sand and gravel near the border of Bond and Clinton counties (Jim Koerkenmeier, Plant Manager, Keyesport Sand and Gravel LLC, personal communication, 2011). Keyesport Sand and Gravel, LLC, a division of Shakespeare Oil Company, has been mining in the vicinity since 1978, beginning with a hill (now gone) at the NW corner of Illinois Route 127 and Keyesport Road. The current pit, where mining has been ongoing in Clinton County (on the south side of Keyesport Rd.) for the past several years, extends about 750 m in the southwesterly direction, with a width of about 250 m, and a maximum depth of about 30 m (100 feet). Earlier mining is now evidenced by a NE-SW trending man-made lake on the north side of Keyesport Road in Bond County. This lake extends more than 750 m northeast of the northern extent of the current pit. In the areas mined, it is important to note that the sand and gravel deposits, in places up to 100 feet thick, have been present in areas that were previously hills as well as in areas in direct line between the hills. Thus, coarse-grained deposits are not exclusive to hills as some have previously implied. Several other smaller kamic hills have been mined by various operations in areas to the east and northeast of the Keyesport pit, in the direction of Carlyle Lake (formerly the Kaskaskia Valley before the lake was created by the U.S. Army Corps of Engineers in the 1960s).

Many other pits in the area (*e.g.*, STOP 7 and STOP 8) utilize dredge operations since most deposits are below the water table. Extensive exposures are viewable at Keyesport due to the fact that the groundwater is being pumped continuously to allow for dry mining. In areas where recent slumping has not affected the exposures, a panoramic view of the geological strata can be viewed --- at least on 3 sides (SE wall, SW wall, and NW wall). About 90 % of the sand and gravel deposits at Keyesport are used in the making of concrete. Of the remaining 10 %, some fine sand is used for mortar sand and some of the gravel is used for decorative landscaping (Jim Koerkenmeier, 2011, personal communication).

The overall sediment package that is being mined varies from well sorted, bedded to cross bedded, fine to medium grained sand, to coarse sand and gravel channel deposits (Figs. 1.2. 1.3). Over the various areas of exposure of Illinois Episode deposits, one can find planar bedded fine sand, coarse gravelly sand channel deposits, diamicton inclusions, and silty clay lake sediments interbedded with sand layers. The thickness of extractable sand and gravel varies from about 40 to 100 feet thick, depending on the current and paleo-landscapes (typically overlies an erosion surface on Glasford till). The sand was clearly deposited during the Illinois Episode based on the presence of a strong interglacial paleosol (Sangamon Geosol), with its solum developed in the upper 6 to 8 feet of the sand. The sand and gravel are thus classified as the Pearl Formation, predominantly within the Hagarstown Member (sandy facies). The Sangamon Geosol is a reddish brown to gray (depending on landscape position), silty clay loam to clay loam (becoming sandier towards the base) with moderate blocky soil structure. Leaching and clay infiltration extend several feet below the paleosol surface and an irregular leaching front can be seen at the top of the pit walls. Thus, clean sand suitable for extraction occur at a minimum of about 15 feet below land surface (Figs. 1.2, 1.3). The Pearl Formation and Sangamon Geosol are blanketed by about 5 feet of loess (Peoria and Roxana Silts), consisting of friable tan to brown silt loam and containing modern soil development. However, the upper 10 feet of deposits (loess and upper Sangamon Geosol) are stripped back from the main highwall and are not visible from inside the pit.

The exposures at the Keyesport Pit have been visited several times by the authors between 2004 and 2011. Based on observations during successive visits, a few general observations can be made on the three primary walls of the active pit: the southeastern, southwestern, and northwestern walls.

Southwestern wall (active mining wall, sand and gravel, high angle reverse faults)

The southwestern wall at the Keyesport Pit is the active mining wall, as progressive excavation is ongoing in a southwesterly direction. The coarsest and thickest deposits of sand and gravel are found on the southwest wall, with grain sizes ranging mostly from medium to coarse sand, with up to 15-20% gravel in some areas. Prominent trough cross bed sets, up to a few inches thick and dipping generally to the southwest, were found along the axis of the ridge, near the center of the southwest high wall (Fig. 1.3A). The total thickness of sand deposits has been as much as 100 feet thick in previous years when the mining had proceeded through the crest of the glacial ridge. The sand and gravel have been observed to overlie a dense, subglacial, pebbly loam diamicton (Glasford Formation till) at the base of the central part of the pit. In a few areas, a thin deposit of coarse sand with gravel was observed as a basal lag or coarse-zone, immediately above the Glasford Formation. The elevation of the Glasford till surface rises, in some places quite sharply, towards the northwest and thus the thickness of sand deceases towards this direction.

High-angle reverse faulting has been noted in the southwestern high wall on numerous occasions from 2004 through 2011 (Fig. 1.3B), particularly in sand deposits beneath high areas of the ridge. In 2008, near the top of a well exposed highwall, beds of laminated silt were observed within the sand that had been cut and offset by a high-angle reverse fault. This type of faulting is similar to that noted by McDonald and Shilts (1975), in ice-proximal glacifluvial environments.

Southeastern wall (finer-grained sands)

Deposits of the Pearl Formation along on the southeastern wall tend to be planar bedded and consist primarily of fine- to medium-grained sand (Fig. 1.3C). These deposits, in places, are overlain by fine-grained, stratified silt beds and, together, are altered by a somewhat poorly drained, more grey-colored, Sangamon Geosol, covered by ~ 5 feet of Wisconsin Episode loess. As the sand has tended to be finer towards the southeast wall, mining has progressed southwesterly, rather than widening to the southeast. Many areas of the southeastern wall, formerly well exposed, are now covered, slumped or unsafe to access along steep slopes so we will not view these deposits at close range on the field trip. However, the overall character of these deposits can be seen from a distance of several hundred feet as we walk down into the pit. This wall is parallel to the overall meltwater flow direction so beds dipping generally to the southwest are sometimes visible in cross section.

Other notable features on the southeast wall exposure are a few small detached bodies of diamicton, one of which was noted to be about 3 feet thick and 20 feet long in 2008. During visits to the pit in previous years, diamicton bodies (3 to 6 feet thick and more than 40 feet long) have been observed within the sand on either the southeast or west-northwest walls (Fig. 1.3D)--- it is possible that we will see one or more on the field trip. The diamicton occurs within otherwise uniform sand. Due to slumping of the sands, some diamicton bodies could not be traced laterally over a great distance. One diamicton inclusion that was observed contained a number of prominent irregularly shaped sand lenses up to a couple inches thick. The basal contact of the diamicton with the underlying sand was irregular, showing the sand pushing up into the diamicton body and a gravel lag was found along the contact in some areas. Sand below the diamicton body exhibited contorted bedding. Some diamicton inclusions, such as the one described, may be debris flows. Other diamicton inclusions may have been incorporated into high velocity glacial meltwater flows as the main channel, prevented from lateral migration by ice-walls, incised into the underlying till. Breaking along fracture plane discontinuities, subglacial till bodies may have been carried a short distance by glacial meltwaters.

Northwestern wall (sand against wall of till, sporadic lake sediments)

The northwestern wall has the most variable and complex sequence of deposits in the exposure. In 2004, on our first visit to the site, a wall of clay on this side of the pit was described by the operator and was confirmed as a wall of dense Glasford till by our observations. In other words, the sand abruptly ended on the northwestern side of the mined area. Jim Koerkenmeier, plant manager, related that the pumping of water from this pit did not affect the water well level for a house a short distance to the northwest, but did affect those in other directions from the pit. The abrupt contact of sand and gravel with hard, pebbly loam diamicton (Glasford Fm.) is visible in Fig. 1.3E. In a few areas, the sand appeared to have been injected into fractures in the till, implying high pressure or lateral filling by high velocity glacial meltwater flows. Below the Glasford Fm., a few feet of calcareous fine sand or silt deposits (Petersburg Silt) with wood fragments were locally exposed; these are interpreted as proglacial lake or deltaic deposits.

In late 2010 and early 2011, as mining has proceeded to the southwest, an area of rhythmically bedded lake deposits was viewed immediately above thin Glasford Fm. till deposits and below about 30 to 40 feet of Pearl Formation sand. Lateral areas have > 60 feet of sand and gravel. The lake deposits, adjacent to sand and gravel deposits laterally, are too fine to be economically useful and have been left in a protruding peninsula with the surrounding deposits already mined away. The lake deposits consist of prominently laminated silt, silty clay loam, and very fine sand and are as much as 5 to 10 feet thick. In some places, the lake deposits (a tongue of the Teneriffe Silt) are intercalated with medium to coarse sand beds (Pearl Fm.), representing alternating lacustrine and fluvial conditions. The lacustrine environment was likely ice-proximal with a rapid sedimentation rate, as evidenced by occasional small pebbles, low clay content, prominent strata, and lack of fossil shells or wood. The lake sediments could have been localized in a small area blocked by ice, before further melting of the glacier caused drainage of the lake and connection to the full-fledged meltwater outburst and drainage southwest within the Kaskaskia Basin. It is possible, however, that the lake deposits are remnants of a much larger regional lake within the Kaskaskia Sublobe area that temporarily formed by morainal ice blockage in the lower

Kaskaskia Valley and drained upon the breaching of such moraine(s). The elevation of the lake deposits is ~430 to 440 feet elevation (approximately), similar in elevation to deposits of Teneriffe Silt many miles to the southwest (Grimley and Webb, 2009, 2010; Phillips, 2004) and to the Petersburg Silt in cores and outcrops such as at STOP #2 and STOP #3, respectively. It is thus intriguing to consider the possibility of a large scale moraine-dammed lake, or a series of lakes, temporarily existing in the lower Kaskaskia Lowland.

Also observed in 2011 near the lake deposits, but below Glasford Fm., were a few feet of noncalcareous, stratified, brownish-gray, silty clay loam, interpreted to represent preglacial or interglacial alluvium. Several large (1 to 3 feet wide) angular blocks of fossiliferous limestone were also found scattered about in the area within about 50 feet laterally from the exposure of preglacial silt. Though not in place, these limestone blocks appear to be fragments of local Pennsylvanian bedrock, likely incorporated from nearby local bedrock into the Glasford till deposits. The depth to intact bedrock is not known as in place bedrock is not exposed at the pit.

Luminescence ages

Two sand samples for OSL age dating were taken from the southwestern wall on 10/31/2007. Sample Keyesport-1 was taken about 55 feet below original ground surface and about 15 feet above the bottom of the pit. Sample Keyesport-2, some tens of feet lateral from the first sample, was obtained about 45 feet below ground surface and about 25 feet above the base of the pit. These samples yielded OSL ages of 153,700 yr ± 19,400 yr (UNL-1873) and 147,100 yr ± 18,700 yr (UNL-1872), respectively, confirming a correlation of the Illinois Episode deposit with oxygen isotope stage 6 (Table 1.1). The water content of these samples was estimated to have been about 23%, based on complete saturation for most of its history. Natural moisture contents were not used because the sand is now being pumped dry for mining; however, iron staining and coloration indicate a natural water table that is many feet above the sampled location (in the lower 20 feet of the Pearl Formation deposits exposed).

Field #	Lat. (N)	Long. (W)	UNL Lab #	Depth (m)	U ppm	Th ppm	K_20 wt %	In Situ H_20 (%)[a]	Dose Rate (Gy/ka)	D_e (Gy) ± 1 Std. Err.	Aliquots (n)[b]	Optical Age ± 1 σ
Keysport-1	38.73792	89.39483	UNL-1872	16.7	0.5	1.5	1.0	23.0	0.85 ± 0.07	131.08 ± 10.79	24/40	153,700 ± 19,400
Keysport-2	38.73825	89.39507	UNL-1873	13.7	0.6	1.7	1.2	23.0	0.97 ± 0.08	142.17 ± 12.25	21/32	147,100 ± 18,700

[a]assumes 30% error in estimate; [b]accepted disks/all disks

Table 1.1. Equivalent dose, dose rate data, and optical age estimates for the two Keyesport Sand and Gravel Pit samples. The optically stimulated luminescence (OSL) measurements utilized multiple grains of quartz (90-150 um) using the single aliquot method. Analyses were made at the University of Nebraska - Lincoln laboratory.

Summary / regional interpretations

At the Keyesport Pit, the sediment package of well-sorted fluvial sands interspersed with faulting and diamicton bodies is interpreted as an ice-walled channel deposit, essentially an open-air esker system. Yet, initial deposition could have been within a subglacial tunnel followed by ice ceiling collapse and transition to an open air channel, which is a typical pathway (Warren and Ashley, 1994). The high-angle reverse faults are interpreted to reflect the removal of a supporting lateral ice wall common in ice-contact glaciofluvial sediments (McDonald and Shilts, 1975). Constraining of the main channel (more than several hundred feet wide) by ice walls probably led to incision of the channel into the underlying Glasford Fm. till deposits and pressurized some sand deposits laterally into fractures in the subglacial till walls. Consequently, some large inclusions of diamicton bodies were eroded out the lateral till walls or basal till floor and carried into the meltwater channel deposits. The diamicton inclusions were not carried far and were sedimented along with the sand and gravel strata. Other inclusions may represent glacial debris flows.

OSL ages of the sand deposits constrain their deposition of the Hagarstown Member, Pearl Fm. to have occurred between about 170 and 130 ka (Table 1.1), confirming an OIS 6 age for these deposits and for the Illinois Episode glaciation in general (McKay et. al., 2008; Hansel and McKay, 2010; Curry et al., in press). The Keyesport Pit exposures and nearby assortment of landforms point to a localized stagnant ice conditions during the melting and deterioration of the Kaskaskia Sublobe and deposition of the Pearl Formation. However, deposition of the underlying Glasford Formation may have occurred during a preceding active ice phase. Although a sublobe *per se* was not suggested by previous researchers, stagnant ice conditions are a recurring theme in the ridged-drift literature for southwestern Illinois (Leighton, 1959; Jacobs and Lineback, 1969; Stiff, 1996). Overall, the timing of the ice-walled channel deposits here at Keyesport likely represent the deterioration of the Kaskaskia Sublobe, coinciding with the opening of meltwater drainage to the southwest down the Kaskaskia Valley. The Kaskaskia Basin was probably temporarily ponded, perhaps multiple times, upon moraine formation in the lower basin --- but the recessional moraines were probably rather quickly overtopped or eroded through by glacial meltwaters from the melting lobe or ice stream. Proglacial lakes, trapped between glacial ice and the moraines, might have been localized or might have been similar in size and duration to Wisconsin Episode proglacial lakes found in central and northeastern Illinois (Lineback, 1979; Hansel et al., 2001).

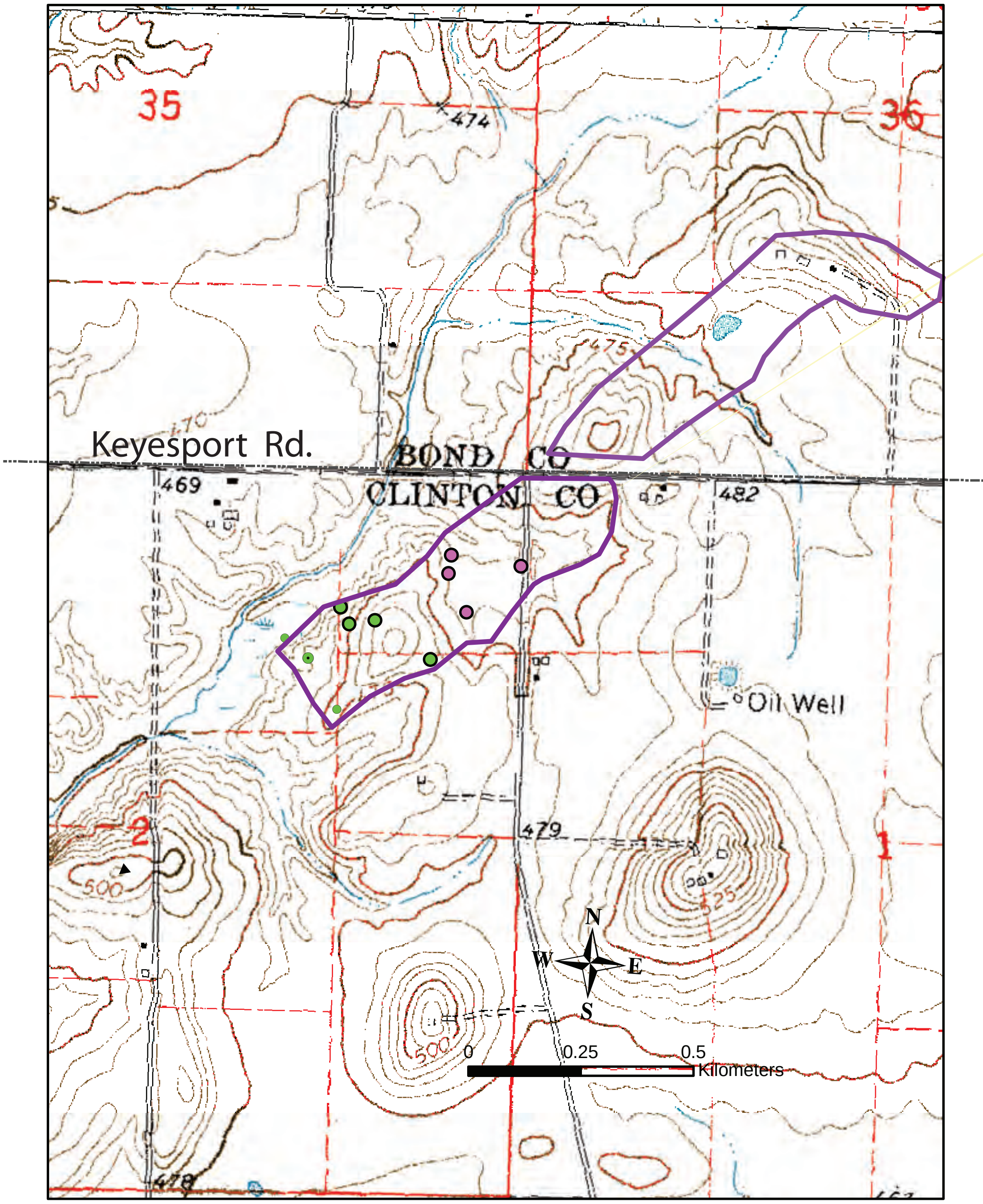


Figure 1.1 Location map for Keyesport Sand and Gravel Pit, Bond-Clinton Counties, IL (STOP #1). Points show GPS of some visited sites over past several years.

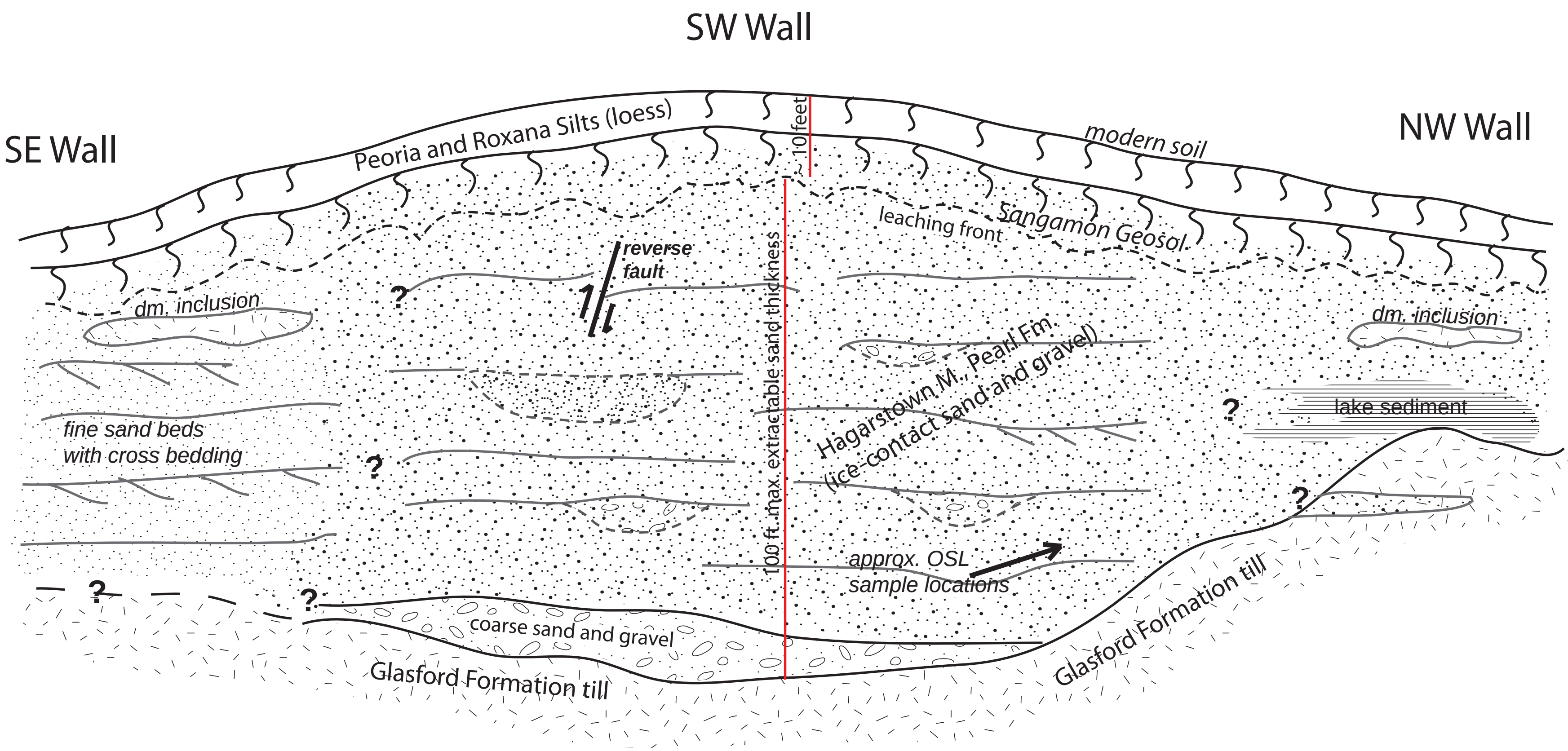


Fig. 1.2. Generalized sketch of Quaternary deposits at the Keyesport sand and gravel pit, based on observations from 2004-2011.

Photo A: Cross bedded Hagarstown M. sand and gravel on southwestern wall.

Photo B: High angle reverse faults in Hagarstown sand on southwestern wall (2006). The Sangamon Geogol solum is visible at the top (loess has been stripped).

Photo C: Planar bedded fine sand (Hagarstown M.) on the southeast wall of the pit in 2004. The Sangamon Geosol is visible near the top (loess stripped).

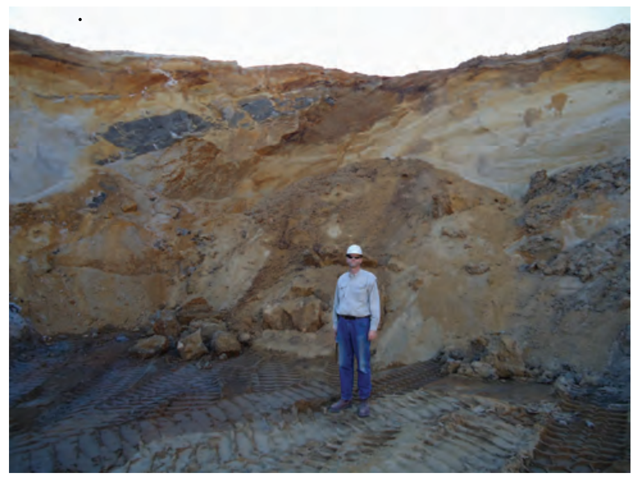


Photo D: Diamicton inclusion (grey) within sand in the western corner of the pit in 2010 (also viewed on SE wall).

Photo E: Wall of Glasford Fm. till below and adjacent to Pearl Fm. sand on northwest wall of pit. Observed in 2004.

Figure 1.3. Photos of various exposures at the Keyesport Sand and Gravel Pit.

STOP 2: Terrapin Ridge (cores/geophysics)

(Andrew Phillips and Tim Larson)

Terrapin Ridge, containing the Archview Estates subdivision (where we plan to stop for the view), is an impressive hill about 3 miles north of the town of Lebanon. The sharp-crested and steep-sided, NE-SW trending ridge rises up to 100 feet above the surrounding plain and is traversed by Illinois Route 4, a major transportation corridor in the region. The Terrapin Ridge area is geomorphically and geologically complex, but fortuitously, we have several high quality continuous cores (from mapping projects -- Phillips, 2004; Grimley and Phillips, 2011; and unpublished data) and several miles of geophysical transects across the area over the past decade.

A cultural note: The historic town of Lebanon (3 miles south) is perched on another smaller glacial ridge and is home to the oldest private college in Illinois, McKendree University, est. 1828. The town boasts that Charles Dickens lunched here on his way from St. Louis to visit Emerald Mound (STOP 4). In addition, Olympic miler Craig Virgin grew up on Terrapin Ridge.

Geomorphology

Terrapin Ridge occurs along a recessional ice margin; just east of where the ridge system crosses the Silver Creek valley (Figs. 2.1, 2.2., Day1). The ridge appears to be amalgamated, from three or more lithologic and geomorphic elements. The peak of the ridge, at our field trip stop, appears to define the head of a west-facing fan superimposed upon the overall ridge form. The southern end of the ridge has significantly lower relief and is separated by a swale, probably comprising a separate element. The longer, linear Becker Ridge intersects the northern tip of Terrapin Ridge at a high angle (Fig. 2.2). A shallow basin to the east includes possible ice-walled lake plain and deltaic forms. Small oriented ridges and isolated mounds dot the surrounding landscape, especially to the west.

The Silver Creek watershed is the second largest tributary to the Kaskaskia River. East Fork Silver Creek, interpreted as an ice marginal stream valley, joins Silver Creek immediately upstream of the area in Fig. 2.2. and flows adjacent the ridge system from its headwaters near Grantfork to west of St. Jacob (Fig. DAY1). Immediately west of Terrapin Ridge, the Silver Creek valley is relatively wide except at the Ogles Creek confluence where the valley narrows abruptly as it cuts through the ridge system. Shale bedrock crops out in the bottom of Ogles Creek and so bedrock control on the valley narrowing is possible. The area of restricted valley and high bedrock may also have controlled the location of archeological sites [see discussion at end of STOP 4]. There is no evidence for continuation of a large ice marginal stream west of Ogles Creek. It is thus possible that such a stream did not exist until the ice had retreated from the highlands to the west and terminated along the east side of the valley

Low mounds and ridges protrude from the plain west of Terrapin Ridge features. Although some appear elongate or oriented, most are irregularly shaped and distributed. The landforms appear to be both depositional and erosional. On the east side of Terrapin Ridge is a small enclosed basin. Several landforms are compelling but their origin is not known. Flat-topped landforms with upper elevations just above 490 feet asl suggest the basin held a proglacial, ice-marginal lake after the ice margin retreated a short distance eastwards from Terrapin Ridge. One rounded, flat topped mound approximately 500 feet across and 10 feet high and northeast of Terrapin Ridge (Fig. 2.2) resembles ice walled lakes plains recently investigated in northern Illinois (Curry et al., 2010). Deltaic forms extend from the south flank of Becker Ridge. As deltas or fans, they may have been fed by small streams flowing from decaying ice.

Geologic succession

Sedimentary and stratigraphic interpretations were made from 8 high resolution borings to bedrock and 5 shallow percussion probe or hand auger borings that were acquired along ridge crests and in the surrounding plains (Fig. 2.2). These are supplemented by several lithologic logs provided by geotechnical borings at bridges and water-well records. In addition, 4 miles of shallow seismic shear wave and 2 miles of resistivity profiling reveal some of the stratigraphic architecture. An auger hole to a depth of 27 feet by Jacobs (unpublished data, ISGS archives) which encountered 10 feet of sand below 16 feet of loess helped to confirm his model for the Hagarstown beds (Fig. 2.3). A borehole by wireline (Virgin Core, Fig. 2.3) completed to bedrock just below the crest and only 700 feet to the east corroborated his findings, but also showed that the base of the ridge is comprised of imbricated till extending below the level of the surrounding plain. At the base of the Virgin Core are pre-Illinois Episode till, outwash, glacial lake, and pre-glacial sediment.

The correlation diagram (Fig. 2.3) shows the subsurface cross section along the crest of the ridge complex and onto the western flank. Shale and sandstone bedrock rise slightly from south, from the trough of the ancestral Silver Creek valley. In the trough are preserved pre-Illinois Episode, pre-glacial (Canteen member), proglacial (Harkness Silt), and glacial (Omphghent member) sediments (Virgin and Grandview Cores, Fig. 2.3). These were eroded out west of the ridge (Mersinger Core, Fig. 2.3) by the ancestral Silver Creek, possibly during ice advance.

Slackwater lake sediment and associated silty alluvium (Petersburg Silt) were deposited during ice advance (Mersinger Core, Fig. 2.3). Slackwater conditions in Silver Creek valley were possibly caused by ice or sediment blockage of the ancestral Kaskaskia River. The Petersburg Silt unit in Mersinger can be correlated across the valley to the exposure we will see during Stop 3 (Fig. DAY1). Fossil gastropods in one layer within the Petersburg Silt at a depth of 106 feet include dominantly *Pomatiopsis* sp. (up to 6 mm long), the much smaller *Carychium* sp. (~ 2mm terrestrial species), and one individual of *Succinea* sp. that is immature. *Pomatiopsis* is an amphibious genera (with lungs) that typically lives along river banks or moist areas near streams (Burch, 1989). *Carychium* is found in moist or very damp areas, such as under forest debris near water (Baker, 1939), but it a terrestrial species not common in frequently flooded areas (Burch and Jung, 1988) although it could have washed into the floodplain. *Succinea* is also terrestrial, but some species live in wet and marshy places near the edge of streams (i.e., *Succinea retusa*; Baker, 1939). The overall paleoenvironmental interpretation based on this assemblage is consistent with a floodplain, edge of floodplain, or possibly a marshy shoreline of a lake against a hillside. All three genera found here are also found in the Petersburg Silt at the Ogles Creek Section (STOP # 3) and so this results in a reasonable biostratigraphic correlation.

Unit/Depth	**Genus**	**Species**	**#**	**comments**
Petersburg Silt 106 ft.	*Pomatiopsis*	sp.	15	many other immatures
Petersburg Silt 106 ft.	*Carychium*	sp.	5	> 2 mm
Petersburg Silt 106 ft.	*Succinea*	sp.	1	immature

Table 2.1. Fossil gastropods from Illinois Episode lake deposits in the Mersinger Core.

A deposit of till marks the advance of the Illinois Episode glacier from the northeast over to its fullest extent. This interface in the Virgin Core (Fig. 2.3) is marked by a striated limestone boulder and sharp drop in gamma log intensity, interpreted as a boulder pavement. The erosional character of the till-lake sediment interval to the west, including a basal mixing zone (deformable bed?), is exposed at Ogles Creek (STOP # 3).

Following its maximum advance, the glacier retreated to immediately east of Terrapin Ridge, though was likely forming other ridges along the Kaskaskia Sublobe margin at the time

(Fig. Q5D). Outwash, possibly transported down the then-ice marginal East Fork Silver Creek, was deposited within the Silver Creek valley, including at the western base of Terrapin Ridge. At Ogles Creek (STOP #3), the outwash with an upper elevation at ~450 ft. asl can be seen to cut out the till and lies directly on slackwater lake sediment.

Ice next readvanced and began to construct the end moraine that constitutes the ridge by shearing and redepositing older sediment as well as by direct till deposition. These processes are evident from mixed borehole lithologies in the Virgin and Grandview core and inclined seismic reflectors on the up-ice side of the ridge (Fig. 2.4).

The highest portion of Terrapin Ridge, the site of Stop 2, was finally formed by construction of an alluvial fan from a supraglacial stream. The topographic expression of the fan is clear in Fig. 2.1. The ~70 ft. of rounded, coarse gravel encountered in the Grandview hole (Fig. 2.3) is the thickest and coarsest glacifluvial deposit we have found in our investigations of these ridges. High resistivity (sandy) landforms determined from EER surveys (Fig. 2.5) on the valley plain could be correlated to this fan. The fan interfingered with or overrode relatively fine outwash and alluvium within the valley. This is illustrated in the Mersinger hole by interbedded fine sand, laminated silt, and laminated silty clay from depth of 13 to 38 feet. The fine sediment may have originated from the fan source or from smaller streams along the glacier front as evident from the high land surface on the west side relative to the east side of Terrapin Ridge.

Rounded, flat-topped terraces and terrace lobes at ~490 ft. elevation are compelling to interpret as ice-walled lake or fluvial sediment that was deposited in a lake dammed between Terrapin Ridge and a recessional ice front or moraine to the east after final retreat of the ice from Terrapin Ridge. The boring # 30036 acquired in the Little Silver Creek valley and the interpreted intermorainal basin east of Terrapin Ridge revealed waterlain sediment throughout the sequence (Fig. 2.2), rather than the expected loess over Illinois Episode till. The top of the Illinoian package includes 50 feet of bedded loam, silt, and clay, interpreted as loess over glacifluvial and glacilacustrine sediment with intercalated debris flow. This could represent the period of buried ice melting and landscape reconfiguration after retreat of the ice front. Underlying the glacifluvial sediment were 10 feet of till (Glasford Fm.) over 15 feet of fossiliferous lacustrine silt (Petersburg Silt). At the base of the sedimentary sequence, a few feet of soil developed in pre-glacial alluvium (Canteen member) lay on top of a fluvial conglomerate comprised of weakly cemented, imbricated, discoid cobbles (bedrock, probably Pennsylvanian).

Electrical resistivity imaging

Approximately 3,200 m (10,500 feet) of continuous resistivity data were acquired on eight profiles in the Terrapin Ridge area (Fig. 2.5). These profiles were acquired with a dipole-dipole electrode configuration using an ABEM SAS 4000 meter and LUND acquisition system. Profiles were processed with RES2DINV (Loke and Barker, 1996). Four short profiles were aligned transverse to the direction of the ridge at approximately ½ mile intervals along the length of the ridge. One profile (Profile C) was acquired at the field trip stop site, just south of the subdivision. The other four profiles cross related ridges, three to the west and one to the east of the main ridge.

Of the four Terrapin Ridge profiles (B, C, D, and E), only one (Profile C) crossing the crest of the ridge at STOP #2 encountered high-resistivity sediments. Profile C also corresponds to the location of the Grandview Core. The gamma log from the Grandview Core (Figs. 2.3, 2.5) correlates the high-resistivity sediments to coarse sand and gravel. The profile here was very short (less than 200 m) and only was imaged to a depth of about 100 feet (30 m), but the resistivity image is very similar to that obtained along the crest of a large ridge south of Pleasant Ridge (Kessler borehole, STOP #5 area). A similar deposit of high-resistivity material was encountered in one other resistivity profile west-southwest of Terrapin Ridge (Profile G, Fig 2.5). Ridge-forming deposits imaged in the other profiles (such as Profile D) are relatively low resistivity sediments, interpreted as likely diamicton or lake sediments based on test drilling (Fig. 2.3). In general, the resistivity images suggest that the sand and gravel deposit encountered at the crest of Terrapin Ridge has limited areal extent. Very low-resistivity deposits were encountered at the base of the ridges in several of the profiles. These deposits probably correlate to alluvial or lacustrine sediments. Very high resistivity deposits encountered in the western and eastern profiles (such as Profile H) at elevations below 400 feet (120 m) probably reflect sandstone or limestone bedrock. High-resistivity bedrock was not imaged beneath Terrapin Ridge. A slight increase in resistivity at some locations may indicate the bedrock.

Topics for discussion

- How did the timing of ridge formation vary across the region?
- What different processes or events combined to produced the varied ridge forms?
- How did the ridges underneath the town of Lebanon (Fig.DAY1) form and what was their timing relative to the ridges further north ?
- Why is the breach of the ridge system by Silver Creek so narrow?
- Are those really sheared till sheets in the geophysical profiles?

