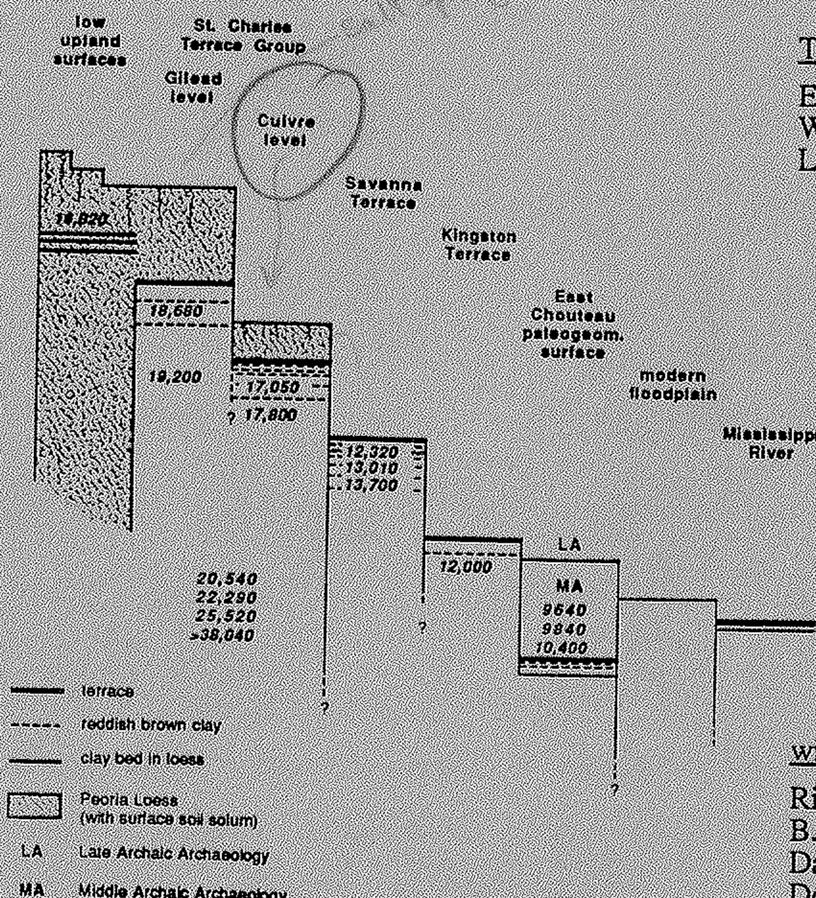
Grimley

MIDWEST FRIENDS OF THE PLEISTOCENE

QUATERNARY DEPOSITS AND LANDFORMS, CONFLUENCE REGION OF THE MISSISSIPPI, MISSOURI, AND ILLINOIS RIVERS, MISSOURI AND ILLINOIS: TERRACES AND TERRACE PROBLEMS



Trip Leaders

Edwin R. Hajic
W. Hilton Johnson
Leon R. Follmer

with contributions by

Richard G. Baker
B. Brandon Curry
David A. Grimley
Donald L. Johnson
Michael O'Brien
Donald Schwert
Alison J. Smith

Sponsored by:
Department of Geology, University of Illinois at Urbana-Champaign
Illinois State Geological Survey, Urbana, Illinois

38th Field Conference **May 10-12, 1991**

MEETINGS OF THE MIDWEST FRIENDS OF THE PLEISTOCENE

1	1950	Eastern Wisconsin	S. Judson
2	1951	Southeastern Minnesota	H.E. Wright, Jr. and R.V. Ruhe
3	1952	Western Illinois And Eastern Iowa	P.R. Shaffer and W.H. Scholtes
U	1952	Southwestern Ohio	R.P. Goldthwait
U	1953	Northeastern Wisconsinan	F.T. Thwaites
U	1954	Central Minnesota	H.E. Wright, Jr. and A.F. Schneider
6	1955	Southwestern Iowa	R.V. Ruhe
U	1956	Northwestern Lower Michigan	J.H. Zumberge and others
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-Missouri Border	C.K. Bayne and others
21	1972	East-central Illinois	W.H. Johnson and others
22	1973	Lake Michigan Basin	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. Olsen
26	1979	Central Illinois	L.R. Follmer 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 Valey, 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 and others

MIDWEST FRIENDS OF THE PLEISTOCENE

QUATERNARY DEPOSITS AND LANDFORMS, CONFLUENCE REGION OF THE MISSISSIPPI, MISSOURI, AND ILLINOIS RIVERS, MISSOURI AND ILLINOIS: TERRACES AND TERRACE PROBLEMS

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TERRACES IN THE CENTRAL MISSISSIPPI VALLEY

Edwin R. Hajic

INTRODUCTION

The Mississippi Valley functioned as a major late Wisconsinan meltwater stream, draining large quantities of meltwater from the Superior, Rainy, Chippewa, Green Bay, Des Moines and Lake Michigan glacial lobes of the upper midcontinent, and transporting material to the delta plain and the Gulf of Mexico (Figure 1). As a result, traceable Mississippi Valley terraces and related sediments record a complex but decipherable history of aggradation and incision episodes generated largely in response to glacial activity effecting changes in discharge and sediment load, magnitude and frequency of flood events, and drainage diversions. The Mississippi Valley serves as a basis for the unification of diverse late Quaternary systems and paleoenvironments along its length. Fluvial activity in the Mississippi Valley was the common major influence on geomorphic and stratigraphic evolution of lower reaches of all tributary streams and was the source control of extensive eolian loess deposits. Sedimentology of Woodfordian deposits holds clues to glacial activity upstream, particularly for the earlier part of the Woodfordian, a time for which the character and age of glacial deposits is poorly understood but for which fluvial deposits are well-represented. Tracing of these terraces and ultimate correlation with lower valley terraces will provide a means for understanding large scale, long term behavior of a major meltwater stream in response to the particular style of glaciation and deglaciation of the Laurentide Ice Sheet. Environmentally, the valley is a link between glaciated and unglaciated environments beyond the ice front. At any time during the late Wisconsinan, the Mississippi River traversed climatic and vegetational gradients. Fossiliferous terrace-related deposits in tributary valleys provide the potential for charting paleoenvironmental changes spatially and temporally by reconstructing ecological parameters down these gradients for multiple time planes. However, interpretations of the foregoing are only as sound as the geomorphic, depositional, and stratigraphic framework on which they are based.

The primary purpose of this trip is to examine the terrace framework and chronology of the central Mississippi Valley, that reach of the valley from northwestern Illinois, where a major Woodfordian drainage diversion occurred, and the head of the Mississippi embayment. In the central valley, we will examine the terraces in the area immediately north of St. Louis, Missouri. Older Woodfordian terraces are preserved only in tributary valleys in this reach. We will focus on them because associated deposits span the last glacial maximum, a period of considerable paleoenvironmental interest, and, because they historically have posed their own set of interpretive problems. A second focus of the field trip is to discuss processes in, and conditions of, tributary valleys that have contributed to stratigraphic and geomorphic variability and confusion. It will be demonstrated that these processes and conditions render in many cases simple geomorphic mapping of terraces in loess-mantled terrain woefully inadequate.

On Day 1 of the field trip, in Missouri, we will introduce the terrace framework and chronology, examine morphology of a typical tributary valley where most terraces are represented, examine proximal and medial sedimentary facies of terrace-related backflood deposits in tributary valleys, and begin our consideration of factors that can complicate terrace interpretation. Several formerly defined terrace type areas will be visited. At Arrowhead Industrial Park, we will begin to demonstrate the futility of traditional geomorphic mapping of loess-mantled terraces. At fossiliferous localities, we will discuss the viability of terrace-related deposits as paleoenvironmental information source, and hear preliminary results of identification and paleoenvironmental interpretations. At Jamestown Quarry, we will view multiple flood clay beds in the Peoria Loess in various landscape positions and discuss their age and significance.

Our demonstration of terrace problems will continue on Day 2 as we visit additional formerly defined terrace type areas related to the Brussels Terrace. First we will assemble at the community of Deer Plain for a brief introduction to the latest Wisconsinan terraces, the Savanna and Kingston Terraces, and the early Holocene Mississippi River. At Greenbay Hollow, we will examine landscape - stratigraphic relationships at an area mapped as the Brussels Terrace. This will lead us to consider upland sediment assemblages, pre-Wisconsinan loess and paleosol stratigraphy, and erosion surfaces, topics that will be pursued at the final stop, Pancake Hollow. In between, at Salt Spring Hollow, we will summarize the Mississippi Valley terrace framework and chronology, wrap-up paleoenvironmental discussions, and discuss strategies and approaches to refining the framework and tracing the

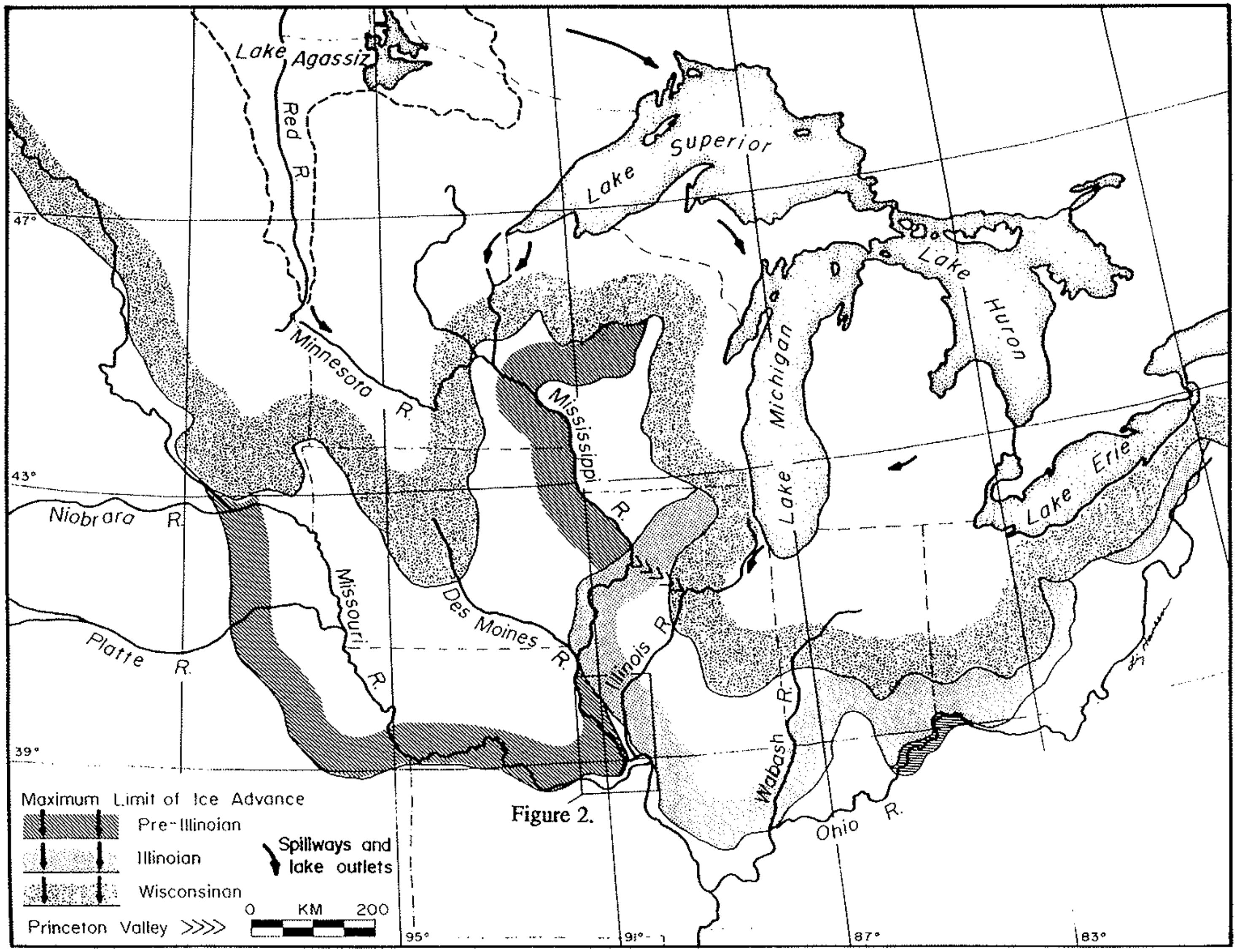

Figure 1. Midcontinental setting of the field trip area relative to late Wisconsinan ice margin position about 20,000 B.P., Great Lakes, and major proglacial lake outlets and spillways (Modified from Styles, 1985).

terraces. Location of field trip stops are indicated on both sides of the back cover, one for each day. A road log is included at the back of volume.

In addition to complexities inherent in glaciofluvial systems, other factors influence terrace interpretation, particularly in tributary valleys, here and probably elsewhere, and these we will consider. A recurring major problem with earlier efforts at terrace definition and interpretation, for numerous reasons, was terrace mapping on the basis of accordant altitudes of land surfaces developed on loess, not alluvium. Full understanding is confounded by (1) accordance of ground surfaces underlain by both loess-mantled terraces and loess-mantled upland sediment assemblages within the region; (2) probable contemporaneity of slope erosion related to evolution of the Iowan Erosion Surface and deposition of terrace-related sediment; (3) potential overlapping of younger flood silt and clay over a range of geomorphic surfaces; and, (4) spatial and temporal variability in the preceding conditions in a downvalley direction, with distance from the main valley, and with size of tributary drainage.

An integrated geomorphic, stratigraphic and sedimentologic framework is outlined from which interpretations of regional and local valley landscape evolution and central Mississippi valley - tributary valley interrelationships can proceed. One terrace family consisting of loess-mantled terraces spanning a range of altitudes, two lower terraces, and one buried surface are defined. Older terraces are preserved only in tributary valleys; they are underlain principally by various slackwater, backflood, and lacustrine facies related in general to aggradation in the Mississippi Valley and backflooding of tributaries. The two youngest surfaces are preserved in the Mississippi Valley where they span a more limited vertical range.

BACKGROUND

In the Three Rivers Area (Hajic, 1990) (Figure 2), the vicinity where the Missouri River enters from the west and Illinois River enters from the north, the Mississippi Valley is cut into Mississippian limestone, dolomite and shale. Wooded uplands are strongly dissected by tributary stream networks. Karst areas occur where limestone susceptible to solution, particularly the St. Louis Limestone, is at or near the surface. On the west side of the Mississippi Valley and north of the Missouri Valley, uplands are mantled by pre-Illinoian till deposited by an eastward advancing lobe of ice. East of the Mississippi Valley, in Calhoun County, Illinois, the uplands remained unglaciated but pre-Illinoian ice was at the position of the Mississippi Valley. Illinoian ice advancing westward across Illinois barely crossed the Mississippi Valley at St. Louis. Just to the north, on the east side of Calhoun County, its western boundary was the Illinois Valley. The entire area is mantled with variable thicknesses of Wisconsinan and pre-Wisconsinan loesses. Grover Gravel, believed to be Tertiary in age (Rubey, 1952), is preserved along principal drainage divides below the loess in unglaciated portions of the area. The gravels are offset by the east-west trending Cap au Gres faulted flexure, a monoclinal fold with downthrown side to the south. This offset results in contrasting topography that we will see on Day 2 of the trip.

Prior to about 20,000 B.P. the Ancient Mississippi River flowed through the Princeton Valley in the Green River Lowland region and occupied the modern middle and lower Illinois Valley (Figure 1). Major valley aggradation occurred as glacier lobes advanced (Hajic, 1990). About 20,000 B.P., advancing ice of the Lake Michigan Lobe blocked the Ancient Mississippi Valley, presumably forming glacial Lake Milan in the lowlands that ultimately discharged down the Ancient Iowa - Cedar Valley (modern Mississippi Valley above the mouth of the modern Illinois Valley) (Shaffer, 1954; Anderson, 1968; McKay, 1977). In the new valley, the Mississippi continued to aggrade. The general style of deglaciation resulted in large proglacial lakes that at times drained catastrophically, ultimately down the Mississippi Valley (Teller, 1987). Major downcutting occurred after 13,000 B.P. as these lake waters drained and scoured earlier fill.

FACTORS AFFECTING TERRACE IDENTIFICATION

When the number and type of factors that can influence terrace identification and correlation are considered, the problems encountered by terrace investigators are easier to understand. Some are related to problems in definition and use of the term 'terrace', many have to do with preservation and environments of deposition in tributary valleys, and some have to do with loess sedimentation. Combined, these factors can potentially seem overwhelming, not only in the Mississippi Valley, but in any valley where similar combinations of factors may be present. Some of the more significant factors are outlined below.

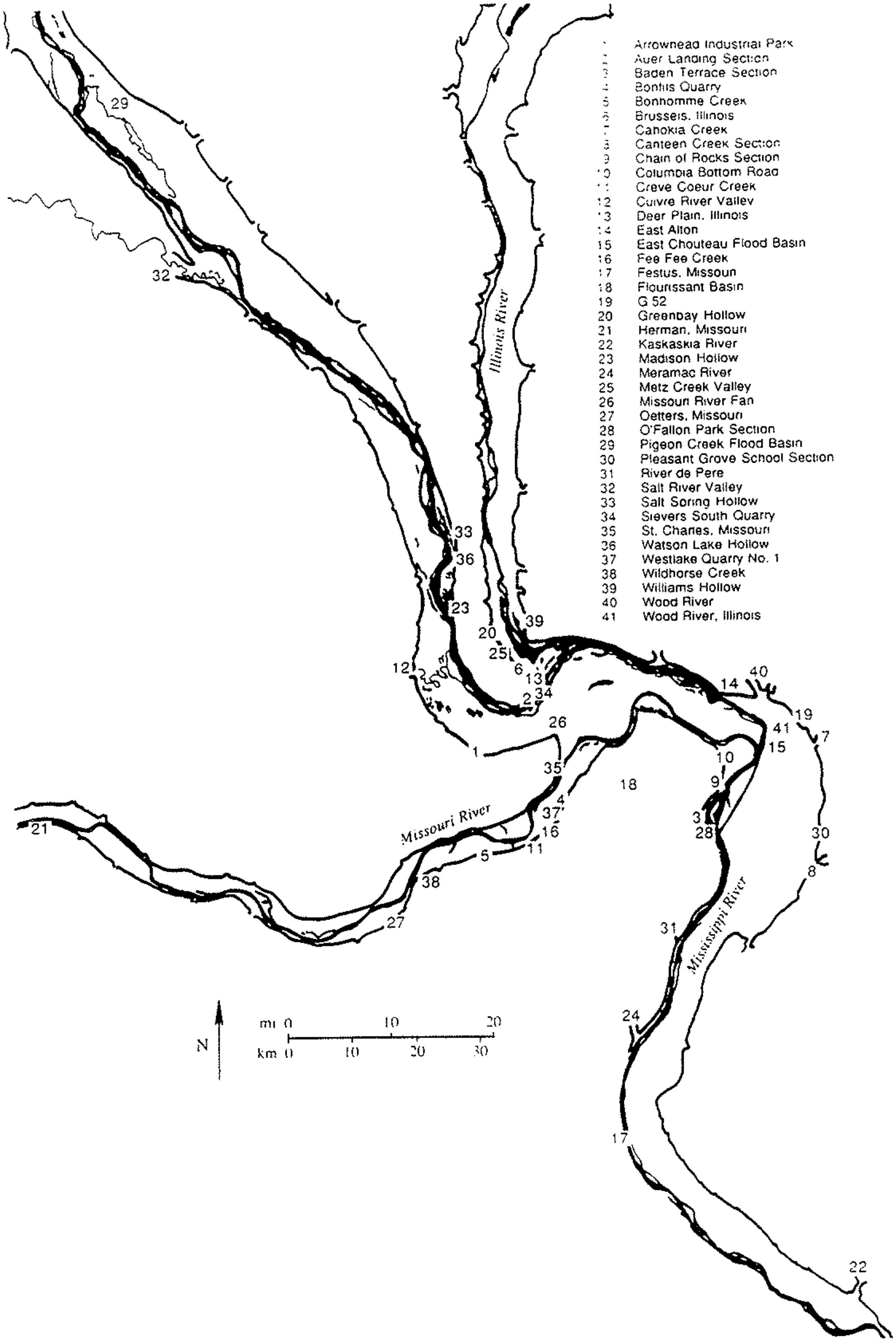

Figure 2. Three Rivers Area illustrating section and core locations and sites discussed in text.