-

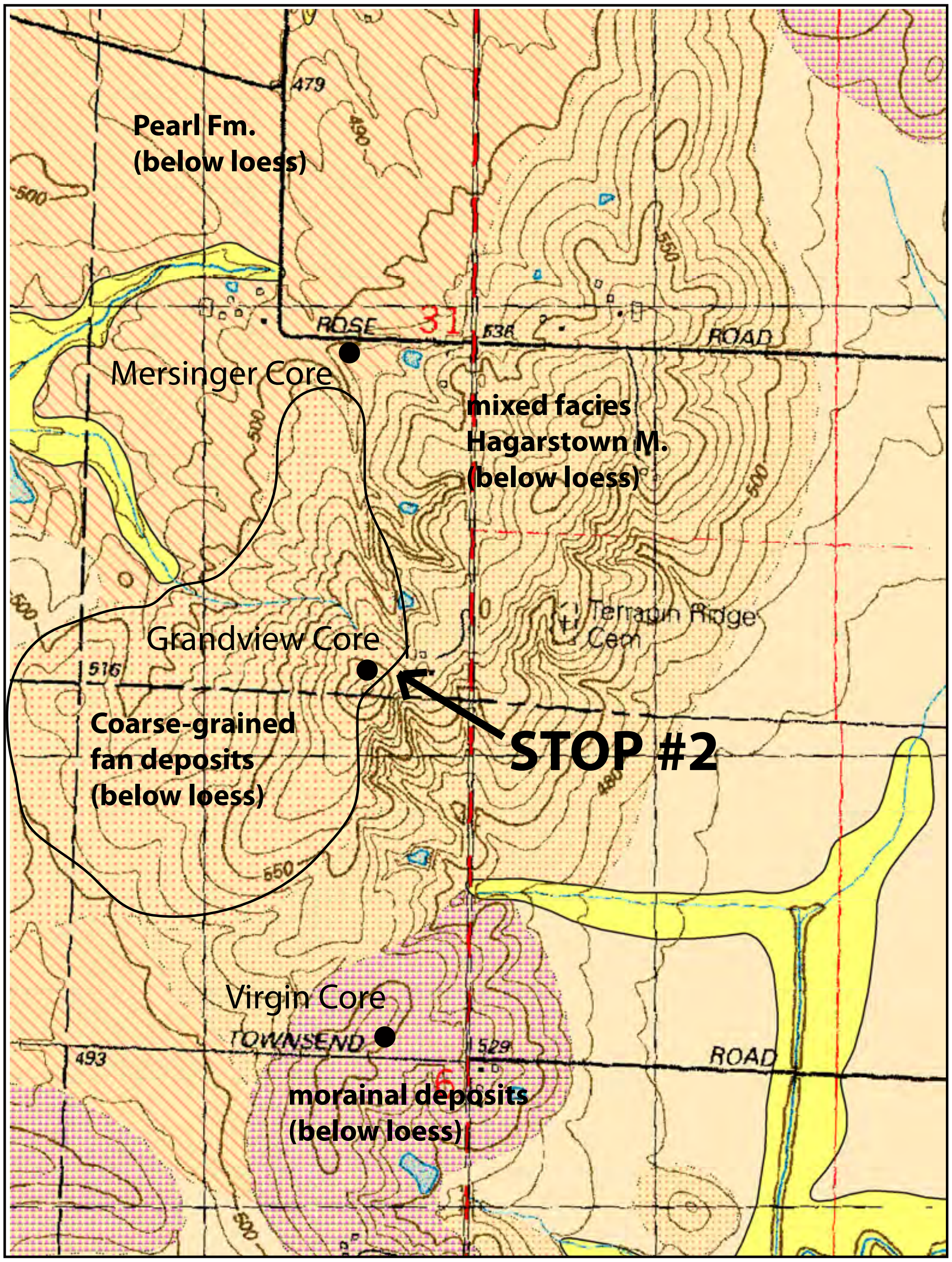


Figure 2.1. Location map for Grandview / Terrapin Ridge area, St. Clair County, IL (STOP #2). The mapped surficial geology (Grimley and Phillips, 2011) is overlain on a portion of the St. Jacob 7.5-minute Quadrangle. Hachured areas (near Mersinger Core) have Wisconsin Ep. loess over Pearl Formation. Areas with dark pink pattern (near Virgin Core) have loess over mainly diamicton (morainal). Stippled areas over most of Terrapin Ridge (near Grandview Core) have loess over mixed or sandy facies of the Hagarstown Member. Yellow areas have Holocene alluvial deposits (Cahokia Fm.).

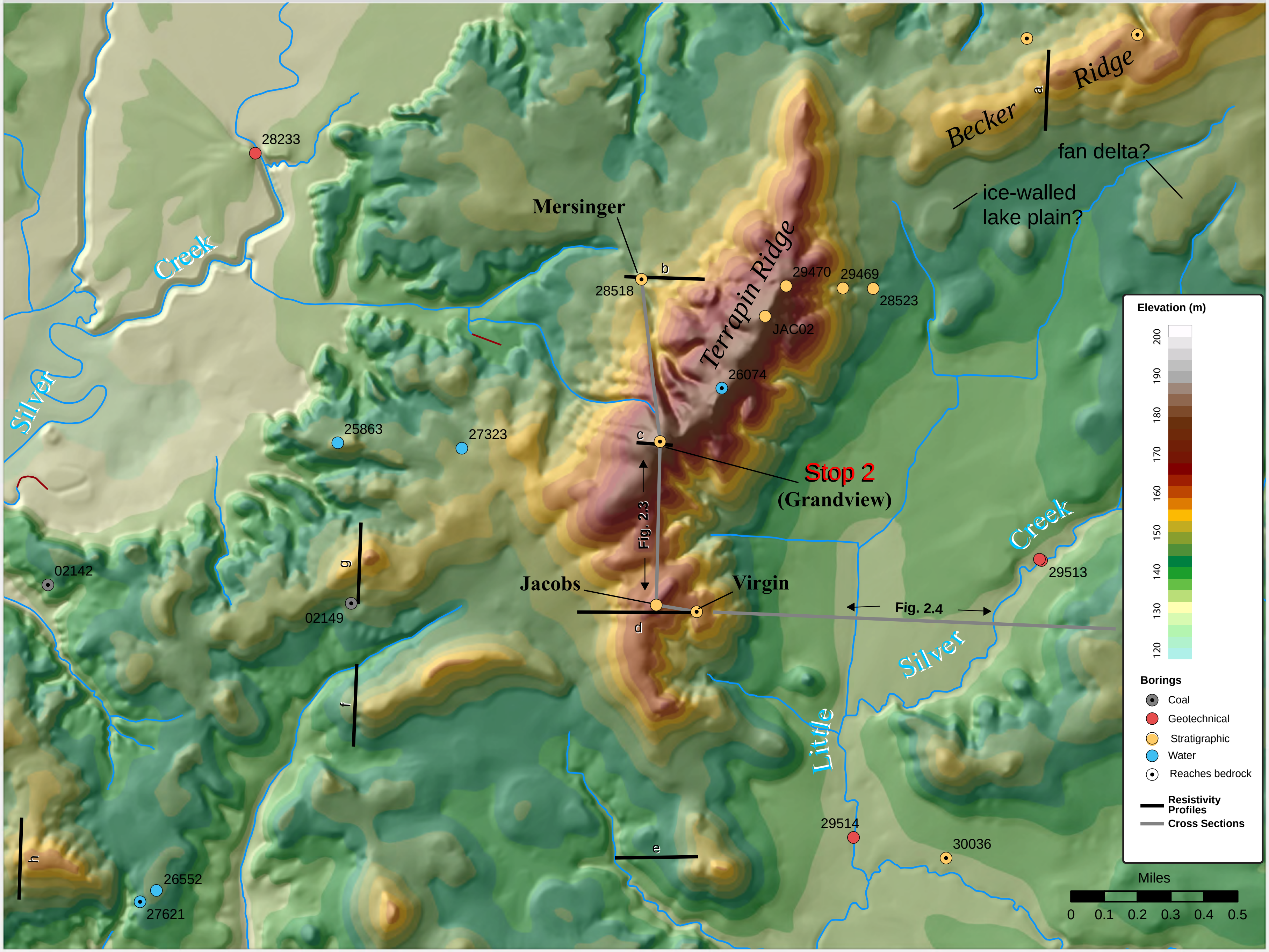


Figure 2.2. Geomorphic map of Terrapin Ridge and vicinity, based on colorized digital elevation map.

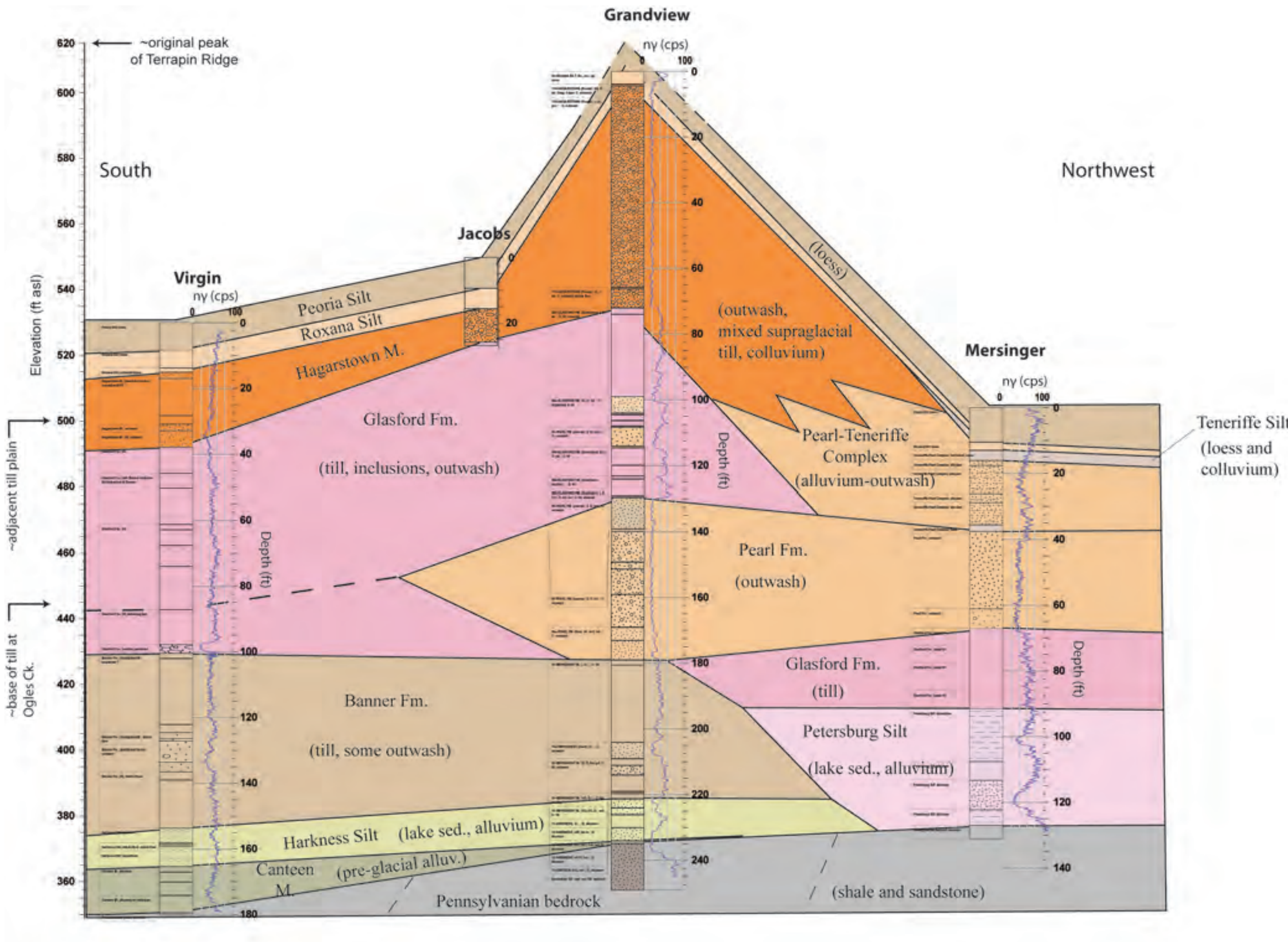


Figure 2.3. Correlation diagram from boreholes along Terrapin Ridge.

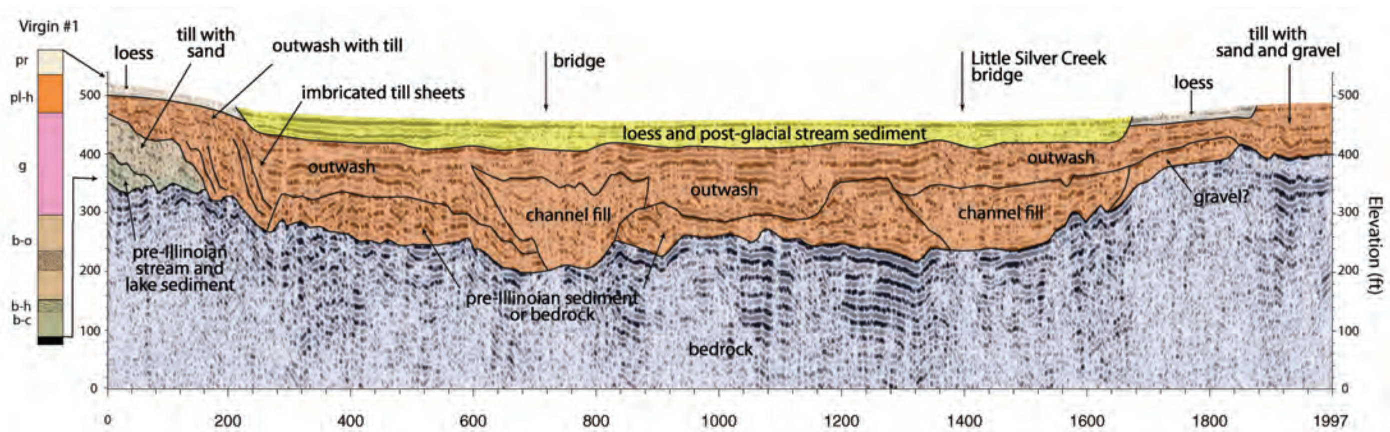
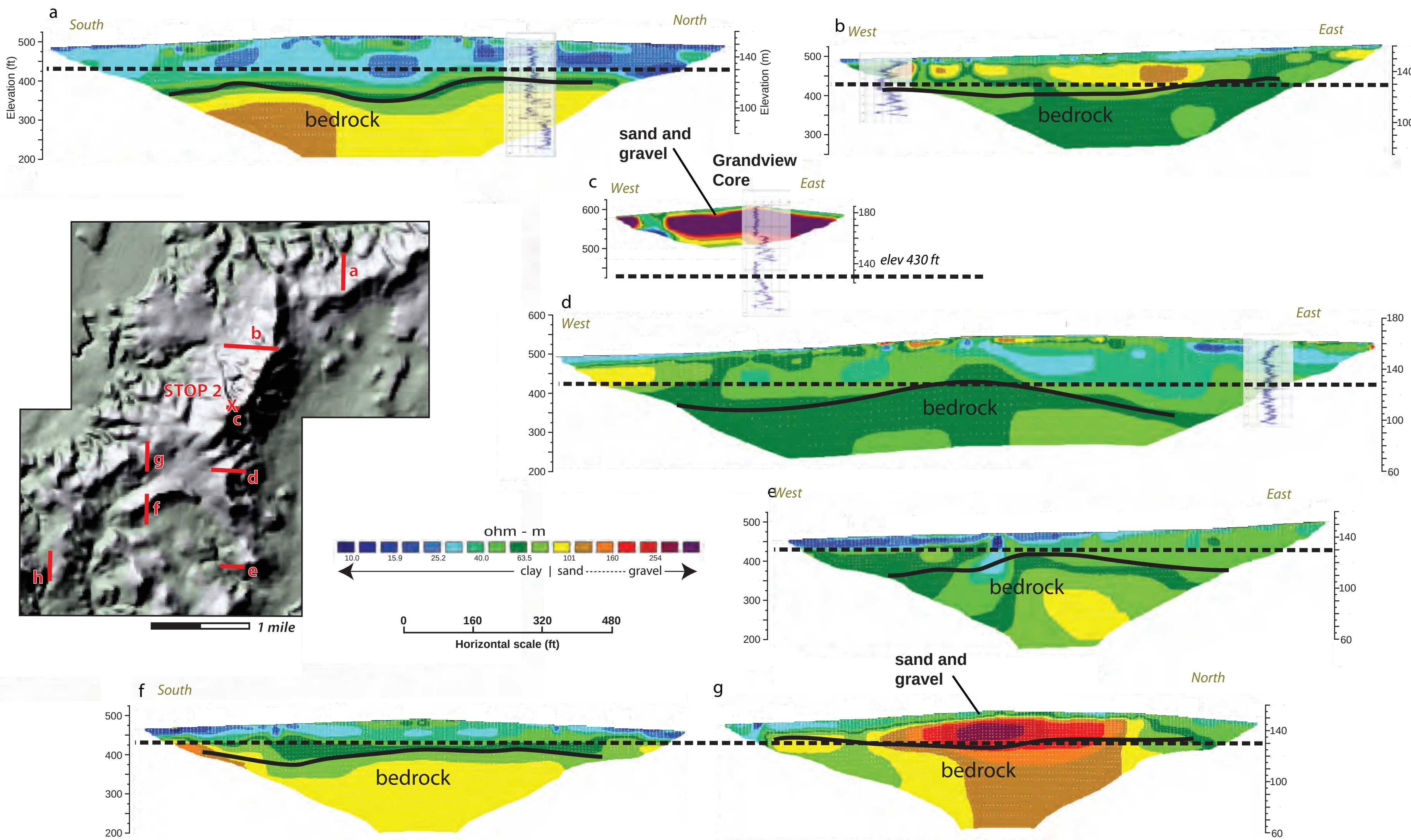


Figure 2.4. Seismic profile from Virgin Core to the east.



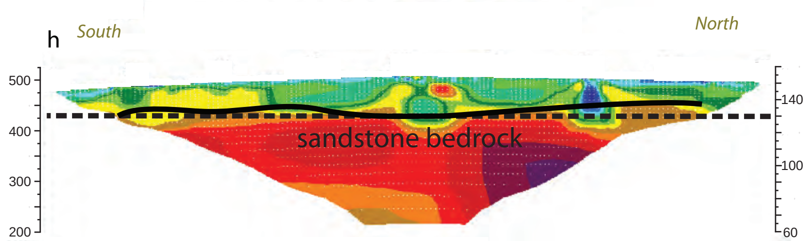


Figure 2.5 Resistivity profiles in the Terrapin Ridge area north of Lebanon. Resistivity profiles are shown at the same relative horizontal, vertical and resistivity scales. The dashed line at 430 feet (131 m) is the approximate elevation of nearby Silver Creek at this location. Distances are in feet.

STOP 3: Ogles Creek Section (David Grimley, Andrew Phillips, Samantha Kaplan, and Elizabeth Geiger)

PLEASE USE CAUTION AT THIS SITE -- DO NOT WALK OR EXCAVATE BENEATH UNDERCUT, STEEP SLOPES; WATCH FOR SLUMP BLOCKS

Introduction

This section is located near O'Fallon, Illinois, St. Clair County along a cutbank on the south side of Ogles Creek in the NE ¼ SW ¼ Section 3, T2N, R7W of the St. Jacob 7.5-minute USGS Quadrangle (Fig. 3.1). The Ogles Creek Section was rediscovered in 2004 by A. Phillips, D. Grimley and others when exploring the area for exposures of Quaternary deposits as part of the St. Jacob quadrangle surficial mapping project (Phillips, 2004). Unknown to the mappers at the time, about 8 feet of "preglacial silt" (Petersburg Silt in current terminology) had previously been noted by Udden and Shaw (1915) at approximately this location. The quality of the exposure from 2004 through 2010 has been ideal for a modern study of the geologic units, with fresh exposures cut by an actively eroding stream (Fig. 3.2). This outcrop is a key location for understanding the paleoclimate, paleoenvironments and glacial processes in southern Illinois during the peak of the Illinois Episode glaciation (OIS 6).

Geologic sequence

The Ogles Creek Section reveals 17 feet of loess (Peoria and Roxana Silts), overlying 22 feet of diamicton (Glasford Formation), overlying about 6 feet of alluvial and lacustrine silts (Petersburg Silt) to creek level (Figs. 3.2). Shale bedrock is buried at the main section, but crops out nearby in downstream and upstream directions (Phillips, 2004), an area of rising bedrock topography on the western flank of the Silver Creek bedrock valley (Grimley and Phillips, 2011). The Glasford Fm. at the site contains a clearly and strongly developed, reddish-brown interglacial paleosol (Sangamon Geosol solum), clay loam diamicton in its upper 5 feet; an 8 foot thick, olive-brown, pebbly loam diamicton, oxidized zone (C horizon) below the paleosol solum (A and B horizons) in the middle; and a 9-foot thick, gray, pebbly loam diamicton, unoxidized zone (D horizon) at its base. The oxidized zone contains abundant iron stains on the till fractures, with oxidized zones around gray diamicton interiors near the unit base (CD horizon transition), transitioning to the gray D horizon. The unoxidized zone consists mainly of gray, massive, pebbly loam diamicton, but also includes isolated sand and gravel lenses up to several feet wide and 3 feet thick (possibly R-channels) and also some sheared, perhaps formerly frozen, inclusions of underlying lake sediment and fossil *Picea* wood (one horizontal log is 4.5 feet long and 4 inches in diameter).

The Petersburg Silt, exposed below the Glasford Fm., consists of weakly laminated to massive, fossiliferous silt loam. The silt is interpreted as a combination of lake sediment, shoreline deposits and alluvium that consists mainly of redeposited loess. Within the unit are numerous fossil *Picea* logs (up to 8 inches diameter), branches and needles (Fig. 3.3) as well as aquatic and terrestrial gastropods (Table 3.1), small fingernail clams, and sparse ostracodes. Two zones are distinguished within the Petersburg Silt: (1) a relatively intact lower zone of dark grayish brown silt loam, with a weak (2-inch thick A horizon) paleosol in its top, and (2) an upper sheared zone of intermixed silt, diamicton, sheared paleosol stringers, and fossil logs. The upper zone varies in thickness (up to about 3 feet) between the lower in-situ silt zone and the overlying Glasford Formation. The sheared zone appears to have been significantly modified and distorted by the weight and movement of the Illinois Episode glacier as it traversed the area and deposited the Glasford till. The lower zone may have served as a soft deforming bed as this was the substrate when glacial ice overrode this area and advanced to the terminal Illinois Episode margin (Fig. Q5B).

About 500 feet downstream (east) from the main Ogles Creek Section is a smaller 25-foot high exposure on the east bank where the river makes a short bend to the north. This section shows Wisconsin Episode loess deposits over a Sangamon paleosol developed in Pearl Formation sand and gravel that in turn overlies several feet of Petersburg Silt (which floors the creek locally). The Pearl/Petersburg contact slopes towards Silver Creek valley. At this section, the Glasford till has been completely cut out prior to or during deposition of the Pearl Formation.

Description of stream bank 500 ft. downstream of Ogles Creek Section:

0-15 feet; Peoria and Roxana Silts; tan to reddish brown silt; not studied; [loess]

15-18 feet; Sangamon Geosol developed in Pearl Fm.; pebbly silty clay loam to silty clay diamicton, deeply weathered to orange-brown, clasts ~60% angular, 40% rounded, pebbles to few cobbles; sharp, undulating contact; [fluvial]

18-25 feet; Petersburg Silt; very dense orange-brown (mottled) silt to silt loam, massive, dry, leached, liesegang banding, Sangamon Geosol B horizon well-developed in upper part, forms creek bed [loess and lacustrine silt]

Plant macrofossils (*Picea* logs), mesofossils, and pollen in Petersburg Silt

Most noteworthy in the Petersburg Silt (at the main section) is the presence of abundant fossil *Picea* (spruce) logs which occur in both vertical and horizontal positions (Fig. 3.3). On the first visit to the site in 2004, an in-situ log was observed in its original growth position. A detailed survey and sampling study was made of the numerous fossil logs in 2005 by Samantha Kaplan and D. Grimley (Fig. 3.4; Kaplan and Grimley, 2006). Over 20 logs were recovered from the Petersburg Silt with some logs up to 4 feet in length and several inches in diameter. The logs within the silt are generally oriented north-south with a slight dip to the north (Fig. 3.4), perhaps reflective of a fan deposit into the edge of a floodplain against a hillside. Three additional logs were noted within the overlying till (Glasford Fm.), having been incorporated into the glacial ice during advance. The tree rings in the *Picea* fossils are very narrow, especially in later stages of growth, and have as many as 200 to 400 rings in cross sections. The minute growth rings suggest harsh growing conditions immediately prior to glacial burial.

Smaller plant mesofossils in sieved fractions (identified by Catherine Yansa, Michigan State University) included *Picea glauca, Picea mariana, Larix laricina ? , Carex* spp., Bryophytae (numerous), Pteridophyta (cf. *Pteridium*), and Ericaceae (cf. *Chamaedaphne).* This assemblage is indicative of shoreline conditions. *Picea glauca* and *Picea mariana* were distinguished based on needle size. The pollen record was analyzed by S. Kaplan in 5 to 10 cm (2 to 4 inch) increments (Fig. 3.5). Spruce (*Picea*), sedges, and mosses dominate both the pollen assemblage and the macro fossil component. *Pinus*, though present in lower portions of the silt, is absent from the profile immediately below the till while *Picea* is still abundant. The dominance of *Picea* in the arboreal pollen, along with minimal deciduous pollen, is similar to that found by Teed (2000) at Pittsburg Basin (Stop #9).

Molluscan fauna in Petersburg Silt

In addition to the plant macrofossils, the Petersburg Silt also contains small aquatic and terrestrial gastropods, and some pill clams. They are all < 1 cm (< 0.4 inch) in size, the larger of which are visible in the field upon close inspection. Three bulk samples (OC-1 [lowest], OC-2, and OC-3 [highest]) were taken from the exposure by Geiger (2008) for examination of the molluscan fauna (Table 3.1). The most abundant species are *Carychium exile canadense*, *Fossaria dalli*, and *Vertigo eliator*. The modern distribution of *V. eliator* is from the southern shores of Hudson Bay to the Great Lakes region (Nekola and Coles, 2010) and lives in such areas as fens, conifer swamps, and other wet areas. *Carychium exile* is another terrestrial snail that lives in similar wetland type environments as *Vertigo eliator*. The aquatic snail *Fossaria dalli* occurs in the northern U.S. and southern Canada and lives in wet marshy areas, shallow lakes and ponds (Clarke, 1981; Burch, 1989). The presence of one individual of *Columella alticola* hints at the possibility of a more northern climate, with modern distributions northward in Manitoba, Ontario, and Quebec (Nekola and Coles, 2010).

Genus	**Species**	**OC-01**	**OC-02**	**OC-03**	**Total #**	**Environment**
Carychium	*exile canadense*	5	105	1	111	terrestrial - wet fens and woodlands
Catinella	*avara*	4	8	0	12	terrestrial
Columella	*alticola*	0	1	0	1	terrestrial --cold
Fossaria	cf. *obrussa*	0	4	1	5	shallow aquatic
Fossaria	*dalli*	8	16	1	25	shallow aquatic
Gastrocopta	*tappaniana*	0	9	0	9	terrestrial – wet fens and woodlands
Gastrocopta	*pentodon*	1	0	0	1	terrestrial
Hawaii	*miniscula*	2	0	0	2	terrestrial
Helicodiscus	*singleyanus*	1	0	0	1	terrestrial
Nesovitrea	*electrina*	7	3	0	10	terrestrial
Punctum	*minutissimum*	3	3	0	6	terrestrial
Strobilops	*labyrinthica*	0	1	0	1	terrestrial
Succinea	cf. *grosvenori*	0	0	1	1	terrestrial
Succinea	cf. *ovalis*	0	3	0	3	terrestrial
Triodopsis	*algonquinensis*	0	1	0	1	terrestrial
Vallonia	*gracilicosta*	1	0	0	1	terrestrial – cold
Vertigo	*eliator*	3	44	0	47	terrestrial – boreal
Vertigo	*sp.1*	0	21	0	21	terrestrial
Total		**35**	**219**	**4**	**258**	

Table 3.1. Molluscan fauna from the Petersburg Silt (Illinois Episode), Ogles Creek Section.

Ostracodes in Petersburg Silt

Though uncommon, a few species of ostracodes were noted in some samples of the Petersburg Silt. Species (identified by B.B. Curry) include *Candona inopinata, Candona candida, Cyclocypris sharpei*, *Cypridopsis vidua*, and *Candona* juveniles. Together, this fauna suggests that a shallow, freshwater lake existed at times. The overlapping distributions of these species point to a modern analog in the northern Great Lakes region (B.B. Curry, personal communication, 2011). Based on the ostracode occurrences and the other paleoecological records, the site probably fluctuated between a floodplain and shallow lake environment.

Overall interpretations

Based on regional mapping (Grimley and Phillips, 2011), the Petersburg Silt at the Ogles Creek Section probably represents the shoreline of a large slackwater lake in the lower Kaskaskia Basin. As the Mississippi River base elevation rose in response to glacial sediment influx, the Kaskaskia Valley and its tributaries were dammed and backflooded up to elevations of about 440 feet asl (~ top of Petersburg at OCS) in this drainage basin. Lake levels fluctuated seasonally and terrestrial material (loess, wood and organics) periodically washed into these ancient lake basins from the surrounding uplands. Advancing glaciers during the Illinois Episode buried and overrode the sediments, in part explaining why the upper contact of the Petersburg Silt is variable (with a few feet of relied) and the upper part of the unit is sheared and mixed. The fossils preserved are probably reflective of the peak glacial climate and environment during the Illinois Episode (OIS 6).

Altogether, the pollen, plant macrofossils, plant mesofossils, and mollusks are consistent with a cold boreal condition, with the nearest modern analog perhaps in western Ontario (north of Lake Superior). The climate and vegetation envisioned in the immediate vicinity of the Illinois Episode ice front appear to have been similar to full-glacial Wisconsin Episode conditions. Future work may involve finding more specific modern analogs for the assemblages in the hopes of better quantifying climatic conditions in the central USA at the OIS 6 glacial maximum. Further study of the tree rings may provide insights into short-term climate change, seasonality, and periodicities during the few hundreds of years immediately prior to glacial advance.

Topics for discussion

- What clues can the sheared and deformed layer in the upper Petersburg Silt tell us about glacial dynamics during the Illinois Episode ?

- Is this site representative of the glacial climate and vegetation in southern Illinois during the peak glaciation of OIS 6 ?

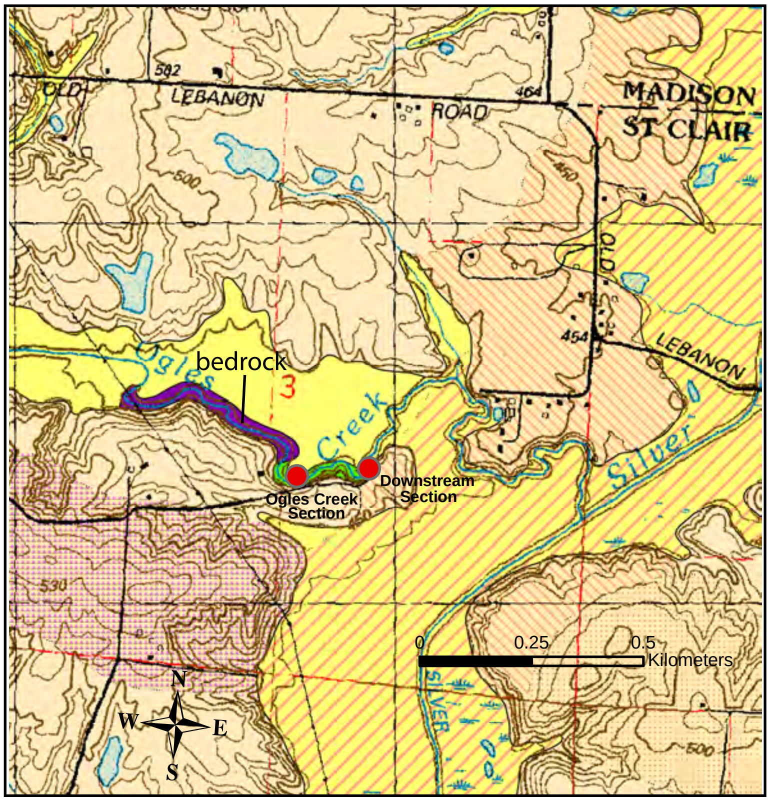
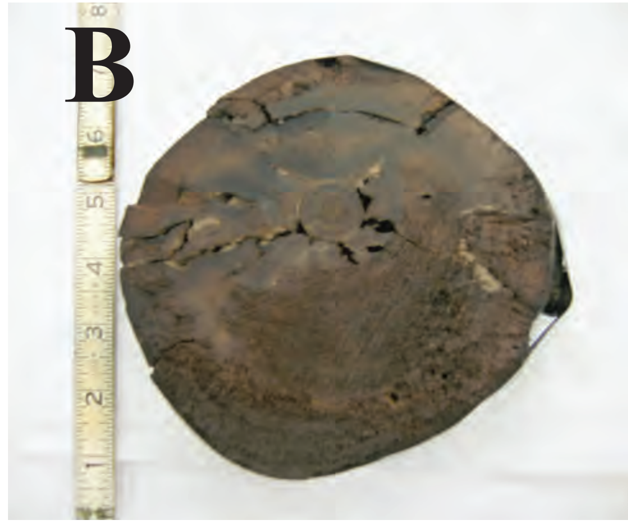


Figure 3.1. Location map for Ogles Creek Section, St. Clair County, IL (STOP #3). Surficial geologic map (Grimley and Phillips, 2011) is overlain on a portion of the St. Jacob 7.5-minute Quadrangle. Map units similar to Fig. 2.1.

Figure 3.2. Ogles Creek Section during the 2004 rediscovery. The "hole" in the bank is likely a sand and gravel channel near the base of the Glasford Formation. The Petersburg Silt is fossiliferous with *Picea* stumps and minute gastropods in the lowest 5 feet of the exposure.



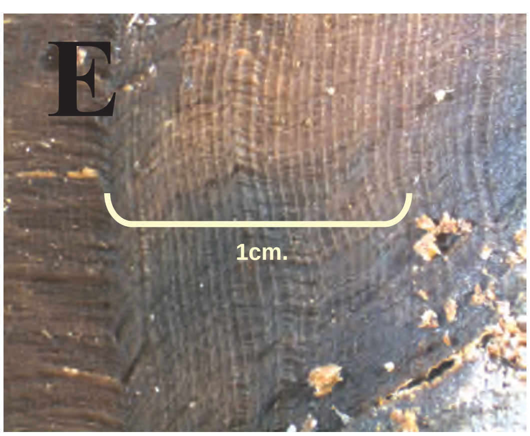


Fig. 3.3 Photomosaic.

A) In-situ Picea log within Peterburg Silt; appears to have been sheared off by the glacial advance that deposited Glasford till.

B.) Cross section of 6” diameter *Picea* (spruce) log.

C.) *Picea* needles washed-out from Petersburg Silt.

D.) *Picea* log OCS-13.

E.) Very narrow rings in close-up of a *Picea* log cross section.

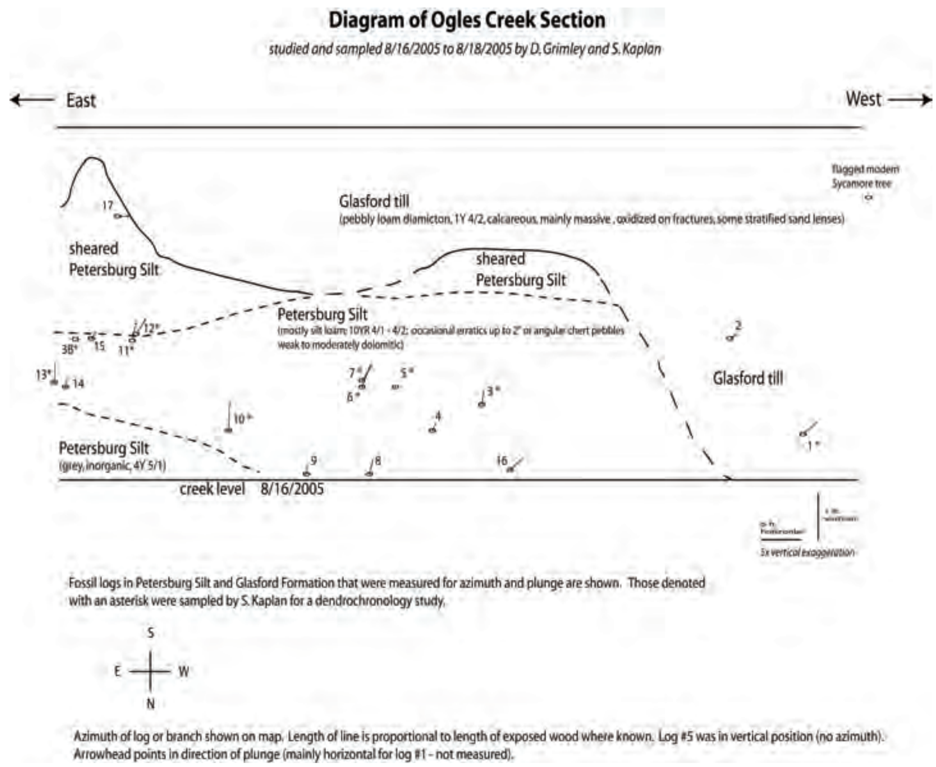


Figure. 3.4. Sketch of Ogles Creek Section with log orientations in Petersburg Silt.