Mapping Ground Surfaces Verses Mapping Terraces

Perhaps the largest source of error in previous attempts to define and trace terraces is that *ground surfaces* developed in Peoria Loess were being mapped, traced, called terraces, and used as surrogates for *former alluvial surfaces (terraces)* believed to be somewhere underneath these mapped modern landforms. The problem is there is accordance of ground surfaces underlain by both Peoria Loess-mantled terraces and Peoria Loess-mantled upland sediment assemblages. Figure 3 illustrates a number of diverse stratigraphic sections below ground surfaces that cluster around 510 - 520 ft (155.4 - 158.5 m) and 485 - 490 ft (147.8 - 149.3 m) in this part of the central Mississippi Valley. Some landforms are underlain by alluvial, slackwater and lacustrine deposits beneath later increments of the Peoria Loess with a *buried terrace* at the top of fluvial or lacustrine deposits that is giving rise to the geomorphic expression of the modern land surface. Other landforms, many originally mapped as terraces, are underlain beneath the Peoria Loess by upland sediment assemblages of loesses, paleosols and colluvium pre-dating later increments of Peoria Loess sedimentation. In these cases, it may be impossible to determine without sampling along strategically oriented transects whether the geomorphic expression of the modern ground surface is due to a buried erosion surface, buried basal bedrock bench, or some much older buried terrace. Further complicating determination are sections with multiple paleogeomorphic surfaces, any of which may be responsible for the general landform morphology expressed today.

Slackwater Terraces

Terraces preserved in tributary valleys with deposits that have a slackwater origin have additional factors to consider. Mississippi flood waters were silt-laden and this material could be deposited as flood drapes on surfaces as high as the flood crests. The record of slackwater aggradation in small tributary valleys is expected to be different than in large tributary valleys. The floors of smaller valleys tend to intersect the Mississippi Valley at slightly higher altitudes than larger valleys so that the oldest increments of backflooding may not have affected them or be well represented. The foci of the slackwater-flood and tributary fluvial interface, and associated deposits, at any time would have varied with tributary gradient, discharge and the magnitude of the Mississippi River floods.

Slackwater Terraces created by impoundment as the main valley aggrades can develop reverse slopes which pose their own set of problems. Altitudinal variation can lead to confusion with conventional terrace mapping, particularly when differential bluff recession is a factor (see below). As the reverse slope develops, the higher proximal zone may eventually be inundated less frequently with the net result that more distal surfaces are slightly younger than more proximal surfaces. The trend of loess thinning away from the valley may be slightly accentuated where loess buries such a terrace; loess increments are more likely to be reworked by flooding where the surface is lower.

Bluff Recession

The width of the Mississippi Valley we see today is not the width of the valley at the time terrace-related deposits were being sedimented in the main and tributary valleys. Rubey (1952) estimated a recession of at least 0.5 mi of the Calhoun County bluffline on the Illinois side of the valley alone. Ample evidence points to valley widening, at least some of which is late Woodfordian in age, in the Mississippi Valley as well. (1) There are very few, if any, remnants of terraces older than late Woodfordian in age preserved within the main valley trench; the pre-late Woodfordian terrace record is preserved within tributaries only. (2) The intersection of the valley wall and inter-tributary valley divides forms a smooth line uninterrupted by topography, lithology or structure; in places the bluffline may cross bedrock-cored upland, erosion surfaces, and early and middle Woodfordian terraces all in the same arc. (3) Alluvial fans at tributary mouths investigated to date have basal deposits no older than about 10,500 B.P.

The effects of past valley widening on terraces preserved in tributaries are at least threefold. First, proximal sediment facies may be removed lending to uncertainty whether hydraulic or sediment damming was responsible for sediment accumulation in the tributaries. Second, altitudes of terraces with reverse slopes defined in tributary settings should be considered minimums because of the potential truncation of the highest parts. Third, bluff recession may have occurred differentially down any valley reach, thus effectively resulting in genetically related surfaces being preserved at a range of altitudes along the main valley.

Erosion Surfaces

Multiple erosion surfaces are likely to be present in tributary valleys and are responsible to some degree for the notable valley asymmetry displayed by east-west oriented tributary valleys. Development of the late Wisconsinan Iowan Erosion Surface extended this far south and was contemporaneous with at least some valley aggradation. Within tributary valleys, terrace-related sediments may overlap, bury and preserve the Iowan or merge with remnants upvalley. Early to middle Woodfordian terraces may be subsequently modified by continuing erosion surface development. Without subsurface work, erosion surfaces may be confused with terraces in surface mapping.

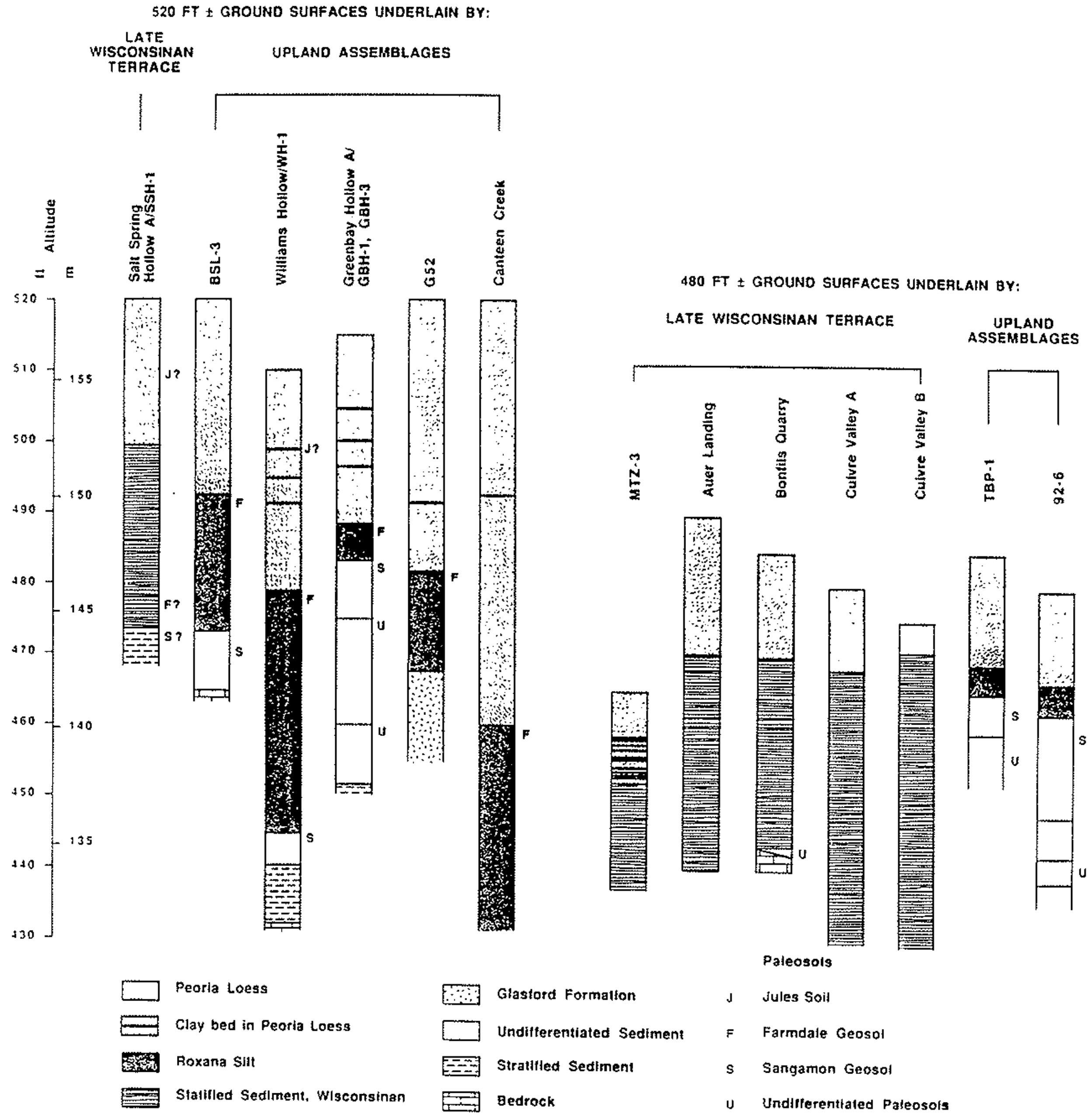

Figure 3. Representative topographic-stratigraphic relationships of ground surfaces intermediate between upland divides and low terraces.

PREVIOUS INVESTIGATIONS OF MISSISSIPPI VALLEY TERRACES IN THE ST. LOUIS VICINITY

Terrace Definition

Numerous names were applied to describe geomorphic surfaces, interpreted as terraces, in the Three Rivers Area (Table 1). Of these, few were ever formally defined, and fewer were traced for lengthy valley reaches. Land surface altitude was the overriding criteria for definition (Table 1) despite the fact that land surfaces usually were developed on loess, not alluvium. Further complications arose from changes in definition and application of "loess", the term at times including, in addition to primary eolian deposits, redeposited but relatively unweathered loess-derived silt. Stratigraphy and sedimentology of associated deposits was given secondary consideration although sometimes was not addressed at all, and radiocarbon dating was, for most studies, decades away.

Field work leading to terrace definition was spasmodic. Earliest focussed investigations leading to considered definition of terraces were by Rubey (1952) and Robertson (1938), although Shaw (1915) originally identified two unnamed terrace levels in Mississippi Valley tributaries. Rubey developed his ideas on the Brussels, Metz Creek and Deer Plain Terraces (Table 1) for the Illinois Valley and Mississippi Valley during field work in 1928 and 1929, although publication did not occur until 1952. Robertson's definition and analysis of the Beouf (Missouri Valley), Cuivre (Mississippi Valley), and Festus (Mississippi Valley) Terraces (Table 1) followed within a decade. Prior to Rubey, local terrace remnants were recognized but went unnamed and untraced. Following a long hiatus marked by only intermittent, local investigations, Goodfield (1965) identified additional terraces in the St. Louis area, and presented a synthesized correlation scheme. The Savanna Terrace in the Mississippi Valley and correlates up tributary valleys, including the Deer Plain Terrace, was identified by Flock (1983). This study demonstrated that terraces had the potential for being traced over long valley reaches. In an effort to understand the relationship between the Mississippi and lower Illinois Valleys, Hajic (1990) began a reevaluation of the terrace situation in the Three Rivers Area. Sites that can be considered to be in type areas of formerly defined terraces were revisited, new sites were investigated, and new radiocarbon ages were obtained. This work is the basis for the proposed terrace framework used on this field trip and much of the data and figures presented here are taken or modified from this dissertation appendix.

Interpretations and Correlations

Almost invariably, lacustrine or slackwater conditions were interpreted for Mississippi and Missouri Valley tributaries to account for thin bedded and laminated silt, clay and fine sand underlying terrace fragments (Table 2). Delta-like deposits were postulated for terrace remnants where terrace altitudes decreased with distance from the master trench. Terrace remnants within the Mississippi and Illinois Valleys, except the Deer Plain Terrace in the Illinois Valley, and a few remnants along the Mississippi Valley, were interpreted as outwash trains because they are underlain principally by sand and gravel.

Most investigators believed deposition of slackwater sediments underlying 520 ft (158.5 m) terraces resulted from an Illinoian till or ice dam at north St. Louis created by westward movement of Illinoian glacial ice across the Mississippi Valley. Interpretation was guided by Rubey's (1952: 85) description of a section in the north part of O'Fallon Park in north St. Louis (Figure 2) where Illinoian till was found interfingering with laminated sand, silt and gravel below a 510 or 520 ft (155.4 or 158.5 m) flat surface and, an apparent horizontality of surfaces in the same altitude range supposedly limited to the valleys north of St. Louis. Robertson (1938) favored tributary damming by aggradation in the Mississippi Valley to account for slackwater sediment below his Festus Terrace, as did Rubey for his Deer Plain Terrace.

Terrace correlation (Table 2) historically has been troublesome. Most often, ground surface altitudes, and secondarily, associated sediments were the basis for correlation. However, a few key observations, interpretations and later, radiocarbon ages, guided correlations and interpretations of causal mechanisms.

Goodfield's correlations meshed the terrace schemes of Rubey and Robertson with his own observations into at least three, and possibly four, recognizable terraces (Table 3). In his outline, the Deer Plain Terrace included all low terraces between about 450 and 430 ft (137.2 and 131.1 m) within the Mississippi Valley and in tributary valleys. A Valderan age interpretation for aggradation to the level of the Deer Plain Terrace (Goodfield 1965:87) was based on 1) the assumption that a radiocarbon age of 12,148 ± 700 B.P. (Flint and Deevey, 1951:267-268) on wood, recovered by Peltier, was from the unnamed low terrace #1 at Bonfils; 2) the assumption that the age was accurate; 3) correlation of the unnamed low terrace #1 to the Deer Plain Terrace; 4) Frye and Willman's (1963a; 1963b)

Table 1 Previously defined and described terraces, central Mississippi Valley.

Terrace	Reference	Valley	Altitude ft (m)	Basis for Definition	Loess	Eolian Dunes	Associated Sediments	Map Index
Baden	Goodfield (1965:67-68; 86)	Mississippi	485 (147.8)	stratified sediment exposed in excavations in bluff hillslope, north St. Louis	yes	no mention	"loess-massive silt"/"clay-silty clay"/"laminated sands, silts and clays"/"silt-massive, loess-like"	3
Beouf	Robertson (1936; 1938:196-200; 231-232)	Missouri	545 (166.1)	dissected surfaces in Missouri Valley tributary valleys between Oetters and Hermann, Missouri; considered to form horizontal surface	yes	no mention	"loess like silt" without "conspicuous stratification"; with non-local erratics in unstratified silt in one section	21, 27
Bonfils	Fenneman (1909:15; 61-62; 1911:10)	Missouri	480 (146.3)	"distinct terrace" within Missouri Valley, along southeast side, in vicinity of Bonfils; terrace 40 ft (12.2 m) above floodplain	yes	no mention	terrace considered bedrock strath on St. Louis Limestone with 20 to 25 ft (6.1 to 7.6 m) of "loess" along terrace edge	4
Brussels	Rubey (1952:82-87; 119-120)	Illinois, Mississippi	520-540 (158.5-164.6)	"extensive and well-defined surface" in mouths of tributaries and along main valleys north of St. Louis, particularly well expressed in vicinity of Brussels, Illinois; apparently flat surface	yes	yes	referred to as Brussels Formation; a) in Brussels area, lower third or quarter massive calcareous clay under laminated and massive beds of silt, cl.y and fine sand; b) Miss. tributaries from Cap au Gres south, silt has "thick masses or lenses" of medium sand; c) Miss. tributaries north of Batchtown Channel, basal bed of chert gravel with gray clay loam matrix overlain by "carbonaceous dark gray silt" and laminated silt; d) Macoupin and Otter creeks, sandy gravel fining downstream to sand or laminated silt	6
Chain of Rocks	Goodfield (1965:62-67; 84-85)	Mississippi	530 (161.5)	cut for interstate I-270 through bluffs on east side of Mississippi Valley, north suburban St. Louis; top of terrace considered top of upper sand and gravel, altitude about 495 ft (150.9 m)	yes	no	"loess"/"sand and gravel"/"stiff,...calcareous, and massive" "bluish gray till-like sandy clay"/"gravel"/"black shale"	9
Cuivre	Robertson (1936; 1938:186-195; 234)	Mississippi, Missouri	510 (155.4)	slightly dissected extensive flat surface along Mississippi Valley and within tributaries, noted as particularly well expressed in a 2 to 8 mile wide belt in vicinity of St. Peters; also identified along Wood River and area between Wood River and Cahokia Creek	yes	no mention	bedded and laminated fine sand, silt and clay, including "reddish clay"; locally, "more or less loess" overlies the terrace	12
Deer Plain	Rubey (1952: 90-96; 120-121; 154)	Illinois, Mississippi	450-460 (137.2-140.2)	small terrace remnants in mouths of Illinois and Mississippi tributaries, extensive along west side of lower Illinois Valley; slopes up Illinois Valley to at least 435 ft (132.6 m)	yes, locally	yes, locally	Mississippi Valley and Illinois Valley mouth: gravel and poorly sorted sand, horizontal and cross-bedded; tributary valleys: sand, silt and clay, laminated and cross-bedded dipping upvalley, fining upvalley and upsection; Deer Plain Formation	13
Festus	Robertson (1936; 1938:179-186; 235)	Mississippi	450 (137.2)	terrace remnants in lower reaches of Mississippi tributaries north and south of St. Louis; remnants gently slope away from Mississippi Valley; terrace gradient slightly less then modern Mississippi gradient; south of Wittenberg, similar remnants about 40 ft (12.2 m) lower included as Festus Terrace; named for remnants at mouth of Plattin Creek, Festus, Missouri	no mention	no mention	near Mississippi Valley, alternating thin beds of, in decreasing abundance, "loess-like silt" and fine sand with a few thin beds of fine gravel	17
Flourissant Basin	Goodfield (1965:29; 71-74; 82-85)	Missouri, Mississippi	510 (155.4)	relatively flat floor of Flourissant Basin, an oval basin with surface altitudes between 550 and 510 ft (167.6 and 155.4 m), north suburban St. Louis	yes	no mention	at least 5 to 7 ft (1.5 to 2.1 m) loess	18

Table 1 continued.

Terrace	Reference	Valley	Altitude ft (m)	Basis for Definition	Loess	Eolian Dunes	Associated Sediments	Map Index
Kaskaskia River Group	Robertson (1936; 1938:201; 234-235)	Kaskaskia (Mississippi)	various altitudes	general elevated surfaces	no mention	no mention	not described	22
Meramac River, 410 ft level	Goodfield (1965:74-76; 88-89)	Meramac (Mississippi)	410 (125.0)	elevated remnants forming horizontal surface in Meramac River Valley; at valley mouth terrace rises about 10 ft (3.0 m)	no mention	no mention	not described	24
Meramac River, 430 ft level	Goodfield (1965:74-76; 88-89)	Meramac (Mississippi)	430 (131.1)	elevated remnants forming horizontal surface in Meramac River Valley; at valley mouth terrace rises about 10 ft (3.0 m)	no mention	no mention	not described	24
Metz Creek	Rubey (1952:83; 120; 154)	Illinois	485 (147.8)	gently sloping spurs in tributaries to the lower Illinois Valley that apparently accord at about 485 ft (147.8 m)	yes	no mention	primarily truncated Brussels Formation; with surface or near-surface nonlocal pebbles within surficial "loess"	25
River de Pere	Goodfield (1965:69; 87)	Mississippi	430 (131.1)	stratified sediment below elevated surface near mouth of River de Pere	yes (?)	no mention	"stratified sandy material...present below loess" or "loess-like silt" (about 5 ft [1.5 m])	31
Savanna	Flock (1983)	Mississippi, Illinois, others	460 (140.2)	stratified "red clay" in solum of modern soil on elevated surfaces in tributaries to the Mississippi Valley	no	no	interstratified red clay, gray clay and yellow silt	-
unnamed high terrace	Goodfield (1965:50-51; 56-57; 85)	Missouri	500-510 (152.4-155.4)	elevated surfaces in Missouri Valley tributary valleys upstream of St. Charles	yes	no mention	at least 20 ft (6.1 m) of loess over fine sand and coarse silt	35
unnamed low terrace 1	Fenneman (1909:15; 61; 1911:10)	Missouri	450 (137.2)	distinct surface 10 ft (3.0 m) above floodplain along southeast side of Missouri Valley and adjacent to higher (Bonfils) terrace, north and northeast of Bonfils School	no	no	"alluvium"	4
unnamed low terrace 2	Goodfield (1965:60; 87)	Missouri, Mississippi	450 (137.2)	continuous surface under north part of St. Charles	no mention	no mention	not described	35
unnamed low terrace 3	Goodfield (1965:60-61; 87)	Missouri, Mississippi	440 (134.1)	broad surface at junction of Missouri and Mississippi valleys about 10 ft (3.0 m) above floodplain along highway 94 north and east of St. Charles	no mention	no mention	not described	35
unnamed low terrace 4	Goodfield (1965:69; 87)	Mississippi	430 (131.1)	slightly elevated surface "east side of Columbia Bottom Road from the Chain of Rocks north to the Missouri River"	no mention	no mention	not described	10
Wood River	Munson (1971:3-4)	Mississippi	440-450 (134.1-137.2)	elevated surface 25 to 35 ft (7.6 to 10.7 m) above floodplain in northern part of American Bottoms	no	yes	sand and gravel	41

Table 2. Previous genetic and age interpretations and correlations of central Mississippi Valley terraces.

Terrace	Reference	Interpretation	Correlation	Age
Baden	Goodfield (1965:67-68; 86)	no mention	to Bonfils Terrace (favored), or Chain of Rocks Terrace	Woodfordian or Altonian [a]
Beouf	Robertson (1936; 1938:196-200; 231-232)	lacustrine; with ice rafted erractics; in response to ice damming of Missouri Valley; resultant lake at least 570 ft (173.7 m)	no mention	probably "Kansan"; possibly "Nebraskan"
Bonfils	Flint and Deevey (1951:267)	accept M.M. Leighton and H.B. Willman (unpublished) correlation of outwash aggradation with "the Mankato maximum" ice advance	to Festus Terrace	"Mankato"
Bonfils	Goodfield (1965:57-60; 77; 86)	outwash train remnant	hints at possible correlation to 470 ft (143.3 m) surfaces up Cuivre River valley and at St. Peters	Woodfordian
Bonfils	Peltier (1951:1558)	"a climatic terrace" [a]	to Festus Terrace	Mankato [a]
Bonfils	Fenneman (1909:15; 61-62; 1911:10)	material overlying bedrock strath aggraded in response to advancing glaciers to the north	no mention	"Wisconsin"
Brussels	Goodfield (1965:62; 79-85; 134)	notes evidence in support of Rubey's (1952) interpretation is abundant; offers possible alternative: aggradation of Altonian outwash train in Mississippi Valley to level of Chain of Rocks and Brussels terraces; coeval ponding and aggradation in the Missouri Valley	possible correlation to surface in Mill Creek Valley 1/4 mi from Missouri Valley, and to surface at the Missouri School for Boys, Fort Bellfontaine, that was probably noted by Robertson	Illinoian; alternatively, Altonian
Brussels	Leighton and Brophy (1961:4-5)	fluvio-lacustrine, accumulated behind Illinoian ice dam; referred to as "Lake Brussels"	no mention	Illinoian
Brussels	Rubey (1952:82-87; 119-120)	slackwater; gradual floodplain aggradation in response to Illinoian ice or till dam at St. Louis; accumulation of eolian dunes in protected areas	to O'Fallon Park section; laminated silt along Quivre River to Brussels Formation in Brussels area	>"Sangamon(?) loess" (Roxana Silt), <"parts of the Illinoian till"
Brussels	Willman and Frye (1970: 74; 127; 132)	based on lack of evidence for Sangamon Soil or Roxana Silt on related sediment, questions Illinoian age; offers no alternative genetic interpretation; rejects "Brussels Formation" and tentatively assigns sediment to both Equality Formation and Teneriffe Silt; reject "Lake Brussels"	accepts Robertsons (1938) correlation to Cuivre Terrace	Wisconsinan or Illinoian
Chain of Rocks	Drushel (1911:29-32)	till-like gray sandy clay and overlying sand and gravel are "Illinoian drift"		Illinoian
Chain of Rocks	Fenneman (1909:8-9)	till-like gray sandy clay and overlying sand and gravel are "Illinoian drift"		Illinoian
Chain of Rocks	Goodfield (1965:62-67; 84-85)	"terrace materials [gray sandy clay and overlying sand and gravel]...represent a buried remnant of an Altonian outwash train deposited along the Mississippi River Valley"; till-like gray sandy clay resulted when "coarse sandy and gravelly outwash from a northern source was mixed with woody and clayey material in a swamp or marsh on an old higher floodplain of the Ancestral Mississippi"	possibly to Brussels Terrace	Altonian; possibly Illinoian
Chain of Rocks	Leverett (1899:64)	till-like gray sandy clay and overlying sand and gravel are "Illinoian drift"		Illinoian

a inferred by author cited, by correlation or other discussion

Table 2 continued.

Terrace	Reference	Interpretation	Correlation	Age
Chain of Rocks	Robertson (1938:233-234)	till-like gray sandy clay and overlying sand and gravel are "Illinoian drift"; deposition of waterlaid sediments occurred in reentrant in Illinoian ice margin		Illinoian
Chain of Rocks	Wermeyer (1955:13-20)	till-like gray sandy clay and overlying sand and gravel are "Illinoian drift"		Illinoian
Cuivre	Robertson (1936; 1938:186-195; 234)	lacustrine; sediments accumulated in lake that rose to an altitude of at least 530 ft (161.5 m) in Mississippi Valley above St. Louis; formed in response to Illinoian ice dam	to ice dam and outwash in Chain of Rocks area	Illinoian, implied continues into Sangamonian
Deer Plain	Butzer (1977:18-19)	outwash at Illinois River mouth, with surficial sloughs and sandbars, and eolian dunes along terrace edge; sediments up Illinois Valley represent "long and complex period of aggradation"; reverse terrace gradient due to "polygenetic development during successively lower stages of river level"	Brownfield Terrace in the lower Ohio River Valley	Woodfordian
Deer Plain	Goodfield (1965:68-69; 87)	does not discount Rubey's (1952) interpretation	to "low level terrace remnants in the 430 to 450 foot range"	Valderan
Deer Plain	Peltier (1951:1558)	"a climatic terrace"	no mention	"Cochrane"
Deer Plain	Rubey (1952: 90-96; 120-121; 154)	"Deer Plain formation was deposited from abnormally high flood stages of an ancient Mississippi River with virtual ponding and backwater for many miles up the lower part of Illinois River"; damming of tributaries created delta-like deposits; surficial features on terrace in Illinois Valley mouth are sand bars; fine sediments possibly from Glacial Lake Agassiz via the Red River Valley	no mention	"very late Wisconsin time"; post-dating large floods through "Lake Chicago" and "Lake Kankakee"
Festus	Goodfield (1965:76; 86)	does not discount Robertson's (1938) interpretation	Festus is "downriver extension of the Bonfils terrace"	Woodfordian [a]
Festus	Peltier (1951:1558)	"a climatic terrace"	to Bonfils Terrace	Mankato
Festus	Robertson (1936; 1938:179-186; 235)	Mississippi River-derived sediments when river stage at least 70 ft (21.3 m) above modern river; aggraded due to "melting glacier"; delta-like deposits in tributary valley mouths	to Deer Plain Terrace [a]	"Wisconsin"
Flourissant Basin	Goodfield (1965:29; 71-74; 82-85)	lacustrine; water backed up behind Illinoian glacial dam, entered basin via Coldwater Creek and possibly Mill Creek valleys, or, deposition in response to aggradation of Altonian outwash train in Mississippi Valley	to Brussels Terrace	Illinoian or Altonian
Kaskaskia River Group	Robertson (1936; 1938:201; 234-235)	related to adjustments to sediment load within valley, not in response to changes in Mississippi River	one to the Festus Terrace; a second higher one exists [a]	"Wisconsin"; Illinoian [a]
Keach School	Butzer (1977:19-21)	glaciofluvial aggradation in braided channel followed by flood silt aggradation; eolian dunes with some niveo-eolian sedimentation	to Beardstown Terrace	late Woodfordian; upper slackwater sediments possibly Valderan
Meramac River 410 ft level	Goodfield (1965:74-76; 88-89)	flooding and aggradation in response to aggradation of Mississippi Valley; delta formed in tributary valley mouths	to Deer Plain Terrace	Valderan [a]
Meramac River 430 ft level	Goodfield (1965:74-76; 88-89)	flooding and aggradation in response to aggradation of Mississippi Valley; delta formed in tributary valley mouths	to Bonfils Terrace	Woodfordian [a]

a inferred by author cited, by correlation or other discussion

Table 2 continued.

Terrace	Reference	Interpretation	Correlation	Age
Metz Creek	Rubey (1952:83; 120; 154)	erosional; primarily cut in Brussels Formation, possibly in response to flood down Illinois Valley from Great Lakes discharge during final glacial retreat	no mention	"Wisconsin" or "Iowan"
Metz Creek	Willman and Frye (1970:135)	erosion surface; rejects "Metz Creek Terrace"	no mention	no mention
River de Pere	Goodfield (1965:69; 87)	not described	to Deer Plain Terrace [a]	Valderan [a]
Savanna	Flock (1983)	"enormous flood of clay-rich water"	includes Deer Plain Terrace	between about 13,100 - 9500 B.P.
unnamed high terrace	Goodfield (1965:50-51; 56-57; 85)	ponding of Missouri Valley due to aggradation of Mississippi River	to Chain of Rocks Terrace or Brussels Terrace	Altonian [a], or Illinoian
unnamed low terrace 1	Fenneman (1909:15; 61; 1911:10)	"change of the Mississippi from an overloaded to a cutting stream"	no mention	post-glacial (?)
unnamed terrace 1	Goodfield (1965:60; 87)	none given	to unnamed low terrace, north part of St. Charles; to Deer Plain Terrace	Valderan
unnamed terrace 2	Goodfield (1965:60; 87)	none given	to Deer Plain Terrace [a]	Valderan [a]
unnamed terrace 3	Goodfield (1965:60-61; 87)	degraded remnant of the 450 ft level" in northernmost St. Charles	to Dear Plain Terrace [a]	Valderan [a]
unnamed terrace 4	Goodfield (1965:69; 87)	possibly eroded remnant of Wood River Terrace	to Wood River Terrace; to Deer Plain Terrace [a]	Valderan [a]
Wood River	Frye and Willman (1963:16)	outwash terrace		Valderan
Wood River	Goodfield (1965:87)	none given	to Deer Plain Terrace [a]	Valderan [a]
Wood River	Munson (1971:3-4)	none given	to Festus Terrace or Deer Plain Terrace	older than Paleo-Indian

a inferred by author cited, by correlation or other discussion

Table 3. Correlation scheme of Goodfield (1965) for central Mississippi Valley terraces .

Altitude m (ft)	155.4-152.4 (510-500)	149.4-143.3 (490-470)	143.3-140.2 (470-460)	137.2-131.1 (450-430)
Terraces	Brussels ——?——	Chain of Rocks ——?—— (?)	Bonfils	Deer Plain
	Flourissant Basin	unnamed high terrace, Missouri Valley tribs.	Baden	Wood River
	Cuivre		Festus	River de Pere
			Meramac River, 430 ft level (131.1 m)	Meramac River, 410 ft level (125.0 m)
				unnamed low terraces between 137.2 and 131.1 m (450 and 430 ft)

interpretation of a Valderan age for the Wood River Terrace; and 5) glacial conditions in Minnesota, identified by Wright (1964), that presumably would result in valley train sedimentation at this time. Robertson (1938) suggested the possible correlation of the Festus Terrace with the Deer Plain Terrace, but Goodfield (1965:76; 86) considered the Festus Terrace higher and older. Recently, Flock (1983) defined the Savanna Terrace, that included the Deer Plain Terrace of Rubey, as an aggradational terrace that accumulated sometime between 13,100 and 9500 B.P. resulting from a catastrophic flood or floods down the Mississippi River.

The Bonfils Terrace was considered by Goodfield (1965) distinct from the Deer Plain Terrace on the basis of stratified sediment at a higher altitude and two radiocarbon ages between 17,000 and 18,000 B.P. (Rubin and Alexander, 1958:1478) on wood collected by M.M. Leighton and R.E. Bergstrom from sediments underneath the Bonfils Terrace. He tentatively equated the Festus and Bonfils terraces. According to Goodfield, the Baden Terrace was a probable correlate to the Bonfils Terrace based on similar altitudes of stratified sediment. However, if the Chain of Rocks Terrace is Altonian, correlation of the Baden Terrace with it can not be ruled out, Goodfield argued, due to the presence of loess-like silt that may be the Roxana Silt at the base of the Baden section. Radiocarbon ages suggested to Goodfield that the Bonfils Terrace in the mouth of the Missouri Valley was part of a Woodfordian Mississippi Valley outwash train. The Metz Creek Terrace was not addressed specifically, but was implied to pre-date the Bonfils Terrace (Goodfield, 1965:76).

Goodfield interpreted the Chain of Rocks Terrace as a buried Altonian outwash train, relying heavily upon two radiocarbon ages between 28,000 and 32,000 B.P. from a till-like sandy clay at the Chain of Rocks cut for Interstate I-270 (Figure 1). He believed an Illinoian age for the Brussels Terrace was warranted based on previous interpretations of an Illinoian ice dam across the Mississippi Valley at north St. Louis (Leverett, 1899:71; Robertson, 1938:233-234; Drushel, 1911:31-32), Rubey's O'Fallon Park section, and the assumed terrace distribution and horizontality. Based on the ice dam scenario and corresponding altitudes, it was not difficult to correlate the Flourissant Basin Terrace with the Brussels Terrace. Goodfield's interpretation of the Brussels Terrace was tempered by reservations expressed in a personal communication by H.B. Willman and J.C. Frye about an Illinoian age for the terrace stemming from the absence of a Sangamon Geosol and Roxana Silt on sediments identified as the Brussels Formation. Goodfield (1965:85) offered an alternative interpretation for the Brussels Terrace that was more accommodating to Willman and Frye's skepticism. Based on ground surface altitudes, he could not rule out correlation of the Chain of Rocks Terrace with the Brussels Terrace; sediments below the Brussels Terrace would then be related to tributary ponding behind an aggrading Altonian valley train. If this correlation was valid, then there might be a genetic link between the Chain of Rocks Terrace and the unnamed high terrace in Missouri Valley tributaries as well.

More recently, Allen and Ward (1978) argued the Brussels Terrace was indeed Illinoian. They interpreted from cores taken at Stop 4, Arrowhead Industrial Park, St. Peter, Missouri, a lateral facies relationship between Illinoian till and laminated sediment they considered Rubey's Brussels Formation.

Problems

The foregoing brief review of terrace investigations indicates the number, age, and origin of widespread terraces in the Three Rivers Area was open to numerous questions. Some of the more pressing problems that needed resolution included:

(1) Is the Brussels Terrace Illinoian or Wisconsinan? Only five sections appear in the literature north of St. Louis where Roxana Silt buried, or Sangamon Geosol modified, sediments of the "Brussels Formation". Willman and Frye (1970) inferred both Illinoian and Wisconsinan ages in different text passages (Table 2). The surface at Arrowhead Industrial Park, location of Allen and Wards (1978) attempt to redefine the "Brussels Formation", is 35 to 40 ft (10.7 to 12.2 m) lower than the Brussels Terrace of Rubey directly across the Mississippi Valley. Finally, investigation of several areas mapped by Rubey as Brussels Terrace in the lower Illinois Valley indicate they are underlain almost entirely by upland sediment assemblages (cf. Stop 8, Green Bay Hollow) (Hajic, 1990).

(2) Is the Metz Creek Terrace an erosional terrace cut into "Brussels Formation"? Pebbles cited as evidence of erosion (Rubey, 1952) occur in the top of loess overlying the terrace and are therefore younger than the terrace.

(3) Does the Chain of Rocks Terrace represent an Altonian valley train? Cores and sections along the east side of the American Bottoms (cf. McKay, 1979) indicate the Roxana Silt was deposited at altitudes at least 90 ft (27.4 m) below waterlain deposits in the Chain of Rocks roadcut.

(4) Were Savanna Terrace-related sediments deposited between 13,100 and 9500 B.P. as suggested by Flock (1983)?; and, can all terraces at and below the Savanna (Deer Plain) Terrace justifiably be considered the same, as suggested by Goodfield (1965)? Flock's age assessment in part is based on a radiocarbon age (Flint and Deevey, 1951; incorrectly attributed to Goodfield, 1965) from questionable geomorphic and stratigraphic context, and radiocarbon ages from the lower Illinois Valley interpreted by Flock to pre-date aggradation to the Savanna Terrace level, actually post-date most of the aggradational episode in the Mississippi Valley (Hajic, 1985).

MISSISSIPPI VALLEY TERRACES

Traceable alluvial geomorphic or paleogeomoprhic surfaces higher or older than the modern floodplain of the Mississippi River are considered terraces or buried terraces. On this basis, available evidence can be marshalled to define four late Wisconsinan to very early Holocene terraces in the central Mississippi Valley (Table 4; Figure 4). Introduction of several new terrace names is warranted based on the presence of newly recognized terraces and investigation of type areas that reveal some former terrace type areas are not terraces (or at least not late Wisconsinan terraces). Selected terrace names are based on formerly used names where ambiguity with the original authors intent is minimal.

Radiocarbon ages related to Mississippi Valley terraces in the Three rivers Area are listed in Table 5. Dated organic material, usually consisting of *Picea* wood, was collected from fluvial and slackwater sediment bodies immediately beneath and related to the terraces.

Previously defined terraces in the Mississippi Valley are correlated to the proposed terrace framework in Table 6. Terrace correlation primarily is based on altitude of the top of alluvial sediment with respect to position relative to Mississippi Valley. Secondary considerations are given to radiocarbon age relationships, presence or absence of a cover of Peoria Loess, and, if present, loess thickness and thickness and degree of surface soil expression. At this time, correlations carry varying degrees of confidence as noted. Correlations of Mississippi Valley terraces to Illinois Valley terraces, based on similar criteria, are given in Table 7.

The terrace framework presented here is based on evaluation of previously defined terraces, initial exploration of landscape-stratigraphic relationships and landform-sediment assemblages, including some previously recognized terraces at what can be considered their type areas, and new radiocarbon ages. Previously mentioned factors that could complicate terrace identification were considered to the extent possible. Altitudes given in Table 4 are for real or projected surfaces at the mouth of the Illinois Valley. Both days of the field trip incorporate stops at formerly defined terrace type areas. Specific problems with previous age estimates, correlation, and interpretation of previously defined terraces, and the rationale for the new terrace framework will be presented and discussed at appropriate stops.