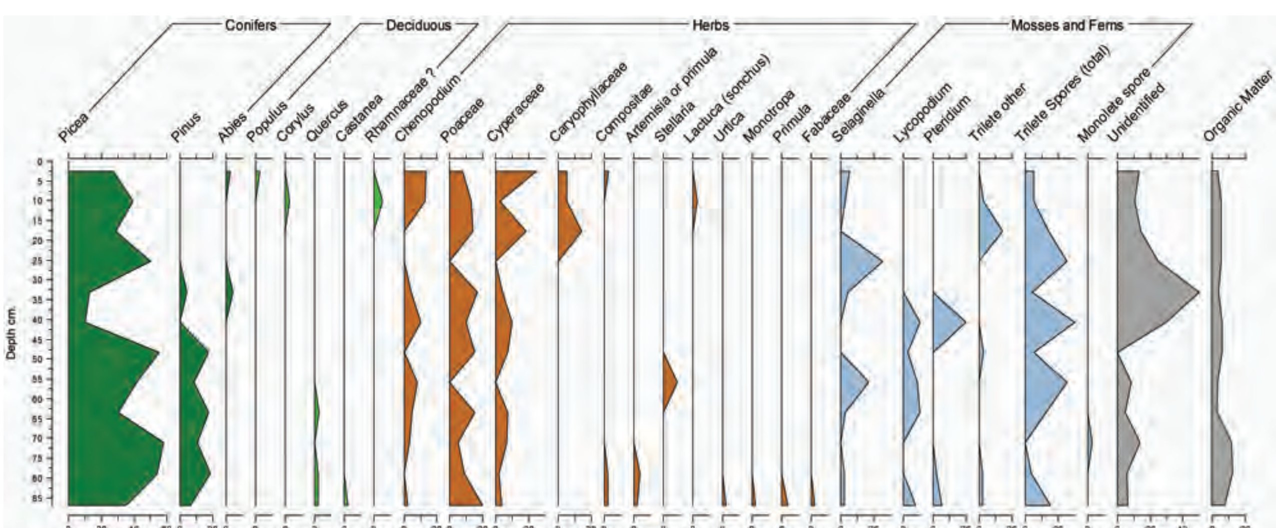


Figure 3.5. Pollen Diagram for Petersburg Silt, Ogles Creek Section (analyst, Samantha Kaplan).

STOP 4: Emerald Mound: Archaeology and History (Brad Koldehoff)

Background and geologic setting

The Illinois Episode till plain in southwestern Illinois is dotted with many isolated knobs and broad hills (Phillips 2004). The Emerald archeological site is located atop one of these knobs (Koldehoff et al. 1993). This ancient Native American settlement contains several earthworks, the largest of which is Emerald Mound. The Emerald site was a mound and town complex constructed by people of the Mississippian culture. Named for the middle Mississippi Valley, Mississippian culture developed and disappeared (A.D. 1050-1350) long before Columbus sailed for the New World (Pauketat 2004). Earthen monuments, like those at the Emerald site and the world-famous Cahokia site (located 24 km to the west in the Mississippi Valley), are the most visible vestiges of this ancient civilization. Researchers believe that the ancient inhabitants of the Emerald site selected this elevated glacial knob for settlement because of its commanding viewshed and because of its proximity to an ancient overland trail that linked the Mississippi Valley with the Wabash Valley (Koldehoff et al. 1993; Pauketat 1998, 2004). From a glacial geology perspective, the site occurs within an irregular, possibly intermorainic, plain (Fig.Day1). The sediments comprising Emerald Mound, based on a 1960s borrow pit cut into its eastern side, is comprised of remolded loess deposits that were likely locally mined and used to construct the mound.

Archeological and recent history

Emerald Mound is a pyramidal platform constructed of thousands of basket loads of locally excavated silty clay loam sediment. It was topped with a temple or elite residence constructed of wooden posts covered with mats and/or thatch. Earthen pyramids, like Emerald Mound and Monks Mound at Cahokia, are characteristic of Mississippian culture. Archaeological excavations conducted in the modern agricultural fields that surround Emerald Mound have documented habitation features—house floors and cooking/storage pits filled with domestic refuse, such as fragments of pottery vessels, stone tools, animal bones, and charcoal. These durable residues of daily life, along with the mounds, are all that remain of the Mississippian culture. Because they left behind no written records, in the nineteenth century their remains were attributed to the mysterious “Mound Builders.” Today, however, it is well established that Mississippian culture is an ancient Native American agriculture-based civilization with far-flung trade networks centered at the massive Cahokia site that is in large part preserved as the Cahokia

Mounds State Historic Site. Located across the Mississippi River from St. Louis, the Cahokia site once held more than 100 earthen monuments. It is the earliest and largest center of Mississippian culture and one of the largest and most complex sites in North America. As such, it is one of only a handful of archaeological sites in the United States that is listed on UNESCO's World Heritage List.

Emerald Mound is a flat-topped pyramid (with a lower terrace) that when first reported stood about 50 feet tall and measured 400 by 250 feet (Snyder 1877, 1909). It is the centerpiece of the Emerald site, a Mississippian settlement with four smaller mounds and associated village areas that encompass several hectares of the surrounding area (Fig. 4.1). The two mounds on the east side of the site (Mounds 1 and 2) were removed in the 1960s and were conical flat-topped mounds. Mounds of this type are rarely found outside of the Cahokia site. The two mounds on the west side (Mounds 3 and 4), when first reported, were oval in shape but may have originally been flat-topped pyramids. Their original size and shape have been greatly altered by much plowing and erosion. Immediately north of these two mounds are three possible mounds that have also been significantly lowered by plowing and erosion. The broad, level area between these five mounds and Emerald Mound on the northeast may have been the location of a community plaza. No confirmed borrow areas have been identified. But the northern slope of the site, which borders a small stream and spring, is suspected to be the location where silty clay loam sediments were excavated to construct the mounds. While controlled excavations into the mounds have been limited, evidence of typical Mississippian basket-load construction has been identified, and Emerald Mound was built in at least four major stages (personal communication, Timothy Pauketat).

Obscured by trees and brush, Emerald Mound derives its name from the green prairie grasses that covered the mound when the area was first settled by EuroAmericans. The Emerald site is the easternmost mound center directly affiliated with the sprawling Mississippian mound center of Cahokia (Koldehoff et al. 1993; Pauketat 1998, 2004). Its location in the uplands away from a major steam valley and adjacent to rolling tall-grass prairie is atypical for Mississippian mound centers, which are typically situated in or along river valleys. Researchers have traditionally considered Mississippian economies to have been primarily based on the exploitation of the fertile and renewable resources found in alluvial valleys, such as fish, waterfowl, and soils suitable for hoe-agriculture. Common crops were maize, squash, tobacco, sunflower, and other native cultigens.

Investigations at the Emerald site and at other upland settlements have demonstrated that there were sizable upland populations that exploited local soils and resources (Koldehoff et al. 1993, Pauketat 1998, 2004). Although only limited excavations have been conducted at the Emerald site, they have, nonetheless, routinely yielded evidence of hoe agriculture, as have excavations at other upland settlements. Thus, it has been suggested that upland prairies may have been farmed by local Mississippian populations, in addition to alluvial soils found along upland streams (Pauketat 1998). Stone hoe-blades, chipped from imported Mill Creek chert (from Alexander County, Illinois), and the flakes produced from resharpening their worn and soil-polished bits are especially common at the Emerald site. While these tools were likely used in mound construction, their ubiquity at the site is characteristic of agricultural pursuits. For example, several caches (hoards) of hoe blades have been discovered. The earliest reported cache is also the largest and was found by accident. The following information is reported by John F. Snyder (1909:76), pioneer archaeologist in Illinois.

> *In 1840 Mr. Baldwin, then proprietor of the premises, built a dwelling house that encroached several feet upon the large square mound near its eastern corner. In excavating the cellar and foundations . . . he unearthed, from about a foot beneath the mound edge, sixteen large flint spades, from ten to eighteen inches in length, smoothly polished at their broad ends by continued use. . . .*

The Baldwin house mentioned by Snyder is depicted in the 1881 history of St. Clair County as part of Mr. Henry Seiter's "Mound Farm" (Brink, McDonough, and Company 1881). Emerald Mound is in the background, and Mound 2 is in the foreground (Fig. 4.2). An aerial photograph taken in February of 1965, some 80 years later, shows Mr. Seiter's house still standing on the east side of Emerald Mound (Fig. 4.3). Also visible is a T-shaped depression atop Emerald Mound. This exploratory trench was excavated in 1964 by Robert Hall, then Illinois State Museum archaeologist. Hall's test discovered segments of a post pattern indicating that a building (temple) once stood atop the mound (Koldehoff et al. 1993).

Hall's work at the site, as well as investigations conducted several years earlier by other State Museum archaeologists were undertaken because Mr. John Hoak, the owner of the "Mound Farm" in the 1960s, considered the mounds to be a nuisance. Therefore, he began removing them—selling their ancient basket loads of sediment by the truckload for fill dirt. After Mounds 1 and 2 were removed, he began cutting into Emerald Mound itself just north of the old Henry Seiter house (Fig. 4.3). It was at this time, with much local support, that the State of Illinois purchased Emerald Mound to ensure its protection. The rest of the site remains in private ownership, but it and other sites in the state are accorded some protection by state and federal laws.

Despite erosion and soil borrowing, the Emerald site is one of the best-preserved Mississippian mound and town complexes in Illinois. It is the largest upland mound center in the region, and the easternmost mound center within the sphere of greater Cahokia. Its location on high upland knob is atypical for a major Mississippian site and likely stems in part from its position along an ancient east-west transportation corridor (Koldehoff et al. 1993). Today, U. S. Highway 50, which runs through the nearby town of Lebanon, essentially retraces the route of the historic St. Louis to Vincennes wagon road, which in turn likely followed a footpath blazed by ancient Native Americans. This overland corridor is the shortest route between the Wabash Valley and the Mississippi Valley. Emerald Mound's prominent location likely provided a commanding view of the ancient footpath, as well as nearby settlements.

Nearby archeological sites

The Copper site is a nearby and much smaller Mississippian mound center. Unlike the Emerald site, which is located about 4 miles (6 km) away on a high knob, the Copper site is located on a ridge along the east bank of Silver Creek at a spot where the otherwise broad and swampy floodplain of the creek constricts, thus affording a good location for a stream crossing. The idea that this general locale was where an ancient trail crossed Silver Creek is supported by the location of other nearby archaeological sites. For example, located across Silver Creek, near the mouth of Ogles Creek, is a late Pleistocene Clovis culture campsite. The Bostrom site was investigated prior to the expansion of a residential development that ultimately destroyed the site (Koldehoff and Walthall 2004; Tankersley et al. 1993). Its position high above the creek valley would have been an ideal location for monitoring the movement of herd animals, especially if they were crossing the creek at this narrow spot in the valley (also see STOP #3 -- Ogles Creek Section)

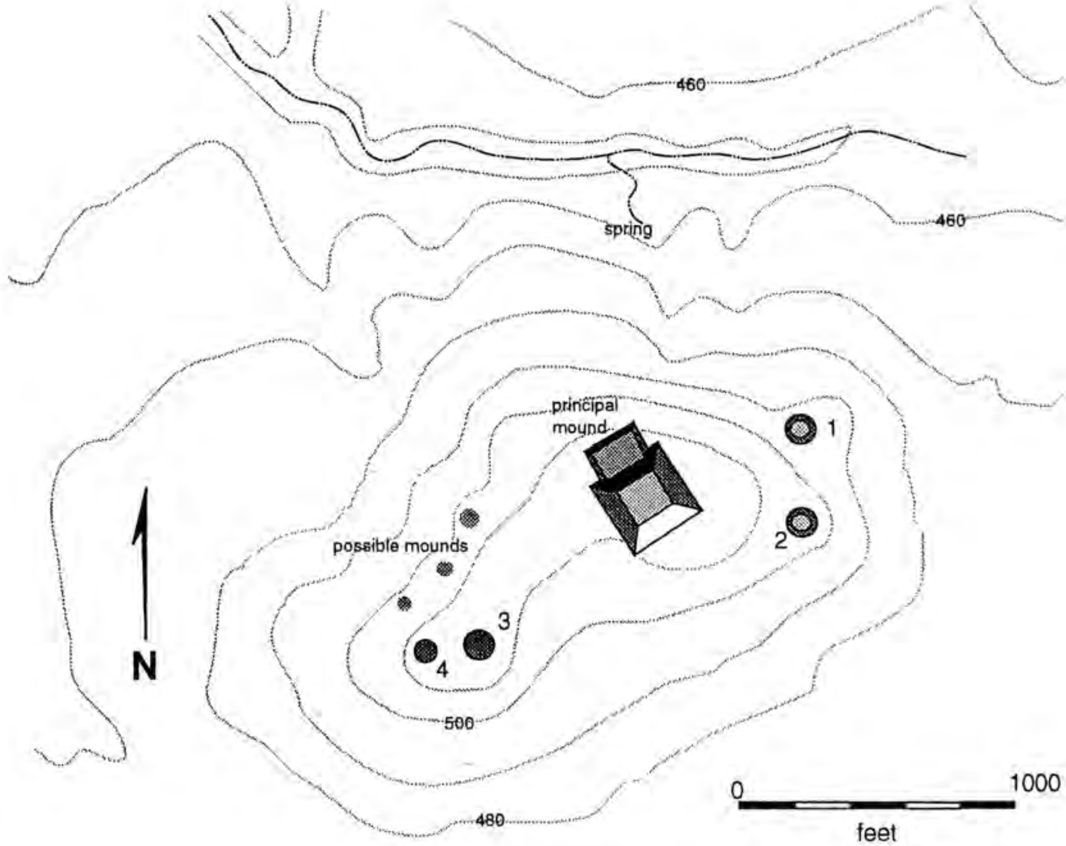


Figure 4.1. Emerald Site Map (from Koldehoff et al. 1993).

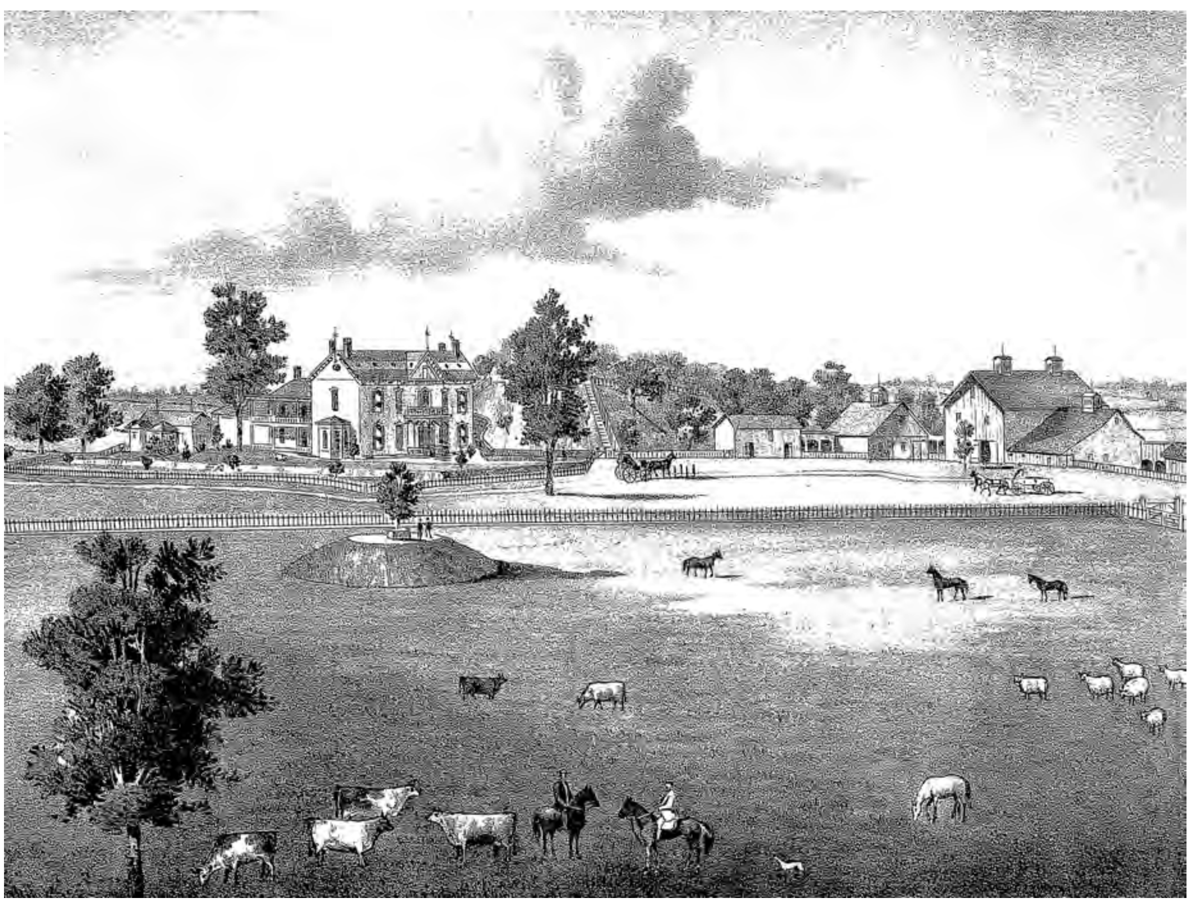


Figure 4.2. Drawing of Mr. Henry Seiter's "Mound Farm" (from Brink, McDonough, and Company 1881).

Figure 4.3. February 1965 Aerial Photographs of Emerald Mound: A) View to East, B) View to North (courtesy of Richard Norrish).

STOP 5: Pleasant Ridge Area (cores/geophysics)

(Tim Larson and David Grimley)

Introduction

The Pleasant Ridge area, in St. Clair County 3 to 5 miles south of Mascoutah, Illinois, is part of a series of glacially constructed Illinois Episode hills and ridges in southwest Illinois (Fig.Day 1, Fig. 5.1). Pleasant Ridge is a relatively narrow, steep, and somewhat elongate hill just north of a complex of several broader ridges that are also about 80 to 90 feet above the surrounding lake plains (these plains were inundated by slackwater lakes during the last glaciation). Some of the ridges in the vicinity of Pleasant Ridge are predominantly fine-grained and appear to be marginal moraines, while others are composed predominantly of sand and gravel, interpreted as glacifluvial. Distinguishing the these types of ridge deposits is important from a geologic standpoint and, also, has economic significance since the predominantly coarse-grained ridges are valuable as construction aggregate. The ridge-forming deposits are capped with 10 to 13 feet of silty loess and underlain by thin pre-Illinois episode deposits or Paleozoic bedrock.

The research presented at this stop integrates extensive geophysical studies (electrical resistivity) with borehole studies taken as part of a 1:24,000-scale surficial geologic mapping project (Grimley, 2010). Both shallow and deep (to bedrock) stratigraphic test holes and lithologic descriptions of water-well records were used to help calibrate the geophysical data.

Geomorphology, geologic history, and test cores

The Pleasant Ridge area consists of curvilinear hills and knolls, mostly having an east-northeast to west-southwest orientation. Lithologically variable deposits in the ridges are classified on the surficial map (Fig. 5.1) as either the mixed or sandy facies of the Hagarstown Member, Pearl Formation. However, the subsurface geology is more complex than can be shown on the 1:24,000 scale surficial map or cross sections.

Deposits within the main portion of Pleasant Ridge (Sections 19 and 20, T1S, R6W; center of Sec. 24, T1S, R7W) include interbedded sand, loam, and variably-textured diamicton, as well as ice-thrusted inclusions of pre-Illinois Episode paleosol fragments (Yarmouth Geosol), glacial, and preglacial materials. The hills south of the main ridge include up to 110 feet of various grades of well sorted to poorly sorted sand, including gravelly zones and zones of very fine sand. These deposits, shown in cross section in Fig. 5.1, are classified as the sandy facies, Hagarstown Member. Sandy areas (with loess cover) are shown with large stipples in Fig. 5.1 and tend to occur in hills on the southeast side of the main ridge system, based on test holes, water well records, and geophysical studies. In the circular-shaped lowland between the ridges, clayey lacustrine sediments were found in a shallow boring to 37 feet (MSC-11: county # 30361). This shallow boring encountered mainly last glacial lake sediment (Equality Fm.), with a radiocarbon age on peaty/organic material at a depth of 34.5 feet determined as 40,500 +/- 1200 C^{14} yr BP (ISGS-6001).

The origin of Pleasant Ridge may be related to the presence of a localized bedrock topographic high underlying the ridge system (Grimley, 2010). The buried bedrock high may have restricted the flow of glacial ice, leading to a natural position of a glacial margin for the envisioned Kaskaskia Sublobe (Figs. Q1, Q3). A stationary or locally fluctuating glacial margin in the area for a period of time could explain the complex association of deposits (lacustrine, fluvial, subglacial) in the Culli boring (Fig. 5.2) and consequently, the formation of a moraine and related deposits. The large sand-rich hills on the southern side of Pleasant Ridge may be related to englacial or ice marginal channels that developed either subglacially or on stagnant ice between the Pleasant Ridge moraine (on the bedrock topographic high) and the active margin of the glacier as it receded. The Kaskaskia Sublobe glacier need not be generalized as active or stagnant ice overall; these conditions would vary both spatially and temporally, dependent on the regional topographic configuration and glacial thickness profile.

Electrical resistivity imaging

A two-dimensional resistivity survey was conducted July 10-14, 2006 on Pleasant Ridge to assist with mapping of Quaternary deposits and with economic assessment of sand and gravel resources. The resistivity survey includes parts of Sections 19 and 30 of T. 1 S., R. 6 W and parts of Sections 24, 25, and 26 of T. 1 S., R. 7 W., St. Clair County. Approximately 23,000 feet (7,000 m) of continuous resistivity data was acquired on five interconnecting profiles (Figs. 5.1, 5.3) using the Wenner electrode configuration with an ABEM SAS 3000 meter and LUND acquisition system (more methods information in Appendix A). Profiles were processed with RES2DINV (Loke and Barker, 1996). Two north-south resistivity profiles are each over a mile long and extend from the lake plain on the south, across the southern ridges, inter-ridge sediments and Pleasant Ridge. The long profiles illustrate the contrasting sediment characteristics within these ridges. Line A begins in a field and continues north along the west side of the road across the low between the ridges and then up and over Pleasant Ridge.

The resistivity profiles (Fig. 5.3) suggest that Pleasant Ridge (the long northern ridge) is composed of low-resistivity, fine-grained sediment (diamicton). This fine-grained sediment also underlies surficial lacustrine sediments between the ridges. Due to their near-surface occurrence and extremely low resistivity values, the lacustrine sediments (mostly Equality Formation, possibly underlain by Berry Clay/Teneriffe Silt) can be accurately imaged in 2D with the resistivity profile data. This is particularly clear in Lines D, C, and A. The low-resistivity lacustrine sediments onlap onto the high-resistivity coarse-grained (Hagarstown Member) sediments of the ridge. In contrast to main east-west hill of Pleasant Ridge, the associated ridges to the south (more circular or smaller in size) are generally cored by high-resistivity coarse-grained sediments. This interpretation is confirmed by the Kessler borehole (county # 30332; Figs. 5.1, 5.2) which encountered coarse-grained sediments (sand and gravel), with zones containing significant calcite cement. Diamicton is of variable and generally low resistivity, but is not specifically highlighted in Fig 5.3. These deposits form the core of Pleasant Ridge and underlie the very low resistivity sediments in other areas. The approximate location of the bedrock surface is indicated on each of the images. The bedrock position is generally determined by a vertical change in resistivity. The depth is confirmed at the Kessler borehole and at a water well on Line D. Four geophysical zones were delineated based on the electrical resistivity data:

<u>Zone 1 --- Very-high resistivity in ridge-core (RED)</u>: This geophysical zone is caused by a combination of coarse sand and gravel and dry conditions on the ridge crests. These materials have the highest resistivity, and are likely the most consistently coarse-textured sediment encountered in the survey. This unit is found on the large hill south of Pleasant Ridge (southern Line D and eastern Line B) and is confirmed by thick sand and gravel in the Kessler borehole (Fig. 5.2). This resistivity unit is also found on Line E and on the northern end of Line 1 (but south of the northernmost area). Although northern Line A appears to be on Pleasant Ridge moraine, there is actually a separate feature adjoining Pleasant Ridge just south of the Culli boring. Overall, Zone 1 is either correlated to thick coarse sediments, dryer conditions (lower water table) or locally may be affected by secondary carbonate zones (all giving higher resistivity). Lithostratigraphically, these areas include thick deposits of the sandy facies, Hagarstown Member, with about a 10 to 13 foot blanket of loess.

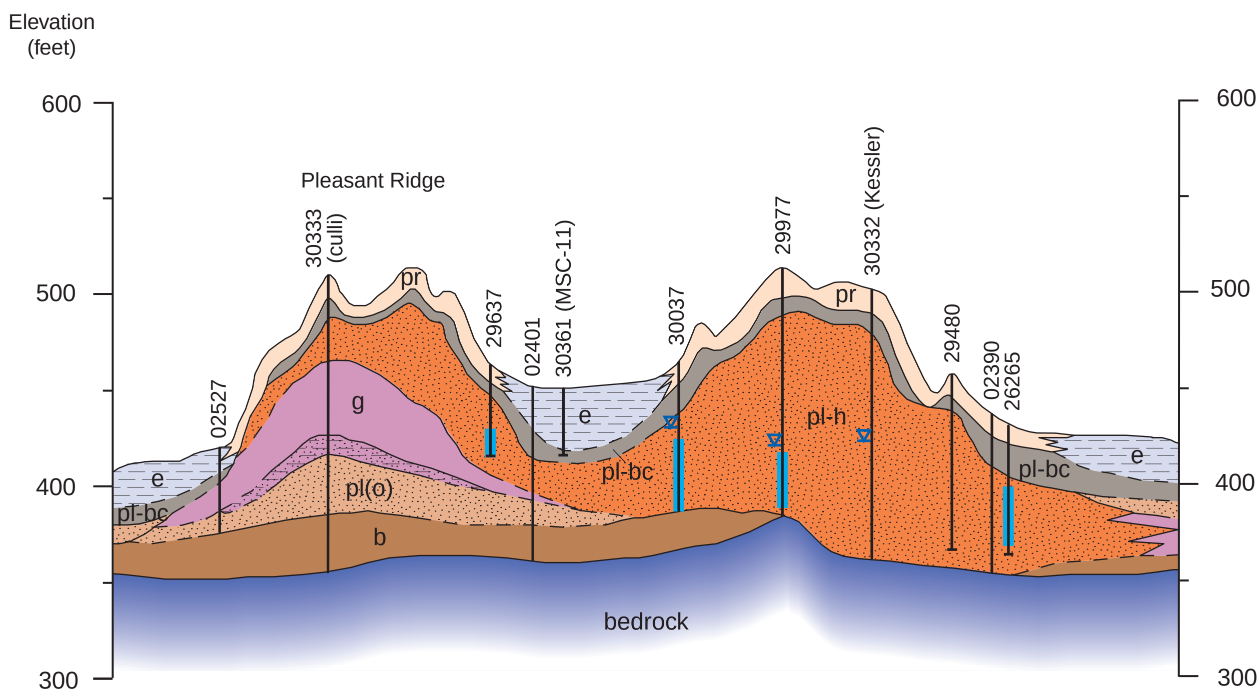
<u>Zone 2 --- Moderately-high resistivity in ridge-core (ORANGE)</u>: This zone is found on the southern part of the Koltz Road line and the eastern part of the Pleasant Ridge School Road East Line. These materials have somewhat lower resistivity compared to zone 1 and in general, it do

not attain the same thickness or elevation. This geophysical zone is likely caused by sand and gravel that is less coarse and/or wetter than zone 1. This zone is found on Line E, Line C, and Line B and southern Line A (where we plan to have our bus stop). Based in part on calibrations to test borings and well records (Grimley, 2010), Zone 2 correlates to sand and gravel that is less thick or not as dry as for Zone 1. Lithostratigraphically, these areas include material of the sandy facies, Hagarstown Member, with about a 10 to 13 foot blanket of loess.

Zone 3 --- Moderate resistivity ridges (GREEN): This zone includes areas on Pleasant Ridge proper (northern Lines A and D) --- that is, the morainic areas that include the Culli boring and geomorphically similar areas to the east and west. Resistivity values are of moderate values, intermediate between areas of exclusive sand and gravel (Zones 1 and 2) and areas of fine-grained lake sediment (Zone 4). Zone 3 deposits include a mixture of some sand and gravel, some buried lake sediments, and significant thicknesses of diamicton with sheared inclusions of older materials. Lithostratigraphically, these areas include material of the Glasford Formation, the Petersburg Silt, mixed facies of the Hagarstown Member, and tongues of the Pearl Formation. These areas have a 10 to 13 foot blanket of loess.

Zone 4 --- Low-resistivity lowland (BLUE): This zone is found below flat intra-ridge areas on eastern Pleasant Ridge School Road, the center of Koltz Road, the west part of the Pleasant Ridge School Road East Line, and the north part of the Brickyard Road Line on lines A, B, C, and D between the ridges. The maximum thickness of this zone is about 65 feet (20 m) in the center of the Koltz Road Line near it's junction with the Pleasant School Road East Line This geophysical zone is probably mainly caused by fine-grained lacustrine sediments, substantiated by deposits in borehole MSC-11 (county # 30361; Fig. 5.1). The lowest resistivity areas within this zone occur at a lower surface elevation, on the south ends of the south-north profiles. These areas range from 30 to 65 feet thick (10 to 20 m), with the base of these zones at a similar elevation to other areas in Zone 4. Lithostratigraphically, these areas include the Equality Formation and the Berry Clay Member, and perhaps some areas of fine-grained Glasford Formation.

Bedrock: Bedrock in the area varies from high-resistivity carbonate to low-resistivity shale. It is difficult in many areas to distinguish the bedrock interface from other materials because the resistivity contrast is low. Where bedrock can be distinguished, it generally occurs at elevations below 360 feet (110 m). This resistivity method is not appropriate for detailed mapping of the bedrock surface in this area.



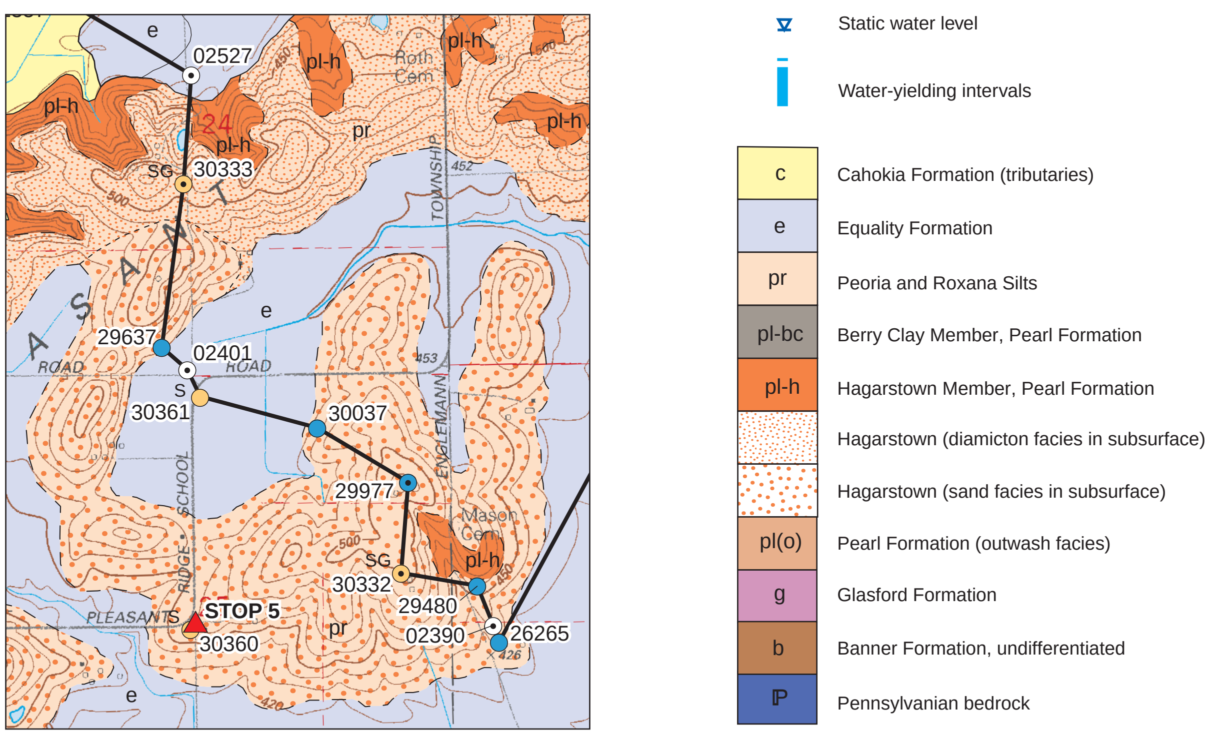


Figure 5.1. Location map (1:24,000) of the Pleasant Ridge area, St. Clair County, IL (STOP #5), a portion of the Mascoutah 7.5-minute Quadrangle. Surficial geologic map and cross sections from Grimley (2010).

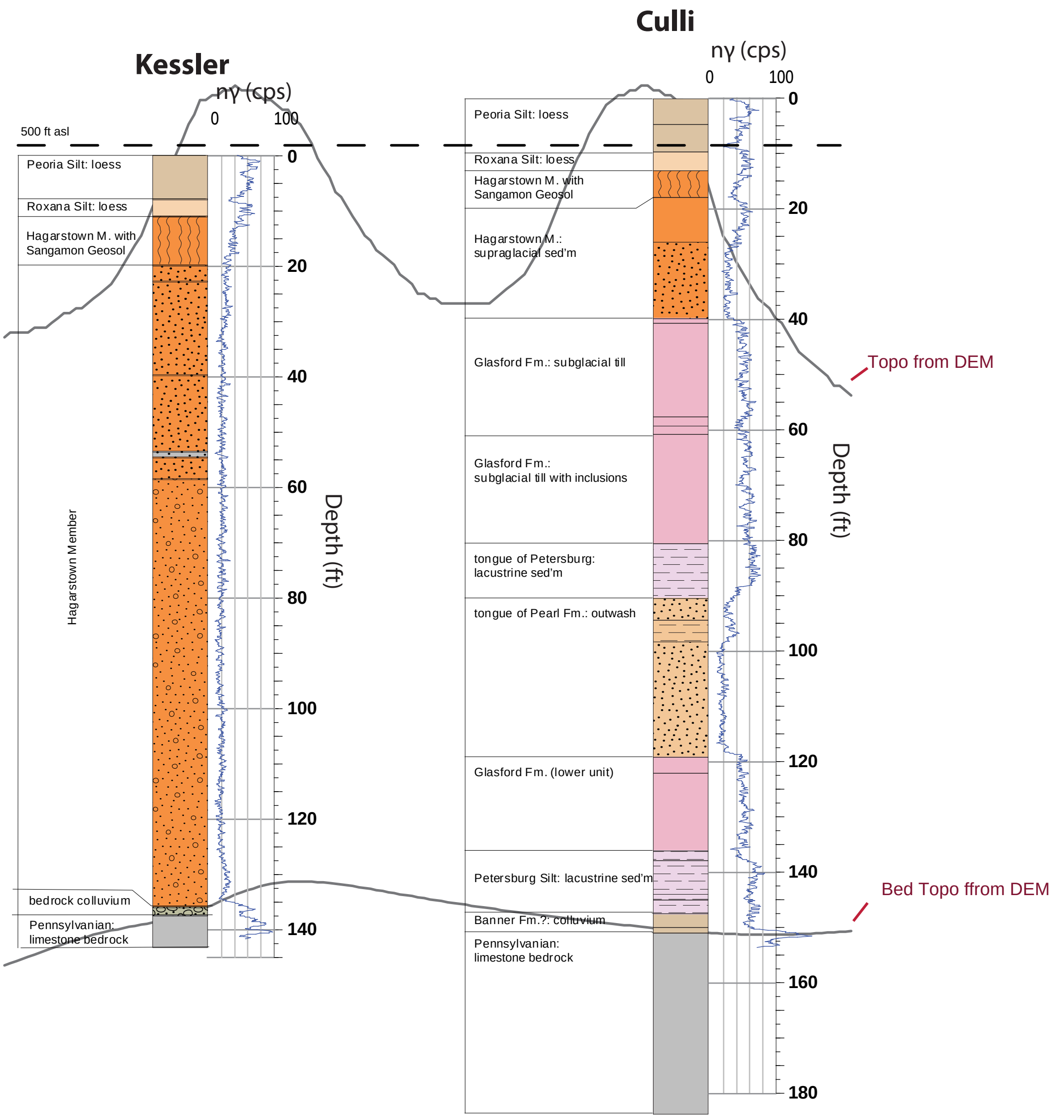
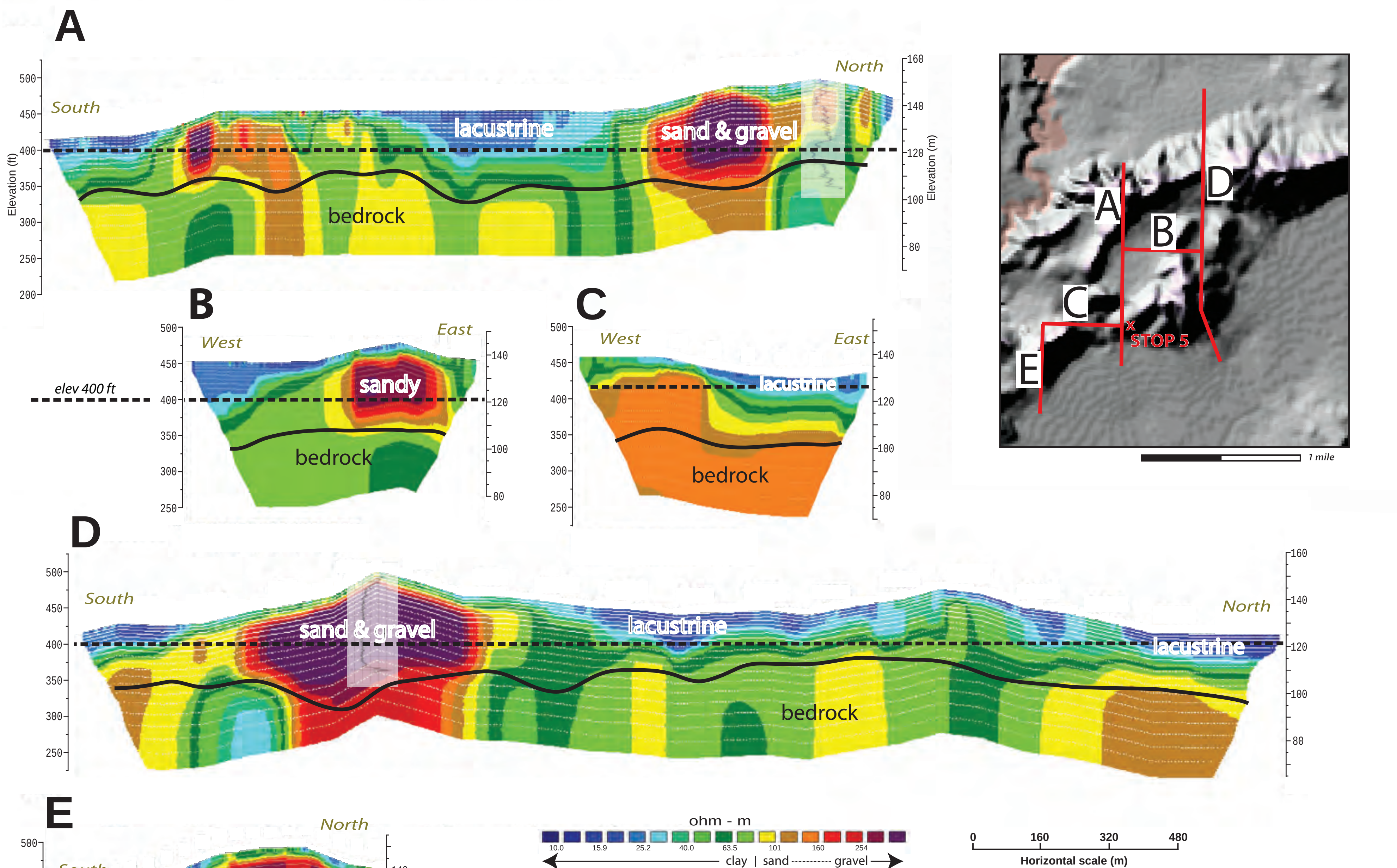


Figure 5.2. Stratigraphic column for the Culli and Kessler borings. The Culli boring is on Pleasant Ridge proper (morainal), whereas the sand- and gravel-rich Kessler boring is on a large hill just south of Pleasant Ridge.