St. Charles Terrace Family (New)

The oldest terrace is best considered at this time a terrace family with two seemingly, but not yet demonstrated, distinct levels. It incorporates a number of previously defined terraces (Table 6). The St. Charles Terrace Family consists of terrace remnants buried by increments of Peoria Loess, preserved only in tributary valleys, and exhibiting reverse or nil gradients relative to lower reaches of tributary streams (Table 4). The name comes from St. Charles County, Missouri, where terraces are particularly well preserved in tributaries to the Mississippi Valley. Buried terraces tend to cluster at two levels, referred to as the Gilead and Cuivre levels (Figure 4). There apparently is a wide altitudinal range among remnants of each level, particularly the younger of the two.

The Gilead level lies at about 150.9 m (495 ft) and is preserved below land surfaces at about 155.4 - 158.5 m (510 - 520 ft). On Day 2 we will visit a representative section below this terrace (Stop 9), as well as a section below a similarly appearing landform that has a contrasting stratigraphy (Stop 8). Morphologically, the Gilead level is recognized in part by a distinct 155.4 m (520 ft) land surface within mouths of tributary valleys on the west side of Calhoun County, Illinois. It is separated from adjacent uplands by relatively steep slopes. Up tributary valleys, stepped surfaces corresponding with either the Iowan Erosion Surface or upvalley terrace extension either grade to the Gilead level at tributary valley mouths or are buried by sediment associated with it. Not all 158.5 m (520 ft) ground surfaces adjacent to tributary valleys represent the Gilead level, or are underlain by sediment of similar age or slackwater-flood origin. Ground surfaces at 158.5 m (520 ft) are commonly underlain by Wisconsinan and pre-Wisconsinan upland sediment assemblages and may be palimpsests of pre-late Wisconsinan erosion surfaces, terraces, or bedrock benches (Figure 3).

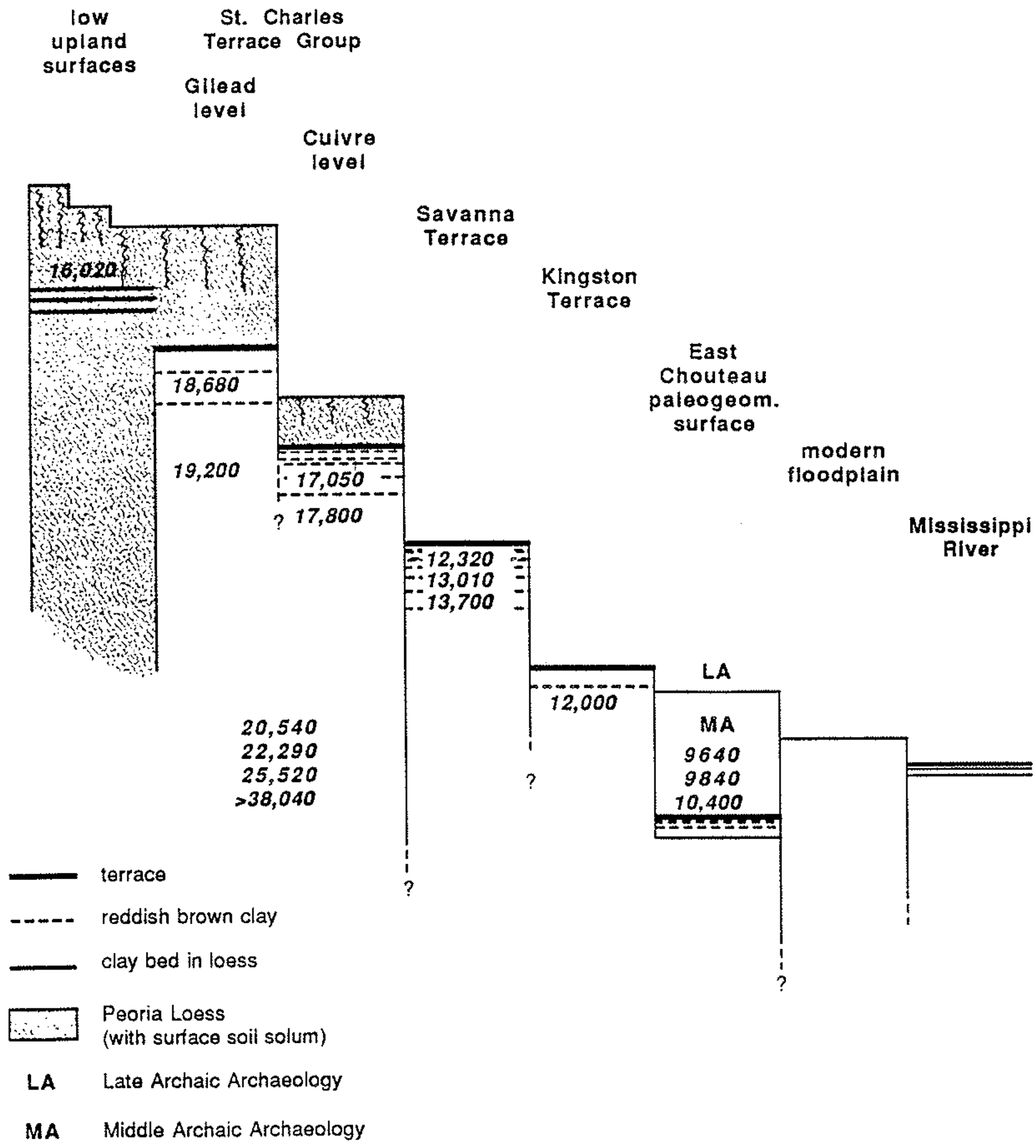

Figure 4. Terrace framework, radiocarbon age relationships, and stratigraphic position of reddish brown clay for central Mississippi Valley terraces and terrace-related deposits in the Three Rivers Area.

Table 4. Terrace framework, central Mississippi Valley, and criteria guiding terrace definition and recognition

Terrace	Est. Altitude at Illinois Valley Mouth m (ft)	Loess Over Terrace			Eolian Dunes	Preservation	Slope, Downstream Tributary Valley Reaches
		Ave. Thickness m (ft)	Ave. Surface Solum Thickness m (ft)	Clay Beds			
St. Charles Group							
Gilead Level	151 (495)	6.2 (20)	1.5 (4.8)	no	yes	tributaries	reverse (?)
Cuivre Level	145 (475)	20 (15)	0.8 (2.7)	many	?	tributaries	reverse
Savanna	139 (455)	<0.6 (<2)	-	-	few	tributaries	reverse
Kingston	133 (433)	-	-	-	very few	main val./tribs.	level to normal
East Chouteau	122 (400)	-	-	-	no	main val.	-

Table 5. Radiocarbon ages, sample descriptions, and contexts, central Mississippi River Valley terraces.

Terrace	Age[a]	Lab No.	Sample No.	Altitude m (ft)	Landform Sediment Context	Material Dated[b]	Reference
St. Charles Group Gilead level	19,200 ± 420	ISGS-1789	SSH 5-1	133.5 (438)	very base of slackwater-flood lithofacies association; Salt Spring Hollow Section E; typical sediment assemblage described by Rubey (1952) for Brussels Terrace	uncarbonized *Picea* wood, cone fragments and Picea and Abies needles	Hajic, 1990
	18,770 ± 310	ISGS-1500	SSH 1-2	138.0 (453)	slackwater-flood lithofacies association; Salt Spring Hollow Section A; typical sediment assemblage described by Rubey (1952) for Brussels Terrace	two uncarbonized pieces of *Picea* wood	Hajic, 1990
	18,760 ± 220	ISGS-1499	WLH 1-1	143.3 (470)	top of terrace and slackwater-flood lithofacies association; Watson Lake Hollow; typical sediment assemblage described by Rubey (1952) for Brussels Terrace	uncarbonized *Picea* branch	Hajic, 1990
	18,680 ± 610	ISGS-1498	SSH 1-1	137.2 (450)	slackwater-flood lithofacies association; Salt Spring Hollow Section A; typical sediment assemblage described by Rubey (1952) for Brussels Terrace	two uncarbonized *Picea* pieces of Picea wood	Hajic, 1990
Cuivre level	>38,040	Beta-26514	SR 1-2	134.1 (440)	tributary fluvial or slackwater-flood lithofacies association; Salt River Valley	uncarbonized twig	E.A. Bettis and E.R. Hajic, unpublished data
	25,520 ± 250	Beta-26515	CR 2-1	131.1 (430)	tributary fluvial lithofacies association; Cuivre Valley Section B; Robertson's (1938) example of Cuivre Terrace	uncarbonized twig	E.A. Bettis and E.R. Hajic, unpublished data
	22,290 ± 190	Beta-26516	CR 2-2	132.0 (433)	tributary fluvial lithofacies association; Cuivre Valley Section B; Robertson's (1938) example of Cuivre Terrace	uncarbonized *Picea* wood	E.A. Bettis and E.R. Hajic, unpublished data
	20,540 ± 160	Beta-26517	CR 2-3	132.9 (436)	tributary fluvial lithofacies association; Cuivre Valley Section B; Robertson's (1938) example of Cuivre Terrace	uncarbonized twig	E.A. Bettis and E.R. Hajic, unpublished data
	17,800 ± 600	W-470	-	?	gray silt; "16 ft below top of terrace"; Bonfils Terrace at Westlake Quarry; Missouri Valley	wood	Rubin and Alexander, 1958; Goodfield, 1965
	17,540 ± 210	ISGS-1811	BQ 4	135.3 (444)	slackwater-flood lithofacies association; Bonfils Quarry; Missouri Valley	uncarbonized *Picea* wood	Hajic, 1990
	17,150 ± 600	W-469	-	?	gray silt; "14 ft below top of terrace"; Bonfils Terrace at Westlake Quarry; Missouri Valley	wood	Rubin and Alexander, 1958; Goodfield, 1965
	17,050 ± 280	ISGS-1790	BQ 5b	143.6 (471)	slackwater-flood lithofacies association; Bonfils Quarry; Missouri Valley	uncarbonized *Picea* wood and bark	Hajic, 1990

a based on C^{14} half-life of 5568 years
b identifications by Nancy Asch and Margorie Schroeder, Center for American Archeology, Archeobotanical Laboratory

c.b. 2

Table 5 continued.

Terrace	Age[a]	Lab No.	Sample No.	Altitude m (ft)	Landform Sediment Context	Material Dated[b]	Reference
Savanna							
	13,710 ± 270	ISGS-1531	MTZ 8b-1	411 (125.3)	Savanna (Deer Plain) Terrace sed. assem., lacustrine silt facies; Metz Creek Valley	uncarbonized *Picea* wood, bark, and needles, *Abies* needles, aquatic and other nonwoody plant debris	Hajic, 1990
	13,390 ± 190	ISGS-894	NLC 42a,b	424 (129.2)	Savanna (Deer Plain) Terrace sed. assem., lacustrine silt facies	primarily uncarbonized *Picea*, cedar wood and bark; some Picea, white cedar and Abies needles	Hajic, 1990; Hajic, 1987
	13,360 ± 100	ISGS-875	EMC 9	445 (135.6)	Savanna (Deer Plain) Terrace sed. assem., lacustrine silt facies; below Koster archaeological site	uncarbonized conifer (*Picea*?) wood and bark	Hajic, in press; Wiant et al., 1983
	13,010 ± 140	ISGS-900	HLC 38c,d	430 (131.1)	Savanna (Deer Plain) Terrace sed. assem., lacustrine silt facies	uncarbonized conifer wood and bark, some charcoal, some *Picea* and *Abies* needles	Hajic, 1990; Hajic, 1987
	12,325 ± 75	ISGS-415	KOSN 717	451 (137.5)	Savanna (Deer Plain) Terrace sed. assem., lacustrine nearshore silt and sand facies; below Koster archaeological site	uncarbonized *Picea* log	Butzer, 1977; Liu, Riley, and Coleman, 1986; Hajic, in press
Kingston	12,148 ± 700	385	-	?	context unknown; from Westlake Quarry area; lower Missouri Valley	wood	Flint and Deevey, 1951; Goodfield, 1965
	12,000 ± 100	ISGS-911	NLC-36a-v	126.2 (414)	fluvial lithofacies association; 14 ft (4.3 m) below Keach School Terrace; lower Illinois Valley	uncarbonized conifer wood (with and without resin ducts), *Picea* needles, some bark, seeds and other non-woody fragments	Hajic, 1990
East Chouteau paleogeom. surface	10,400 ± 130	ISGS-1301	-	135.6 (445)	basal proximal alluvial fan lithofacies association; immediately above erosional discontinuity that cuts East Chouteau surface and reddish brown clay; Mississippi Valley north northeast of Hannibal, Missouri	uncarbonized organic debris; includes few conifer needles that are possibly reworked	D. Leigh, unpublished data
	9,840 ± 170	ISGS-1306	-	136.2 (447)	slackwater-flood or distal alluvial fan lithofacies association; immediately above erosional discontinuity that truncates East Chouteau surface and reddish brown clay; Mississippi Valley north northeast of Hannibal, Missouri	uncarbonized woody and nonwoody plant debris	D. Leigh, unpublished data
	9,640 ± 460	ISGS-1470	-	121.8 (400)	slackwater-flood lithofacies association; 5 ft (1.5 m) above East Chouteau surface and reddish brown clay; Mississippi Valley, northern American Bottoms, south of Wood River	small piece of wood and bulk organics	J. Rissing, unpublished data

Table 5 continued.

Terrace	Age[a]	Lab No.	Sample No.	Altitude m (ft)	Landform Sediment Context	Material Dated[b]	Reference
	9,510 ± 80	ISGS-1158	-	135.9 (446)	slackwater-flood or distal alluvial fan lithofacies association; immediately above erosional discontinuity that truncates East Chouteau surface and reddish brown clay; Mississippi Valley north northeast of Hannibal, Missouri	uncarbonized woody and nonwoody plant debris	D. Leigh, unpublished data

a based on C^{14} half-life of 5568 years
b identifications by Nancy Asch and Margorie Schroeder, Center for American Archeology, Archeobotanical Laboratory

Table 6. Correlation of previously recognized terraces, central Mississippi Valley, to proposed terrace framework.

Terrace	Correlated Terrace	Degree of Confidence[a]
St. Charles Group		
Gilead level[b,c,d]	Brussels[e] (Rubey, 1952)	1
	Flourissant Basin (Goodfield, 1965)	2
	Cuivre[f] (Robertson, 1938)	2
	unnamed high terrace in Missouri Valley tributaries (Goodfield, 1965)	3
Cuivre level[b]	Metz Creek (Rubey, 1952)	1
	Cuivre[g] (Robertson, 1938)	2
	Baden (Goodfield, 1965)	2
	Bonfils (Fenneman, 1909; Goodfield,1965)	2
	Festus[h] (Robertson, 1938)	2
Savanna	Savanna (Flock, 1983)	1
	Deer Plain (Rubey, 1952)	1
	Festus[h] (Robertson, 1938)	2
	Meramac River, 430 ft level (Goodfield,1965)	2
	Wood River (Munson, 1971)	3
Kingston	unnamed low terrace 2 (Goodfield, 1965)	1
	unnamed low terrace 4 (Goodfield, 1965)	1
	unnamed low terrace 1 (Fenneman, 1909)	2
	Meramac River 410 ft level (Goodfield, 1965)	2
	Wood River (Munson, 1971)	2
	Kearch School Terrace (Butzer, 1977; this study)	2
East Chouteau	floodplain area west and southwest of Wood River Terrace (Hajic, 1987)	1
	floodplain areas north and northeast of Hull, Illinois (Leigh, unpublished data)	1
Missouri River Alluvial Fan	unnamed low terrace 3 (Goodfield, 1965)	2

a 1= definite; 2 = probable; 3 = possible
b may be difficult to distinguish morphologically from stepped upland surfaces and spurs
c does not include Chain of Rocks Terrace (Goodfield, 1965) which is here considered to be underlain by Illinoian diamicton and pro- or supraglacial sand and gravel
d Beouf terrace (Robertson, 1938) either is an older terrace, or, more likely, erosion surface
e as mapped by Rubey (1952: Plate 1) in the Mississippi Valley only
f Cuivre Terrace noted by Robertson (1938) in lower Missouri Valley tributaries only
g exposures cited in Cuivre Valley, not surfaces cited as basis for definition
h two levels are present at Festus and in many tributaries south of St. Louis

Table 7. Correlation of lower Illinois Valley and Mississippi Valley Terraces and paleogeomorphic surfaces.

Central Mississippi Valley Terraces	Lower Illinois Valley Terraces
St. Charles Group Gilead level	Bloomington Outwash Terrace
St. Charles Group Cuivre level	Manito Terrace Bath Terrace
	Bluffs Terrace
Savanna Terrace	Savanna (Deer Plain) Terrace
Kingston Terrace	Keach School Terrace
East Chouteau paleogeomorphic surface	reddish brown clay at base of Swan Lake paleochannel fill

The Cuivre level, which we will examine at Stops 1 and 2, lies at about 144.8 m (475 ft) and is preserved below land surfaces at about 147.8 - 149.4 m (485 - 490 ft). It takes its name from the Cuivre Terrace remnants in the Cuivre Valley described by Robertson (1938). Up tributary valleys ground surface altitudes decrease to 143.3 m (470 ft) or less. Compared to the Gilead level, the Cuivre level is covered by thinner increments of Peoria Loess in which the surface soil solum is thinner and multiple clay beds may be present (Figure 3; MTZ-3). Cuivre level occurs both as spurs inset below 158.5 m (520 ft) land surfaces, such as in Metz Creek Valley over which we will drive on Day 2, and extensive areas such as those found in the Cuivre River Valley. A range of stratigraphic variability similar to that encountered under 158.5 m (520 ft) land surfaces is detected beneath 146.3 m (480 ft) land surfaces (Figure 3). Nevertheless, below 146.3 m (480 ft) ground surfaces, Peoria Loess is consistently thinner than below the 158.5 m (520 ft) land surfaces, regardless of the underlying sediment sequence. Surface soils are not as well expressed as on 158.5 m (520 ft) ground surfaces and B horizons are shallower.

The St. Charles Terrace Family are depositional slackwater terraces formed by aggradation in the Mississippi Valley trench with sediment and hydraulic damming of tributary valley mouths accompanied by slackwater accretion in the tributary valleys. Sediments associated with the terrace family largely consist of laminated to thin bedded silt. Closer to the Mississippi Valley they contain more sand and become progressively finer away from the main valley. The dominance of silt reflects both the large silt load of the glacier-fed Mississippi River as well as contributions from loess deposition and slope erosion in tributary valleys. Beds of reddish brown clay are often interstratified with the silt. They have a distinct mineralogy that indicates a source in the Lake Superior Basin (Flock, 1983; Hajic, 1990). Their presence in tributary valleys indicates a Mississippi Valley origin for at least some of these backflood deposits. Organic debris is sometimes preserved in abundance in the silt beds. In these slackwater sequences, exposure features are rare suggesting frequent flooding or nearly continuous ponding. The equivalent Mississippi Valley deposits were eroded to at least below modern floodplain level, but likely consisted of sand and gravelly sand deposited by some form of braided stream.

Aggradation of lower parts of terrace-related fill are probably common to both terrace levels of the St. Charles Terrace Family. However, greater frequency of reddish brown clay in the upper part of the Cuivre level sediment assemblage in Mississippi Valley tributaries probably indicates a younger increment of fill not represented below the Gilead level. The two terrace levels have not been investigated where they occur adjacent to each other and the degree of incision post-dating the Gilead level and pre-dating the Cuivre level is unknown at this time (Figure 4).

The Gilead and Cuivre terrace levels are early to middle Woodfordian in age. Peoria Loess, thinner than on higher upland surfaces, rests directly atop the terrace surfaces and related stratified sediment (Figures 3 and 4). The distinctive Roxana Silt is nowhere present above terrace surfaces, the contact between Peoria Loess and stratified sediment is conformable, and there is no evidence of soil formation or significant weathering in the top of stratified sediment that might suggest a significant depositional hiatus. Radiocarbon ages indicate the Gilead level post-dates 18,680 B.P.and the Cuivre level post-dates 17,050 B.P. (Table 5; Figure 4). Aggradation of Gilead level-related sediment was underway by 19,200 at the latest (Table 5). Radiocarbon ages on wood recovered below the Cuivre level in the Cuivre Valley at Stop 3 indicate aggradation was underway as early as 25,500 B.P. (Table 5). However, the older radiocarbon ages from below the Cuivre level are from organic material collected from tributary fluvial lithofacies; major aggradation of flood and slackwater sediments overlies these deposits and post-dates about 20,500 B.P.

Both terrace levels pre-date 13,710 B.P. based on radiocarbon ages from alluvial fill inset within, and therefore younger than the Cuivre level (Table 5; Savanna Terrace). Geomorphic evidence and radiocarbon ages from the lower and lower-middle Illinois Valley suggest the age of both terraces can be further narrowed to pre-date about 15,500 B.P. (Hajic, 1990).

Savanna Terrace

The Savanna Terrace (Flock, 1983; Table 1), our rendezvous for the beginning of Day 2 (Stop 7) consists of the highest terrace remnants lacking a significant loess mantle and, in the Mississippi Valley, typically have reddish brown clay beds and laminae within the surface soil solum (Figure 4). In the central Mississippi Valley, extensive tracts of Savanna Terrace are preserved in some tributary valleys, but only a rare sliver is preserved along the edge of the valley. In tributaries it exhibits a reverse slope. Locally, small eolian dunes and thin loess cover the terrace. At the mouth of the Illinois Valley, it stands at an altitude of about 138.7 m (455 ft). The Savanna Terrace is morphologically distinct from other higher surfaces including the Cuivre level of the St. Charles Terrace Group, at least in the lowest reaches of tributaries. Although the Savanna Terrace includes the Deer Plain Terrace of Rubey (1952) and precedence for the latter could be argued, Savanna Terrace is used because of the lengthy extent over which it was traced by Flock (1983).

In the Mississippi Valley, sand and gravel is overlain by a variable but usually thin increment of slackwater-flood lithofacies characterized by stratified reddish brown clay, gray clay and silt. Up tributary valleys such as the Illinois Valley, the Savanna Terrace immediately is underlain by lacustrine clay and silt. Lithofacies geometry, descendence of terrace slopes in tributary valleys away from the Mississippi Valley, and mineralogy of reddish brown clay argue for an episode of glaciofluvial aggradation by the Mississippi River in some braided form, sediment dam construction across mouths of tributary valleys, and lake formation. Horizontal projection of the altitude of lowest lacustrine sediments beneath the Savanna Terrace in the lower Illinois Valley to the valley mouth yields a difference of 19.8 m (65 ft) between Savanna Terrace and the base of the related lacustrine facies (see Stop 7). This difference provides a minimum estimate of the extent of incision forming the Cuivre terrace level as well as thickness of sediments aggraded to the Savanna Terrace level.

Net aggradation to the Savanna Terrace level occurred between about 13,400 and probably about 15,500 B.P. Savanna Terrace and associated sediments are inset below, and therefore younger than the Cuivre terrace level. Thus, associated sediment definitely post-dates about 17,000 B.P. (Table 5). Radiocarbon evidence from the middle Illinois Valley suggests it post-dates the Kankakee Torrent, or between about 16,000 and 15,500 B.P. (Hajic, 1990). Wood collected in the lower Illinois Valley from the basal lacustrine lithofacies unit of terrace-related sediment in direct association with reddish brown clay dated between 13,710 and 13,010 B.P.. Radiocarbon ages and continuity of reddish brown clay up the lower Illinois Valley, from overbank sediment atop the sediment dam into basal lacustrine silt, indicate the period of Mississippi Valley aggradation that deposited the sediment dam was nearly completed by about 13,400 B.P. Stratigraphic and geomorphic relationships of radiocarbon samples from the lower Illinois River Valley indicate downcutting that formed the Savanna Terrace dated about 12,300 B.P. (Hajic, 1990). Mastadon bones and Clovis artifacts were identified by Graham (197) at Kimmswick, Missouri, buried in colluvium over a terrace correlative with the Savanna Terrace.

Kingston Terrace (New)

The Kingston Terrace consists of sandy remnants preserved in the Mississippi Valley and correlative terraces are present in at least some tributaries (Figure 4). In the vicinity of the Illinois Valley mouth, Kingston Terrace remnants are usually defined between 131.1 and 134.1 m (430 and 440 ft) contours and rise 4.6 to 6.1 m (15 to 20 ft) above adjacent flood basins. However, in some areas, terrace remnants are nearly flush with flood basins. In the Three Rivers Area, only isolated fragments remain. The terrace takes its name from the town of Kingston, Iowa, where more extensive remnants are represented (E.A. Bettis, personal communication, 1989; Benn et al., 1988). Where best represented in the Three Rivers Area, north northeast of Hannibal, Missouri, on the east side of the valley, remnants occur associated with reaches of a paleochannel system consisting of multiple channels at least 15 times broader than the modern Mississippi River. Some remnants exhibit large scale streamlined mid-channel bar morphologies. A fine braid pattern is often superimposed on the terrace surface as well as in the broad paleochannel system. Small eolian sand sheets sporadically cover the terrace.

Sediment underlying the Kingston Terrace and associated channels is sand and gravelly sand. Thin increments of overbank silt, silty clay loam, and loam, sometimes incorporating reddish brown clay, caps the sand in local swales. Channel and bar morphology suggest the terrace formed as part of a sluiceway when the Mississippi River was carrying floods of at least moderate magnitude, then later modified by a braided stream with considerably smaller discharge. Finer textured sediment in depressions may be related to younger floods.

The Kingston Terrace is inset below, and therefore younger than the Savanna Terrace, or younger than about 12,320 B.P. (Figure 4). Extent of incision and reaggradation to the terrace level is unknown. Final cutting of the terrace post-dates 12,000 B.P. and predates 10,400 B.P. based on a radiocarbon age (D.S. Leigh, personal communication, 1987) on organic debris collected from basal fill within the associated paleochannel (Table 5). However, this sample contained some *Picea* needles which may represent contamination at this time: the youngest radiocarbon dated material containing *Picea* elements from the lower Illinois Valley region is 12,000 +/- 100 B.P. (ISGS-911) and the oldest radiocarbon dated material containing no coniferous elements is 11,070 +/- 190 B.P. (ISGS-1277) (Hajic, 1990). A more conservative estimate for cutting of the terrace and abandonment of the associated paleochannel is about 9850 B.P.

East Chouteau Paleogeomorphic Surface (New)

The East Chouteau surface is a buried paleogeomorphic surface defined by a discontinuous paleosol developed within the basal sediment fill of the paleochannel system related to the Kingston Terrace (Figures 4 and 5). No formerly recognized terraces are correlated with it. Basal sediment fill typically includes or consists entirely of thick beds to laminae of reddish brown clay. The surface is named for the township in the northernmost part of the

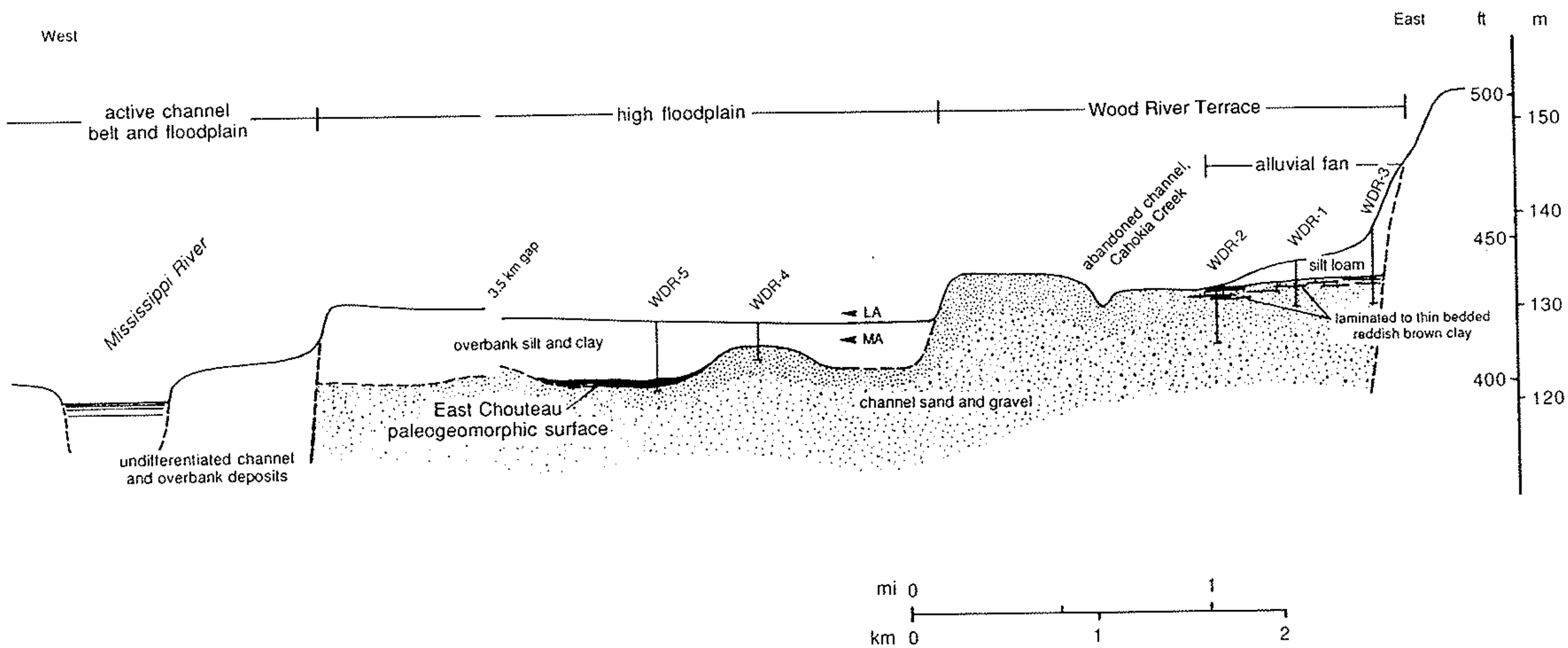

Figure 5. Schematic cross-section of Wood River (Savanna) Terrace and East Chouteau paleogeomorphic surface in the northern American Bottoms, central Mississippi Valley.

American Bottom where an extensive tract is preserved south and west of the town of Wood River. Reddish brown clay in the northernmost part of the American Bottom correlates with the reddish brown clay at the base of lacustrine fill in the Swan Lake paleochannel in the lower Illinois Valley (Hajic, 1990). A second extensive tract is associated with channels cutting and associated with the Kingston Terrace between Hannibal and Quincy (Leigh, 1985; unpublished data). The paleosol is located below (1) flood basins within the paleochannel system that are relatively featureless and have not been reworked by a younger meandering or island braided Mississippi River, and (2) relatively large alluvial fans that prograded into these flood basins. Although flood basin ground surfaces underlain by the East Chouteau surface are nearly flat, preservation of pedogenically altered reddish brown clay is discontinuous. Well records from the Wood River area suggest it fills swales in a buried sandy ridge and swale topography. Stratigraphic relationships in the Hannibal area suggest erosional discontinuities due to tributary stream activity as well. In the Wood River area, the paleogeomorphic surface rests below flood basins at about 121.9 m (400 ft) and is buried by about 6.1 to 9.1 m (20 to 30 ft) of sediment. South of Quincy, it lies at about 135.6 m (445 ft), about 3.0 to 4.6 m (10 to 15 ft) below flood basins, with a maximum altitude of about 454 ft (138.4 m).

Red clay that is probably correlative with the East Chouteau reddish brown clay was described as far south as the head of the Mississippi Embayment in the Morehouse Lowland 35 km southwest of Thebes Gap and about 180 km south southeast of St. Louis. King and Allen (1977) reports 0.2 m of "red clay" at the base of fill in the Old Field swamp. The red clay rests on sand and is overlain by 0.15 m of gray clay and 2.3 m of peat.

Gray clay, silty clay and silty clay loam overlies the East Chouteau surface and associated reddish brown clay. Gray clays were derived from Holocene Mississippi River flooding and deposited in flood basin lakes of variable character and permanence. For a soil to form in this relatively low landscape position, overbank sedimentation rates must have been limited in order not to overwhelm pedogenesis. Either the Mississippi River was not prone to frequent flooding at the time the paleosol associated with the East Chouteau surface developed, or it was somewhat incised and the East Chouteau surface was temporarily in a terrace landscape position.

The East Chouteau paleogeomorphic surface is inset below, and therefore younger than Kingston Terrace, or about 12,000 B.P. Initial influx of flood sediment, consisting largely of reddish brown clay, into broad paleochannels following their abandonment occurred probably just about 9850 B.P. and definitely prior to about 9650 B.P. (Table 5; Figure 4). Pedogenic alteration of that material representing the East Chouteau surface occurred before 9650 B.P. in the northern American Bottom. The oldest radiocarbon age from basal peat in the Old Field Swamp overlying reddish brown clay is 8810 ± 90 B.P. (ISGS-326). In the northern American Bottoms, Late Archaic archaeological debris is found on ground surfaces overlying areas where the East Chouteau surface is preserved, and a buried Middle Archaic site was excavated in an area underlain by the East Chouteau surface.

DISCUSSION

Long Distance Correlations

Terraces in the Three Rivers Area of the Mississippi Valley correspond with terraces reported in the Mississippi Valley to the north. Within Mississippi navigation pools 17 and 18, between Muscatine, Iowa, and just south of Oquawka, Illinois, and about 250 km north of the Illinois River mouth, Bettis (1988) identified three terraces within the Mississippi Valley: (1) a high loess mantled terrace with patterned ground at the mouth of the Edwards River Valley; (2) a high sandy surface with eolian dunes 11 to 18 m (36.1 to 59.1 ft) above the river; and, (3) a low sandy terrace approximately 1 to 3 m (3.0 to 9.8 m) above the river with a superposed relatively fine braid pattern. The latter surface is cut by several broad paleochannels now filled to floodplain level with Holocene sediments, including a basal reddish brown clay unit.

The high loess mantled terrace probably corresponds with the Gilead level of the St. Charles Terrace Group. Bettis correlated the high sandy terrace to the Savanna Terrace. Radiocarbon ages reported in association with the low sandy terrace, relative geomorphic position within the valley, associated braided pattern, and paucity of surficial reddish brown clay below the terrace correspond well with the Kingston Terrace in the Three Rivers Area. The age estimate on downcutting to this level predates corresponding downcutting in the Three Rivers Area by a minimum of several hundred years. Minor adjustments just before 12,000 B.P. established the low sandy surface as a terrace. Additional radiocarbon ages reported by Bettis from basal fill within broad paleochannels cutting the low sandy terrace also agree with downstream ages and stratigraphic relationships of the East Chouteau paleogeomorphic surface.

Sediment below the Savanna Terrace in east central and northeastern Iowa temporally correlates with sediment below both Cuivre terrace level and Savanna Terrace in the Tree Rivers Area (Figure 6). Radiocarbon ages between about 17,700 and 16,500 B.P. are reported from well below the Savanna Terrace in northeastern Iowa and near-surface radiocarbon ages are around 13,100 B.P. (Bettis and Hallberg, 1986). The Cuivre level apparently is not represented morphologically to the north in east central and northeastern Iowa. An erosional event is represented in the Three Rivers Area that is not represented in northeast Iowa; rather, valley aggradation continued to the north (Figure 6). The erosional event probably accounts for the marked increase in former floodplain gradient from the St. Charles Terrace Group to the Savanna Terrace in the upper Mississippi Valley. The temporal framework suggests the erosional event represented in the Mississippi Valley in the Three Rivers Area likely was initiated in response to downcutting of the Illinois Valley by the Kankakee Torrent sometime between about 15,500 and 16,000 B.P. (Hajic, 1990). The Mississippi Valley south of the Illinois Valley mouth probably was similarly incised for some distance downstream; adjustments in the Mississippi Valley above the mouth of the Illinois Riveras would have been initiated, but in Iowa these adjustments were either not of significant magnitude to be obvious, or were not translated this far upvalley.

In southeast Iowa, Esling (1984) reports three terraces in the lower Iowa and Cedar valleys: (1) Early Phase High Terrace, Illinoian or early Sangamonian in age; (2) Late Phase High Terrace, early Woodfordian in age (est. between 21,000 and 17,000 B.P.), grading laterally into the Iowan Erosion Surface; and, (3) Low Terrace System, late Woodfordian to Twocreekan in age (circa 13,000 to 12,000 B.P.), consisting of multiple terrace levels (see also Bicki, 1981 and Nott, 1981). The Late Phase High Terrace shares similar geomorphic relationships to erosion surfaces and stratigraphic relationships to loess as the Gilead level, St. Charles Terrace Group. Bettis (1988) correlates his high sandy surface with the low terrace system of Esling, thus relating it to the Savanna Terrace. Radiocarbon ages of 12,425 ± 115 (Beta-1751; Nott, 1981) and 11,800 ± 200 B.P. (I-3654; Ruhe and Prior, 1970) collected near the transition from coarse to fine sediment near the top of low terrace remnants in tributaries to the Iowa River suggest some level(s) of the low terrace system may correspond with the Kingston Terrace.

Relationships to Peoria Loess

Terrace chronology indicates aggradational sediments immediately underlying the St. Charles Terrace Family, Savanna Terrace, and Kingston Terrace were, or are directly related to, the alluvial surfaces that supplied deflation material for the Peoria Loess. Peoria Loess Zones p-1, p-2, and p-3 were deposited between about 25,000 and 20,000 B.P.; Zone p-4 between about 20,000 and 18,000 B.P.; and, Zones p-5 and p-6 between about 18,000 and 12,600 B.P. (McKay, 1977). Zone p-6 was deposited north of the Illinois-Mississippi valley confluence; Zone p-5 was deposited in the Illinois Valley and below the Illinois-Mississippi valley confluence. Zones p-1 through p-4, and perhaps the oldest increments of p-5 and p-6, are temporally related to aggradation to the St. Charles Terrace Family levels. Peoria Loess overlying St. Charles Terrace Family levels and possibly interbedded with flood clay beds above the Cuivre level should consist of Zone p-5 and p-6 mineralogies. Zones p-5 and p-6, except for the oldest increments, are temporally related to aggradation to the Savanna Terrace level.