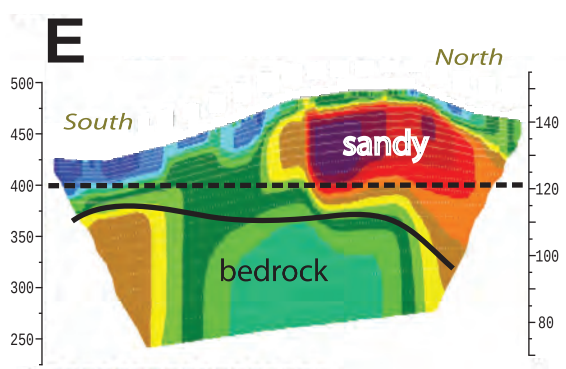


Figure 5.3 Resistivity profiles in the Pleasant Ridge area south of Mascoutah, IL. High resistivity areas (generally coarse-grained) have more reddish colors. The color legend differs from that used in Figures 2.5 and 7.5. The dashed line at 400 feet (122 m) is the approximate elevation of nearby Silver Creek. Distances are in meters.

STOP 6 : Highbanks Road Section (David Grimley and Elizabeth Geiger)

PLEASE USE CAUTION AT THIS SITE -- SLOPES MAY BE VERY SLIPPERY IF MOIST OR WET (MOST UNITS ARE SILTY OR CLAYEY)

Introduction

The Highbanks Road Section is on the Mascoutah 7.5-minute Quadrangle in the SW, SW, Section 22, T1S, R6W in St. Clair County, Illinois (Fig. 6.1). This site was discovered during mapping of the surficial geology of the Mascoutah Quadrangle (Grimley, 2010). The section contains an extensive exposure, several hundred feet long and up to 35 feet high, of mostly last glacial slackwater lake deposits (Equality Formation) along a northward eroding cutbank of the Kaskaskia River. These deposits contain a record of deposition and paleoenvironment during the existence of glacial Lake Kaskaskia during the Wisconsin Episode. The actively meandering Kaskaskia River has led to 100 to 200 feet of erosion northward here during the last 20 years (based on orthophoto comparisons), resulting in slumping of the soft banks and destruction of a small road and several cabins over recent decades. The elevation of the terrace surface and the top of the described section is about 405 feet asl. Although this site reveals mainly last glacial slackwater lake deposits, periods of fluvial deposition are also recorded within the last glacial sequence. Holocene alluvium (Cahokia Fm.) can also be viewed cut into a terrace deposit at the western or downstream portion of the section. Several well exposed Holocene alluvial sections can be seen by canoeing downstream along the Kaskaskia River between here and Fayetteville.

Geologic Strata

The geologic strata exposed at the Highbanks Road Section are divided into five units: units A (oldest) through F (youngest) (Figs. 6.2, 6.3). At the base of the section, about 3 feet (1 m) of well sorted sand (Unit A) are exposed at low stages of the Kaskaskia River. Once interpreted as the Pearl Fm. (Grimley, 2010), Unit A has been reinterpreted as the Henry Fm. (Wisconsin Episode) based on younger than anticipated radiocarbon ages in the overlying units in a seemingly conformable sequence. The Henry Formation sand continues below the river level to an unknown depth. Sandy deposits in the lower Kaskaskia Valley can be 50 feet or more thick (Larson, 1996; Grimley, 2010; Grimley and Phillips, 2011), with basal portions probably of Illinois Episode age.

Units B through F are mainly lacustrine sediments (Equality Fm.) deposited during the last glacial maximum. Unit B is an interbedded sand and silt loam that varies from 0.5 to 1.5 feet (0.2

to 0.5 m) thick. Above that are 6 feet (2 m) of silty clay loam in Unit C. The next younger strata is a fossiliferous silt deposit, Unit D, containing reddish brown nodules and about 6 feet (1.9 m) thick. Unit E contains abundant molluscan fossils and so was the primary focus of study. Unit E is about 10 feet (3.2 m) thick and is subdivided into three units: E1 (lowest) is a calcareous silty clay loam with a one-inch layer of secondary carbonate; E2 is a laminated silt that contains interbedded very fine sand (probably fluvial or deltaic); E3 contains a more clayey zone within mostly laminated silt. Unit F, the uppermost unit at the section, is a 12 foot (3.6 m) thick dark brown, silty clay loam to silty clay that is laminated, with common secondary carbonate concretions (especially near the basal contact), and hackly structure. The clayey, smectitic material is highly fissured from shrinkage when dry. The modern soil solum is contained within uppermost Unit F. The uppermost foot (0.3 m) of the soil is silty and could be interpreted as eolian (loess), but due to weathering, an interpretation of waterlain silt is difficult to rule out.

Description of Highbanks Road Section:

Based on field descriptions by David Grimley on November 8th, 2005 and Elizabeth Geiger in May 2006; large cutbank (several hundred feet or more wide) along Kaskaskia River; near intake for water treatment plant; river level ~ 372' from topographic map; base of section at river level.

API 121633027500; **ELEVATION** 405TM; **FIELD ID**: MSC3f
LATITUDE 38.425236 N **LONGITUDE** 89.756133 W

0 to 1 feet Peoria Silt ?, heavy silt loam, dark brown, A and E horizons of modern soil profile

1 to 10 feet UNIT F of Equality Formation, silty clay loam, brown, thickly bedded, contains multiple alluvial deposition events and paleosols

10 to 18 feet UNIT E of Equality Formation (E1, E2, and E3); 1.5 to 4.0 tsf, contains fossil mollusks (mainly aquatic) including *Fossaria*, *Pomatiopsis*, and small fingernail clams;

E3 (upper): silt loam, light olive brown (2.5Y 5/4), well sorted, calcareous, laminated; fossiliferous w/ gastropods are concentrated in a bed near top of unit

E2 (middle): silt, light brownish gray (10YR 6/2); well sorted, dolomitic to calcareous, contains zones of very fine sand, cross-bedding in some areas (dipping to east)

E1 (lower foot): silty clay loam, with a one-inch layer of secondary calcium carbonate; yellow (2.5Y 7/6), well sorted, fossiliferous

18 to 23 feet UNIT D of Equality Formation, silty clay loam to silty clay; light yellowish brown 2.5Y 6/3 to 10YR 5/4; weakly dolomitic; contains few fossil mollusks, some iron nodules (7.5YR 6/8)

23 to 30 feet UNITS B and C of Equality Formation, silty clay loam, 2.5Y 5/2 grayish brown to 5Y 4/1 (dark gray), leached to slightly calcareous; some secondary carbonate and iron nodules; basal 0.5 foot is a noncalcareous, yellowish brown (10YR 5/4), silt loam

30 to 33 feet UNIT A: Henry Formation, medium sand, well sorted, leached, 10YR 7/6 (yellow), base of unit at Kaskaskia River level (11/8/2005).

Paleontology / paleoecology

The molluscan fauna and associated paleoecology was studied by Geiger (2008). This study focused on the gastropod fauna, although small bivalves (*Pisidium* sp. and *Sphaerium* sp.) were also present. Four large grab samples (one-gallon bags) were collected from zones with visibly abundant gastropod shells in Unit E1 (HBC-1, HBC-2) and Unit E3 (HBC-3) in May 2006, and in Unit D (HBC-4) in November 2006. After soaking in water for 48 hours in the laboratory, samples were wet-sieved and the collected shells were identified and catalogued. Subsequently, AMS radiocarbon dates were obtained on some shells in Fall 2010 to provide age constraints on glacial Lake Kaskaskia.

Most mollusk shells are < 1 cm, except *Stagnicola elodes* is up to 1.5 cm in length. The results of the molluscan study (somewhat revised from Geiger (2008) after further study) are reported in Table 6.1. Extremely minute (~ 1 - 2 mm) juvenile individuals of various species are not reported in Table 6.1. For instance, hundreds of minute juveniles of *Fossaria* sp. and *Stagnicola* sp. were found in sample HBC-2, probably indicating a period of rapid deposition.

Unit D, the oldest unit sampled (HBC-4), has a molluscan assemblage dominated by *Valvata tricarinata*, *Fossaria* sp., and *Gyraulus parvus*, with minor occurrences of *Physella gyrina*. This assemblage suggests perennial lake conditions (genera *Valvata* and *Gyraulus* have gills rather than lungs) with high alkalinity (Cvancara, 1983). A few individuals of *Catinella avara*, sometimes found along vegetated lakeshores (Burch and Jung, 1988), suggest minor wash-in from a nearby shore. Overall, the assemblage is consistent with a large slackwater lake that contains aquatic vegetation as a food source and habitat. The lake existed during the last glacial maximum, based on a radiocarbon age of 21,340 +/- 140 ^{14}C yr BP (ISGS-A1652) on *Valvata tricarinata* shells with $\delta^{13}C = -8.0$.

In Unit E1, one sample (HBC-2) has primarily freshwater aquatic species, whereas the other sample (HBC-1) has a mixture of terrestrial and shallow aquatic species. HBC-2 is dominated by *Fossaria* sp., *Gyraulus parvus*, *Helisoma anceps*, *Physella gyrina*, and *Stagnicola elodes*. Minor occurrences of terrestrial species, such as *Vertigo eliator* and *Vertigo modesta*, are also found. Overall, the implied environment is a shallow lake with some species washing in from nearby muddy lakeshores (i.e., *Oxyloma retusum*). The lake level likely fluctuated, with some aquatic species having lungs (*Helisoma anceps* and *Stagnicola elodes*), and thus able to withstand temporary lake conditions. The presence of *Planorbula armigera* indicates a eutrophic lake (Cvancara, 1983). Climatically, the occurrences of northern species *Fossaria galbana* (common name: Boreal Fossaria) and *Vertigo eliator* point to a modern analog in the northern Great Lakes region, western Ontario or Manitoba (Burch, 1989; Nekola and Coles 2010). *Stagnicola elodes* shells in Unit E1 were radiocarbon dated at 19,020 +/- 110 ^{14}C yr BP (ISGS-A1650), with $\delta^{13}C$ = -9.4.

The presence of an individual of the terrestrial species *Columella alticola* in sample HBC-1 (Unit E1) further substantiates cold, moist conditions during the last glacial maximum (LGM). *Columella alticola* has a present distribution in northern portions of Quebec, Ontario and Manitoba (Nekola and Coles, 2010), as well as in high elevations of the Rocky Mountains (Hubricht, 1985). However, the presence of one individual should not be over-interpreted. Other indicator species include *Vertigo eliator* and *Vertigo modesta*, which have considerable abundance in HBC-1 and have distributions today in Ontario, Manitoba, and the northern Great Lakes area, with *V. modesta* restricted to mainly Canada (Nekola and Coles, 2010). The additional presence of *Carychium exile* suggests a moist area or spring at the base of a slope or edge of a floodplain. Lastly, the occurrence of *Fossaria* sp. (shallow lacustrine), *Pomatiopsis lapidaria* (amphibious), and *Stagnicola elodes* (shallow lacustrine) imply a fluctuating slackwater lake to shoreline environment. *Pomatiopsis* shells were radiocarbon dated at 20,010 +/- 120 ^{14}C yr BP (ISGS-A1649) with $\delta^{13}C$ = -6.1. This age is 1000 years older than the shells dated from sample HBC-2 that was collected 10 feet laterally in the same Unit E1 and so the actual subunit age may range from 20,000 to 19,000 ^{14}C years BP.

Unit E3 is the uppermost fossiliferous unit of the Equality Formation. The molluscan assemblage (sample HBC-3) records a return to shallow lacustrine conditions. Terrestrial and amphibious gastropods are absent, but the fossil concentration is very low in this sample. The presence of *Fossaria dalli*, *Physella gyrina*, and *Stagnicola elodes* all suggest shallow lacustrine conditions in a mesotrophic or eutrophic lake (Cvancara, 1983). A *Stagnicola elodes* shell was radiocarbon dated at 20,560 +/- 130 ^{14}C yr BP (ISGS-A1651) with $\delta^{13}C$ = -9.1. This age is slightly older than ages for Unit E1, suggesting minor hard water effects, rapid deposition, or slight reworking of shell material.

GENUS	SPECIES	HABITAT	HBC-3	HBC-1	HBC-2	HBC-4
			Unit E3	Unit E1	Unit E1	Unit D
GASTROPODS (total # discludes many immatures)			*8*	*225*	*405*	*103*
Carychium	*exile canadense*	terrestrial	0	31(4 iso)	1	0
Catinella	*avara*	terrestrial	0	15	0	6
Cochlicopa	*lubrica*	terrestrial	0	3	0	0
Columella	*alticola*	terrestrial (cold)	0	1	0	0
Columella	*simplex*	terrestrial	0	4	0	0
Discus	*whitneyi*	terrestrial	0	9	0	0
Euconolus	*fulvus*	terrestrial	0	2	0	0
Fossaria	*dalli*	shallow lake	4	30	0	0
Fossaria	*galbana*	shallow, cold lakes	0	0	31	0
Fossaria	*obrussa*	shallow lake	0	20	1	1
Fossaria	*parva*	amphibious	0	0	26	23
Gastrocopta	*tappaniana*	terrestrial	0	4 (2 iso)	2	0
Gyraulus	*hornensis*	perennial lake	0	0	6	2
Gyraulus	*parvus*	perennial lake	0	0	200	30
Helisoma	*anceps*	shallow lake	1	1	22	0
Nesovitrea	*electrina*	terrestrial	0	6	0	0
Oxyloma	*retusum*	lakeshore	0	0	17	0
Physella	*gyrina*	shallow lake	1	10	24	6
Planorbula	*armigera*	eutrophic lakes	1	5	19	0
Pomatiopsis	*lapidaria*	amphibious	0	34 (^{14}C)	0	0
Punctum	*minutissimum*	terrestrial	0	1	0	0
Stagnicola	*caperata*	shallow lake	0	0	12	7
Stagnicola	*elodes*	lake	1 (^{14}C)	4	39(^{14}C)	0
Vallonia	*sp.*	terrestrial	0	5	0	0
Valvata	*tricarinata*	perennial lake	0	0	0	28(^{14}C)
Vertigo	*eliator*	terrestrial	0	15 (3 iso)	5	0
Vertigo	*hubrichti*	terrestrial	0	20 (3 iso)	0	0
Vertigo	*modesta*	terrestrial (cold)	0	5	0	0
BIVALVES						
Sphaerium	*lacustre (~5 - 8 mm)*	eutrophic lakes	0	0	> 60	0
Pisidium	*casertanum (4-5 mm)*	lakes	0	0	> 20	0
Pisidium	sp. (< 3 mm)	lakes	4	6	0	0
OSTRACODS						
Candona	*caudata ?*	fresher water ?	0	0	>1	0
Candona	*caudita ?*	fresher water ?	0	0	>1	0
unknown ostracods			7	0	0	0

Table 6.1. Molluscan fauna from 4 grab samples (one-gallon bags) at the Highbanks Road Section. Fauna identified by E. Geiger and D. Grimley

Isotopic data

Carbon and oxygen isotopes were analyzed for several individuals of the genera *Carychium*, *Vertigo*, and *Gastrocopta* (all terrestrial species). All samples were from HBC-1 because this unit contained the greatest abundance of terrestrial gastropods. The original purpose of this study was to compare last glacial maximum shells with modern shells (of the same genus) in the same geographic area, in order to determined if significant climatic shifts (temperature or precipitation) are recorded in the oxygen isotope data. Modern shells have not yet been analyzed as of March, 2011. The *Vertigo* samples appear to have less variation than the *Carychium* samples. For *Vertigo*, the $d^{18}O$ varies between 0.7 and 2.6. The carbon isotope data is probably reflective of the gastropod diets (type of vegetation present).

Table 6.2. Carbon and oxygen isotopic data from gastropod shell carbonate.

Sample #	Sample ID	ISGS #	$\delta^{13}C_{VPDB}$	$\delta^{18}O_{VSMOW}$	$\delta^{18}O_{PDB*}$
HBC-1	C. exile (A)	KL008074	-6.76	33.31	2.33
HBC-1	C. exile (B)	KL008075	-5.37	27.54	-3.27
HBC-1	C. exile (C)	KL008076	-5.53	29.67	-1.20
HBC-1	C. exile (D)	KL008077	-6.67	29.76	-1.12
HBC-1	V. eliator (A)	KL008078	-6.59	32.32	1.37
HBC-1	V. eliator (B)	KL008079	-9.39	31.71	0.78
HBC-1	V. eliator (C)	KL008080	-8.55	32.31	1.36
HBC-1	V. hubrichti (A)	KL008090	-7.57	32.35	1.40
HBC-1	V. hubrichti (B)	KL008082	-9.40	31.08	0.17
HBC-1	V. hubrichti (B) Dup	KL008087	-9.17	33.63	2.64
HBC-1	V. hubrichti (C)	KL008083	-8.14	31.89	0.95
HBC-1	G. tappaniana (A)	KL008085	-7.53	32.95	1.98
HBC-1	G. tappaniana (B)	KL008086	-6.92	31.46	0.54

* Used conversion equation: $\delta^{18}O_{VPDB} = 0.97002 * \delta^{18}O_{VSMOW} - 29.98$ [Clark & Fritz 1997; Coplen et al, 1983].
isotopic values were calibrated based on NBS18 & 19 standards
Keith C. Hackley/ Shari Fanta, Isotope Geochemistry Section, ISGS (Jan. 2011)

Regional interpretations / conclusions

The Highbanks Road Section records the episodic deposition of the Henry and Equality Formations in fluvial and extensive lacustrine environments, respectively. Depositional environments in units B through F varied with fluctuating lake levels and include shallow lacustrine facies, near-shore facies, lakeshore facies, and brief periods of fluvial deposition (Unit E2). The deposition of units D and E is documented by radiocarbon dating to have occurred between about 21.5 and 19 ^{14}C ka BP, coincident with the last glacial maximum (LGM). This timing of Equality Formation deposition probably records a period of maximum onlap of Glacial Lake Kaskaskia in this area, located ~ 30 miles northeast of the confluence of the Kaskaskia and Mississippi Rivers. The spread in ages of ~ 2500 years over about 4 m (13 feet) of section thickness, suggests an average deposition rate of 1.6 cm (0.6 inches) per decade for units D and E. Based on the radiocarbon ages, the overlying, non-fossiliferous Unit F is likely latest Wisconsin Episode, but possibly may be early Holocene if found to be younger than 11,700 calendar years (Walker et al, 2009), equivalent to about 10,000 ^{14}C years.

The gastropod shell radiocarbon ages of about 21.3 ^{14}C ka BP for Unit D and ranging between 20.5 and 19.0 ^{14}C ka BP for Unit E (including subunits E1, E2, and E3) indicate that deposition is essentially coincident with the global LGM (Mix, 2001). Unit E is also synchronous with the advance of Wisconsin Episode glaciers in east-central Illinois to their southern terminus (Shelbyville Moraine), based on *Picea* wood and organic silt ages ranging from 20.6 to 19.3 ^{14}C ka BP below till at the Charleston Quarry (Hansel et al., 1999). This correspondence in age may suggest input of Lake Michigan Lobe sediment to Unit E from the upper Kaskaskia Valley, which would have drained a relatively small portion of the southwesternmost Lake Michigan Lobe (~500 mi^2) during this geologically brief time period. Units E2 and E3 have a distinctly lower clay content than units below (Appendix B) and include beds of very fine sand --- this may suggest more rapid deposition rates from a distal source of outwash that was transported southwesterly into Glacial Lake Kaskaskia. The faster deposition rates during this time period of enhanced sediment loads in the Kaskaskia River probably helped serve to quickly bury and preserve the molluscan shells. Alternatively, more rapid deposition could have been controlled by faster loess deposition and erosion into valleys as a result of more limited vegetation on landscapes during this time period. However, the distal glacial source is preferred as the dominant source for Unit E. Deposition of the more clayey units (units B, C, D, and F) perhaps represent times before and after peak glacial advance (time of unit E), when distal outwash inputs were minimal or nonexistent. During these periods, the Lake Michigan Lobe would not have been far south enough to provide glacial meltwaters to the Kaskaskia Valley; but rather would have ponded meltwater or discharged meltwater to the Wabash, Illinois, and other river valleys.

Based on the modern distribution of gastropod fossils (Nekola and Coles, 2010; Clarke, 1981), the climatic conditions during deposition of Units D and E were perhaps similar to that found today in western Ontario ~ 49 to 50 degrees latitude (north of Lake Superior). This region is far north enough to have cold-climate species *Fossaria galbana* (Burch, 1989), *Vertigo modesta*

(Nekola and Coles, 2010), and *Columella alticola* (Nekola and Coles, 2010), but south enough to be within the modern distribution of species such as *Gastrocopta tappaniana* (Nekola and Coles, 2010) and *Pomatiopsis lapidaria* (Clarke, 1981). The regions in Manitoba and Ontario between the Great Lakes and Hudson Bay is also a good analog for the boreal forest vegetation which are known to have been present in this area during the last glaciation based on numerous fossil wood finds of *Picea* and other paleobotanical records (Curry and Delorme, 2003).

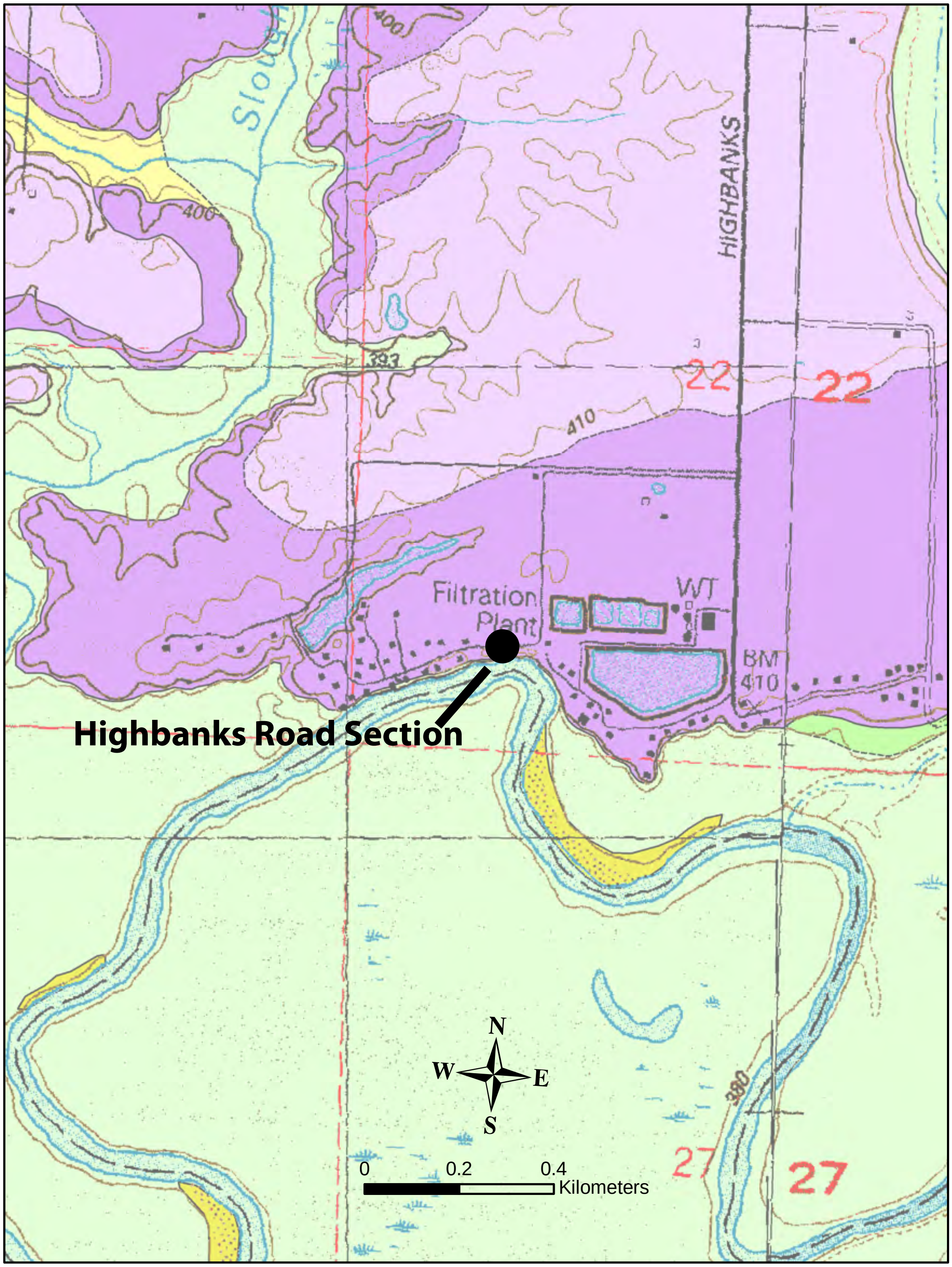


Figure 6.1. Location map of the Highbanks Rd. Section, St. Clair County, IL (STOP #6). Surficial geologic map (Grimley and Phillips, 2011) is overlain on a portion of the Mascoutah 7.5-minute Quadrangle. Areas shaded light and dark purple are last glacial terraces containing Equality Formation. Areas shaded yellow (sandy) and green (clayey) contain late Holocene alluvium.

Figure 6.2. Photograph of Highbanks Road Section. The light colored bed is the silty and fossiliferous Unit E.

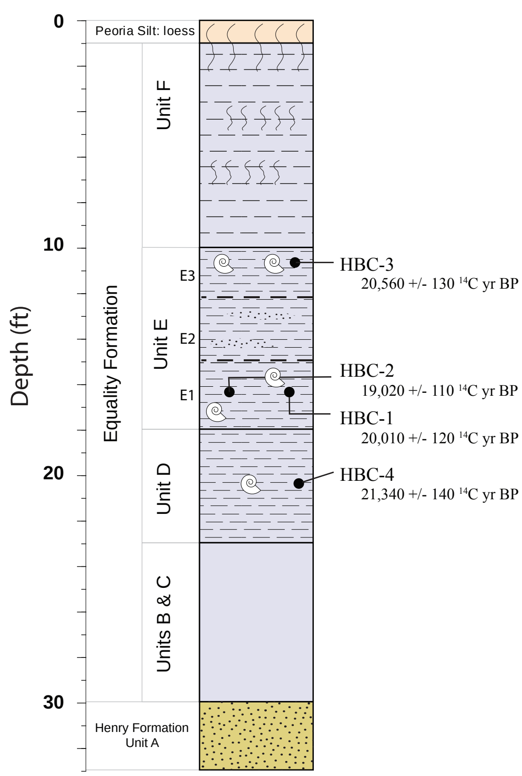


Figure 6.3. Stratigraphic column and location of mollusk collection sites at Highbanks Road Section.

DAY 2 ROAD LOG (May 22nd, 2011):

LEAVE MARINER'S VILLAGE MOTEL (8 AM)

- turn right on William Rd. [0.5 mi]
- turn right on IL-27 [16.9 mi]
- turn right and merge onto Interstate-70 towards Effingham [6.8 mi]
- take exit ramp at exit 52 (Mulberry Grove exit) [0.3 mi]
- turn left on Mulberry Grove Rd./ County Rd. 1900E [0.4 mi]
- turn right on US-40 east [0.9 mi]
- bear right onto County Rd. 700 E (sign to Hagarstown) [7.9 mi]
    - proceed under I-70 (former Mulberry Grove Section (Jacobs and Lineback [1969] on immediate right at former borrow pit wall;
    - pass through town of Hagarstown after a few miles
- turn right on County Rd. 700 E @ VFW Post #3862 [0.4 mi]
- turn left and go down into sand and gravel pit

STOP # 7: Vandalia Sand and Gravel Pit

- turn left and go south on County Rd. 700 E [0.9 mi]
- turn left on County Rd. 1375 N [0.1 mi]
- turn right on 715E/County Rd. 10/Fayette County Rd. 1 [1.5 mi]
- turn right on County Rd. 1275 N, becomes County Rd. 1300 N [0.8 mi]
- turn left on gravel rd. to office; then south on dirt rd. (weather permitting) to site [0.7 mi]

STOP #8: Central Illinois Materials Sand and Gravel Pit

- take dirt rd. south to paved rd. [0.1 mi]
- turn right onto County Rd. 1225 N, becomes County Rd. 1150 N [1.8 mi]
- pull off on grassy upland area on right side of road (an abandoned, or periodically used, small sand pit is found here on this ridge); overlooks circular basins to south and north

STOP #9: Pittsburg Basin

- go southwest on County Rd. 1150 N to County Rd. 1100 N [0.6 mi]
- turn left on County Rd. 300 E [2.0 mi]
- turn right at County Rd. 10./ County Rd. 900 N, pass through Pittsburg, road winds around and crosses creek [4.0 mi]
- turn left on Mulberry Grove Rd. (1900 E), becomes Mulberry St. [8.3 mi]
- Mulberry St. turns right and becomes W. Clinton St. [0.1 mi]
- turn left on Main St. [0.1 mi]

REST AREA / SNACK BREAK --- Keys Restaurant and Lounge

(nice view of lake from upstairs deck)

- turn around and go left (west) on W. Clinton St./Keyesport Rd. [1.0 mi]
- turn left at onto N. Emerald Rd., turn west after a couple miles [3.5 mi]
- at stop sign, turn left on Hopewell Rd. [1.0 mi]
- bear right on Marydale Rd. [0.5 mi]
- take first left onto Fisher Rd. [2.0 mi]
- turn right on Hazlet Park Rd. [0.3 mi]
- turn right into gravel driveway

STOP # 10: Sodium Affected Soils

- go west on Hazlet Park Rd. [0.6 mi]
- continue onto Lake Rd. [2.8 mi]
- turn right onto Resort Dr. [0.1 mi]; back at Mariner's Village Motel

LUNCH: enjoy in the adjacent park or take with you for the road ! have a safe trip home.

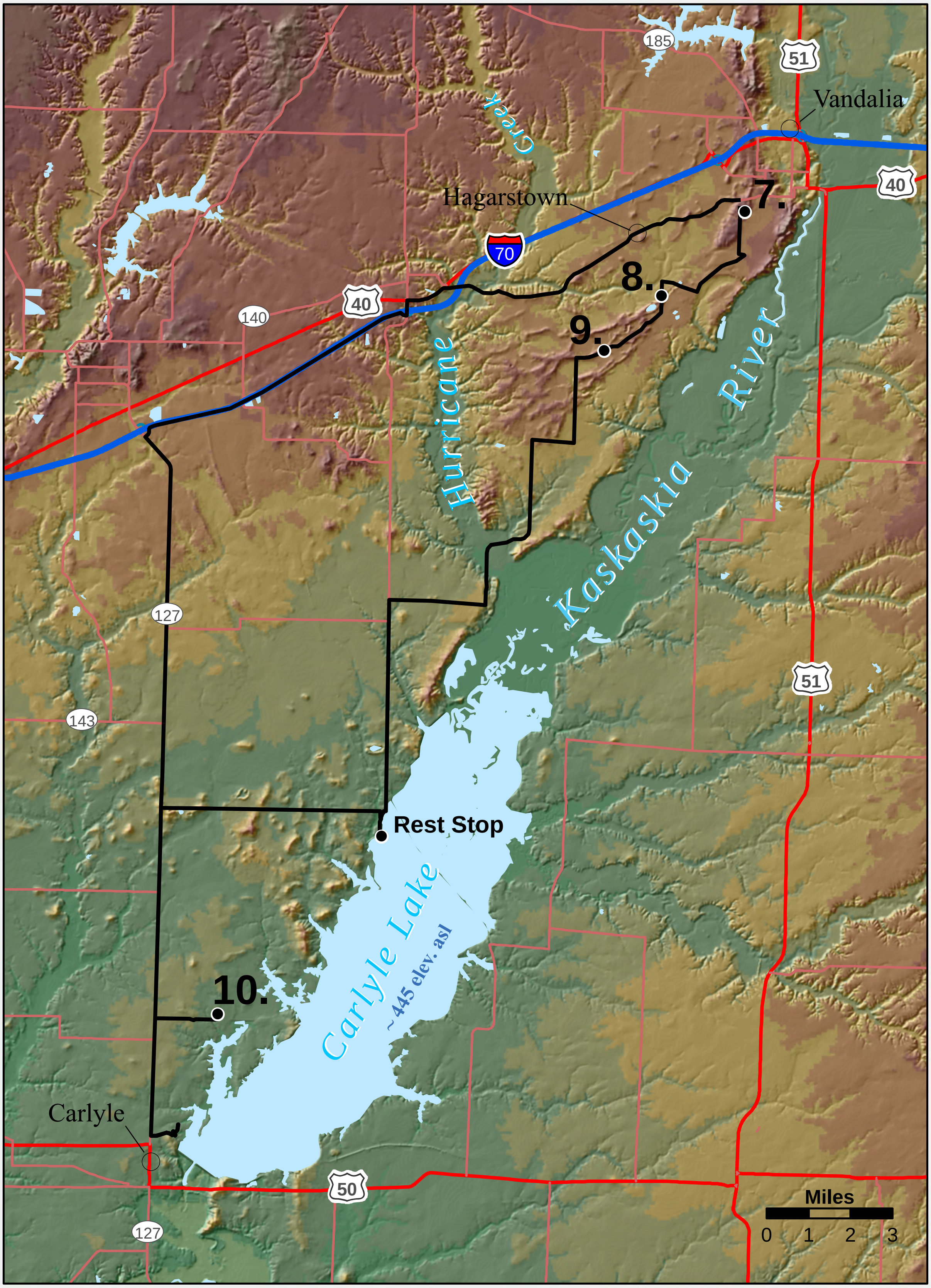


Figure DAY2. Location map of plannedtrip route for Day Two of the field trip. Colors are from 30m statewide digital elevation map. Higher elevations are in orange-red (to > 600 ft.) and lower elevations in green (to < 425 ft. SW of Carlyle Lake).

DAY 2 BACKGROUND: Illinois Episode Glacial Sediments and Landforms in the Vandalia Area

Geomorphology

A striking train of ridges arc southwestward along the west side of, and subparallel to, the Kaskaskia Valley near Vandalia (Fig. 7.2). From an arbitrary head at the peak of Thrill Hill immediately north of the Vandalia Geologic Area to the banks of Hurricane Creek, the train is ~17 km (11 mi) long. The train is comprised of three parts. Thrill Hill appears to be an amalgamation of several ridge forms, generally peaked and steep-sided. The Vandalia Geologic Area (Fig. 7.2) was designated by the ISGS and the Illinois Department of Natural Resources as representative of the "Ridged Drift" for the purposes of landscape preservation in the state (Department of Landscape Architecture, 1978). The impressive view is now enjoyed by subdivision residents. South of Vandalia the system transitions to Hickory Ridge, which is flat-topped, narrow, and with steep flanks. With summits ~650 feet elevation asl, the ridge stands about 125 feet in relief over the surrounding plain. The southwestern third of the system is an anatomizing, fan-shaped network standing 25-35 feet in relief over the surrounding plain (Fig 7.2). This network terminates gradually to about the edge of the Hurricane Creek valley. Within and around the fan-shaped network of thread-like ridges occur several flat-bottomed and mainly circular basins (*e.g.*, STOP #9). West of the main ridge belt, isolated hills or knobs and small subparallel ridges are dispersed across the landscape. In overall shape, the train of ridges appears to comprise a continuous feature, but is interrupted by several saddles. Sand and gravel is exploited from several pits along the train, some of which we will visit (STOPS #7 and #8). Another train of ridges, here referred to as the Kaskaskia Bluff ridges (Fig. 7.2), rise from the area immediately west of the Kaskaskia Valley wall and extend northwards, eventually amalgamating with the Thrill Hill complex. They are peaked rather than flat-topped, with higher summits than Hickory Ridge.

Landform-sediment assemblages

Based on limited data, the sediment thickness of the plain west of the Vandalia ridge system is 40 - 80 feet, thickening towards the Kaskaskia Valley as the bedrock deepens. The bedrock lithology is predominantly shale. Pre-Illinois Episode till, distinguished from overlying deposits by occurrence of the Yarmouth Geosol, was described from an outcrop on the western valley wall at the Vandalia Bridge Section (Jacobs and Lineback 1969). However, the pre-Illinois Episode till has not been readily identifiable within the area of Hickory Ridge, probably being cutout. Two till members of the Illinois Episode Glasford Formation have previously been described across the map area (Jacobs and Lineback 1969). These till units have a total thickness of ~30 feet where described, and are loam to clay loam diamicton that were distinguished mainly by clay mineralogy and texture. Overlying the Glasford till, sand with gravel deposits typically 15 feet thick are ubiquitous. These outwash deposits are classified as the Pearl Formation. The upper portion is typically strongly weathered by the Sangamon Geosol. The weathered sand, locally known as "red dog", with uses including baseball infields, locally has accumulated sufficient illuvial clay to be described as pedogenic diamicton (typically clay loam texture in a Sangamon Bt horizon).

In some geotechnical borings along Interstate 70 west of Vandalia (Fig. Day2), 3 to10 feet of silty clay, possibly organic, were described, presumably within or below the Sangamon Geosol. These lacustrine to alluvial deposits occur at least locally across the plain west of the Vandalia ridge system (Fig. 7.2). Jacobs and Lineback (1969) mapped lacustrine sediments in a flat-bottomed basin between Hickory Ridge in the Vandalia ridge system and the Kaskaskia Bluff Ridges (Fig. 7.2). This basin is in a reasonable geomorphic position to be an ice-marginal lake. Furthermore, the upper reaches of Raccoon Creek, that cuts the saddle between Hickory Ridge and the ridges in the ice-contact fan, are geomorphically compelling as a spillway for the drainage of that lake. Larson (see STOP #7), however, concluded that the basin is underlain by 10-130 feet of sand, likely fluvial in origin.

Kettle lake deposits also dot the landscape, particularly entwined in the anatomizing threads of the southern train. When geologists investigated the area in the early 20th century (e.g. Mackintosh, 1927, ISGS field notes), several of the basins were still closed and undrained. Most basins have since been opened to provide drainage for agriculture. Due to excellent preservation in sub-water table unoxidized conditions, lacustrine deposits in the kettle basins contain unusual and important records of the fauna and flora from the Wisconsin, Sangamon, and late Illinois Episodes (see STOP #9).

Ridge deposits across southwestern Illinois vary from sand and gravel- to diamicton-dominated. Aspects of his regional variability were recognized by early researchers including Leverett (1899) and Maclintock (1927). Jacobs and Lineback (1969) described the Vandalia area ridges as composed of well-sorted gravel or sand that grades into gravelly till between the ridges. Recent investigations have shown that not all of the ridges are dominated by sorted sand and gravel, and that sorted sand and gravel occur between ridges on the surrounding plain (T. Larson, STOP 7; Stiff 1996; Grimley and Phillips, 2011).

Jacobs and Lineback (1969) distinguished four sediment-landform associations within the "Hagarstown beds" in their Vandalia area study: 1.) gravelly till – drift plains, 2.) poorly sorted gravel in drift plains near ridges, 3.) well sorted gravel in elongate ridges, and 4.) sand in drift plains near Mulberry Grove. These units have graded facies relationships and their distribution was interpreted as representing a drainage system on top of stagnant glacial ice (Jacobs and Lineback, 1969). Reworking of sediments in ice-walled channels caused sorting and distribution into elongate bodies and mounds (kames). Post-depositional melting of the ice caused mass wasting and topographic inversion. They interpreted intact cross-bedding to indicate widespread glacier stagnation, with local ice blocks in nearby kames suggesting local ice thrusting over stagnant ice. Mean cross-bed dip vectors, along with sub parallelism to the Kaskaskia bedrock valley, indicate drainage towards the southwest. All uplands are blanketed by a surficial cover of 3 to 9 feet of Wisconsin Episode loess, containing the modern soil profile. This loess cover is thick enough to preserve, nearly intact, the Sangamon Geosol developed into the upper part of the Illinois Episode glacial ridge deposits. The last glacial loess in this area provides just enough separation of the Sangamon Geosol and modern soil sola so that there is little overlap in primary horizonation and thus are clearly distinguished in most areas.

STOP 7: Vandalia Sand and Gravel Pit

(Andrew Phillips, David Grimley, and Tim Larson)

Historical exposure

The Vandalia sand and gravel pit (Vandalia Sand and Gravel, Inc.) was the location of Jacobs and Lineback's (1969) Hickory Ridge Section. The area of their study sits probably just south of where the scale and office are located (currently an open area with slightly vegetated highwalls). The deposits we can view today in the eastern part of the pit appear to be fairly similar in character, but perhaps slightly more sandy and less gravelly (Fig. 7.3).

The Hickory Ridge Section was identified as the type locality for the Hagarstown Member of the Glasford Formation (Jacobs and Lineback, 1969; Willman and Frye, 1970, p. 58), later reclassified within the Pearl Formation (Killey and Lineback, 1983). Both Jacobs and Lineback (1969) and Willman and Frye (1970) noted the gravel pit exposure to be located at SW, NW, Section 30, T6N, R1E. However, the inset map of Jacobs and Lineback (1969, p. 4) show the site one mile northeast in Section 20 where the Vandalia Gravel pit is currently located and has been operating for several decades. There are no potential outcroppings in the NW quarter of Section 30 and so we feel confident this location was a typographic error and should have been Section 20.

According to the owner Michael Themig, and generally confirmed by aerial photography, excavation of sand began in the 1930s as a dryland operation in the southeastern end of the Vandalia Sand and Gravel pit (Fig. 7.1). The operators expanded northwards in 1970, just after Jacobs and Lineback described the type section, and they may well have described the northern face that is visible in aerial photographs from 1973. Much of the current demand for the sand is for concrete production.

Reformatted description of the Hagarstown Member type section (Jacobs and Lineback, 1969):

Peoria and Roxana Silts *(Wisconsin Episode)*
Silt and loess ……………………………………………...... 0 to 3 feet

Hagarstown beds *(Illinois Episode)*
Gravel, silty and clayey, brownish red, poorly bedded and cross-bedded, noncalcareous; B-zone of Sangamon Soil in upper 6.6'………………………… 3 to 13 feet

Gravel and sand, well sorted, very light brown, cross-bedded, largely uncemented, calcareous; intermixed in thick lenses, base of section…………………….... 13 to 33 feet

Current exposure (2010-2011)

The pit in 2011 is excavated into the east flank of a wide (maximum width ~0.5 mi), elongate (~1.9 mi), flat-topped ridge segment that rises ~50 feet above the plain to the west, but only ~30 feet above the basin to the east (Figs. 7.1, 7.2). The ridge top includes several flat-bottomed depressions that are consistent with a kettle origin. Soils mapped on top of the ridge indicate ~ 5 feet of loess over paleosol developed in sand (Soil Survey Staff, 2011b).

Dredging began in the northern part of the pit in about 1990. The dredge typically excavates from depths of 35-40 feet below water level. The dredge reached as deep as 53 feet in the northeast corner. “Blue clay”, which could be till, lake sediment, or possibly weathered shale (see T. Larson; Fig. 7.5), occurs below this level.

Here we will have an opportunity to examine the edge of a large sand-dominated ridge (Fig. 7.3.). We will have access to the pit wall on the southern end of the dredge area. The overlying loess is sometimes visible below this cover (~ 30 feet) of spoil or fill from previous mining. The lower part of the Sangamon Geosol developed in sand, and the more unweathered (but oxidized) sand below are more accessible (Fig. 7.4a). We will find intercalated gravel and sand beds that generally fine upwards within multiple sequences or pulses of deposition (Figs. 7.4b,c). We will look for sedimentological clues to interpret flow dynamics and discuss englacial versus subglacial origins. One difference between the present section and the historical Hickory Ridge Section (Jacobs and Lineback, 1969) is that the latter section was described as predominantly gravel, implying less sand than we observe today. Possibly, the Hickory Ridge Section was located more near the center of the ridge, and thus in the area of higher flow velocities.

A brief description was made at the section available for study in Fall 2010.
About 30 feet of mine spoil caps the natural sequence of deposits described below:

below original ground surface (approx. elevation of 575 ft.):

0- 6 feet: Peoria and Roxana Silts [loess], silt loam, yellow brown to brown, contains modern soil solum in upper part; partially truncated by anthropogenic activity [loess]

6-12 feet: Sangamon Geosol developed in Hagarstown M., Pearl Fm.[ice-contact]; gravelly clay loam, reddish brown; Bt and BC horizons of Sangamon Geosol, included weathered beds of fine and medium sand;

12 - 35 feet (base at lake level): Hagarstown M., Pearl Fm. [ice-contact]; alternating beds of sandy gravel and fine to medium sand; the gravelly beds are 1 to 5 feet. thick; the fine-medium sand beds are 2 to 8 feet thick, well sorted, yellow-brown (10YR 5/4-6/4), cross-bedded, and include a few thin layers that contain small blocky coal fragments (< 5 cm); Sampled for OSL at ~ 20 feet (VSG-2) and 29 feet depth (VSG-1) in areas of well sorted fine or medium sand (photos of sand in Fig. 7.4d); unit measured base is at the lake level.

OSL sample (VSG-2) at ~20 feet depth from well sorted medium sand, light yellowish brown (10YR6.4); about 5 inches above a fine sand bed and 18 inches below a sandy gravel bed. [Easting = 316333 m ; Northing = 4313657 m; UTM16, NAD83]

OSL sample (VSG-1) at ~29 feet depth in fine sand to medium sand, cross-bedded, well sorted, yellow brown (10YR5.5/4), a layer of blocky coal fragments up to 5 cm occurs within adjacent sand beds (not in layer sampled). Laterally about 75 feet east of VSG-2. [Easting = 316357 m; Northing = 4313659 m; UTM16, NAD83]

35 to 75 feet (all below lake): Hagarstown M., Pearl Fm. [ice-contact]; sand and gravel mined up to 40 feet below lake level from dredging (according to operator Mike); material excavated is mostly sand with about 15 % gravel; hit "blue clay" at bottom which could be till [Glasford Fm.], lake deposit [Petersburg Silt] or weathered shale.

Luminescence ages

Optically stimulated luminescence ages were measured from Hagarstown Member sand samples VSG-1 and VSG-2 at 20 feet (6.1 m) and 29 feet (8.8 m) depth, respectively, below original ground surface. The ages are 177 +/- 15 ka (ISGS-71) for VSG-1 and 163+/-15 ka (ISGS-72) for VSG-2, although both samples were probably deposited within a few decades of each other. The OSL ages (Table 7.1) for Illinois Episode deposits are not as precise as for younger OSL ages, but do confirm the deposition within OIS Stage 6. Based on global records of ice volume within OIS 6, which indicate more extensive ice volumes within the latter half of OIS 6 (Martinson, 1987), we favor the younger age range for the Illinois Episode glacial deposits (*i.e.*, closer to 150 ka than to180 ka). OSL ages were also measured from similar glacial ridge-forming sandy deposits (Hagarstown Member) at the Munie Sand and Gravel Pit, about 30 miles to the southwest in the Grantfork Quadrangle within Madison County (Grimley and Phillips, 2005). The OSL ages from the ice-contact sand deposits at the Munie Pit were determined as 140 +/- 11 ka (ISGS-73) for sample MGP-1 and 125 +/- 10 ka (ISGS-74) for sample MGP-2, taken only seven inches laterally from MGP-1. The more reasonable Munie Pit MGP-1 age is still slightly younger than expected, though it fits within late OIS 6 when the error bars are considered. Conceptually, by recessional morainic relationships, we believe that the ridge dated at Munie Pit is actually slightly older (but probably no more than a few thousand years older) than the Vandalia area ridges. It is thus perhaps reasonable to average the sets of ages together to provide an approximate age for the entire Kaskaskia Basin ridge system. The mean and standard deviation of the 4 ages (177, 165, 140, and 125 ka) is 152 +/- 24 ka. The mean and standard deviation for 6 OSL ages on ice-contact sand deposits (Hagarstown M.) in the region, including 154 and 147 ka from UNL analyses at the Keyesport site (STOP #1), is 151 +/- 18 ka. This leads to a reasonable age estimate for the Illinois Episode glaciation between 133 ka to 169 ka --- clearly within the range of peak global ice volumes during the penultimate glaciation. The ages in the Kaskaskia Basin are also similar to those reported by McKay and Berg (2008) and McKay et al. (2008) for Illinois Episode deposits in the middle Illinois River valley region.

Electrical resistivity imaging

Approximately 10,600 m (over 6.5 miles) of continuous resistivity data were acquired on eight profiles using the dipole-dipole electrode configuration with an ABEM 3000 meter and LUND imaging system (one profile with ABEM 4000 meter system), subsequently processed with RES2DINV software (Loke and Barker, 1996). The profiles link together to form two long north-south profiles and one long west-east profile across plains and ridges south of Vandalia, one short profile along the Kaskaskia River floodplain, and one short profile ascending the bluff (Figs. 7.2, 7.5) One of the north-south profiles (Fig. 7.5a) continues north along the large ridge which has been extensively mined at the Vandalia Sand and Gravel pit (Fig. 7.2). Geologic information along these profiles is provided from logs of water wells. A heavy dashed line across all of the profiles at an elevation of 470 feet (142 m) marks the approximate level of the Kaskaskia River.

In general, the resistivity profiles are characterized by zones of elevated resistivity highlighted in yellow, orange, and red. Several areas with very high resistivity values are 30 to 50 feet (10 to 20 m) thick, and so we have used a different resistivity color scale for this figure compared with STOPS #2 and #5. Similar very high resistivity values were recorded in the ridges south of Pleasant Ridge (STOP #5), but were more limited in extent. As expected, high resistivity deposits dominate Profile (e) near the sand and gravel pit. However, similar deposits also extend beneath the plain to the southeast in Profiles (b), (c), (d), and (e). The very high resistivity values could be caused by thick, coarse sand and gravel, unsaturated sand and gravel, cemented sand and gravel, or a combination of these.

The very high resistivity deposits do not extend to the southwest in Profile 2. Materials in a small rise crossed in Profile (a) could be the southern continuation of the ridge crossed in Profile (e). These materials have elevated resistivity (highlighted in yellow), but not to the same magnitude as beneath the main ridge. However, these moderately high resistivity values are similar to the resistivity values obtained beneath Grandview Farm north of Lebanon (STOP #2) and beneath several of the ridges south of Mascoutah (STOP #5).

A series of ridges south of Vandalia intersect the west bluff of the Kaskaskia Valley. Resistivity Profiles (c), (f), and (d) were designed to investigate the deposits within these ridges. As expected, an area of very high resistivity was found beneath the southern end of Profile (d). This area of very high resistivity is beneath the ridge and continues south to the face of the bluff. Preliminary interpretation of this zone of very high resistivity is a deposit of unsaturated sand and gravel. A similar area of very high resistivity beneath Profile (f) extends from the north, beneath the flat, but not beneath the ridge at the river bluff. Profile (g), though very short, is similar to Profile (f). A preliminary interpretation of these profiles is that the northern ridge in this area is not cored with sand and gravel, but is composed primarily of low-resistivity diamicton. The very low resistivity deposits encountered beneath the flood plain on Profiles (f), (g), (h) and to a lesser degree, Profile (f), suggests that the sand and gravel deposits are restricted to higher stratigraphic levels with fine-grained deposits on the edge Kaskaskia River floodplain.

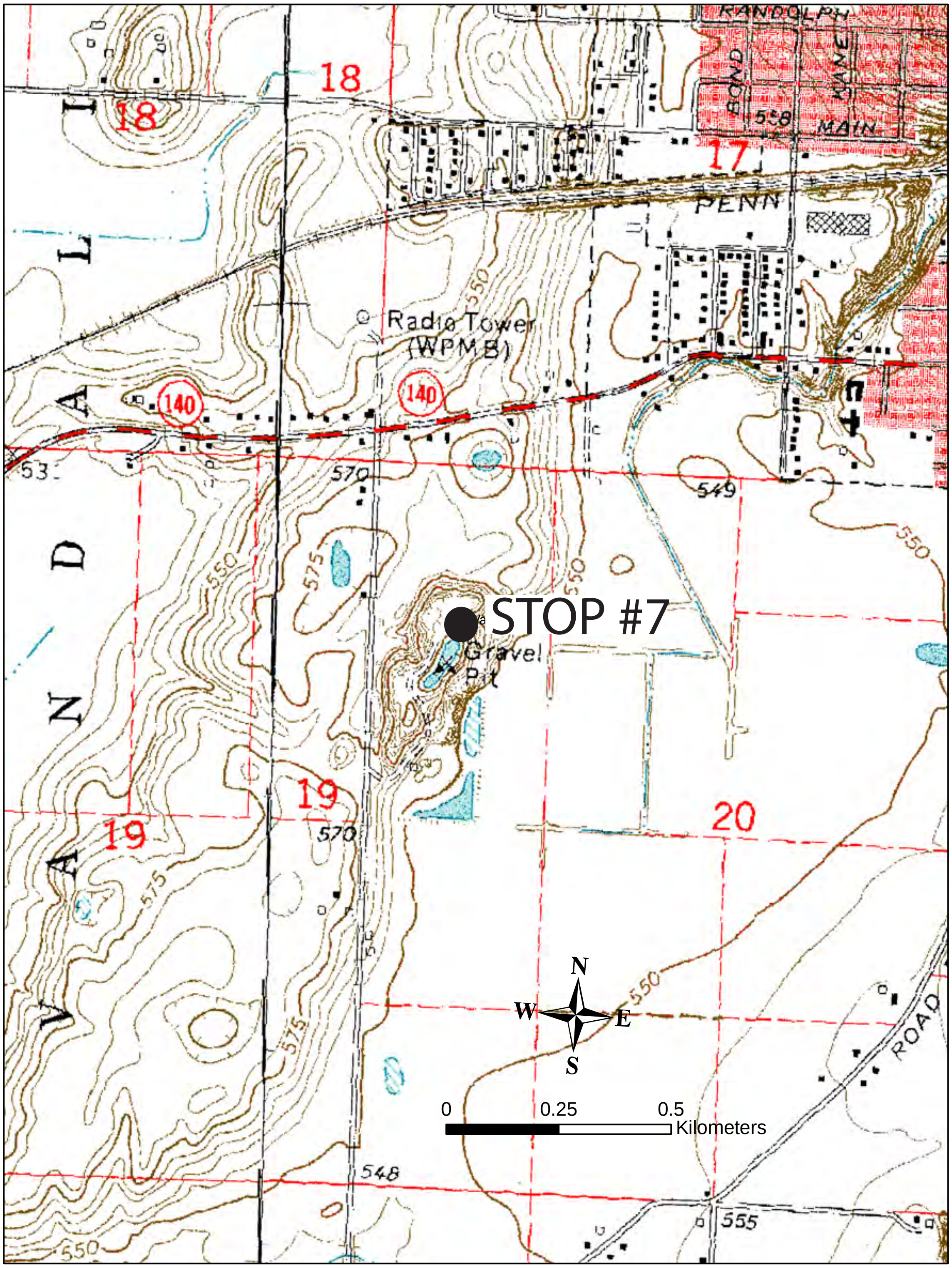


Figure 7.1 Location map for Vandalia Sand and Gravel Pit, Fayette Co., IL (STOP #7).

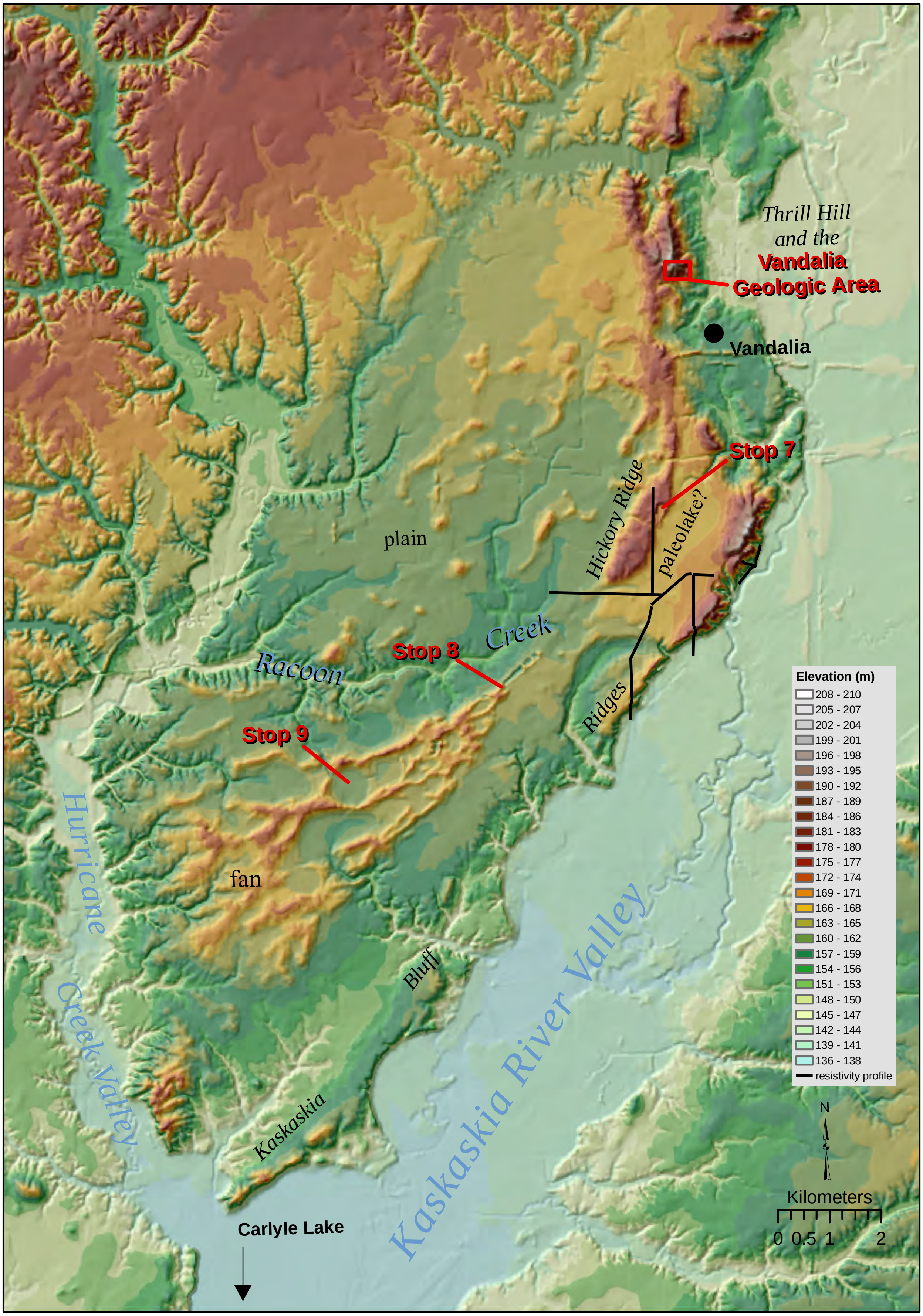


Figure 7.2. Digital elevation map of the Vandalia ridge system, including esker and terminal fan. (STOPS 7, 8, and 9 labeled). Electrical resistivity lines of Figure 7.5 shown in black.

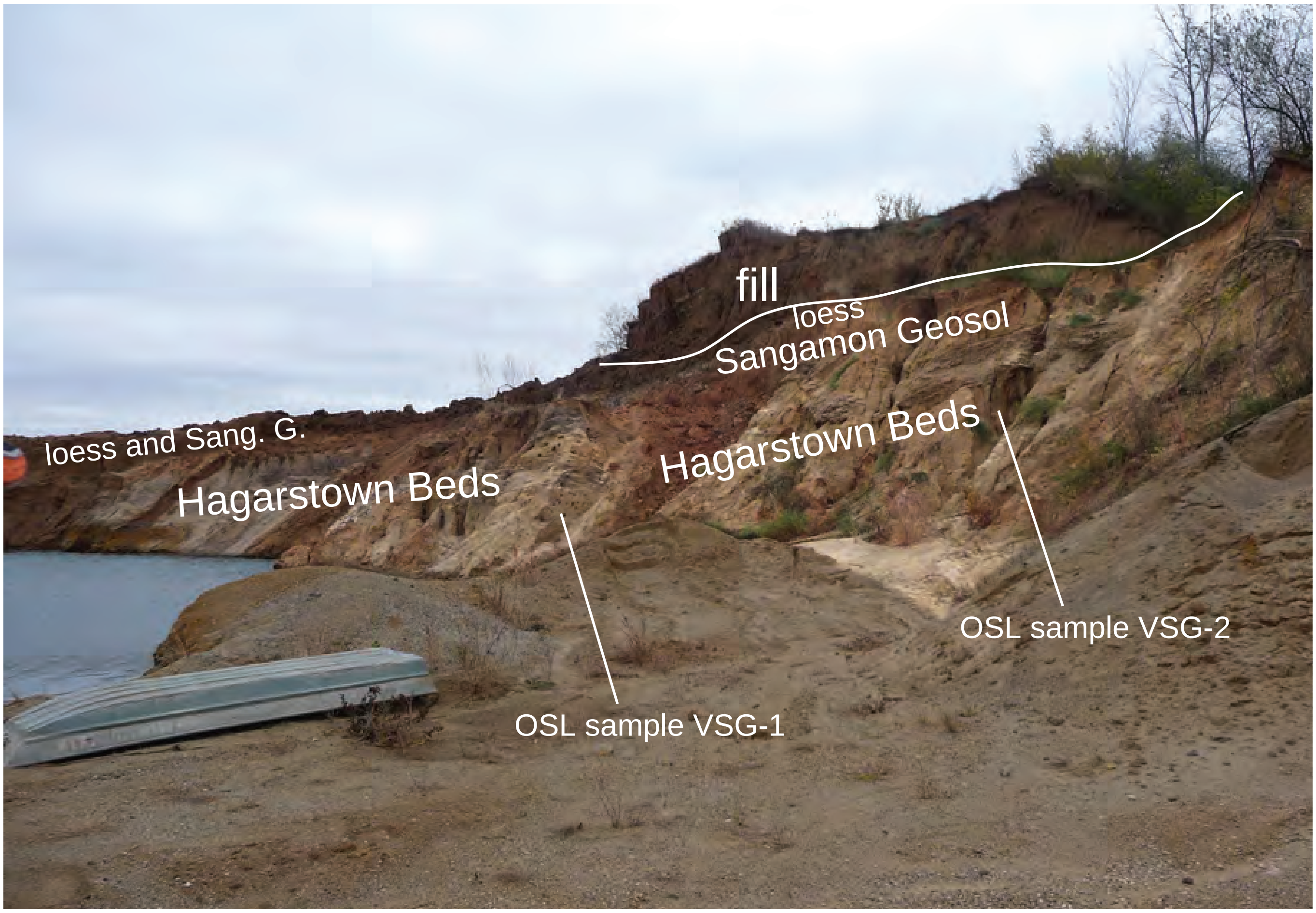


Figure 7.3. View of the active wall at the Vandalia Sand and Gravel Pit. Reddish brown Sangamon Geosol in the upper portion of interbedded sand and gravelly sand of the Hagarstown Member, Pearl Formation. Beds are 3 to 7 feet thick and several can be traced across the outcrop. Some of the bed dip may be depositional, but slumping after undermining also occurs. The punt is in case you fall in.

Figure 7.4. (a) Impossibly protruding cobble, possibly emplaced by rafting or sliding on gravel deposit, is buried by low angle, thin-bedded fine to medium sand. (b) Poorly sorted gravel with rounded clasts grades upwards to gravelly sand. Bed conformable with underlying fine sand. Irregular bed traceable across outcrop for perhaps 10 m. Crude internal bedding; coal clasts highlight one internal contact. (c) Dipping sequence of climbing ripple drift grading to low angle to planar cross bedding in fine sand. (d) Location of OSL sample VSG-2 from fine sand at base of section.

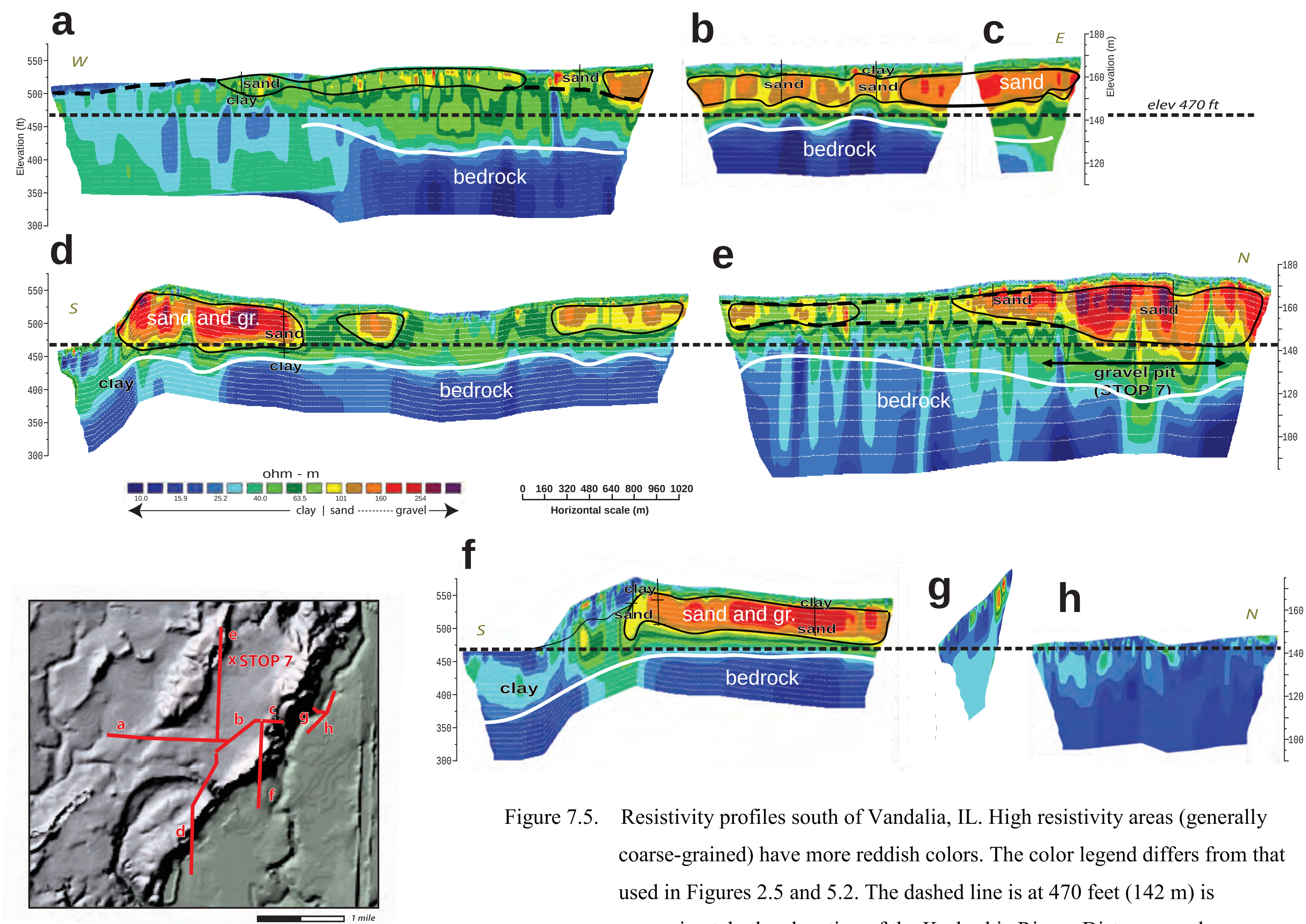


Figure 7.5. Resistivity profiles south of Vandalia, IL. High resistivity areas (generally coarse-grained) have more reddish colors. The color legend differs from that used in Figures 2.5 and 5.2. The dashed line is at 470 feet (142 m) is approximately the elevation of the Kaskaskia River. Distances and elevations are in meters.

STOP 8: Central Illinois Materials Sand Pit / Catfish Pond Paleoecology

(David Grimley, Rebecca Teed, and Andrew Phillips)

Overview

The Central Illinois Materials sand pit occurs at the apex of a large ice-walled fan system (Figs. 7.2, 8.1) that discharged glacial meltwater and sediment to the southwest. The fan system is interpreted as ice-walled due to the presence of sand in raised ridges that form an anastomosing distributary system and that are separated internally by large (~ 0.5 mile) wide circular lake plains (Fig. 7.2). We will visit one such lake plain at STOP #9. The ice-walled fan is interpreted to have been genetically connected to the esker or ice-walled channel system that formed Hickory Ridge (STOP #7) and drained the Kaskaskia Sublobe from the Vandalia area down-gradient to the southwest.

The areas of sand-rich sediment emanate from the surrounding flats and lake plains as slightly winding fingers to the southwest. It is clear that the mining of sand and gravel deposits follows these somewhat elevated, narrow, winding hills (~ 300 to 1000 feet wide). The coarsest sediment has presumably been mined from the apex of this fan but a systematic study or detailed mapping has not yet been conducted in the area of this pit. A dozen water supply test holes were drilled in these hills by the village of Mulberry Grove in 1969, but apparently insufficient water was found in the deposits since the city currently obtains it water supply from Hurricane Creek valley aquifers. Only a somewhat cursory description (see below) is provided in this guidebook since it was not in our area of detailed mapping in past years. For this field trip, we will likely stop where fresh excavation are found at the end of a narrow and elongate area of dredge mining (below what was once a raised ridge) towards the southwest end of the pit area. A brief description ws made during a visit by D Grimley and S. Brown on Nov. 8, 2010:

***0 - 5 feet depth**: loess with modern soil development (Peoria and Roxana Silts)*

***5 - 10 feet**: Sangamon Geosol in gravelly deposits (Hagarstown M.)*

***10 -14 feet**: gravel, with numerous igneous clasts, chert , sandstone, etc. (Hagarstown M.)*

***14 - 30 feet**: fine to medium sand, stratified; limited areas of coarse sand and gravel (Hagarstown M.); base of observation at water level in lake*

***30 - 55 feet**: plant manager says an additional 20 to 30 feet of sand with gravel is found below the lake level (probably similar to above unit)*

*>**approx. 55 feet**: plant manager says that shale or clay shale was encountered [possibly bedrock or could be hard, clayey, shale-rich till]*

Of practical concern, subhorizontal zones of iron-cemented sand and gravel are found just above the lake level in some parts of the pit. The hardness of these zones can make extraction difficult according to the owner, Charles Barenfanger. Based on ISGS X-ray diffraction analyses, the iron oxide in the cementing agent is mainly goethite. It is suspected that the zones of iron cementation reflect mobilization of iron oxides from the upper beds and reprecipitation at or near the water table level during the Sangamon Episode and later times, perhaps continuing up to the present.