The Jules Soil was determined by McKay (1977) to occur within Peoria Loess Zone p-5. Previously, it was suggested the Jules Soil may be related to a major retreat of the Michigan Lobe (Willman and Frye, 1970; McKay, 1977). Development of the Jules Soil indicates a temporary cessation or substantial reduction in loess sedimentation that must be related to fluvial conditions in the valley source area. An alternative suggestion for conditions favoring development of the Jules Soil is that they were established when the Mississippi River downcut from the Cuivre level, or just prior to this incision. The temporal framework is accommodating. The timing of the Jules Soil apparently overlaps with catastrophic flooding and major incision in the Illinois Valley (see Hajic, 1990, Catastrophic flooding (Kankakee phase); this event may have led to temporary cessation or reduction in loess sedimentation allowing the Jules Soil to form. It may also account for the Jules Soil having a distribution apparently limited to the middle and lower Illinois Valley region and the Three Rivers Area.

The youngest generally acceptable radiocarbon age on Peoria Loess from Illinois is 13,700 B.P. (Frye et al., 1968). Final cessation of Peoria Loess sedimentation was estimated by extrapolation at about 12,600 B.P. (McKay, 1977). This age post-dates slightly a shift that occurred about 13,400 B.P. in fluvial sedimentation recorded in surficial sediment below the Savanna Terrace. It is likely the shift from sandy braided to a more stable channel with finer overbank sedimentation at the close of aggradation to the Savanna Terrace level more closely approximates termination of large-scale loess sedimentation. Sporadic eolian dunes and patchy thin silt increments on the Savanna Terrace attest to only limited eolian activity after 13,400 B.P. The lake that existed in the lower Illinois Valley between about 13,400 and 12,300 B.P. effectively would have eliminated the lower Illinois Valley as a sediment source for loess for this interval.

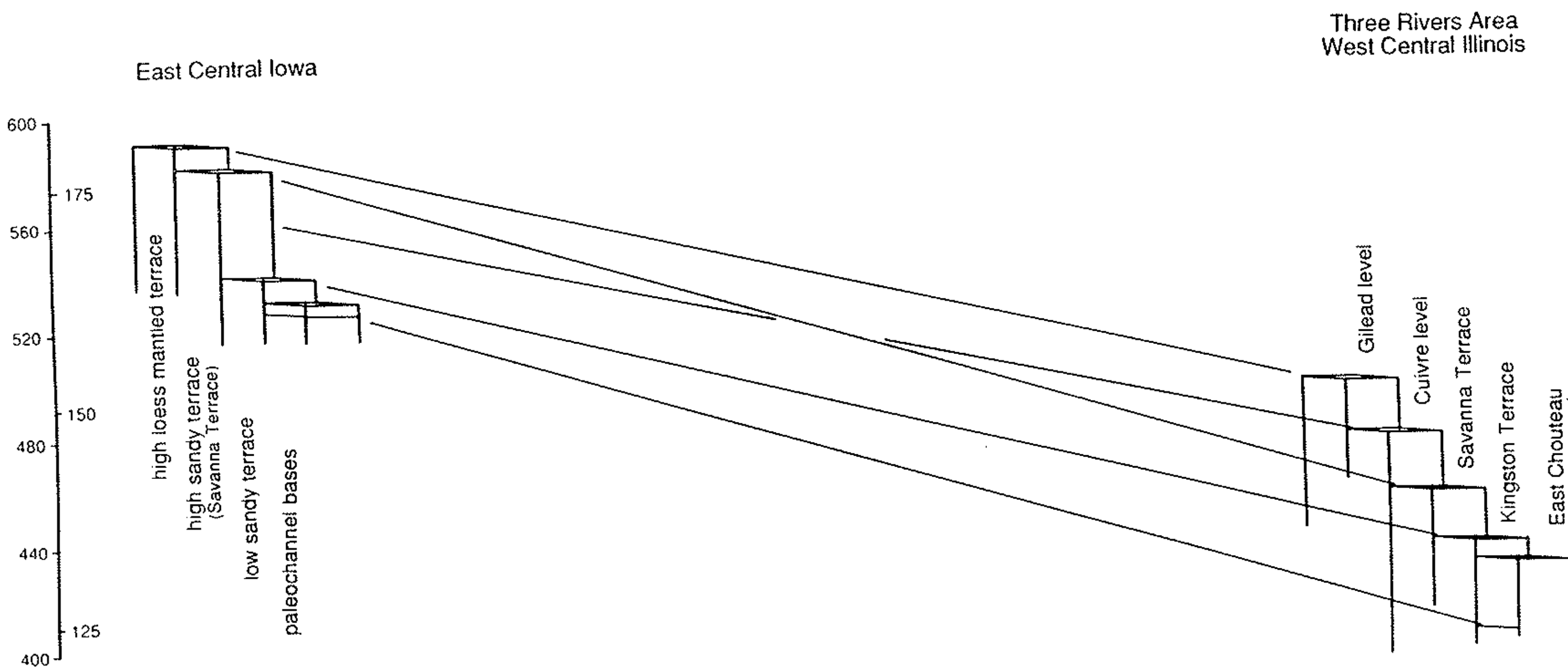

Figure 6. Schematic representation of upper and central Mississippi Valley terrace correlations and gradients.

Reddish Brown Clay

Sporadic deposition of reddish brown clay with a Lake Superior Basin source spans a temporal range minimally of between about 18,700 and 9600 B.P. Near the base of several sections and cores (MTZ-3, Auers Landing, Salt River; Figure 2), unoxidized silt and silt loam exhibit a slight reddish brown chroma suggesting possibly older occurrences. Whether this is due to admixture with reddish brown clay, reworking of Roxana Silt, or admixture of sediment related to reddish brown diamictons such as the Tiskilwa Till Member of the Wedron Formation, has yet to be determined. Reddish brown clay in a number of landform - stratigraphic contexts casts doubt on its utility as a "marker bed" indicative of the Savanna Terrace as suggested by Flock (1983) (Bettis, 1988). However, within the context of landscape and stratigraphic position, recognition of reddish brown clay may be of supplemental use in identifying terrace-related sediments.

Flock (1983) related reddish brown clay to discharge of proglacial lake waters in the central and eastern part of the upper Mississippi Valley drainage during the latest part of the Wisconsinan Age. Given the potential diversity of sediment input in the upper Mississippi River basin, it is reasonable to expect relatively unmixed beds of reddish brown clay can only be derived from rapid lake discharges. Presence of earlier distinct reddish brown clay beds suggests discharge of proglacial lake waters was a relatively common process during retreatal phases of at least the Superior Lobe and its sublobes.

Broader Geomorphic Relationships

Evolution of the Mississippi Valley landscape undoubtedly was influenced both by glaciation and deglaciation. During deglaciation, the presence and character of glacial lakes and the magnitude and frequency of lake discharge undoubtedly played a major role. The early Woodfordian glacial record in the upper Midwest is sketchy and chronology is speculative at best. In general, glacial ice was advancing southward across the upper Midwest and into the Mississippi drainage basin between at least 25,500 and 20,000 B.P. After 20,000 B.P., ice fronts fluctuated in an overall retreating manner (Clayton and Moran, 1982; Eschman and Mickelson, 1986; Matsch and Schneider, 1986; Hallberg and Kemmis, 1986). Terraces and associated sediments in the Mississippi Valley span the same time interval, but the relationships between glacial advance and retreat and valley aggradation and degradation is not as straightforward as classical interpretations suggest (cf. Frye, 1961).

If aggradation in the lower reach of Cuivre River, underway by 25,500 B.P., was in response to glaciation, as is likely the case, it did not take long for the impact of meltwater discharge to translate downstream. Highest aggradation crested sometime after 18,700 B.P., slightly more than a millennium after the estimated maximum ice advance. In the Illinois - Ancient Mississippi Valley, maximum fill levels were achieved by about 20,000 B.P. Prior to about 20,000 B.P. there is no strong evidence for large magnitude floods preserved in tributaries although aggradation in these locations was undoubtedly influenced by a rise in Mississippi Valley base level. After about 20,000 B.P. and diversion of the Ancient Mississippi Valley to the modern valley, during glacial retreat, the alluvial record indicates a shift towards multiple flood events, potentially of large magnitude, that periodically both choked lower tributary valley reaches with sediment and at times downcut and trimmed back the valley bluffline. Although at times the Mississippi River was undoubtedly a "typical" braided stream of the sort often associated with meltwater valleys, flooding, probably from glacial lake discharge, was a major factor that shaped the Mississippi Valley sediment record and landscape. Apparent differences in behavior of the Mississippi River before and after about 20,000 B.P. may be the result of moraine-dammed glacial lakes forming upon glacial retreat.

During the latest stages of deglaciation, readvance maxima took place about 14,000, about 12,300, at 11,800, and at 9900 B.P. (Clayton and Moran, 1982). There is no apparent direct correspondence between these later glacial readvances and valley aggradation, and glacial retreats and valley degradation. At 14,000 B.P., central Mississippi Valley was aggrading to the Savanna level which it attained nearly a millennium later. The advance peaking about 12,300 B.P. corresponds with incision forming the Savanna Terrace. The latest readvances correspond with activity in broad paleochannels with relatively little net valley aggradation or degradation.

During at least the latest stages of deglaciation, proglacial lake outbursts and jokulhlaup discharge reached the Mississippi Valley above the mouth of the Illinos Valley via the Minnesota (Clayton and Moran, 1982; Fenton et al., 1983), St. Croix (Clayton, 1983), and Des Moines (Kemmis et al., 1985) Rivers. The Rock and Green Rivers also may have drained glacial lakes. Formerly, Flock (1983) attributed aggradation of Savanna Terrace-related sediment to flood discharge from glacial lakes Superior, Grantsburg, or Agassiz. However, drainage from these proglacial lakes post-dates aggradation to the Savanna Terrace level by about a millennium. Lake Agassiz, a huge proglacial lake that formed as ice retreated through the Red River basin of northern Minnesota and North Dakota and south central Canada, is the most notable and best dated of these glacial lakes. At times when eastern outlets were blocked by glacial ice, discharge from Lake Agassiz flowed through the Minnesota River via River Warren. The River Warren outlet is estimated to have been active from about 11,600 to 10,900 B.P. (latter part of the Cass Phase through the Lockhart Phase of Lake Agassiz) and definitely from 9900 to an estimated 9500 B.P. (Emerson Phase) (Clayton and Moran, 1982; Clayton, 1983). The Regina flood (Kehew, 1982; Kehew and Clayton, 1983; Kehew and Lord, 1986), originating in southern Saskatchewan, emptied into Lake Agassiz and probably caused flooding down the Mississippi Valley. The Regina flood was estimated to have occurred sometime between 12,000 and 11,000 B.P. Much smaller lakes, antedating Lake Agassiz, are believed to have discharged through the Minnesota River Valley at about 12,800, 12,400 and between about 12,100 and 11,800 B.P. (Clayton 1983). Phases of Glacial Lake Superior, with drainage principally through the Brule spillway to the St. Croix River and finally to the Mississippi River are believed to have existed from about 12,000 B.P. to about 10,900 B.P. and again between 9900 and about 9600 B.P. (Clayton, 1983; Lineback et al., 1979). Glacial Lake Grantsburg is estimated to have formed between 12,700 and 11,800 B.P. (Wright, 1964; 1972). During these later lake intervals, the broad paleochannels inset below Kingston Terrace were sculpted by glacial lake discharge. Overall, these glacial lake intervals temporally correspond to the time of relative valley stability at the level of the Savanna Terrace through downcutting and modification of the broad paleochannel system that lead to formation of the Savanna level as a terrace.

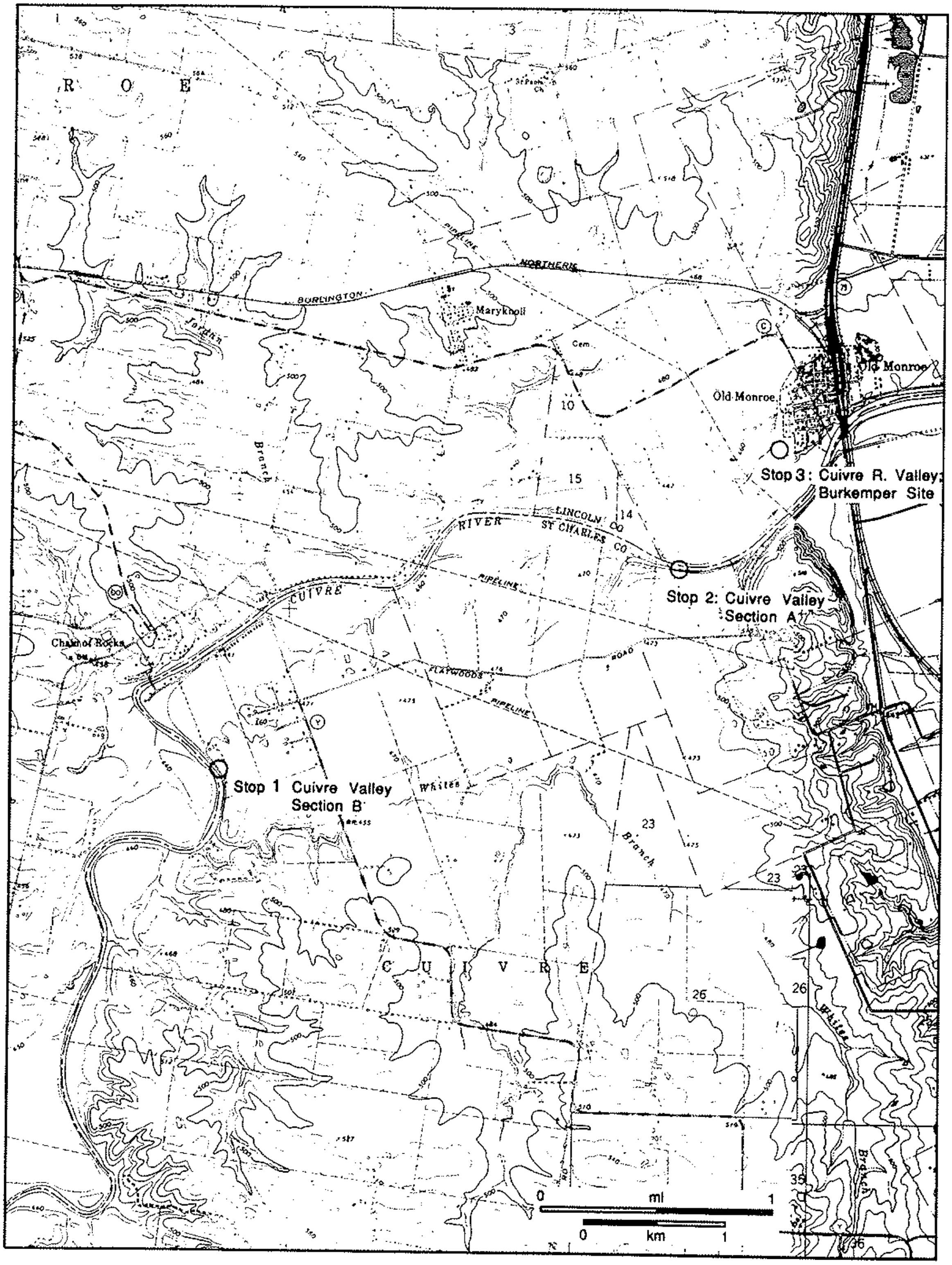

Figure 7. Location of Stop 1, Cuivre Valley Section B (SW NE 21 T48N R2E); Stop 2, Cuivre Valley Section A (NE SW 14 T48N R2E) and Stop 3, Burkemper archaeological site (NW NE 14 T48N R2E).

DAY 1

STOP 1. CUIVRE VALLEY SECTION B

The purpose of this stop is to examine typical sedimentology of the slackwater - flood lithofacies association underlying the lower level of the St. Charles Terrace Family in a moderately sized Mississippi Valley tributary, and to compare these deposits with underlying tributary alluvium. Terrace-related sediments exposed here will be compared to lithofacies in a more proximal position relative to the Mississippi Valley at the next stop. We will also begin our discussions of terrace chronology, correlations and paleoenvironments.

Cuivre Valley Section B is located 2.8 mi (4.6 km) west of the Mississippi Valley (Figure 7). The section is a cutbank under attack by the Cuivre River that is cut into an extensive terrace remnant preserved on the south side of the Cuivre Valley. At the Mississippi Valley the ground surface is just above the 480 ft (146.3 m) contour and slopes away from the Mississippi Valley up the Cuivre Valley to 470 ft (143.3 m). A thin increment of Peoria Loess mantles the terrace and Weller silt loam is mapped across the land surface (Tummons, 1982). Lower surfaces that include the Savanna Terrace are visible across the river. This section is at the location of Robertsons (1936; his Figure 15) photograph of Cuivre Terrace - related deposits, although the section has retreated several tens of feet.

Sediments exposed are typical of the medial slackwater - flood lithofacies association (Figure 8). They consist of horizontal thin massive and laminated beds of deoxidized and unoxidized silt loam, silt, and silty clay loam interstratified with laminae of fine sand and fine sandy loam. Some of these coarser strata have graded tops. In the upper half of the section, olive silty clay laminae appear. Small scale soft sediment deformation caused by relatively rapid sediment loading and increased pore water pressures is common. Individual laminae often are disrupted or have finely irregular contacts. Reddish brown clay beds and laminae are common except in the lower two meters. The reddish brown clay has a Lake Superior Basin source and demonstrates the extent of backflooding up tributaries by the Mississippi River. Many beds consist of laminae couplets of reddish brown clay and silt that represent individual flood episodes. Slackwater sediments are calcareous but only a few isolated snail and bivalve shells were found. There is no evidence of significant pedogenic alteration although some zones have pores and oxide stains.

Slackwater - flood lithofacies abruptly and in places unconformably overlies tributary fluvial lithofacies. The tributary alluvium consists of unoxidized, variably calcareous, massive, laminated, and cross - stratified horizontal to discontinuous thin beds of fine sand and silt. Some of the beds are shallowly channeled and scoured. Snail shells and discontinuous lenses of organic material are common, and exposure features are lacking. The base of this facies was not exposed and continues below river level.

Three radiocarbon ages have been obtained from Cuivre River alluvium and they fall in stratigraphic order (Table 5). The oldest date is 25,520 ± 250 BP (Beta-26515) and was on material collected just above river level. It is expected these sediments will be below river level at the time of the field trip. The youngest age is 20,540 ± 160 BP (Beta-26517) and dates material collected less than two meters below the base of overlying slackwater sediments. The radiocarbon ages suggest aggradation in at least the larger tributaries was underway by 25,500 BP and that the Farmdalian flood plain was at or below modern flood plain levels. The ages also indicate substantial tributary backflooding and slackwater sedimentation did not begin until after 20,500 BP.