Origin of the ridge fan

The flat, pitted surficial expression and the sand- and gravel-rich sediments within Hickory Ridge are consistent with its interpretation as an esker. The transition from the esker to the fan network was possibly a transition from pipe flow to open channel flow, though the flat top of Hickory Ridge indicates open channel flow during at least the waning stages. The depositional environment of the fan network itself is less certain. Although stratified coarse sediments attest to the fan network's glacifluvial origin, the system now stands above the surrounding plain, and so must have been supported laterally by ice. Gravel pits and test holes indicate that the sand and gravel also extend 20 to 40 feet below the surrounding plain, suggesting channelized flow. The occurrence of contemporaneous buried ice blocks is evident by kettle lakes entwined with the ridge threads. Two hypotheses are here suggested:

Hypothesis A (favored)

A subglacial drainage system broke to the glacier surface south of today's Racoon Creek (Fig. 7.2). A distributary fan then developed as meltwater flowed through a stagnant, decaying ice margin. The anastomosing ridge pattern developed as either multiple contemporaneous channel threads or as isolated threads that were stacked during postdepositional melting. Some or all of the channels eroded through the ice into the substrate. Blocks of ice were buried or isolated between the channel threads. These blocks melted long after ice margin retreat, leaving basins that were later filled with redeposited loess and colluvial sediment. A modern analog of this scenario was described in Iceland by Evans and Twigg (2002). This scenario appeals to the anastomosing shape, the irregular elevations of ridge crests, and weak correlative deltaic facies evidence. *[What can we look for to support this interpretation?]*

Hypothesis B:

The anastomosing fan network has been described anecdotally as a "delta" by some. This may be mainly a reference to its fan shape, but they could conceivably have formed as outwash transgressed into a proglacial lake. The lake could possibly have been supported by outwash or ice damming the Hurricane Creek drainage. Although correlative lacustrine sediments have been identified on the adjacent plain, their extent is not known, and detailed quadrangle surficial mapping (such as that in the St. Louis Metro East region) has not yet occurred on the west side of the Hurricane Creek valley. Although the core of the ridges contains large, steeply dipping cross beds, associations of the beds with topsets and bottomsets (critical elements of deltaic deposits) have not yet been identified. Furthermore, a deltaic environment is likely to result at least partly in a deltaic plain, although some of the ridge (channel) threads could be explained by occurrence of buried or grounded ice blocks in the outwash trajectory. *[What can we look for to support this interpretation?]*

Diatom and Pollen Record from Catfish Pond (Rebecca Teed)

Immediately adjacent to current mining in the Central Illinois Materials sand and gravel pit, and still separated by an earth berm, is a natural pond (called Catfish Pond) that was one of the few natural water bodies of this type in an area that was not drained for agriculture. As part of a thesis study (Teed, 1999), a core was taken in Catfish Pond to help decipher the late Wisconsin Episode and Holocene records (Fig. 8.2) and to tie in with the older Pittsburg Basin record (STOP #9). Previously, little was known of the Holocene pollen record in southern Illinois. Below are some key details and findings from this study:

- *Methods:* Analyzed the pollen (5.86 m of data) and diatom records from a core taken from Catfish Pond in 1996. Three AMS radiocarbon dates were obtained.
- Diatom assemblages at the deepest levels contain mostly *Eunotia monodon* and large (80 μm+) *Pinnularia* spp., including *P. maior* and *P. viridis*. These levels are also rich in pine, oak, ash, and sedge pollen.
- Sediments dated to late Wisconsin Episode, just over 22,000 ^{14}C years ago, also contain abundant spruce pollen (Fig. 8.2), indicating a cooler climate. *Eunotia monodon* accounts for >60% of diatom valves counted, up from ~ 20% in older levels.

- Between 6,000 and 200 years B.P., the pollen assemblages indicate that the landscape was a mosaic of oak-hickory forest and prairie (Fig. 8.2). *Eunotia monodon* decreases to less than 10% of diatom valves counted and the diatom flora becomes more diverse, including substantial amounts of *Stauroneis phoenicenteron* and *Neidium affine*.
- In the last 200 years, the sedimentation rate and ragweed pollen percentages increased, indicating homesteading and associated intense agriculture in south-central Illinois. The diatom assemblages have become even more diverse, dominated in the upper levels by *Aulacoseira italica*.

Throughout the record, there is a tight correlation between *Eunotia monodon*, as a percentage of diatom valves counted, and coniferous tree pollen, as a percentage of terrestrial pollen types ($r^2 = 0.7924$, $p < .0001$). Perhaps both the diatom flora and tree taxa are responding synchronously to climate change, or perhaps there may be a more direct link. For instance, coniferous tree litter tends to decompose slowly and to acidify the soil of the catchment area. This would in turn decrease pH and increase dissolved organic carbon content of the lake, which might favor *Eunotia monodon* over its competitors.

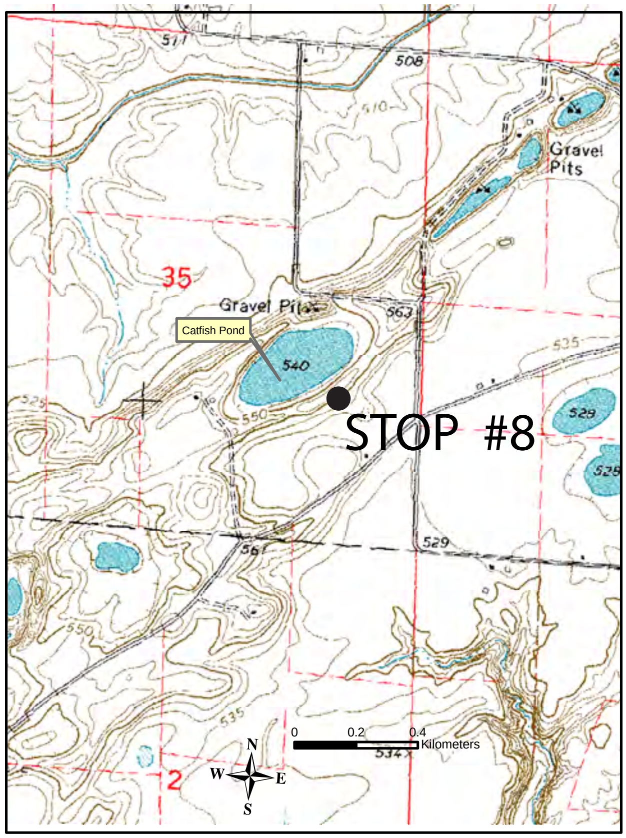


Figure 8.1 Location of Central Illinois Materials Sand and Gravel Pit, Fayette County, IL (STOP #8).

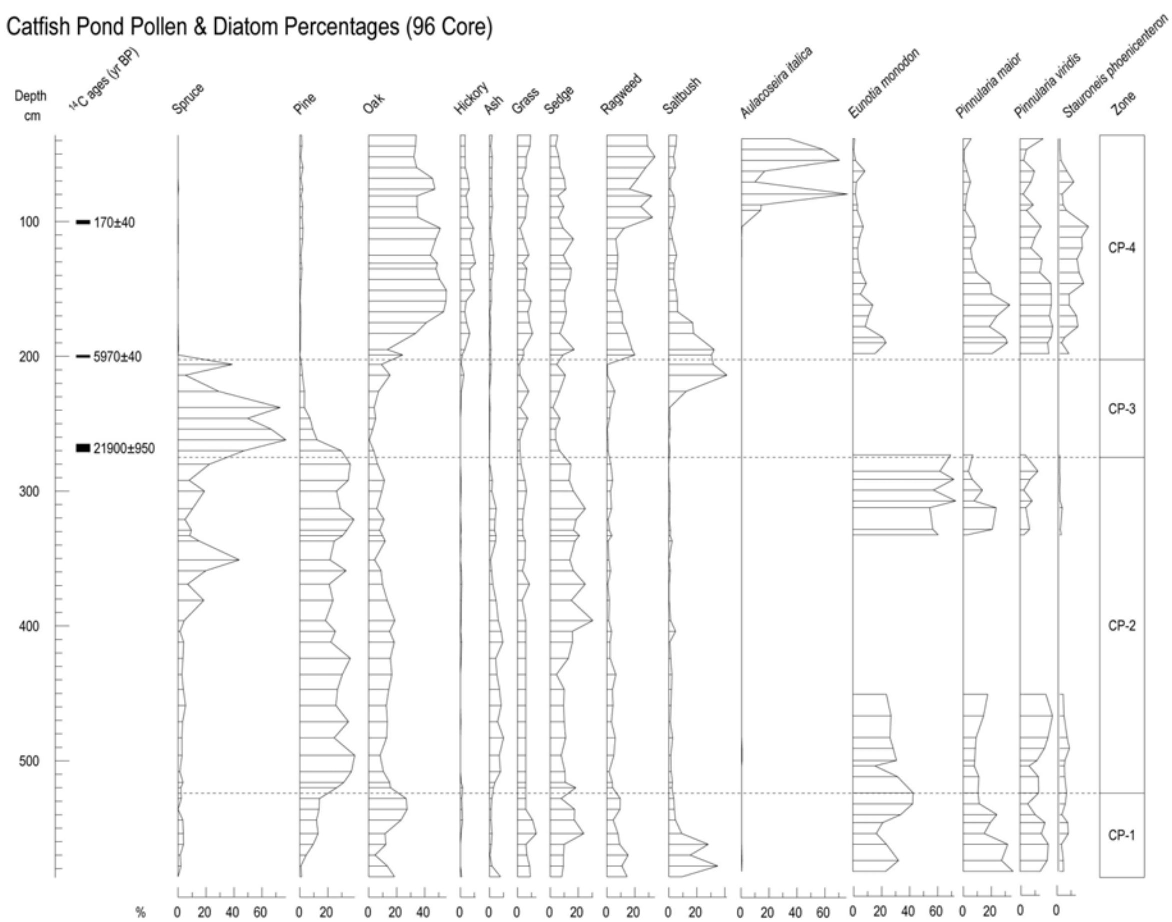


Figure 8.2. Catfish Pond Pollen Diagram (from Teed, 1999).

STOP 9: **Pittsburg Basin** Paleoenvironmental History from Fossil Pollen and Ostracode Records in South-Central Illinois

(Brandon Curry, Hong Wang, Jeff Dorale, Bonnie Blackwell, and Craig Lundstrom)

Pittsburg Basin record

In 1816, Pittsburg Basin was "a beautiful lake surrounded by a handsome bluff; except a small outlet at the NW end where there is an outlet leading NWterly" (Illinois Archives Land Records, 1949). A lake is shown on the 1857 plat map (Illinois Archives Land Records, 1949). In 1911, the Pond Lily Drainage District began to drain the lake, but a small pond is shown in the SW part of the basin in 1915 (Curry, 1995). In the 1920's, Pittsburg Basin was completely drained for agricultural purposes by blasting and dredging of sediment at the overflow channel, and installation of tiles.

Pittsburg Basin, about 0.5 mile in diameter, is the westernmost and largest of a series of smaller basins outlined by sandy ridge deposits (Figs. 7.2, 9.1). The sandy ridges around the rim of Pittsburg Basin (where we will stand on the field trip), are about 35 to 50 feet above the basin floor. This area, about 2 miles northwest of the present-day Kaskaskia Valley, was clearly an area where glacial meltwater was focused from the melting Kaskaskia Sublobe. The basins and narrow ridges are seemingly arranged within a large subglacial or ice-marginal fan-delta (Fig. 7.2) that formed in a reentrant area of the receding ice sheet. The origin of the kettle basins, being nearly circular, is most likely from in-situ remnant ice blocks that were isolated by meltwater stream flow and became detached from the main body of the ablating glacier in the Kaskaskia Basin (see Hypothesis A described in STOP #8).

Over the past few decades, the paleoenvironmental (Grüger 1972a, b; Curry 1995; Teed 1999, 2000) and enviro-magnetic (Geiss and Banerjee, 1997) records at Pittsburg Basin have been studied from various testcores across the feature. Key cores for paleoecology were all collected fairly close to the center of the basin (Curry, 1995; Geiss and Banerjee, 1997; Teed 2000). Based on a several cores taken in 1994 (Teed, 2000), the uniformity of the basin floor elevation is notable. One representative core sampled from near the center of Pittsburg Basin yielded the following stratigraphy (Curry, 1995):

0-1.03 m, varicolored silty clay, vaguely laminated in places, leached, bioturbated, no fossils. [Equality Fm.]

1.03-1.95 m, finely laminated dark silty clay intercalated with gleyed (gray) silty clay loam; strong to medium platy structure imparted by laminae. [Equality Fm.]

1.95-6.14 m, black silty clay and dark, gleyed sapric peat with gastropod shell fragments [Equality Fm./Berry Clay-Teneriffe Silt]

6.14-6.84 m, olive gray to black silty clay; few gastropod shells; some zones with abundant ostracode valves [Berry Clay-Teneriffe Silt]

6.84-6.97 m, black and gray laminated silty clay, leached. [Berry Clay-Teneriffe Silt]

6.97-7.00 m, black rock fragment. [a rock]

7.00-7.20 m, gray sand. [Pearl Fm.]

A similar core, also taken near the center of Pittsburg Basin, was analyzed for pollen by Teed (2000) and the results are shown in Fig. 9.2. The dominance of *Picea* in pollen zone PB-1 suggests a cold and moist climate of the late Illinois Episode. An abrupt shift to deciduous tree and non-arboreal pollen marks the interglacial Sangamon Episode, represented by pollen zones PB-2, PB-3, and PB-4 (Fig. 9.2). Teed (2000) interpreted all three zones to correlate to OIS 5e, but it is also possible that the zones correlate to additional substages of OIS 5 (Curry and Baker, 2000). PB-5 is characterized by abundant non-arboreal pollen, and PB-6 by *Picea*, *Pinus*, and non-arboreal pollen. Grüger (1972b) found that the relative percentage of tree pollen to non-arboreal pollen was strongly influenced by the size of the basin, with smaller basins yielding higher tree pollen percentages. Radiocarbon ages verify that PB-6 was deposited during the Wisconsin Episode (Teed, 2000). PB-7, the youngest pollen zone, is comprised of forest and prairie taxa, and correlates to the Holocene Epoch (Teed, 2000).

Paleoenvironmental records among four basins in south-central Illinois

Regionally, Pittsburg Basin (Fig. 9.1) is one of four kettle basins on the Illinois Episode till plain that have yielded fossiliferous lacustrine deposits dating from the late Illinois, Sangamon, and Wisconsin Episodes. The other sites are Hopwood Farm, Raymond Basin, and Bald Knob Basin (Fig. 9.3). All four basins occur within or abut against constructional hills formed by Illinois Episode glaciers and/or associated meltwaters. Regional pollen zones (RPZ-1 through RPZ-7), with statistically unique pollen spectra, have been identified from core records in three of the four basins, the Raymond, Bald Knob, and Pittsburg basins (RBKP basins). The fourth basin, the Hopwood Farm locality, has a different pollen record (Fig. 9.4) that may reflect more rapid infilling due to a smaller lake-to-watershed ratio (Curry, 1994; Table 9.1). In central Illinois, and throughout the Midwest, the regional pollen zones typically vary among three basic types: boreal trees, deciduous trees, and herbaceous taxa such as sagebrush and grass.

The paleoclimate and paleohydrology of the past 150,000 years (150 ka) have been estimated from pollen and ostracode records from the four kettle basins in south-central Illinois, including Pittsburg Basin (Table 9.2). Of the four basins, Raymond Basin (about 35 miles northwest), has the longest and most complete fossiliferous lacustrine record; in particular, it records conditions during the late Illinois Episode when dead-ice permafrost was present. The Holocene and late Wisconsin Episode are not clearly represented in the fossil records, although Wisconsin Episode silt deposits (redeposited loess) are ubiquitous. RPZ-4 of the RBKP records, representative of the middle Sangamon Episode, is of special interest because it contains abundant *Liquidambar* pollen (Zhu and Baker, 1994), a deciduous tree most abundant in southern deciduous forests today. In other Sangamon Episode deposits, the subtropical ostracode *Heterocypris punctata* occurs in low percentages (its northernmost occurrence today is near Galveston, Texas; Curry, 1995; Curry and Baker, 2000). The difficulty in correlating the RBKP and Hopwood Farm records is especially vexing because the fossil *Geochelone crassiscutata* (an extinct giant tortoise) was found at Hopwood Farm (King and Saunders, 1986). This large reptile has similar-sized cousins that live today on the Galapagos and Seychelles Islands and they cannot burrow to escape winter cold (King and Saunders, 1986). Although *Geochelone crassiscutata* and *Heterocypris punctata* represent very limited sub-freezing Sangamon Episode temperatures, they are not present at the same site (Curry and Baker, 2000). Paleosalinity reconstructions and open hydrological conditions indicate that, at Hopwood Farm, the lake salinity was likely too low to support *Heterocypris punctata.*

Another notable feature in the RBKP fossil records is the abrupt species shift in pollen and ostracodes across the boundary between RPZ-4 and RPZ-5. The lower part of RPZ-5 at Raymond Basin contains ostracodes that today live in springs and streams (e.g., *Limnocythere reticulata* and *Pelocypris tuberculatum*) and a mixture of *Picea* and *Liquidambar* pollen that suggest low lake levels and sediment mixing under a variable (continental) climate (Curry and Baker, 2000). The lack of evidence for weathering or desiccation, where abrupt changes occur in the ostracode and pollen records, suggests a climatic shift across the RPZ-4 / RPZ-5 boundary. However, the age of this climatic shift has been difficult to elucidate.

Chronology

Several problems have been encountered regarding absolute ages from Pittsburg Basin and the other three kettle basin sites. Four themes of age determinations emerge from review of more than 40 years of work at these sites: 1) Bulk ^{14}C ages of detritus gyttja 2) U-series and electron spin resonance (ESR) dating of mastodon teeth at Hopwood Farm 3) pollen record correlations to the well-dated Crevice Cave speleothem record in Missouri (Dorale et al., 1998) and, 4) optically stimulated luminescence (OSL) dating of sediments.

Radiocarbon dating (Pittsburg Basin and others)

Radiocarbon ages of bulk organic-rich gyttja core samples from Pittsburg Basin provided the first chronological data (Grüger (1972a,b) including seven ages ranging from 24,200 ± 800 to >42,000 ^{14}C yr BP (Table 9.3). Most ages are in chronological order with respect to depth (Table 9.3, Figure 9.3). Teed (2000) reexamined the pollen record and chronology at Pittsburg Basin, but only one horizon at ~2.75 m depth (Fig 9.4) yielded enough material (bulrush seeds) for an AMS radiocarbon age of 47,900 ± 320 14C yr BP (AA21053; Teed, 2000). The several other ages from the other basins are indicated in Table 3.

ESR and U-series dating (Hopwood Farm)

At the Hopwood Farm Section, a nearly complete mastodon skeleton (*Mammut americanum*) was found atop pollen-bearing sediment (Fig 9.4, asterisk), covered by 3 m (10 feet) of smectite-rich clay and ~ 0.7 m (2.3 feet) of Wisconsin Episode loess. Electron spin resonance (ESR) analysis of a mastodon molar fragment resulted in ages ranging from 73 ± 9 to 141 ± 17 ka, depending upon the Uranium (U) uptake model used (Blackwell et al., 1990). More recently, the ESR age estimate on this fossil has been refined to 88 ± 8 ka (Dr. Bonnie Blackwell, Williams College, unpublished data, 2011) utilizing a newly acquired U-series dentine age of ~ 26 ka to represent late stage Uranium uptake in the sediment and fossil (ESR ages are highly dependent upon Uranium uptake history).

Enamel and dentine from the mastodon was dated through mass spectrometric analysis of U and two of its short lived radiogenic daughters, ^{230}Th and ^{231}Pa by Dr. Craig Lundstrom (Department of Geology, University of Illinois at Urbana-Champaign). The combination of U-Th and U-Pa provides two independent dating systems allowing a check on dates and providing information about the extent to which the system has remained closed. The basic assumption is that U (a fluid mobile element) is taken up by the mastodon tooth during life but that Th and Pa (fluid immobile elements) are not. Thus, measurement of the amounts of ^{230}Th and ^{231}Pa relative to U provides two different dates since the time of death.

For the enamel, the ^{230}Th age and ^{231}Pa age are not concordant with the ^{230}Th age being 7,000 yrs and the ^{231}Pa age being 19,000 yrs. These data lie to the left of "Concordia", indicating the enamel system was not closed and most easily explained as late uptake of U. By drawing a line corresponding to a removal of the late added U, one can determine a possible date when the sample was last concordant as ~ 36 ka (unpublished data). The dentine, which is U rich and unlikely to be a closed system, gives a ^{230}Th age of 31 ka and a ^{231}Pa age of 26 ka. The 36 ka age is the best constrained estimate that can be given. While the assumption that Th and Pa are fluid immobile is generally well evidenced by observed concentrations in surface waters, if Th or Pa were fluid mobile for some reason during diagenesis, then the estimated age by this technique may be inaccurate.

In the opinion of Dr. Blackwell, the original Uranium and Protactinium were leached from the system, and Lundstrom's reported ages primarily reflect resetting of the U-Pa "clock" by a younger introduction of U. Within the context of our understanding of the ages of these sediments (e.g., Curry and Baker, 2000), Dr. Blackwell's assessment fits our preconceived ideas, but we cannot rule out Dr. Lundstrom's conclusions. In sum, the mastodon is either about 90 ka (based on ESR) or about 36 ka (based on U-series and supporting Pa ages). The *Geochelone* fossil, which provides evidence for non-freezing winters, is older than one of these options (and younger than the late Illinois Episode).

Correlation of pollen and speleothem records

An alternative chronology for the regional pollen zones from RBKP was obtained by wiggle-matching between the pollen record of Zhu and Baker (1995) and the $\delta^{13}C$ profiles of well dated stalagmites collected at Crevice Cave, Missouri (Dorale et al., 1998). The pollen record is represented by the stratigraphically constrained detrended correspondence analysis (DCA) axis 2 (Fig. 9.5). The DCA analysis is a multivariate technique used to group variables, such as pollen percentages, that behave similarly in abundance profiles. The principal assumption for this correlation is that both records are proxies for paleoprecipitation. In DCA axis 2, larger values are associated with arboreal pollen and smaller values with non-arboreal pollen. DCA axis 1 (Fig. 9.5) is a proxy for temperature (Zhu and Baker, 1995). In the stable isotope record, higher proportions of $\delta^{13}C$ are associated with vegetation that photosynthesizes using the C_4 pathway rather than the

C_3 pathway. Dorale et al. (1998) argue that the C_4 vegetation in the region is primarily prairie plants whereas the C_3 vegetation is forest.

A wiggle-matching program, written by Dr. Robert Hanson (University of North Carolina at Greensboro), determined an r^2 value of 0.74 for the linear correlation of the pollen record (DCA axis 2) and the speleothem record. Through Monte Carlo analysis, it was shown that the correlation could not be random (Curry et al., 1992). The results of this method, utilizing correlations to dated speleothems, estimate ages for RPZ-4 and RPZ-5 as ranging from 77 to 70 ka, and 70 to 55 ka, respectively. The ramifications of these inferred ages have been presented at professional meetings by Dorale (1994) and Curry and Dorale (2008).

Luminescence dating (Raymond Basin)

Encouraged by infrared stimulated luminescence results of Dr. Sanda Balescu at Pittsburg Basin, ranging from 69 ± 7 ka at the top of RPZ-4 to 126 ± 16 ka at the top of RPZ-2 (Teed, 1999), a recent attempt was made to confirm the speleothem-tuned chronology at Raymond Basin with optically stimulated luminescence (OSL) dating. The lacustrine sediments sampled were from a replicate of the original core RB-2 (Fig. 9.6) that was used for ostracode, pollen, particle-size distribution, and clay mineralogy analyses (Zhu and Baker, 1995; Curry,1995; Curry et al., 1997; Curry and Baker, 2000). Initial samples were sent to the Luminescence Dating Research Laboratory at the University of Illinois-Chicago (UIC). A sample of lake sediment just above Glasford Formation till (Vandalia Member) at a depth of 1250 cm (RPZ-1) yielded ages of 64 ± 5 ka and 67 ± 5 ka. Another sample at 508 cm depth (RPZ-5) yielded an age of 54 ± 4 ka. The layer of silty sediment at 300 cm (redeposited Peoria Silt; RPZ-6) yielded an age of 14 ± 1 ka (Table 4). Based on the widely held assumption that Glasford Formation sediments were deposited during Oxygen Isotope Stage 6 (e.g., Curry and Follmer, 1992; Curry and Baker, 2000), the basal ages were much younger than expected. To test the initial results, additional OSL ages were determined of ice-contact glacifluvial sediments (Hagarstown Member, Pearl Fm.) exposed in a sand pit in a constructional Illinois Episode ridge adjacent to Raymond Basin (see Fig 9.6). Duplicate samples were submitted to two labs: the UIC lab (again) and the new (as of 2009) Optical Stimulated Luminescence Laboratory at the Illinois State Geological Survey. The UIC lab results (Table 4) were consistent with their earlier results. OSL ages from the ISGS lab were 138 ± 10 ka and 122 ± 11 ka, nearly twice as old. The ISGS and UIC labs utilized different methodologies, with the ISGS using single aliquot regenerative (SAR) protocol on 90-250 μm quartz and the UIC lab used multiple aliquot regenerative (MAR) protocol on fine fraction (4-11μm) polyminerals, including quartz. Additionally, the dose rate is calculated differently at each laboratory. The UIC lab determines in-situ radiation dose from ICP-MS sediment analysis, with the assumption that most radiation is derived from ^{40}K and ^{238}U. The ISGS lab determines the dose rate from gamma-ray spectrometry measurements of subsamples in contact with the primary OSL sample.

Encouraged by the results from the ISGS lab, Brandon Curry and Hong Wang sampled replicate cores RB-7 and RB-8 located between the master core RB-2 and the highest ancient shoreline at Raymond Basin (Fig 9.6). Key biostratigraphic contacts were marked by layers of sand in cores RB-7 and RB-8. The sand layer between the basal, barren silty clays and organic-rich silts (RPZ-1) yielded an OSL age of 129 ± 8 ka; the sand layer between the organic silts of RPZ-1 and gray clays of RPZ-2, an age of 124 ± 6 ka. These age results are consistent with the results of the pollen-speleothem wiggle-matching exercise, albeit by virtue of the ages being beyond than the oldest Crevice Cave age of 109 ± 1 ka. However, the date from the sand layer that caps the fossiliferous succession was 107 ± 7 ka compared to an estimate of about 50 ka based on the pollen-speleothem calibrated ages (Fig 9.7). Two additional samples, dated by the ISGS, from the lower part of the silty lithofacies at depths of 230 and 270 cm have ages of 41 ± 3 and 53 ± 3 ka, respectively (Fig. 9.7), and are not unreasonable considering the regional records.

Summary --- where to go from here ?

Based on the preceding discussion, it is clear that there is considerable conflict in results among the various dating methods, and even from results of different labs using the same dating method. Although it is not obvious at this moment which dates are most accurate, it is clear that one should take caution in sampling methodology and carefully record any related data that may bear on the final results and errors. We hope that the age issue may become resolved in the coming months and years as new approaches are taken and methods are improved for older (pre-55 ka) materials.

One approach underway to help resolve the dating controversy at Raymond Basin is to determine meteoric ^{10}Be profiles (Graly et al., 2011), focusing on the interval above the fossiliferous section. If the OSL ages from the ISGS lab are accurate, then the thin (~ 1 m) interval above the fossiliferous section, and below the redeposited Peoria Silt, will be concentrated in ^{10}Be relative to the sediment above and especially below. If the speleothem-tuned chronology is accurate, then the ^{10}Be profile will be relatively constant. Whichever dating method is more correct, the results of the Monte Carlo simulation indicate that the wiggle-matching is not random and suggests a fundamental pattern that may exist at smaller harmonic. We plan to refine our OSL results by determining the saturation of outer atomic shells after incremental heat treatments (Stevens et al., 2011). As far as other possible analyses, we encourage new amino acid racemization analyses of the aquatic gastropods at Hopwood Farm. Previously determined values of amino acid racemization ratios of aquatic gastropods from this site were found to be variable and inconclusive (McCoy et al., 1995). However, the advancement of this technique with multiple amino acid assays (Oches and McCoy, 2001) and additional data in the region (Curry et al., 1997; Grimley et al., 2001, 2010) may help to resolve the age controversy for the mastodon skeleton.

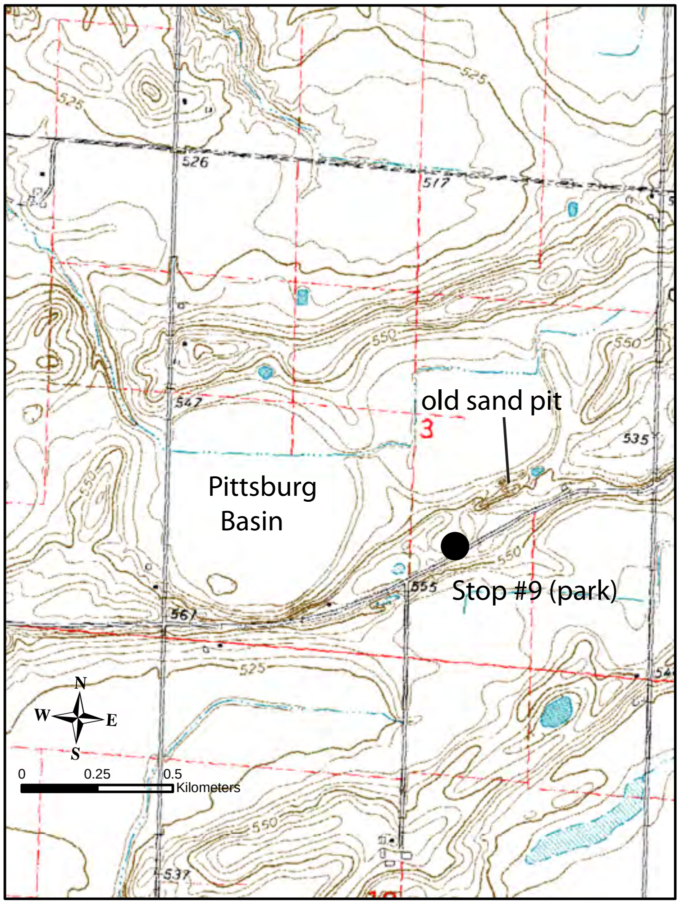


Figure 9.1 Location map for Pittsburg Basin, Fayette County, IL (STOP #9). Approximate locations of borings taken for paleoenvironmental study are shown.

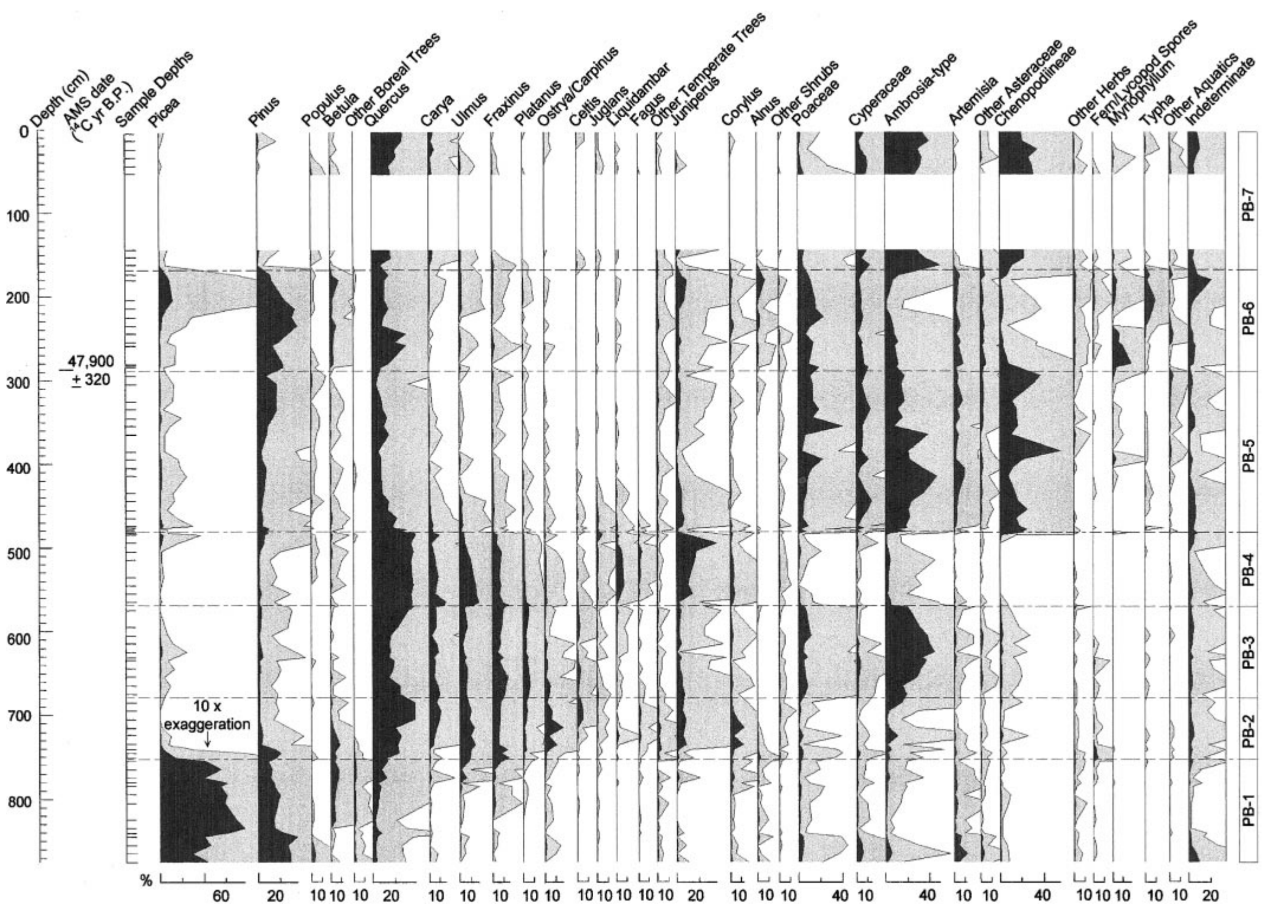


Figure 9.2. Pollen percentages from Pittsburg Basin core (from Teed, 2000).

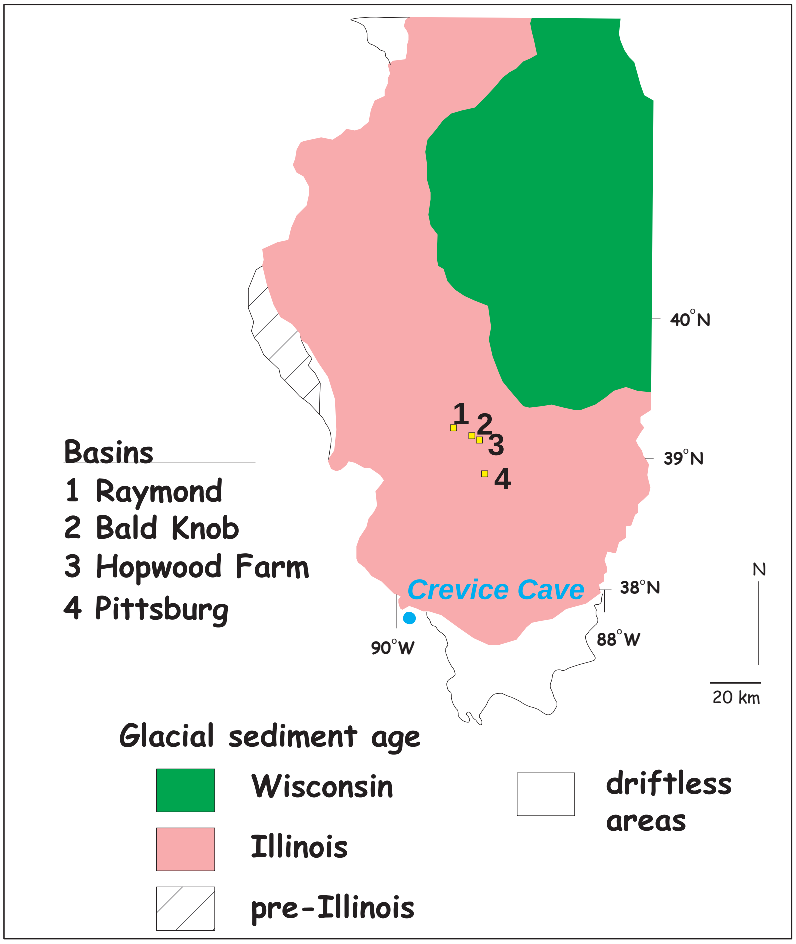


Figure 9.3. Location of Pittsburg Basin and other sites that have yielded fossil records in south-central Illinois spanning from the late Illinois to the early Wisconsin episodes.