The Cuivre level correlates include the Cuivre Terrace in Mississippi Valley tributaries similar to the exposure cited by Robertson (1938) in the Cuivre Valley, as well as Metz Creek, Baden, and Bonfils terraces. Surfaces cited by Robertson as the basis of the Cuivre Terrace, at least in the St. Peters vicinity, are unrelated to his described section in the Cuivre Valley. Rather, they are cored by bedrock with overlying upland lithofacies associations (Stop 4). Rubey (1952) described the Metz Creek Terrace as an erosion surface, citing pebbles at and near the ground surface. However, the inclusions are in and on Peoria Loess or loess-derived silt stratigraphically above the terrace and therefore post-date terrace formation. It is possible that erosion surfaces exist in the region at comparable altitudes. The pebbles are enigmatic but may consist entirely of prehistoric cultural remains. Where examined, the Metz Creek Terrace is an aggradational terrace buried by loess, not erosional, and is probably part of the Cuivre level. A photograph

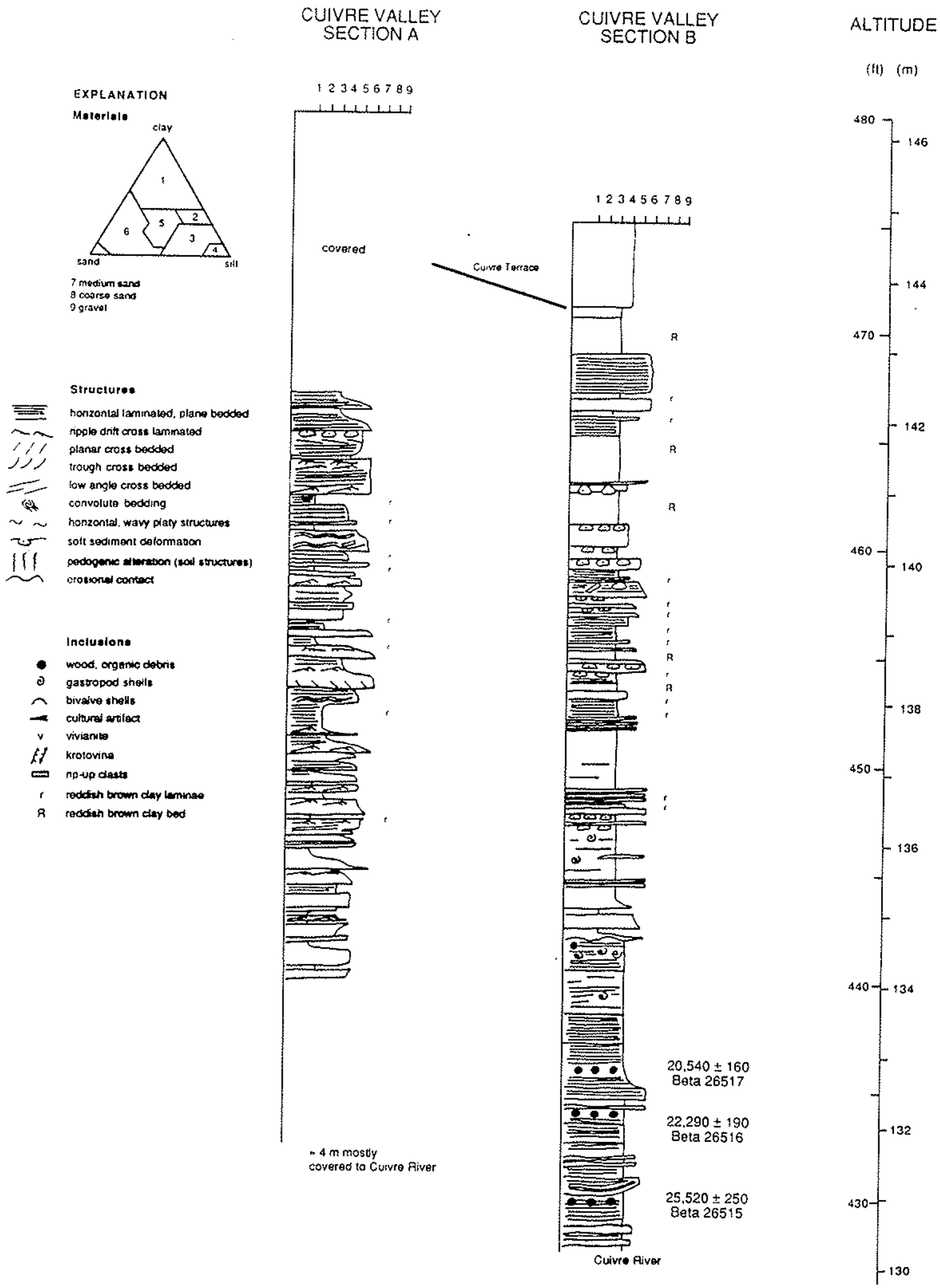

Figure 8. Stratigraphy and sediment logs of Cuivre Terrace sediment assemblages, Cuivre River Valley. Section A illustrates proximal lithofacies association. Section B illustrates medial lithofacies association.

of the Baden Terrace section (Goodfield, 1965:68; his Figure 15) illustrates what can be interpreted as rhythmic bedding, appearing similar to sediments at Cuivre Valley Section A. It is likely some of the higher remnants of Robertson's (1938) Festus can be correlated to the Cuivre level as well.

The Peoria Loess is relatively thin at this stop compared to other examined sections in the Cuivre level of the St. Charles Terrace Family. This may in part be due to the reverse slope of the terrace, with progressively more distal reaches being inundated more frequently and for longer periods of time.

STOP 2. CUIVRE VALLEY SECTION A

At this stop we will examine the slackwater - flood lithofacies underlying the Cuivre level of the St. Charles Terrace Family in a proximal setting and contrast these deposits with those seen at Stop 1. Cuivre Valley Section A is a cut bank 0.7 mi (1.1 km) up Cuivre Valley from the Mississippi Valley and about 2.1 mi (3.5 km) downvalley from Section B (Figure 7). Altitude of the land surface is greater than 470 ft (143.3 m) but less than 480 ft (146.3 m). Weller silt loam is the mapped surface soil, although a slight rise parallels this reach of the Cuivre River suggesting some eolian dune formation as well loess accumulation.

The sediments exposed were deposited mostly by traction currents, with current directions both up and down the Cuivre Valley, and secondarily, by sedimentation from suspension. Most of the section consists of successive 5 to 15 cm thick beds of rhythmites that are horizontal to slightly undulatory across the outcrop (Figure 8). Many rhythmites are normally graded from fine sand or fine sandy loam to silt loam and silty clay indicating decreasing current velocities. The sand is either horizontally laminated or ripple cross-laminated; planar cross-beds and sinusoidal ripple lamination, indicative of large sediment loads deposited under waning current conditions, are rare. The coarser material is typically the thickest part of a rhythmite. An intermediate unit of horizontally laminated or massive silt, fine sandy loam, or loamy fine sand is sometimes present. Laminae and ripple drapes of silty clay loam top most sequences. This thin increment is often complicated by interlaminated fine sand, reactivation surfaces, and occasionally a reddish brown clay laminae. Overall, sand units become more prominent and slightly thicker in the upper half of the section suggesting backfloods of increasing magnitude . Tops of rhythmites show little or no evidence of pedogenesis, indicating lack of any significant subaerial exposure. Inverse grading is common, and ripples indicating opposing current directions are sometimes found at the top and bottom of an individual sand bed, or in successive rhythmites. These features suggest multiple flood surges may have been a common process.

Comparing proximal with the medial backflood lithofacies at Cuivre Valley Section B, the overall fining upvalley trend is obvious. Current deposits predominate in the proximal location and sedimentation of clay from suspension is of minor importance. Upvalley, the medial facies is dominated by silt and clay deposited from suspension and deposition from traction currents is of minor importance. The laminated clayier units probably represent lacustrine sedimentation, punctuated by pulses of coarser material from larger magnitude Mississippi Valley floods. Reddish brown clay laminae in lacustrine deposits probably represents introduction of minor floods into the valley lake.

A number of lines of evidence point to a backflood origin for the terrace-related deposits at Stops 1 and 2. Perhaps the strongest argument is the presence of reddish brown clay with a Lake Superior Basin source. The only way it could be introduced to the Cuivre Valley is via the Mississippi Valley. Upvalley decrease in amount and thicknesses of traction current deposits and upvalley paleocurrent directional indicators also are strongly supportive of backflooding. That multiple flooding episodes are involved is evidenced by the reversals of paleocurrent directions in the proximal facies and the multiplicity of distinct reddish brown clay beds and laminae in the medial facies. Reverse slope of the terrace hints some degree of sediment damming by the Mississippi Valley was probably involved.

STOP 3. ARCHAEOLOGY AND GEOMORPHOLOGY OF THE BURKEMPER SITE

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The Burkemper site (23LN104) is located on a low flood plain terrace of the Cuivre River in eastern Missouri, 0.5 km west of the junction of the Cuivre and the Mississippi River valley (Figure 7). The site was recorded in 1980 by Missouri Highway and Transportation Department personnel during a survey in connection with the proposed relocation of Missouri Route 79 to the west of the town of Old Monroe. In 1980 personnel from the University of Missouri-Columbia assisted MHTD archaeologists in designing and implementing a controlled surface collection of that portion of the site to be affected by construction activity. The distribution of surface materials was then used to structure large-scale excavation of a portion of the site in 1984 and 1985.

Occasional visits to the site between 1980 and 1983 strengthened our belief that Burkemper was an important archaeological resource from numerous standpoints. The most noticeable feature of the site was the abnormally large quantities of surface archaeological materials. After heavy rains, especially those following periods of cultubation, the site surface was literally paved with artifacts. Animal and human bone, fresh-water-mussel shell, pottery fragments, and lithic items occurred with frequencies rarely encountered on Midwestern sites. The majority of pottery types present on the surface were recognized as belonging to the Havana series from western and west-central Illinois, and together with contemporary hafted-biface types pointed to a large Middle Woodland-period (ca. 2200 - 1600 B.P.) occupation. The site also contains a large early Late Woodland (1600 - 1250 B.P.) occupation and a smaller late Late Woodland (1300 - 1100 B.P.) occupation. A single broken Cahokia cordmarked jar points to a much smaller Mississippian (post-1100 B.P.) occupation. The terrace containing the site apparently has been built up fairly rapidly, judging from the presence of a buried Middle Archaic component found 2 m below present ground surface. The short length of time available for excavation precluded further examination of the level.

The thickness of the plow zone across the site was fairly uniform, ranging from 24 to 26 cm. To give you some idea of the amount of material in the plow zone, unit 510/522 (2 m^2) contained 26.8 kg of limestone, 2109 sherds, and 2.32 kg of bone. Unit 496/476 (2 m^2) produced 38.3 kg of limestone, 1754 sherds, and 2.58 kg of bone. As expected, surface densities were fairly precise indicators of what was found in the plow zone: the density of archaeological materials in the plow zone was higher in areas of high surface density and lower in areas of less surface material.

Burkemper presented numerous problems in terms of excavations. The uppermost 60 - 80 cm of soil was uniformly black across the site, and until crew members became accustomed to detecting slight changes in soil texture and to recognizing pit outlines in plan view, work progressed slowly. In one sense, Burkemper is one large midden composed of black, organically rich soil containing enormous amounts of cultural materials. Prehistoric pits were excavated through the accumulating midden and, in some cases, into lighter terrace soil, but pit orifices were difficult to detect. In many cases pits were recognized only because of the presence of dense circular concentrations of debris. The problem was exacerbated by the depth of plowing (averaging 25 cm across the site), which removed the tops of countless pits.

Another problem that soon became evident after excavation of the test units began was a lack of intact superpositioning of Late Woodland materials above Middle Woodland materials. Numerous crossmends of portions of ceramic vessels were made using pieces removed from each other vertically by as much as 30 cm. In many cases the lowermost 10-cm excavation level in a test unit contained higher proportions of Late Woodland pottery relative to Middle Woodland pottery than did higher levels.

It became increasingly clear during the 1984 field season that our only hope of obtaining relatively undisturbed deposits lay with the prehistoric pits. Fieldwork slowed considerably as our attention shifted toward the careful excavation of pits to the exclusion of the surrounding midden deposit. Care was exercised in analyzing pit deposits, with an eye toward noting how individual pits were filled and how long it might have taken a pit to fill. Vertical positioning of bones, shells, and sherds became the most valuable dimensions to observe. Pits were excavated, when possible, by natural levels that corresponded to individual fill episodes. Careful observation of artifact position and amount of lensing present in a vertical profile helped us determine whether a pit filled rapidly or slowly and whether ceramic items and faunal remains were sealed in place by later fill. Hand excavation and mechanical removal of topsoil yielded 246 pits.

Several decades of intensive archaeological work in the lower Illinois River valley, just to the east of Burkemper, have yielded a remarkable understanding of cultural developments there, especially the history of plant use, settlement dynamics, ceramic technology, and mortuary practices. We viewed anticipated work at Burkemper as an opportunity to build on work in western Illinois and to determine whether Middle Woodland peoples on the west bank of the Mississippi River were doing similar things and at roughly the same time as their neighbors to the east. Research is still ongoing, but several trends have become apparent in the data. The range of floral and faunal materials found in western Illinois is present at Burkemper, as is the full range in ceramic decorative types. Ceramic analysis demonstrates the same decrease in vessel-wall thickness noted by Braun for western Illinois, though vessels at Burkemper tend to be approximately 2 mm thicker than those to the east. By 1400 B.P., if not slightly earlier, Burkemper potters had developed the technology necessary to create large-diameter vessels with wall thicknesses in the 4-mm range - vessels strikingly different from earlier products, which exhibit a linear relation between girth and wall thickness. Current efforts are directed toward examining technological aspects of vessel production relative to other trends in the Burkemper archaeological record.

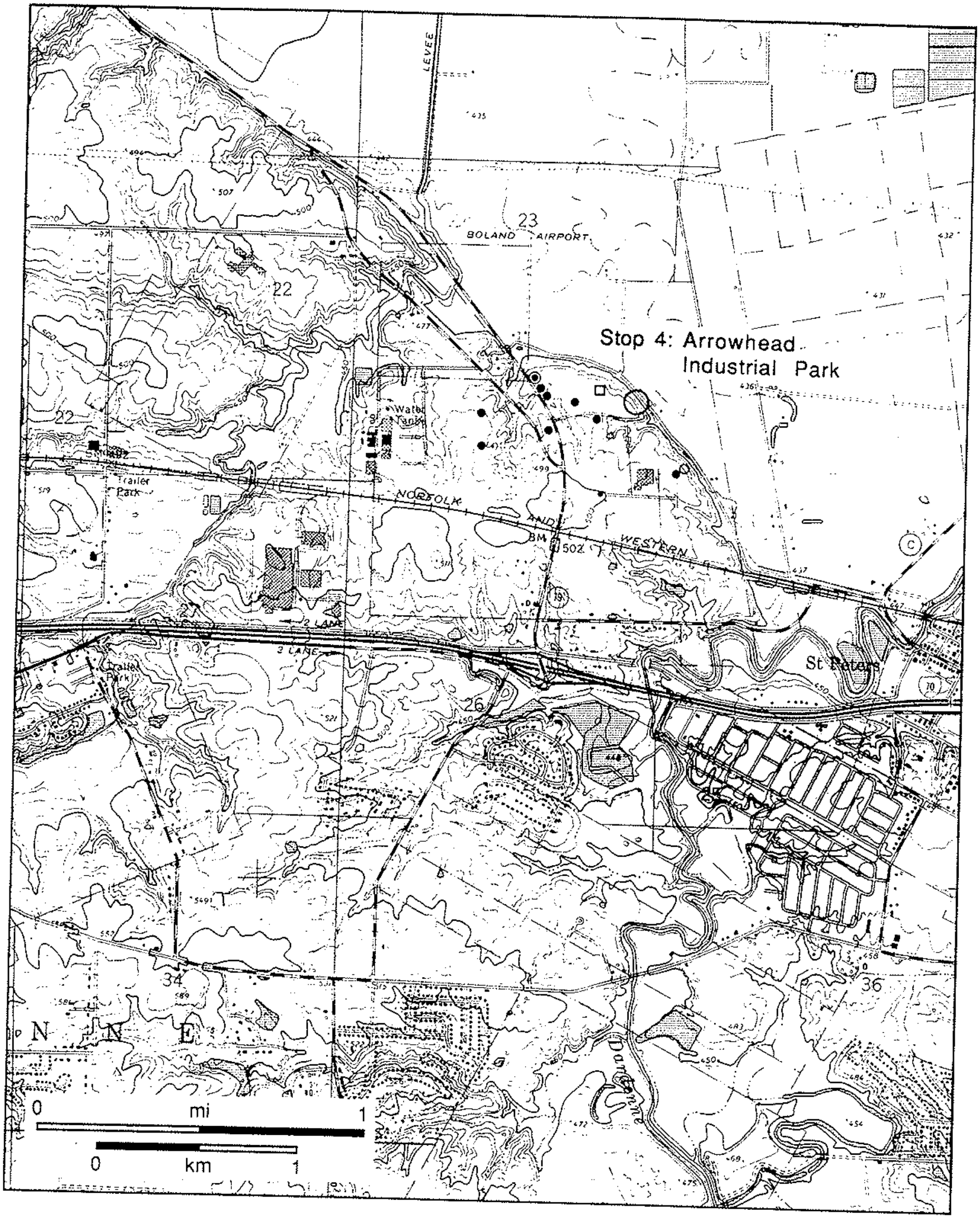

Figure 9. Location of Arrowhead Industrial Park, SW NE SE 23 T47N R3E, O'Fallon, Missouri, 7.5' quadrangle. Location of cores taken by Allen and Ward (1978) indicated by black dots. Their core 92-6 has ring around black dot. Missouri Department of Transportation core indicated by open square. Core collected for Mississippi Valley studies indicated by open circle.

STOP 4. ARROWHEAD INDUSTRIAL PARK

At this stop we will examine the stratigraphy below a land surface of relatively intermediate altitude at the Arrowhead Industrial Park in St. Peters, Missouri (Figure 9). This site will be our first experience with the fact that not all is what it at first morphologically appears to be. We will discuss landscape - stratigraphic relationships, including our first look at multiple pre-Wisconsinan loess and paleosols, giving particular consideration to whether a terrace is present. The site has historic significance as well. Originally pointed out by Robertson (1936) as an example of his Cuivre Terrace based on geomorphic criteria, this location formed Allen and Wards (1978) basis for re-establishing the Brussels Member of the Glasford Formation, a reincarnation of Rubey's (1952) enigmatic "Brussels Formation" and genetically related Brussels Terrace, after it was discarded by Willman and Frye (1970).

Arrowhead Industrial Park is located on a land surface that lies at an altitude of about 480 - 495 ft (146.3 - 150.9 m) (Figure 9), just slightly higher than the land surface overlying the Cuivre level of the St. Charles Terrace Family in the Cuivre Valley where it meets the Mississippi Valley. The surface is situated between the mouths of Belleau Creek and Dardennes Creek valleys, both of which have St. Charles Terrace and probably Savanna Terrace remnants. The surface appears nearly flat but gently ascends away from the Mississippi Valley to a knoll at about 510 ft (155.4 m), now mostly destroyed by road construction activity, and descends to about 470 - 480 ft (143.3 - 146.3 m) toward either creek valley. A relatively steep 30 ft (9.1 m) high escarpment demarcates the southwestern edge of the modern Mississippi Valley. The surface is moderately dissected by several minor first order side valleys.

Gullies cutting grass in first year growth on the valley-side escarpment provide good exposures of the stratigraphy and allow consideration of landscape - stratigraphic relationships. The northern third of the escarpment facing the Mississippi Valley and curving into the mouth of Belleau Creek valley was trimmed back and exposed in the summer of 1990 (notice old road bed for general reference to former location of escarpment). Cursory examination in the late fall suggested a uniform stratigraphy along the length of section. The section description is a composite compiled from a core taken in the summer of 1989 (Peoria Loess and Peoria - Roxana contact) and reported in Hajic (1990), description this spring from one of the gullies, and observations of a core collected by Missouri Department of Transportation personnel on the day the gully was described. All core locations, including the 9 taken by Allen and Ward (1978) are plotted on Figure 9.