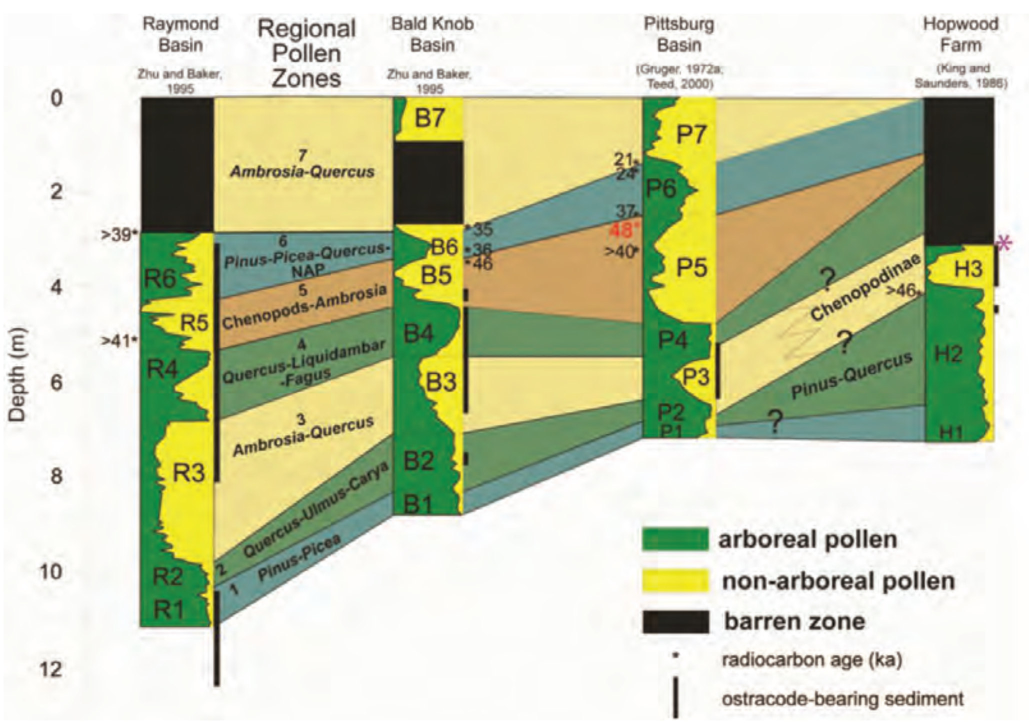
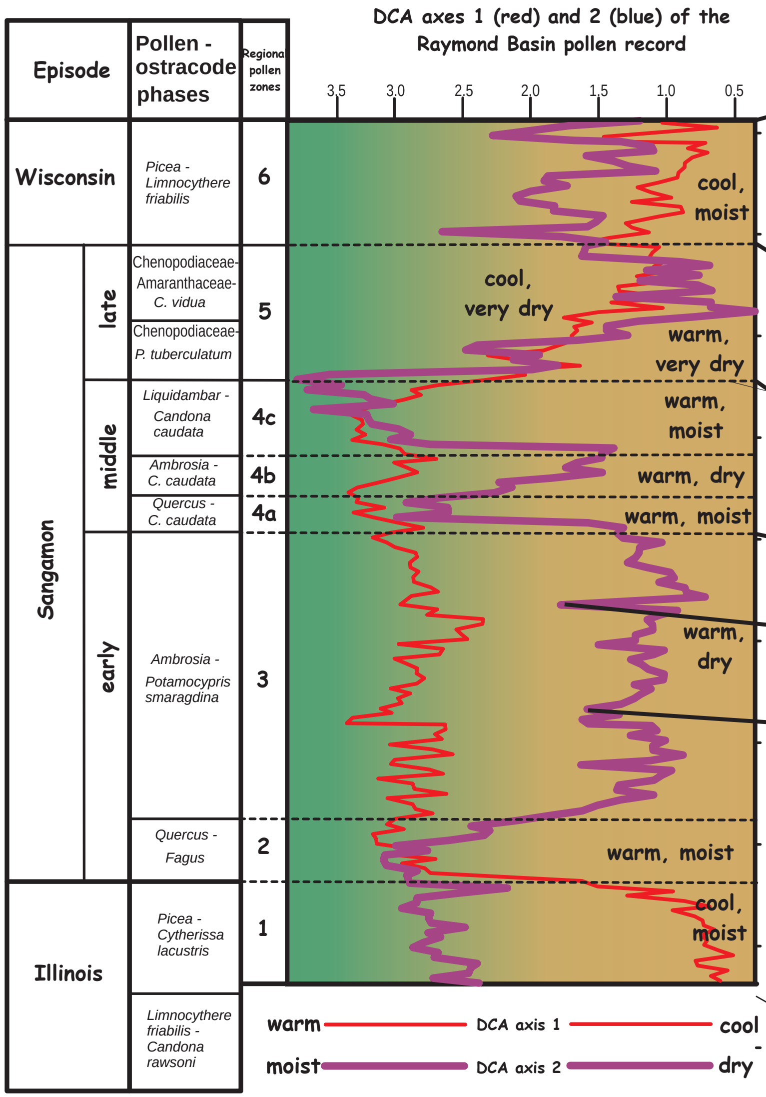
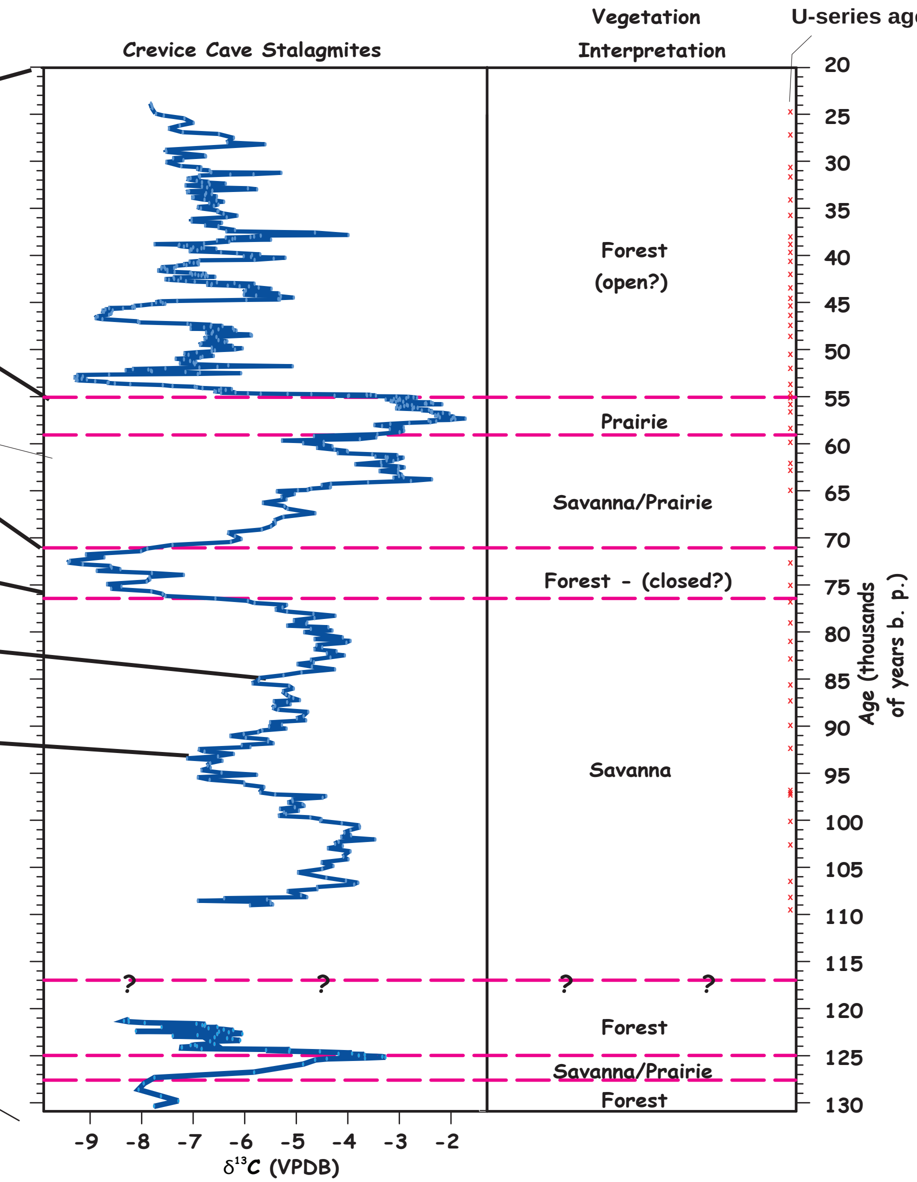


Figure 9.4. Regional pollen zones (RPZs) across south-central Illinois. The magenta asterisk shows the stratigraphic position of the mastodon skeleton discussed in the text.



Stratigraphic plot of DCA axes 1 and 2 values, their general paleoevnironmental interpretations, and biostratigraphic correlations (Zhu and Baker, 1995; Curry and Baker, 2000)



U-series $\delta^{13}C$ record from Crevice Cave, MO, and vegetation (intepreted independent of the pollen record (Dorale et al., 1998; Dorale and Edwards, 1999).

Figure 9.5. Basis for wiggle-matching between DCA axis 2 (purplish curve) of the pollen diagram from Raymond Basin (Zhu and Baker, 1994) and the carbon isotope data from Crevice Cave, MO speleothems (Dorale et al., 1998). Pollen-ostracode phases are discussed in Curry and Baker (2000).

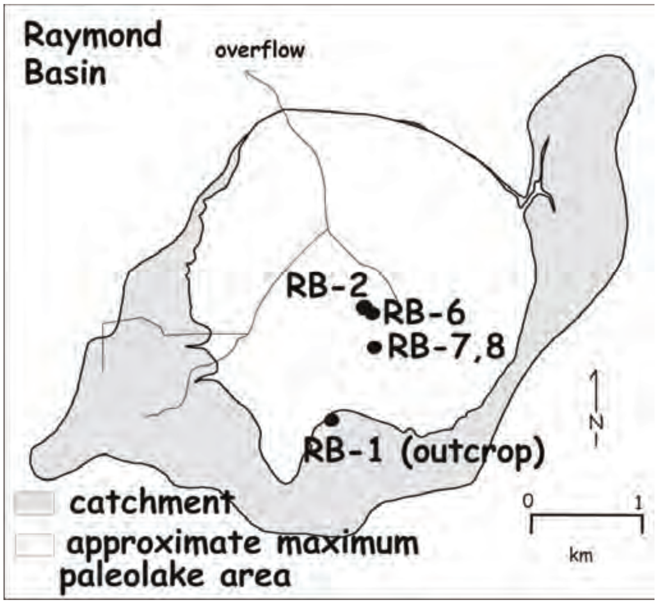


Figure 9.6 Location of cores studied in Raymond Basin and the adjacent sand and gravel pit exposure.

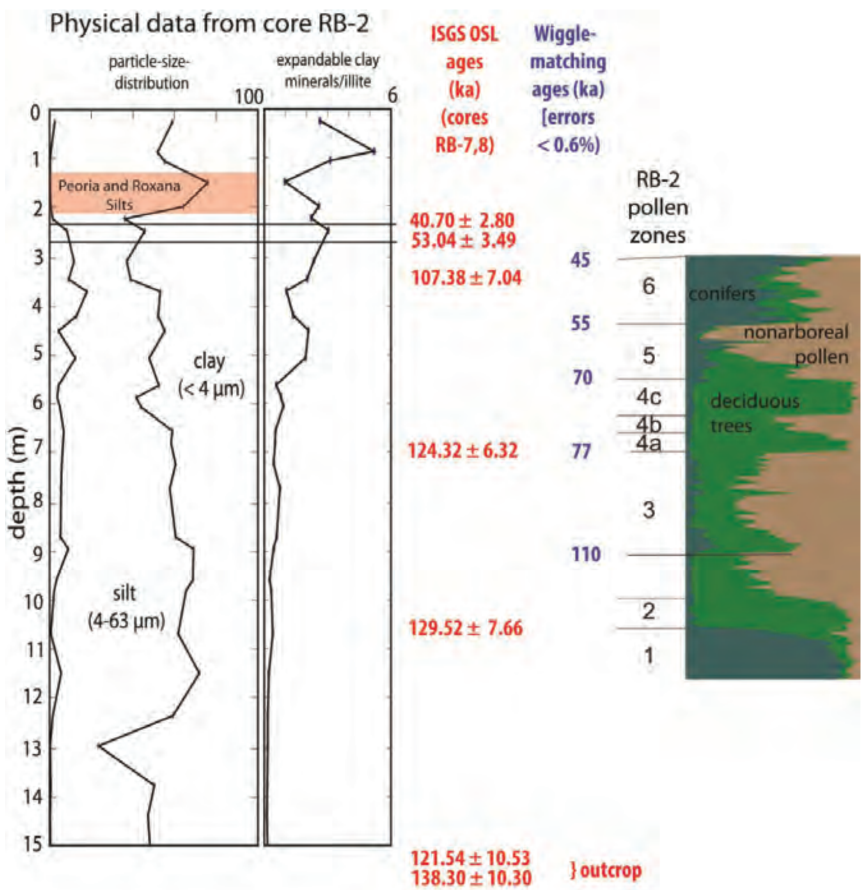


Figure 9.7. Comparison of speleothem calibrated ages of key biozone contacts with optically stimulated luminescence (OSL)in cores from Raymond Basin.

STOP 10: Sodium Affected Soils in South-Central Illinois:

Relationships with Relict Patterned Ground

(Samuel Indorante, Michael Konen, and Erik Gerhard)

Sodium affected soils (SAS) are those that have been adversely affected by sodium salts and/or exchangeable sodium (Indorante, 2002; Indorante et al., 2011). They usually occur in arid, semiarid, and subhumid climates where rainfall is insufficient to leach soluble salts from the soils where internal drainage is restricted. To a much lesser extent, SAS occur in humid regions with a mean annual precipitation > 100 cm (> 39 inches) due to factors that restrict leaching of soluble salts from the soil (Indorante, 2002). The main factors for SAS soil development are: 1.) sources of sodium, 2.) high water tables, 3.) clayey dense subsoils, 4.) impermeable underlying geologic strata, and 5.) seasonal periods of high evapotranspiration.

High pH, SAS occupy ~ 383,000 hectares in south central Illinois. In general, SAS soils in Illinois occur in areas where the Wisconsin Episode loess is 1 to 2 m thick over the leached, less permeable Sangamon Geosol, such as is the case at this field trip stop (Fig. 10.1). Sodium feldspars in the parent loess are the primary source of the sodium (Wilding et al., 1963). The SAS occur in a seemingly unpredictable patterns among normal acidic soils and are typically mapped in complex with non-SAS (Figs. 10.2, 10.3). Most areas of SAS/non-SAS soil complexes are currently farmed. Prior to settlement, these areas had a mixture of prairie and forest vegetation.

The impact of SAS on Illinois agriculture is significant. The non-SAS Cisne soil (fine, smectitic, mesic Vertic Albaqualf) and the SAS Huey soil (fine-silty, mixed mesic Typic Natraqualfs) are commonly mapped in complex in south-central Illinois. Under the same climate and management factors, and under non-irrigated conditions, the Huey soils with more than 15% exchangeable sodium or sodium adsorption ratios > 10 in the subsoil had an average of 18% yield reduction for soybean and an average of 38% yield reduction for corn when compared to the Cisne soils (Table 10.1). The yield reduction is caused primarily from the poor physical makeup of the dispersed soil caused by the high sodium concentration

The intricate pattern of SAS and non-SAS on level to nearly level uplands indicates differential redistribution of sodium derived from primary minerals in the loess. Previous research suggests that differential water movement and variations in evapotranspiration, both associated with current and historical soil landscape settings, were the mechanisms responsible for redistribution of sodium in solution (Wilding et al., 1963; Frazee et al., 1967).

Recent updating and digitization of Illinois soil surveys has revealed the occurrence of large areas of polygonal patterned ground associated with SAS, although not all SAS is associated with polygonal patterned ground. The polygonal patterned ground is interpreted to have formed as a result of Wisconsin Episode permafrost formation and degradation (Johnson, 1990), particularly during the last glacial maximum (~19 ka to 25 ka calendar years). Most polygons are 10 to 80 m in diameter with 4 to 6 m borders. Polygon interiors are darker colored and slightly lower in elevation, and polygon borders are lighter colored and slightly higher in elevation. SAS occurrences are associated with the patterned ground polygon borders in south-central Illinois (Fig. 10.4). While there are multiple pathways responsible for the formation of SAS, our working model hypothesizes that permafrost-related processes may have led to a unique microtopography that affected local hydrology and in turn resulted in the formation of SAS in south-central Illinois.

Map symbol and soil name	Depth	Cation exchange capacity	Effective cation exchange	Soil reaction	$CaCO_3$	Salinity	Na absorption ratio
	(inches)	*(meq/100 g)*	*(meq/100 g)*	*(pH)*	*(%)*	*(mmhos/cm)*	
912 A: Hoyleton (non-SAS)	0-9	14-22	---	4.5-7.3	0	0	0
	9-15	9.0-17	---	4.5-6.5	0	0	0
	15-36	---	21-28	4.5-6.0	0	0	0
	36-60	9.0-21	---	5.1-7.3	0	0	0-5
Darmstadt (SAS)	0-14	7.0-20	---	5.1-7.3	0	0.0-2.0	0-5
	14-20	16-23	---	4.5-7.8	0	0.0-2.0	10-20
	20-40	16-23	---	6.6-9.0	0-5	0.0-2.0	10-25
	40-60	9.0-20	---	7.4-9.0	0-5	0.0-2.0	5-20
912B2: Hoyleton (non-SAS)	0-7	14-22	---	4.5-7.3	0	0	0
	7-12	9.0-17	---	4.5-6.5	0	0	0
	12-32	---	21-28	4.5-6.0	0	0	0
	32-60	9.0-21	---	5.1-7.3	0	0	0-5
Darmstadt (SAS)	0-6	7.0-20	---	5.1-7.3	0	0.0-2.0	0-5
	6-14	16-23	---	4.5-7.8	0	0.0-2.0	10-20
	14-27	16-23	---	6.6-9.0	0-5	0.0-2.0	10-25
	27-60	9.0-20	---	7.4-9.0	0-5	0.0-2.0	5-20
Cisne (non-SAS)	0-8	11-22	---	4.5-7.8	0	0	0
	8-15	---	9.0-17	4.5-6.0	0	0	0
	15-51	---	21-28	4.5-6.0	0	0	0
	51-60	13-19	---	5.6-7.3	0	0	0-3
Huey (SAS)	0-7	11-22	---	5.1-7.8	0	0.0-2.0	0-20
	7-12	6.0-10	---	5.1-7.8	0	0.0-2.0	0-20
	12-15	12-22	---	5.6-8.4	0-15	0.0-2.0	0-20
	15-51	15-21	---	7.4-9.0	0-25	0.0-2.0	15-40
	51-60	11-21	---	6.6-8.4	0-30	0.0-2.0	10-40

Table 10.1. Chemical properties for selected soils in Clinton Co., IL (Soil Survey Staff, 2011a).

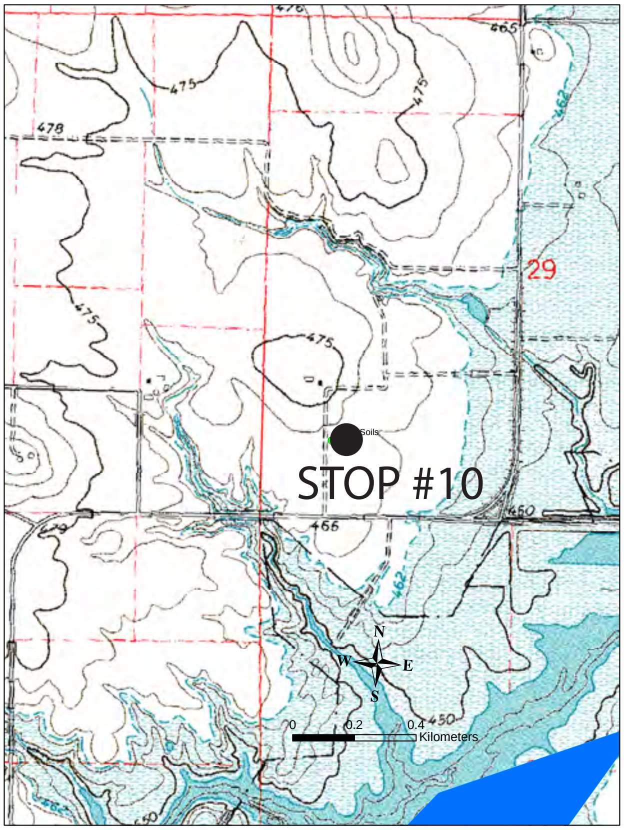


Figure 10.1 Location map for field trip stop examining sodium affected soils in Clinton County, IL (STOP #10).

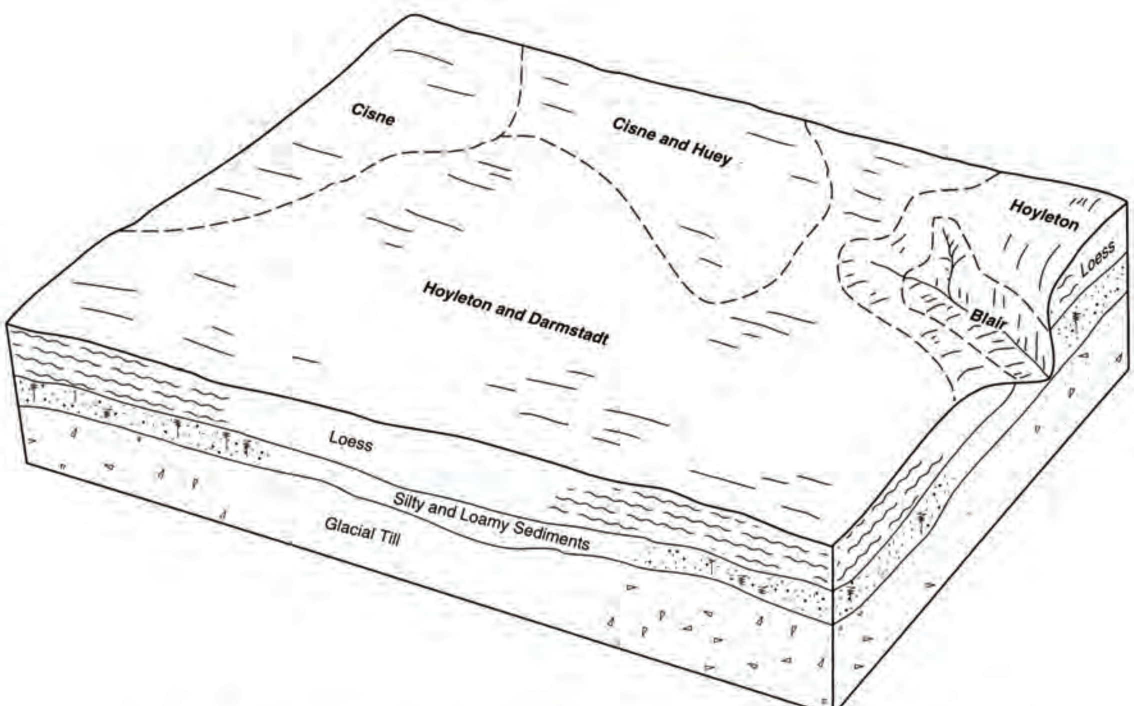
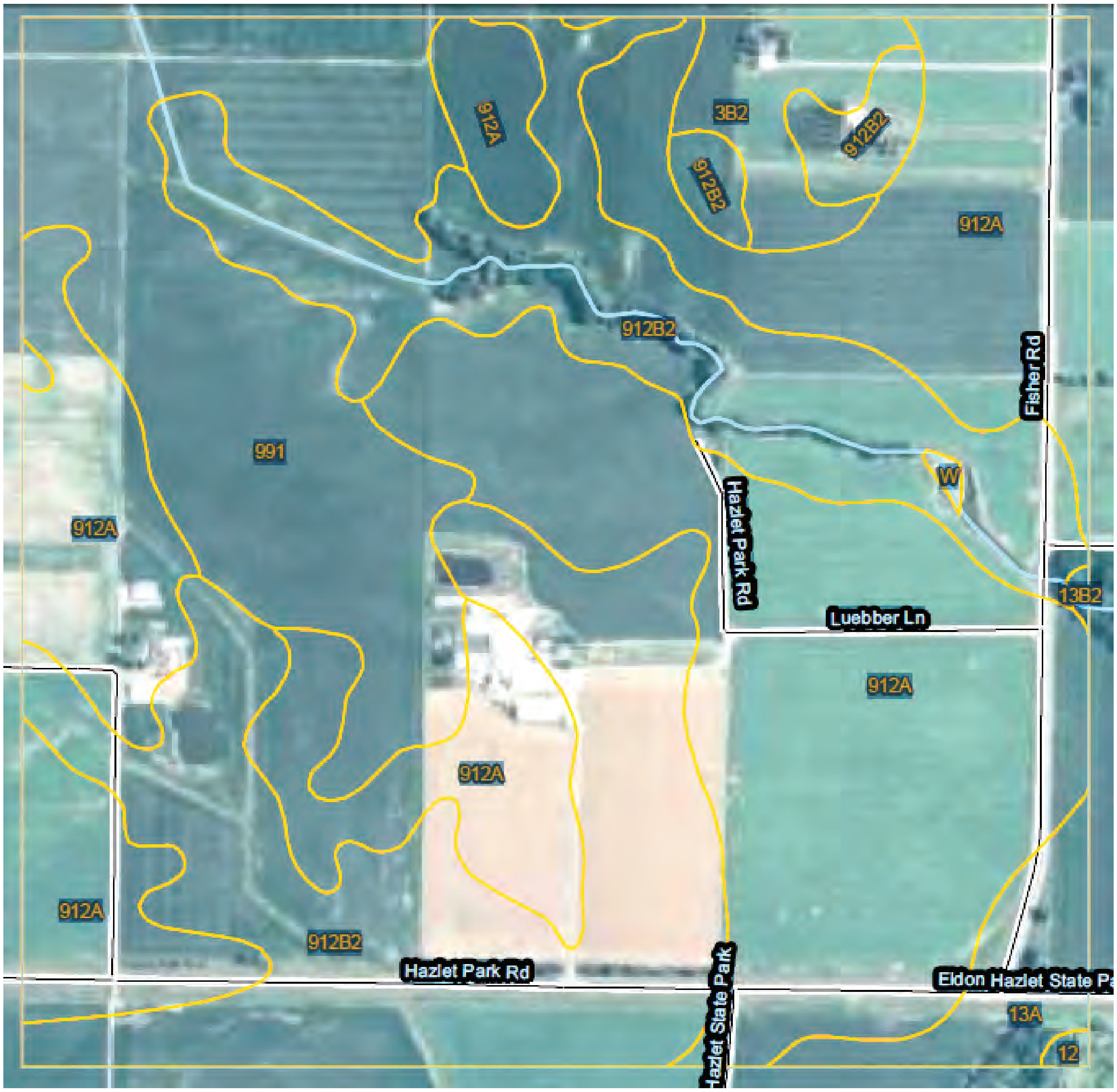


Figure 10.2. Soil Landscape Block Diagram of Stop Area. Typical pattern of soils and parent material in the Hoylton-Darmstadt-Cisne-Huey (Hamil ton, 2002) 2002)Association.



Map Unit Legend

Clinton County, Illinois (IL027)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
3B2	Hoyleton silt loam, 2 to 5 percent slopes, eroded	12.7	2.7%
12	Wynoose silt loam	0.6	0.1%
13A	Bluford silt loam, 0 to 2 percent slopes	12.5	2.6%
13B2	Bluford silt loam, 2 to 5 percent slopes, eroded	0.4	0.1%
912A	Hoyleton-Darmstadt complex, 0 to 2 percent slopes	218.0	45.5%
912B2	Hoyleton-Darmstadt complex, 2 to 5 percent slopes, erod ed	153.1	31.9%
991	Cisne-Huey complex	81.4	17.0%
W	Water	0.5	0.1%
Totals for Area of Interest		**479.3**	**100.0%**

Figure 10.3. Soil map and legend of stop area (from Hamilton, 2002 and Soil Survey Staff, 2011b). Site located in Clinton County, IL (S1/2, Sec. 29, T3N, R2W) between Carlyle and Keyesport.

PART III: SUPPLEMENTAL DATA

APPENDIX A: Geophysical and Laboratory Methods

Electrical Resistivity (Tim Larson)

Resistivity data were acquired using 2 different electrode configurations. Data from the Mascoutah area used the Wenner electrode configuration, in which four stakes (electrodes) are equally spaced along a line with two potential electrodes inside two current electrodes. Each measurement involves a hemispheric volume of material surrounding the potential electrodes. Deeper measurements were made by increasing the spacing between electrodes. Data from the Lebanon and Vandalia areas were acquired using the dipole-dipole electrode configuration, in which four electrodes (stakes) are placed in a line with two electrodes forming a current dipole next to two electrodes forming a potential dipole. The depth of penetration can be controlled by varying the distance between the two electrodes in each dipole (dipole length) and the spacing between the dipoles (dipole separation). Although raw data from the two configurations look different, processing software accounts for these differences and produces comparable images.

For the High Resolution Electrical Earth Resistivity (HREER) images constructed for this project, up to 60 stainless steel stakes are pushed into the ground at intervals of 5 m along each resistivity profile. The stakes are connected through four 100-m long multi-core cables to a computer-controlled resistivity meter (ABEM Terrameter 1000 or 4000) and switching system (LUND imaging system). A control program sequentially switches over 100 combinations of electrodes, operates the instrument, and stores the data. After a set of readings are completed, the resistivity equipment is moved in 100 m increments and more data is acquired.

Using this method, profiles of continuous resistivity measurements were obtained at 15 feet (5 m) spaces and more than 200 feet (60 m) deep. For this project, individual resistivity profiles range in length from about 0.4 to 2 km. A two-dimensional resistivity image was produced from the electrical data using a finite element inversion program (RES2DINV, Loke and Barker, 1996) that calculates an approximation of the true resistivity of the earth materials. Finally, topographic information was added to the model along the line of profile.

Color Coding for Figures

Because of the large variation in resistivity values within this study area, resistivity values are represented using two different logarithmic scales. Data from the Mascoutah and Lebanon areas are plotted using a resistivity range of 10 ohm-m to 320 ohm-m. Typically, geologic materials having resistivity values less than 50 ohm-m are silt or clay-rich in texture. Lower resistivity corresponds to higher clay content. The materials with lower resistivity are coded green and blue on the figures. Materials identified by dark green, yellow, orange or red colors have resistivity greater than 50 ohm-m and are generally composed of coarser sediments, such as sands and fine gravel. In some instances, these materials may also contain beds or lenses of sand and clay. Very coarse sand or gravel in this area have resistivity values >226 ohm-m and are identified by the orange and red shading on the figures.

In the Vandalia area, materials were encountered that have very high resistivity values. For this area only, a different color scale was used to better represent the wider range in resistivity values, ranging from 10 ohm-m to greater than 1810 ohm-m. Using this scale, the unconsolidated sediments with resistivity values of less than 56 ohm-m are silty or clay-rich. Smaller (or lower) resistivity corresponds to more clay content. These materials are coded blue. Materials depicted in shades of green, between 56 and 226 ohm-m generally are composed of increasingly coarse sands. In some instances, these materials may also include intervening layers of sand and clay. Very coarse sand with gravel in this area, having resistivity values that exceed 226 ohm-m are shaded in yellow and brown. These very high resistivity values may be caused by dry (unsaturated) conditions or zones of calcite cement. These zones are depicted by dark brown to black shades. Small areas with similarly very high resistivity were encountered in several of the ridges south of Mascoutah, but because these were localized we did not use the wide-range color scale here.

Optically stimulated luminescence dating:

For OSL dating at the ISGS laboratory (ages reported at STOP #7 for Vandalia Pit and Munie Pit; and STOP #9, Raymond Basin), directed by Dr. Hong Wang, samples were sieved to extract 90-125 (or up to 150) μm size fractions that were treated with 2M HCl and bleach. Quartz grains were separated using a density of 2.70 g ml^{-3} of lithium metatungstate liquid and followed by 40% HF and 2M HCl etching for 80 and 50 minutes, respectively. The single aliquot regenerative (SAR) protocol used here corrected the natural and five regenerative OSL signals by a corresponding OSL signal produced by a small but constant test dose, known as sensitivity corrected OSL (Murray and Wintle, 2000; Wintle and Murray, 2006). The paleodose in quartz grains was obtained from the interpolation of sensitivity corrected natural OSL signals on the sensitivity corrected regenerative dose-response curve on six cycle sequence with a preheat temperature of 260° C and a cut-heat temperature of 220° C. All paleodose were measured using a RISØ TL-DA-20 reader with $^{90}Sr/^{90}Y$ in-built source, blue LEDs centered at 470 nm, Hoya 2×U340 and Schott BG-39 filters, and an EMI 9635 QA Photomultiplier tube. The dose rate was obtained on 100 g pulverized and preheated at 450 °C samples that were tightly held in Marinelli Beakers using an ORTEC GEM-40190P Gamma Spectrometer.

OSL dating at the University of Nebraska - Lincoln laboratory (Keyesport samples, STOP #2) used the methodology of Miao et al. (2007). This analyses used the single aliquot regenerative (SAR) protocol. Multiple aliquots are prepared from a single sample, each of which produces an individual value for equivalent dose (De). After discarding aliquots with unsatisfactory behavior during luminescence measurements, the remaining aliquot De values were combined to determine the final age. Samples were collected in aluminum tubes pushed into the exposure. Dose rate values were calculated from the bulk sediment concentrations of K, Rb, U, and Th as measured by ICP-MS and ICP-AES. Samples were opened in the laboratory under dim amber light and wet sieved to separate the 90-150 µm grains. The grains were treated by flotation in 2.7g/cm^3 sodium polytungstate to remove heavy minerals, and hydrofluoric and fluorosilicic acid treatments to etch the quartz and remove feldspars. The isolated quartz grains were then applied to aluminum disks using silicon spray and a 5 mm mask. The quartz aliquots were analyzed with Risø Model DA-20 TL/OSL reader. The range on the final age estimates incorporates errors from the De values, analytical errors in elemental concentrations, and with an assumed relative variation of ± 30% in water content. The water content for the Keyesport sand samples was estimated based on water contents for saturated sand of similar grain size in Illinois Department of Transportation bridge borings in the region.

Other laboratory methods (compositional and grain size analyses)

Data for **carbonate analyses** utilized either the methodology of Dreimanis (1962) for the Chittick apparatus, or an alternative high precision method devised by H. Wang (ISGS) for % carbonate based on dissolution and capture of purified carbon dioxide. Both methods used the < 74 um fraction. For chittick analyses, calcite and dolomite percentages were calculated in addition to total carbonate; however, the % calcite is not very reliable (low precision). **Clay mineralogy** procedures and percentage calculations were based on methodology of Hughes et al. (1994) and Moore and Reynolds (1997), using the glass slide method developed by H.D. Glass. **Grain size analyses** used standard hydrometer analyses and were performed at the ISGS sediment laboratory.

APPENDIX B: Core Descriptions and Analytical Data

Core descriptions

Core Name	Top (ft.)	Bottom (ft.)	Description
Kessler	0.0	8.0	Peoria Silt, silt loam to heavy silt loam, mainly 10YR 5/5, modern soil in upper 4 feet
Kessler	8.0	11.0	Roxana Silt, heavy silt loam, 8YR 4/4, leached
Kessler	11.0	20.0	Sangamon Geosol in Hagarstown M., loam to clay loam, 7.5YR 3.5/4, leached, upper 5 ft. is solum of Sangamon Geosol
Kessler	20.0	23.0	Hagarstown M., medium to coarse sand, reddish-brown (7.5YR 4/6), moderately well sorted, some fines
Kessler	23.0	40.0	Hagarstown M., medium to coarse sand, some gravel and some fines, 10YR 4/6, leached, moderately sorted
Kessler	40.0	54.0	Hagarstown M., medium to coarse sand, common gravelly zones (mostly < 1- inch), subangular, some cemented zones, calcareous
Kessler	54.0	55.0	limestone cobble; drilled through
Kessler	55.0	59.0	Hagarstown M., fine sand to medium sand, well sorted, calcareous
Kessler	59.0	135.0	Hagarstown M., zones of medium to coarse sand and gravel [lots of core loss in places], moderately sorted, subangular to angular, noncohesive, < 10 % fines, calcareous
Kessler	135.0	137.0	no sample
Kessler	137.0	138.5	bedrock colluvium, pebbly diamicton, 10YR 5/6
Kessler	138.5	142.5	Pennsylvanian bedrock, limestone and siltstone, gray, layer of soft shale at base, has fossils including crinoids
Culli	0.0	4.5	Peoria Silt, heavy silt loam to silty clay loam, 10YR 5/6, leached, modern AE and Bt horizons (AE in upper half foot)
Culli	4.5	9.5	Peoria Silt, silty loam, 10YR 5/4, leached, contains clay lamellae ~ 2 mm thick every 1-2 cm
Culli	9.5	13.0	Roxana Silt, heavy silt loam, 9YR 4/4, leached, weak crumb soil structure
Culli	13.0	18.0	Hagarstown Member (Sangamon Geosol A and Bt), sandy clay loam diamicton, 7.5YR 4/6, clay skins, weak mottling, more gravelly in lower portion
Culli	18.0	20.0	no sample
Culli	20.0	26.0	Hagarstown Member, sandy loam diamicton, 10YR 5/6, leached, some Mn stains and minor clay accumulations, rotten weathered pebbles, upper C horizon [supraglacial drift]
Culli	26.0	40.0	Hagarstown Member, predominantly loamy sand and medium sand, some coarse sand, fine sand and minor clay, 10YR 5/4 - 4.5/4, moderately sorted, leached, significant core loss (but gamma log confirms mainly sand)
Culli	40.0	40.8	Glasford Fm., pebbly loam diamicton, more dense than above, 2.5Y 5/4, calc., C horizon, some iron stains
Culli	40.8	58.0	Glasford Fm., pebbly loam diamicton (upper) to silt loam diamicton (lower), 5Y 4/1.5, dense, hard, uniform [subglacial till], variety of pebbles include coal, shale, carbonate, and fine-grained sandstone, calcareous
Culli	58.0	59.5	Glasford (complex); intermixed leached greenish (10Y 4/1) silty clay with brown (2.5Y 4/2) calcareous diamicton;
Culli	59.5	61.0	very fine sand, 5Y 5/2, faint stratification, strongly calcareous, well sorted
Culli	61.0	81.0	Glasford ? (complex); mostly silty clay loam diamicton (2.5Y 4/1.5 and calcareous) with significant inclusions of greenish-grey silty clay (10Y 4/1 to 10GY 4/1 - leached Lierle Clay with clay skins and soil structure) as well as inclusions of brown silty clay to clay lake sediment (2.5Y 4/2) such as at 65 to 66.7 ft.; [this unit is a mixed zone of subglacial diamicton with clasts of the underlying Lierle Clay /Yarmouth Geosol Btg horizon and lake sediment that was incorporated into the glacier]; the Lierle Clay inclusions are sometimes more than one-foot thick in the core and in other areas are small wispy contortions that are in contrast to intervening diamicton
Culli	81.0	91.0	tongue of Petersburg Silt; clay to silty clay (lake sediment), 2.5Y 3/2, faintly laminated, knife cuts it like soap or chocolate !
Culli	91.0	95.0	very fine sand to fine sand, moderately sorted, some fines, 2.5Y 5/2, calcareous, loose to weakly cohesive
Culli	95.0	99.0	coarse silt and very fine sand, few Mn stains, mostly oxidized with some mottling, 2.5Y 6/5, friable
Culli	99.0	105.0	mostly coarse sand, some very coarse sand, medium sand and fines, moderately sorted, sub-angular to sub-rounded, calcareous, 2.5Y 5/5, friable
Culli	105.0	115.0	no sample, but coarse sand according to gamma log
Culli	115.0	118.0	coarse sand and very coarse sand, loose to weakly cohesive, sub-angular, moderately sorted, some fines, 2.5Y 5/4, calcareous
Culli	118.0	120.0	no sample
Culli	120.0	120.5	silt loam, dense, faintly laminated ?, laissez-gang banding, 4Y 5/4
Culli	120.5	123.0	no sample (maybe silt or diamicton from gamma log)
Culli	123.0	137.0	lower unit of Glasford Fm.; pebbly loam diamicton, (till), dense, some large (2") fragments of carbonate and red shale, few conifer wood fragments (especially near base), few thin sandy or gravelly lenses (<0.3' thick), pebbles include shale, carbonate, coal, 5Y 4/2
Culli	137.0	138.6	very fine sand and silt, crudely laminated, calcareous, some wood fragments, (plant macrofossils?), 5Y 4.5/2
Culli	138.6	139.0	clay-rich diamicton, (silty clay loam to silty clay), 2.5Y 4/2, calcareous, has some shear planes at 45 degree angle (mixed with underlying lake sediment)

Core Name	Top (ft.)	Bottom (ft.)	Description
Culli	139.0	145.0	Petersburg Silt; silty clay to clay, massive to laminated lake sediment, some layers slightly contorted, calcareous, 10YR 4/2, (slight pinkish hue)
Culli	145.0	146.0	very pebbly silty clay loam (?) diamicton, lots of pebble lithologies, sandstone, granite, chert, other, 1Y 4/2
Culli	146.0	148.5	Petersburg Silt; silty clay to clay, thickly laminated--reddish brown to gray, some contortions in layers, calcareous, 1Y 4/2
Culli	148.5	151.0	clay loam diamicton, clay, 10YR 4/3, local orange shale fragments, calcareous
Culli	151.0	152.0	clay loam diamicton and silty clay, mottles, 2.5Y 5/4 and 10YR 4/3 (diamicton) and 10Y 6/1 in silty clay, (residual soil mixed with diamicton --- colluvium ?),
Culli	152.0	155.0	limestone, argillaceous, fractures in upper part, fossiliferous, light grey
Grandview	0	3.9	soft brown (7.5YR4/3) SILT LOAM, laminated 0.5-1.5 but otherwise massive, few pebbles, non-reactive to very weakly dolomitic; loess, Roxana Silt
Grandview	3.9	4.4	strong brown very pebbly SILT LOAM DIAMICTON, leached but with local secondary calcite accumulation; contact between loess and glacifluvial sediment, root (upper C) of Sangamon, Hagarstown Member.
Grandview	4.4	65.7	coarse GRAVEL, rounded, to bedded pebbly very coarse SAND and medium SAND, reactive, light yellow brown, n-gamma logs bedded (1-4') on left, (complete recovery in augured 4-9' interval but retained only sub samples; very poor recovery below); glacifluvial, possibly outwash portal, Hagarstown member.
Grandview	65.7	66.2	yellow brown pebbly CLAY LOAM, laminated; lower flow facies, Hagarstown Member
Grandview	66.2	72	No recovery, n-gamma logs left, likely coarse grained
Grandview	72	74	No recovery, n-gamma logs right, likely fine grained (DIAMICTON?), Glasford Formation
Grandview	74	98.9	bedded DIAMICTON, more gray in upper part, more oxidized in lower 4', including dark gray brown (2.5Y4/2) LOAM, 2% clasts (round quartzite, siltstone); olive gray (5Y5/2) CLAY; gray (2.5Y5/1) LOAM, 3% clasts (quartz, siltstone), gray brown (2.5Y5/2) LOAM, 3-5% clasts (siltstone, igneous quartz, red chert); silty and gravelly zones, other clasts include shale, brown chert, white chert, limonite nodule, disturbed zones; sheared sheets of till, 2-8' thick, Glasford Formation
Grandview	98.9	99	gray brown (2.5Y5/2) SANDY LOAM DIAMICTON, disturbed; Glasford Fm.
Grandview	99	104	No recovery, n-gamma transitional to right, defining higher block that is distinctive to 108'; inclusion of Banner Fm., Glasford Fm
Grandview	104	104.5	gray brown SANDY LOAM DIAMICTON, intercalating with gray brown LOAM DIAMICTON, clear contact; sheared inclusions, Glasford Fm.
Grandview	104.5	106.2	dark gray (10YR4/1) oxidized to olive brown LOAM DIAMICTON, 5-10 % clasts (igneous, metaquartz, siltstone), gradual transition, >1' healed subvertical joint, secondary calcite, small intersecting horizontal joints; elevation is approximately elevation of surrounding plain; inclusion of upper C of Yarmouth in "Hillery", Glasford Fm
Grandview	106.2	107.9	dark gray (10YR4/1) LOAM DIAMICTON, pink cast when dry, 5-10 % clasts (igneous, metaquartz, siltstone), wood fragments, likely spruce; till, inclusion of Banner Formation (Hillery-like), Glasford Fm.
Grandview	107.9	108.3	olive brown (2.5&4/3) very pebbly LOAM DIAMICTON, 1-2 cm clasts (chert, sandstone, subrounded to subangular) at contact; color similar to ~98, but from gravel and n-gamma is transitional; oxidation may be from below; till, Glasford Fm.
Grandview	108.3	114	no recovery; n-gamma logs left - likely coarse-grained facies, tongue of Pearl Fm.
Grandview	114	114.5	veneer of brown SAND over SILT, laminated to horizontal bedded, few granules, disturbed by coring, sharp contact; glacifluvial sediment, tongue of Pearl Fm.
Grandview	114.5	119.8	dark gray (2.5Y(4/1) to gray SILTY CLAY LOAM DIAMICTON, bedded, with very silty to sandy beds, 7-10% clasts (siltstone, shale, coal, chert, mainly angular to subangular, reactive, contact missing, color distinctly grayer than surrounding units; morainic deposits, mainly till, Glasford Formation
Grandview	119.8	123	No recovery, n-gamma similar to overlying unit, logging right, likely DIAMICTON; Glasford Fm
Grandview	123	124	BOULDER, sandstone; Glasford Fm.
Grandview	124	129	0.5-1' thick beds of olive gray pebbly LOAM, soft, dark gray (10YR4/1), lean CLAY and dark brown CLAY (shear zone) at bottom, reactive; morainic till, Glasford Fm.
Grandview	129	129.5	yellow brown (10YR5/4) to light olive brown (2Y5/4) SILTY CLAY LOAM DIAMICTON, with siltstone, chert, metaquartz clasts, strong reaction, over strong brown CLAY (shear zone), n-gamma transitional from far right; glacitectonized till, Glasford Fm.
Grandview	129.5	139	No recovery, n-gamma logging far left, likely SAND and GRAVEL, bedded; tongue of Pearl Fm.
Grandview	139	139.8	brown fine SAND over pebbly SAND; tongue of Pearl Fm.
Grandview	139.8	149.1	No recovery, n-gamma near minimum, likely SAND and GRAVEL, bedded; tongue of Pearl Fm.
Grandview	149.1	151.3	brown (oxidized) poorly sorted granular coarse SAND grades down to gray medium to coarse SAND, LOAMY SAND and sandy fine GRAVEL, bedded, strong to very strong reaction; glacifluvial sediment; tongue of Pearl Fm.
Grandview	151.3	159	No recovery, n-gamma similar to adjacent, likely sandy GRAVEL, bedded; tongue of Pearl Fm.
Grandview	159	169	Recovered handful of pebbly SAND or sandy GRAVEL, n-gamma similar to overlying, but logging slightly to right; tongue of Pearl Fm.
Grandview	169	173	gray very fine to fine SAND and silty SAND, few pebbles, disturbed by sampling, but weak bedding apparent **[thickness?]**, fluidized zones, strong reaction; glacifluvial sediment, tongue of Pearl Fm.
Grandview	173	179	No recovery, n-gamma similar to overlying, likely fine SAND; tongue of Pearl Fm.
Grandview	179	180.5	gray brown pebbly LOAM DIAMICTON, subrounded to angular sandstone, rhyolite, milky quartz; till
Grandview	180.5	204	No recovery, n-gamma logs mostly moderate to right, 2' thick left blocks, possibly interbedded GRAVEL and DIAMICTON
Grandview	204	209	Virtually no recovery except for a handful of granules, n-gamma strong to left; glacifluvial lens

Core Name	Top (ft.)	Bottom (ft.)	Description
Grandview	209	211	gray brown (2.5Y5/2) SANDY LOAM DIAMICTON, 10-50% gravel up to 2.5 cm, ign. and sed. lithologies including sandstone, quartzite, chert, subangular to subrounded, strong reaction; till w/glacifluvial sediment
Grandview	211	214	no recovery, no change in n-gamma
Grandview	214	219	recovered only 2 large gravel clasts and a smear of diamicton, n-gamma in same block as adjacent samples; till?
Grandview	219	219.6	gray SILTY CLAY LOAM to SILT LOAM DIAMICTON, sharp contact; till
Grandview	219.6	221	light olive brown (2.5Y5/3) SILTY CLAY LOAM DIAMICTON, massive, 2-3% clasts (red, brown and gray sandstone, rounded, brown coral), oxidized zones with secondary calcite, strong reaction, graded contact (reaction much stronger than below), n-gamma transitional from overlying block; till, but possibly inclusion of upper C horizon material
Grandview	221	221.4	gray (2.5Y4/1) SILTY CLAY LOAM to SILT LOAM DIAMICTON, 2-3% clasts (granite, sedimentary), wood (flattened twigs, likely spruce), moderate reaction, contact missing; till
Grandview	221.4	224	no recovery, n-gamma logs left, similar to below, likely sandy
Grandview	224	226	gray very fine SAND, no pebbles, massive to weakly bedded, reactive; alluvium Petersburg or Harkness?
Grandview	226	230	dark gray brown (10YR4/2) SILT LOAM, massive, very dark gray ((10YR3/1) SILTY CLAY LOAM, laminated, browner SILTY CLAY LOAM and SILT, laminated, variably leached to dolomitic to calcareous, sharp contacts, disturbed in upper foot, fine root or twig fragments (spruce?); lacustrine and alluvial sediment, Petersburg or Harkness?
Grandview	230	234	gray brown loamy very fine to fine SAND, horizontal bedded, contact missing, n-gamma in steady block
Grandview	234	234.8	olive gray (5Y5/2) SILTY CLAY LOAM, weak bedding, irregular contact, no reaction; alluvium, Canteen member
Grandview	234.8	249	gray to olive gray fine SANDSTONE, cross-bedded, weathered in upper part, missing 235-240; bedrock, Pennsylvanian (undifferentiated)
Mersinger	0.0	4.5	1 ft of roadbed recovered, lower part likely soft silt loam; loess with modern soil.
Mersinger	4.5	7.6	Soft, moist dark yellow brown (10YR3/4), mottled with reddish hue, SILT LOAM, 0.5 tsf, leached; loess, Peoria Silt.
Mersinger	7.6	10.5	dark brown (7.5YR4/3.5), distinct color change, SILT LOAM, 0.75 tsf, leached; loess, Peoria Silt.
Mersinger	10.5	13.0	Brown (7.5YR4/3.5), soft SILT LOAM, massive; softens downwards (2.25-0.75 tsf) and becomes more loamy with few fine subangular pebbles; gradational contact; cumulic soil below 12.4; loess, Roxana Silt.
Mersinger	13.0	16.0	stronger brown SILT LOAM to LOAM, few round to subrounded pebbles, common root traces, blocky structure, increasing soil strength with depth, gradational contact; Cumulic Sangamon Geosol in colluvium and loess, Teneriffe Silt
Mersinger	16.0	17.6	Strong brown (7.5YR5/6), mottled with orange hue, very fine sand LOAM, 0.75- 1.0 tsf grades to very soft strong brown (7.5YR4/6) LOAM; leached; sharp contact. Sangamon Geosol in alluvium; Pearl-Teneriffe complex.
Mersinger	17.6	19.3	Dark yellow brown (10YR4/6) loamy fine SAND with granules, coarsens downwards, weakly bedded, leached, sharp contact; upper C horizon, Pearl-Teneriffe complex.
Mersinger	19.3	22.2	brown (10YR4/6) pebbly loamy SAND, very poorly sorted, bedded, graded; leached, contact missing; alluvium, Pearl-Teneriffe complex.
Mersinger	22.2	26.0	No sample, gamma log similar to above; alluvium, Pearl-Teneriffe complex
Mersinger	26.0	28.8	Firm brown (10YR6/4-5/6), mottled or banded, SILT, massive to laminated; 0.25-0.75 tsf, increases to 2.25 by 28 ft; calcareous; sharp contact; alluvium, Pearl-Teneriffe complex.
Mersinger	28.8	29.5	Very fine SAND, massive; alluvium, Pearl-Teneriffe complex.
Mersinger	29.5	33.9	Light yellowish brown (2.5Y6/4) medium SILT, laminated, clay laminae in lower 0.5'; 1.0 tsf; sharp color contact; alluvium, Pearl-Teneriffe complex.
Mersinger	33.9	35.5	Gray SILTY CLAY and CLAY, laminated, interbedded; 0.5-1.25 tsf; calcareous; sharp contact; alluvium, Pearl-Teneriffe complex.
Mersinger	35.5	37.5	Gray brown (2.5Y5/2) SILT, soft, bedded, sharp contact; loess, Pearl-Teneriffe complex
Mersinger	37.5	38.4	Brown SILT LOAM, laminated, dry, 3.25 tsf, grades down to fine SAND, bedded; alluvium, Pearl-Teneriffe complex.
Mersinger	38.4	40.0	No sample, gamma log drops sharply at 40.
Mersinger	40.0	61.0	Light yellow brown (10YR6/5) to brown fine SAND and loamy SAND, loose to soft; contact missing (partial sample recovery); outwash, Pearl Formation.
Mersinger	61.0	67.0	Clean GRAVEL, clayey GRAVEL, coarse SAND, subangular to subrounded; bedded, loose; poor recovery, driller estimated lower limit; outwash, Pearl Formation.
Mersinger	67.0	67.9	Brown pebbly LOAM DIAMICTON, weakly bedded, calcareous, sharp contact; debris flow, Glasford Formation
Mersinger	67.9	72.2	Dark gray brown (2.5Y4/2) pebbly LOAM DIAMICTON, massive, very dense; coal fragment, cobbles > 2.5 in; >4.5 tsf; calcareous. Basal till; Glasford Formation.
Mersinger	72.2	77.5	Dark gray brown (2.5Y4/2), slightly more olive than above, pebbly LOAM DIAMICTON, bedded, gravel and silt beds less than 0.1' thick; calcareous, gradational contact; till, Glasford Formation.
Mersinger	77.5	80.0	dark gray brown (2.5Y4/2), pebbly LOAM DIAMICTON, massive, no discernable change in effervescence, but lower total carbonate than above; contact missing; till, Glasford Formation.
Mersinger	80.0	86.0	No sample; gamma log is similar to above, but gravelly 84-86; till, Glasford Formation
Mersinger	86.0	91.6	Olive brown (2.5YR4/3) SILT LOAM DIAMICTON, irregular fracture, possibly weakly bedded, small wood fragments; till with incorporated lacustrine sediment from below, deformable bed?, Glasford Formation.
Mersinger	91.6	96.0	Olive gray (5Y6/1) SILT, laminated; very dense (>4.5 tsf), disseminated organics. Lacustrine sediment, possibly backwater lake of Kaskaskia, Petersburg Silt.
Mersinger	96.0	99.6	Olive gray SILT, laminated, clay laminae, firm (1.5-3.75 tsf); disseminated organics with common wood fragments, including 0.25' spruce branch; increased deposition rate with onset of glaciation, Petersburg Silt

Core Name	Top (ft.)	Bottom (ft.)	Description
Mersinger	99.6	106.0	No sample; gamma logs left in upper half, right in lower half; sandy zone? Petersburg Silt
Mersinger	106.0	106.5	Dark gray brown SILT LOAM, diffuse brown mottle, gastropods (Pomatiopsis sp., Carychium sp. Succinea sp.), calcareous, distinct contact; lacustrine sediment, Petersburg Silt
Mersinger	106.5	107.5	Dark gray brown (2.5Y4/2) SILT LOAM to SILTY CLAY LOAM, massive to weakly bedded, weak paleosol at top, dolomitic; distinct contact; shallow lacustrine sediment, Petersburg Silt.
Mersinger	107.5	113.2	Gray brown (2.5Y5/2) SILT LOAM, olive hue, very stiff, grades to beds of SILTY CLAY LOAM and SILT LOAM, lam. zones, sandy at ~109.5; wk. paleosol, root traces through interval, leached to weakly dol.; grad. contact; top of floodplain dep., Petersburg Silt.
Mersinger	113.2	117.0	Dark gray brown (2.5Y4/2) LOAM, coarsening with depth, root traces, >4.5 tsf; fractured, leached; weak paleosol in alluvium, Petersburg Silt
Mersinger	117.0	118.0	Loam, laminated, organic, leached; alluvium, Petersburg Silt.
Mersinger	118.0	121.0	Recovered only a handfull of fine SAND; alluvium, Petersburg Silt
Mersinger	121.0	122.2	Coarse SAND (1 ft), calcareous; alluvium, Petersburg Silt
Mersinger	122.2	126.0	SILT LOAM to loam, laminated, over SILTY CLAY bed; calcareous; alluvium, Petersburg Silt.
Mersinger	126.0	127.0	Gray brown SILTY CLAY LOAM, laminated; alluvium, Petersburg Silt
Mersinger	127.0	131.0	Recovered bit of shale at 127. Bottom of hole.
Virgin	0.0	8.3	Dark yellow brown (10YR4/4) silt loam contains A horizon of modern soil, lightly bleached and bedded below ~3ft. Loess, Peoria Silt.
Virgin	8.3	8.3	N.B. 0-9 contains ~10ft; footages normalized
Virgin	8.3	13.7	Brown (7.5YR4/4) silt loam, massive, leached, few silans. Loess, Roxana Silt
Virgin	13.7	15.0	Strong brown (7.5YR4/6) granular silty loam diamicton, massive, angular LF, leached. Colluvial loess facies, Roxana Silt.
Virgin	15.0	17.0	Strong brown pebbly silty clay loam diamicton, massive, argillans >1cm, Fe-Mn concentration >1cm, angular clasts 1-10mm, leached. B Paleosol in till, Sangamon/Hagarstown M. (diamicton)
Virgin	17.0	20.3	Soft, yellow brown (10YR5/6), bleached-mottled, pebbly silty clay loam diamicton, to loam diamicton, crudely bedded, clasts to 25mm, argillans, leached, strong horizontal fabric, possibly highlighted by pedogenic features including liesegang bands. Sangamon B horizon in supraglacial till, Sangamon/Hagarstown M. (diamicton).
Virgin	20.3	27.0	No sample
Virgin	27.0	28.2	Soft, yellow brown (10YR5/6), bleached-mottled, pebbly silty clay loam diamicton, to loam diamicton, crudely bedded, clasts to 25mm, argillans, leached, strong horizontal fabric, possibly highlighted by pedogenic features including liesegang bands. Sangamon B horizon in supraglacial till, Sangamon/Hagarstown M. (diamicton).
Virgin	28.2	30.8	Yellow brown loam diamicton, horizontally bedded, pebbly, strong subhorizontal fabric, calcareous, oxidized. Sangamon upper C, Hagarstown M. (diamicton).
Virgin	30.8	32.0	No sample - sand and gravel?; Hagarstown M.
Virgin	32.0	32.8	Yellow brown, gravel with fine sand matrix, graded, sharp contact, calcareous; outwash, Hagarstown M.
Virgin	32.8	33.8	Yellow brown, pebbly loam diamicton, bedded, sand and gravel horizon < 0.1 ft. thick, heterolithic clasts; outwash, Hagarstown M.
Virgin	33.8	37.0	No sample - sand and gravel? Hagarstown M.
Virgin	37.0	37.8	Yellow brown, coarse gravel over pebbly loam diamicton, horizontal fabric, platy structure in lower part, abrupt color contact, very stiff; outwash, Hagarstown M.
Virgin	37.8	45.8	gray brown (10.5YR5/2), pebbly loam diamicton, massive, weak horizontal fabric (shearing?) highlighted by slight oxidation, calcareous, abrupt contact (erosion surface); till, Glasford Fm.
Virgin	45.8	50.3	Yellow brown (10YR5/6) silty clay loam diamicton, soft, horizontal fabric (shearing?), argillans, Fe-Mn concentration <5mm, clay-rich at bottom, leached, inclusion of Yarmouth B/Banner; till, Glasford Fm.
Virgin	50.3	61.1	Yellow brown, silt loam diamicton, massive, jointed with bleaching along joints, clasts mainly very coarse sand to fine gravel but up to coarse pebbles (4cm), oxidized, calcareous, distinct color contact. inclusion of Yarmouth upper C/Banner Formation; till, Glasford Formation
Virgin	61.1	62.8	dark gray, diamicton, massive, oxidized on joints, calcareous, gradational contact (mixture with lower unit). DC horizon, till, Glasford Formation
Virgin	62.8	67.5	Dark gray brown, silt loam diamicton, heterogeneous, sand and thin granule layers. At 65.2, sharp contact between brownish gray ("pink"?) and grayish brown. Unit possibly includes amalgamated till sheets, although to no shear zones or slickensides are apparent; Glasford Formation
Virgin	67.5	74.0	Dark gray brown to slightly olive (2.5Y4/2) clay loam to silty clay loam diamicton, massive, fine shale clasts abundant, wood fragments, chert cobble at base, distinct color contact, subhorizontal fabric and bedding or shear planes; Glasford Formation
Virgin	74.0	87.1	(No Sample 85.4-87, 87-87.1 cobble at top of run). Brown (10YR4/3) silt loam to loam diamicton, massive, similar color and texture to ~64ft (trace element data appear to support correlation), yellower in lower 2 ft, gradational, vague horizontal clast fabric, subangular to well round sedimentary clasts, few wood fragments, quartzite cobble at base below gravel broken by drilling, sharp contact. C horizon till, Glasford Fm.
Virgin	87.1	97.7	Dark brown (10YR3/3) loam diamicton, horizontal fabric, sedimentary clasts to very fine pebble size, fine wood fragments, possibly horizontal fabric, gravel and sandy loam beds <= 0.2 ft thick. Dark gray brown (10YR4/2) silt bed at 93.7ft, clay-rich. Yellow brown to gray with yellow brown mottle, horizontal fabric, shear zones at 90, 92.2, 94.2 ft with sharp contacts. Angular to well round chert and sedimentary lithic fragments. Distinctly higher natural gamma signature from overlying diamicton units. Till, mixing with underlying units, Glasford Fm.
Virgin	97.7	100.4	Limestone boulder
Virgin	100.4	100.6	Disturbed silt and clay, originally stratified. Banner Fm.

Core Name	Top (ft.)	Bottom (ft.)	Description
Virgin	100.6	102.0	No Sample
Virgin	102.0	119.2	Light olive brown (2.5Y4/3) pebbly loam diamicton, massive; 1 granite, ss, sh, cht clasts to fine pebble size overall larger than overlying units, subangular to well rounded; no wood; 0.1-0.3 ft thick sand, sandy gravel zones; graded clayey gravel to very fine sand bed in lowest ft, calcareous; till, Omphghent Member
Virgin	119.2	122.0	No Sample, natural gamma log increasing from 120ft
Virgin	122.0	122.1	Light brown diamicton, massive, calcareous, sharp contact; Omphghent Member
Virgin	122.1	124.5	Yellow brown (10YR5/6) loam diamicton, massive, leached, liesegang banding in upper foot, clay or Mn laminae at base. Truncated paleosol in till? Banner Fm.
Virgin	124.5	126.4	Light yellow brown (oxidized) to gray (lower part) loam diamicton, massive, calcareous, distinct but graded contact. Debris flow, Banner Formation
Virgin	126.4	127.1	Yellow brown pebbly sand grades up to gray brown silty loam laminated, calcareous. Glacifluvial sediment
Virgin	127.1	132.0	No sample - sand and gravel?
Virgin	132.0	133.5	Olive brown fine sandy gravel with clay, loose, round to subang clasts, calcareous. Glacifluvial sediment
Virgin	133.5	135.5	No Sample
Virgin	135.5	136.5	Reddish brown fine gravel, massive, rounded clasts, mainly resist lithologies, sharp contact. Glacifluvial sediment
Virgin	136.5	136.8	Reddish brown loam diamicton, massive; till, Banner Formation
Virgin	136.8	137.2	Gray brown diamicton, disturbed, clay-rich; till, Banner Formation
Virgin	137.2	137.5	Gray loam diamicton, massive, clasts to 3 cm; till, Banner Formation
Virgin	137.5	139.0	No Sample
Virgin	139.0	153.5	Gray brown loam diamicton, horizontal bedded, sand lenses, rounded and angular shale fragments, coal, heterogeneous, random fabric of lithics, soft lithics unbroken imply short transport; grades to silty clay loam diamicton, massive, more uniform, with wood fragments at ~147.5,sharp contact; till, Banner Formation
Virgin	153.5	158.0	Dark gray to yellow brown silt loam, fractured in lower part, rich in disseminated organics, calcareous, 155.3-157 missing, sharp contact. Alluvium, Harkness Silt
Virgin	158.0	158.5	Gray brown, silty clay loam diamicton, massive, calcareous, sharp contact; Harkness Silt
Virgin	158.5	159.2	Gray brown silt, horizontally bedded, calcareous at top but gradually leached with depth. Alluvium, Harkness Silt.
Virgin	159.2	165.3	Gray brown silt loam, horizontally bedded, dolomitic, gradational color contact; Alluvium, Harkness Silt
Virgin	165.3	165.9	Olive brown (2.5Y4/3), silt loam, massive to faintly bedded, vivianite, leached. Paleosol in alluvium, Canteen Member A.
Virgin	165.9	167.0	No Sample
Virgin	167.0	170.0	Olive (5Y4/3) silt loam, faintly laminated, vivianite, root traces in upper 0.5 ft, leached, gradual color change. Alluvium.
Virgin	170.0	174.1	Olive brown very fine sandy loam, laminated grades to loam, horizontally bedded, grades to very fine sand, horizontally bedded to massive, leached, sharp contact. Alluvium.
Virgin	174.1	179.4	Yellow brown conglomerate, bedded, large shale fragments, iron-rich, poorly to well indurated. Alluvium or colluvium, reworked Tertiary or older units. Canteen Member B.
Virgin	179.4	181.1	Gray shale, laminated. Bedrock

Particle size analysis

			% within the < 2 mm fraction			
Site Name	**Sample ID**	**Gravel % > 2 mm**	**Sand % 63-2000 μm**	**Silt % 2-63 μm**	**Clay % < 2 μm**	**USDA texture**
Ogles Creek Section	Top of Petersburg Silt	0	1	88	11	Silt
Ogles Creek Section	Bottom of Petersburg Silt	0	1	84	15	Silt loam
Highbanks Road Sect.	HBC-E3	0	1	86	13	Silt loam
Highbanks Road Sect.	HBC-E2	0	2	88	10	Silt
Highbanks Road Sect.	HBC-E1	70	9	60	31	Silty clay loam
Highbanks Road Sect.	HBC-E	0	2	67	31	Silty clay loam
Highbanks Road Sect.	HBC-D	1	3	56	41	Silty clay
Highbanks Road Sect.	HBC-C	0	13	59	28	Silty clay loam
Highbanks Road Sect.	HBC-B	0	25	56	19	Silt loam
Highbanks Road Sect.	HBC-A	0	98	0	2	Sand

			% within the < 2 mm fraction		
Core Name	**Depth**	**Gravel**	**Sand**	**Silt**	**Clay**
	(feet)	**< 2 mm**	**63-2000 μm**	**4-63 μm**	**< 4 μm**
Grandview Core	1	0	3	73	24
Grandview Core	75	7	35	39	26
Grandview Core	85	7	35	41	24
Grandview Core	107.1	5	39	41	20
Grandview Core	116	2	21	44	35
Grandview Core	126	22	42	33	25
Grandview Core	179	6	44	35	21
Grandview Core	210	9	40	38	22
Grandview Core	226.6	0	7	60	32
Grandview Core	234.1	0	17	63	20
Virgin Core	7	0	3	78	19
Virgin Core	148	3	19	51	30
Virgin Core	152	1	15	55	30
Virgin Core	158	2	14	54	33
Virgin Core	162	0	9	62	29
Virgin Core	168	0	23	63	14
Virgin Core	170	0	41	49	10

Carbonate content

Core Name	Depth	% Calcite	% Dolomite	Total Carb. %	Method
	(feet)	(< 74 μm)	(< 74 μm)	(< 74 μm)	
Culli Core	40			13.2	H. Wang
Culli Core	42			16.4	H. Wang
Culli Core	44			15.8	H. Wang
Culli Core	46			14.3	H. Wang
Culli Core	48			10.5	H. Wang
Culli Core	50			7.8	H. Wang
Culli Core	52			7.3	H. Wang
Culli Core	58			1.7	H. Wang
Culli Core	60			11.8	H. Wang
Culli Core	62			0.6	H. Wang
Culli Core	64			5.0	H. Wang
Culli Core	66			24.5	H. Wang
Culli Core	68			13.9	H. Wang
Culli Core	70			13.3	H. Wang
Culli Core	72			5.2	H. Wang
Culli Core	74			5.5	H. Wang
Culli Core	76			17.6	H. Wang
Culli Core	78			5.3	H. Wang
Culli Core	80			10.8	H. Wang
Culli Core	82			16.0	H. Wang
Culli Core	84			7.1	H. Wang
Culli Core	86			7.8	H. Wang
Culli Core	88			14.7	H. Wang
Culli Core	90			6.2	H. Wang
Culli Core	92			23.6	H. Wang
Culli Core	95			29.6	H. Wang
Culli Core	98			24.9	H. Wang
Culli Core	100			23.9	H. Wang
Culli Core	102			28.6	H. Wang
Culli Core	104			29.2	H. Wang
Culli Core	115			19.5	H. Wang
Culli Core	116			19.5	H. Wang
Culli Core	117			19.5	H. Wang
Culli Core	118			19.5	H. Wang
Culli Core	119			17.9	H. Wang
Culli Core	120			17.9	H. Wang
Culli Core	121			17.9	H. Wang
Culli Core	122			17.9	H. Wang
Culli Core	123			17.9	H. Wang
Culli Core	124			15.2	H. Wang
Culli Core	126			13.6	H. Wang
Culli Core	128			13.5	H. Wang
Culli Core	130			9.0	H. Wang
Culli Core	132			16.0	H. Wang
Culli Core	134			15.5	H. Wang
Culli Core	136			13.1	H. Wang
Culli Core	138			16.4	H. Wang
Culli Core	140			24.4	H. Wang
Culli Core	142			24.0	H. Wang
Culli Core	144			22.7	H. Wang
Culli Core	146			13.2	H. Wang
Culli Core	148			6.4	H. Wang
Culli Core	150			5.8	H. Wang
Culli Core	152			3.4	H. Wang
Culli Core	154			78.9	H. Wang
Culli Core	155			85.6	H. Wang
Grandview Core	75	6.5	11.9	18.4	Chittick
Grandview Core	85.5	4.7	9.2	13.9	Chittick
Grandview Core	107.1	12.0	12.3	24.3	Chittick
Grandview Core	116	7.0	5.6	12.6	Chittick
Grandview Core	126.6	2.1	3.2	5.3	Chittick
Grandview Core	129.1	2.0	10.8	12.8	Chittick
Grandview Core	179.5	8.9	18.1	27.0	Chittick

Core Name	Depth	% Calcite	% Dolomite	Total Carb. %	Method
	(feet)	(< 74 μm)	(< 74 μm)	(< 74 μm)	
Grandview Core	210	5.1	17.2	22.3	Chittick
Grandview Core	219.9	7.6	9.2	16.8	Chittick
Grandview Core	221.3	1.7	5.3	7.0	Chittick
Grandview Core	226.7	2.2	10.4	12.6	Chittick
Grandview Core	227.8	1.1	15.9	17.0	Chittick
Grandview Core	228.9	17.6	11.8	29.4	Chittick
Mersinger Core	19.0			0.0	H. Wang
Mersinger Core	21.0			0.0	H. Wang
Mersinger Core	27.0			27.8	H. Wang
Mersinger Core	29.0			27.2	H. Wang
Mersinger Core	31.0			27.9	H. Wang
Mersinger Core	33.0			28.1	H. Wang
Mersinger Core	35.0			32.1	H. Wang
Mersinger Core	37.0			30.1	H. Wang
Mersinger Core	39.0			27.7	H. Wang
Mersinger Core	41.0			28.2	H. Wang
Mersinger Core	47.0			26.5	H. Wang
Mersinger Core	49.0			28.7	H. Wang
Mersinger Core	51.0			25.6	H. Wang
Mersinger Core	53.0			31.6	H. Wang
Mersinger Core	55.0			33.0	H. Wang
Mersinger Core	57.0			33.2	H. Wang
Mersinger Core	59.0			35.8	H. Wang
Mersinger Core	65.0			25.0	H. Wang
Mersinger Core	71.0			27.4	H. Wang
Mersinger Core	73.0			24.2	H. Wang
Mersinger Core	77.0			22.2	H. Wang
Mersinger Core	79.0			14.4	H. Wang
Mersinger Core	87.0			11.4	H. Wang
Mersinger Core	89.0			17.6	H. Wang
Mersinger Core	91.0			7.4	H. Wang
Mersinger Core	93.0			16.0	H. Wang
Mersinger Core	97.0			16.1	H. Wang
Mersinger Core	108.0			1.9	H. Wang
Mersinger Core	110.0			1.0	H. Wang
Mersinger Core	112.0			0.3	H. Wang
Mersinger Core	114.0			1.7	H. Wang
Mersinger Core	116.0			2.6	H. Wang
Mersinger Core	122.0			0.3	H. Wang
Mersinger Core	126.0			16.0	H. Wang
Virgin Core	28.6	9.3	6.3	15.5	Chittick
Virgin Core	30.2	6.1	14.1	20.3	Chittick
Virgin Core	33.2	2.8	7.8	10.6	Chittick
Virgin Core	45.1	4.6	8.5	13.1	Chittick
Virgin Core	46.2	0.0	0.0	0.0	Chittick
Virgin Core	49	0.0	0.0	0.0	Chittick
Virgin Core	59.6	10.4	8.4	18.7	Chittick
Virgin Core	64	12.7	9.8	22.5	Chittick
Virgin Core	73.7	2.3	2.9	5.2	Chittick
Virgin Core	75.9	12.5	10.5	23.0	Chittick
Virgin Core	84	11.9	12.9	24.8	Chittick
Virgin Core	89.5	2.3	2.2	4.5	Chittick
Virgin Core	93.4	1.6	2.5	4.1	Chittick
Virgin Core	109.5	5.2	7.5	12.7	Chittick
Virgin Core	117	2.0	10.6	12.5	Chittick
Virgin Core	123.7	0.0	0.0	0.0	Chittick
Virgin Core	124.9	12.1	7.7	19.8	Chittick
Virgin Core	125.8	13.7	8.6	22.4	Chittick
Virgin Core	140.2	6.4	6.0	12.5	Chittick
Virgin Core	144.5	2.7	3.3	6.0	Chittick
Virgin Core	148	0.8	4.9	5.7	Chittick
Virgin Core	150.5	1.7	3.1	4.8	Chittick
Virgin Core	152	1.0	3.0	4.1	Chittick
Virgin Core	158.1	2.7	4.7	7.4	Chittick
Virgin Core	158.9	2.3	4.4	6.7	Chittick
Virgin Core	162	0.8	1.2	2.0	Chittick
Virgin Core	170	0.0	0.0	0.0	Chittick

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