Although historically interpreted as a terrace, the stratigraphy in core and sections consists of upland sediment assemblages of loessal silt, paleosols and colluvial diamicton. About 17 ft (5.2 m) of Peoria Loess conformably overlies 3.6 ft (1.1 m) of Roxana Silt that in turn overlies a thin diamicton that slopes toward the Mississippi Valley. With depth the Roxana Silt exhibits progressively greater degrees of pedogenic alteration associated with the Sangamon Geosol, and both clay content and granule and pebble clast content increase. The maximum Bt horizon of the Sangamon Geosol is developed in the diamicton and an underlying silt loam interpreted as a loess that is about 5.9 ft (1.8 m) thick. This unit abruptly overlies, with a nearly level contact, a deoxidized silty clay that coarsens downward to a silt loam with a well expressed paleosol developed in it. This possible fluvial unit overlies another silt loam modified by another paleosol. This second unnamed unit rests on bedrock slightly below the base of the escarpment and the lower few centimeters contains a few pebbles and is slightly clayier. Except for the Peoria Loess, the entire section is leached. The surface soil mapped by the USDA is a Harvester/Menlo silt loam, but the surface has been badly disrupted with industrial park construction.

With reference to the question of whether this surface is a late Wisconsinan terrace, the answer is 'no', even though the land surface is in the range of altitudes of land surfaces under which St. Charles Terraces are preserved. None of the cores or the exposed sections had any fluvially stratified materials that were clearly Wisconsinan in age, and only one of the cores had stratified materials that could even possibly be of this age (Allen and Ward, 1978; core 92-6). This raises the question as to which paleogeomorphic surface is responsible for the geomorphic expression of this landform: the bedrock strath on which the unlithified deposits rest, the nearly level contact between Loveland Silt and the underlying unnamed silt and clay, the erosion surface demarcated by the colluvial diamicton stone zone, or some other surface? Without

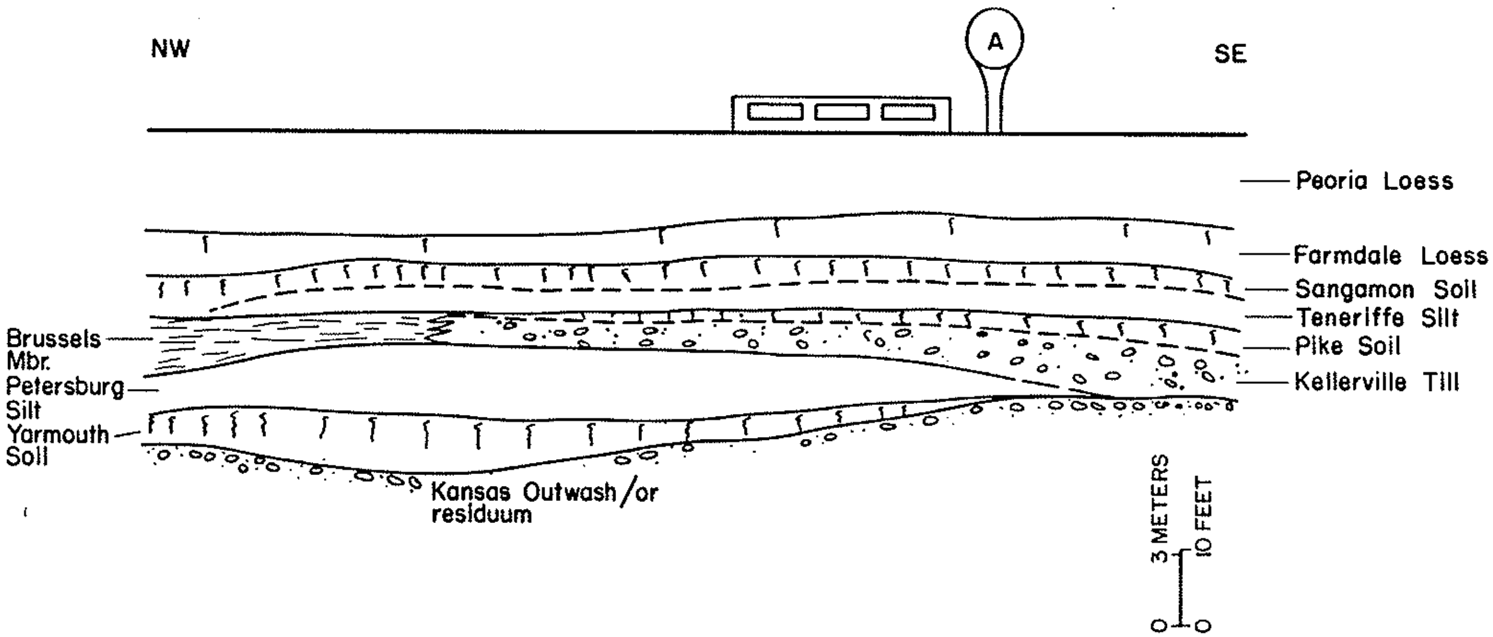

Figure 10. Diagrammatic northwest - southeast cross-section of Pleistocene deposits at Arrowhead Industrial Park. Figure reproduced from Allen and Ward (1978), their Figure 5.

coring of strategically aligned transects to higher and lower landscape positions, this question is unanswerable with certainty.

The only place where stratified material was reported, other than basal sand and gravel, is in core 92-6, the core closest to Belleau Creek valley (Figure 9). Calcareous "varved" silt and clay was interpreted by Allan and Ward (1978) as the Illinoian "Brussels Member" on the basis of an immediately overlying Sangamon Geosol (Figure 10). The Sangamon Geosol was traced to the southeast where it was interpreted to modify the Teneriffe Silt which in turn overlies the Pike Soil interpreted to be developed in the Kellerville Till Member of the Glasford Formation (Figure 10). The original concept of the Brussels Formation and Terrace has Illinoian glacial ice of the Lake Michigan Lobe crossing the Mississippi River in the St. Louis vicinity and damming at that point the Mississippi River (Rubey, 1952). Lacustrine silt comprising the Brussels Formation was interpreted to have been deposited in the Illinois and Mississippi valleys above St. Louis, and extensive areas of related terrace were mapped in the past. The "Brussels Formation" and Terrace are a focus of several stops on Day 2. We will discuss the Brussels in more detail at that time.

The interpretation of the diamicton unit at this stop offers an alternative to the interpretation forwarded by Allen and Ward. Rather than an Illinoian glacial till, it is suggested that the diamicton and pebbly zones in the Loveland Silt, and occasional pebbles in the underlying unit, are colluvial in origin, resulting from extensive erosion upslope of pre-Illinoian till and transportation and redeposition of this material as colluvial veneers. If this is the case, it brings into question whether the stratified material encountered near Belleau Creek is actually laterally related to the diamicton, thus bringing into question its age. It is possible the lowest parts of the industrial park surface immediately adjacent to either of the two creeks are reflecting a buried terrace. A colluvial interpretation also brings into question some of the pre-Sangamonian stratigraphic unit assignments illustrated in Figure 10.

Section: Arrowhead Industrial Park composite
Location: SW NE SE 23 T47N R3E, O'Fallon, Missouri 7.5' quadrangle
Landscape Position: gently sloping upland spur truncated by Mississippi Valley; severely disturbed surface
Altitude: approx. 485 ft (147.8 m)
SCS Mapped Soil Series: Harvester/Menfro silt loam

Depth (m)	Horizon	Description
Peoria Loess		
0.00 - 4.06	C1	silt; dark yellowish brown (10YR 4/4) silt; massive; friable; strongly effervescent; clear boundary.
4.06 - 4.40	C2	silt; grayish brown (2.5Y 5/2) silt; massive; friable; leached; clear boundary.
4.40 - 4.85	C3	silt; grayish brown (2.5Y 5/2) silt; strong platy; friable; leached, with few fine secondary nodules; gradual boundary.
4.85 - 5.20	C4	silt; grayish brown (2.5Y 5/2) down to dark brown (7.5YR 4/4); weak platy to massive; friable; leached; clear boundary.
Roxana Silt		
5.20 - 5.46	2C5	silt; dark brown (7.5YR 4/4) silt; massive; friable; leached; clear boundary.
5.46 - 6.30	2C-2Bwb	silt; dark brown (7.5YR 4.5/4) silt down to silt loam, with rare chert pebble, with common oxide dots; weak coarse and medium subangular blocky, with common (10YR 6/2) silans on ped faces; friable; leached; weakly bioturbated; clear to abrupt boundary.
unnamed colluvium		
Sangamon Geosol		
6.30 - 6.48	3Btb1	silt diamicton; dark brown (7.5YR 4/4) heavy silt loam to loam diamicton, with much fine and medium sand, few granules, few cobbles, and common fine and very fine chert, quartz and igneous pebbles, with few fine brown (10YR 5/3) mottles; moderate coarse breaking to medium subangular blocky, with common thin brown to dark brown (10YR 4/3) argillans on ped faces and lining pores; firm; leached; clear boundary.

Loveland Silt	
6.48 - 6.97 4Btb2	silt; dark brown to reddish brown (7.5 - 5YR 4/4) silt loam diamicton down to heavy silt loam, with few pebbles, with few fine and medium dark yellowish brown (10YR 3.5/6) mottles and black oxide stains and dots; moderate coarse breaking to medium subangular blocky, with many thin brown to dark brown (10YR 4/3) argillans on ped faces and lining pores; firm; leached; gradual boundary.
6.97 - 7.78 4Btb3	silt; dark yellowish brown (10YR 5/4) heavy silt loam with much sand and few granules, with few fine brown (10YR 5/3) mottles; moderate coarse breaking to medium subangular blocky, with many thin to moderately thick dark yellowish brown (10YR 3/4) argillans on ped faces and lining pores; firm; leached; common black oxide stains; gradual boundary.
7.78 - 8.31 4Btb4	silt; coarsely mottled grayish brown (10YR 5/2) and brown (10YR 5/3) heavy silt loam, with common dark yellowish brown (10YR 3/6) mottles; moderate coarse breaking to medium subangular tending to angular blocky, few to common dark brown (10YR 3/3) to dark grayish brown (10YR 4/2) argillans on ped faces and lining pores; firm; leached; abrupt boundary.
unnamed silt and clay	
unnamed paleosol	
8.31 - 8.61 5Btb1	clay; grayish brown (10YR 5/2) silty clay, with few fine dark yellowish brown (10YR 4/6) mottles; moderate to strong medium breaking to fine angular blocky; firm; leached; common black oxide stains; clear boundary.
8.61 - 9.25 5Btb2	silt; grayish brown (2.5Y 5/2) silty clay loam, with common fine light olive brown (2.5Y 5/4) mottles and few fine dark yellowish brown (10YR 3/6, 4/6) mottles; moderate coarse breaking to medium angular blocky tending to platy, with many thin dark yellowish brown (10YR 4/4) and very dark grayish brown (10YR 3/2) argillans on ped faces and lining pores; clear boundary.
unnamed silt	
unnamed paleosol	
9.25 - 9.71 6Btb1	silt; grayish brown (10YR 5/2) down to yellowish brown (10YR 5/4) heavy silt loam, with many fine and medium dark yellowish brown (10YR 3/6, 4/6) mottles and any light olive brown (2.5Y 5/4) mottles; moderate medium subangular blocky, with common argillans on ped faces; firm; leached; many black oxide stains; clear boundary.
9.71 - 10.11 6Btb2	silt; yellowish brown (10YR 5/4) - light olive brown (2.5Y 5/5) heavy silt loam, with increasing pebble content to a diamicton to the south, with many medium and coarse dark yellowish brown (10YR 4/6) mottles; moderate coarse breaking to medium subangular blocky, with many thin to moderately thick very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) argillans on ped faces and lining pores; firm to friable; common black oxide stains.

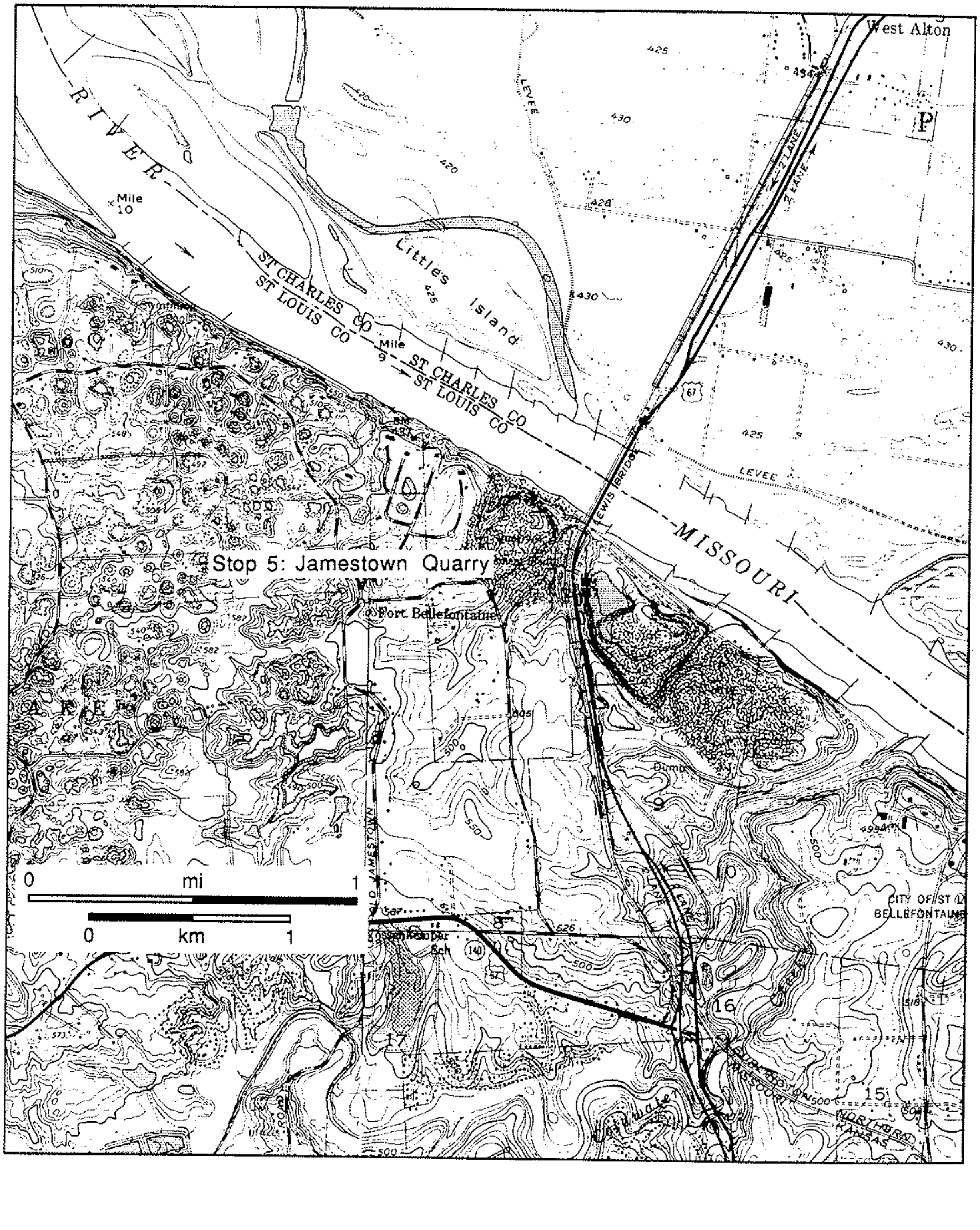

Figure 11. Location of Jamestown Quarry along the Mississippi Valley. 5 T47N R7E, Florissant and Columbia Bottom, Missouri, 7.5' quadrangles.

STOP 5 JAMESTOWN QUARRY

At this stop we will examine in extensive exposure three clay beds in the Peoria Loess and lacustrine sinkhole fill, and their relationships to the modern and pre-late Wisconsinan landscapes. Radiocarbon ages from the sinkhole fill that are available at this time bracket the age of the middle clay bed and date the oldest clay bed. Our paleoenvironment discussion will continue based on preliminary analyses of fossils from the sinkhole fill (also see contributed papers, this volume, by Curry and Smith, and Miller).

Jamestown Quarry is located along the Missouri River where it flows in the Mississippi Valley just upstream of where it enters the Mississippi River (Figure 11). Here the dissected uplands are at an altitude of about 510 to 520 ft (155.5 to 158.5 m) and are pocked by karst topography immediately to the west. The quarry is extracting the Salem Limestone and surrounding karst topography is reflecting solution of the St. Louis Limestone.

Exposed sections (Figure 12) reveal oxidized and deoxidized Peoria Loess, approaching 35 ft (10.7 m) thick in places, overlying the Roxana Silt with a very weakly expressed Farmdale soil developed in its top. In the south end of the pit, Roxana Silt is at least 17 ft (5.2 m) thick. The basal Roxana Silt contains granule and pebble clasts, is pedogenically altered by upper horizons of the Sangamon Geosol with increasingly stronger expression with depth, and shares a gradual contact with the underlying strong red loam to pebbly loam. The loam is altered by the Sangamon Geosol which is up to 8 ft (2.4 m) thick in places. Sand and granule content increase with depth. Along the west wall of the pit, Roxana Silt overlies the Sangamon Geosol where it is developed in a poorly sorted fluvial pebble gravel that grades rapidly downward to a loam and clay loam. The gravel bed pinches out to the south away from the Mississippi Valley. The loam unit overlies limestone bedrock with solution cavities filled with strongly oxidized clay loam to clay diamicton.

Three continuous clay beds charged with secondary carbonate are present about midway in the Peoria Loess, and the intervening silt is thinly bedded. Locally there is evidence of incipient pedogenic alteration on the order of a 'Jules class' soil. The maximum altitude of the youngest clay bed is estimated to be about 490 ft (149.4 m). Clay beds run subparallel to the Peoria - Roxana contact and decrease in altitude in approaching the head of a former drainageway (center back of Figure 12). Over the local rise at middle left of Figure 12 the thickness of clay beds between loess decreases slightly and there is some indication of clay bed deformation towards the drainageway. Clay beds also run subparallel to the modern ground surface except in the area to the far right of Figure 12. Here the clay beds are lost in the modern solum and apparently are truncated by the modern hillslope towards the Mississippi Valley.

Quarry operations bisected a sinkhole, the fill and steep sides of which were well exposed during 1990 (Figure 13). According to long-time quarry workers, the sinkhole had no surface expression, but was underneath the shoulder slope of the tributary valley side whose head is seen in Figure 12. Stratigraphy of the sinkhole fill is illustrated in Figure 14. At the axis of the fill exposed in section, about 5 ft (1.5 m) of the modern soil profile was removed and an abrupt irregular weathering front cross-cuts strata. Laminated, organic and fossiliferous calcareous lacustrine silt forms the uppermost increment of sinkhole fill. In some strata the laminae appear rhythmic with rhythmites consisting of either couplets of Chara-rich / non-Chara-rich laminae or couplets of silt with a relatively thin upper increment that has a slightly darker color and possibly slightly more clay than the thicker lower increment. Two clay beds are interbedded in the silt and a third clay bed, the thickest with wood in the basal few centimeters, is at the base of the strongly laminated silt. All three clay beds are interpreted as flood clay beds emplaced by Mississippi River flooding and correlative with the clay beds in the Peoria Loess exposed in the surrounding walls. All three clay beds have very abrupt upper and lower contacts except the top of the clay bed #3 which rapidly grades to silt over 1 to 2 cm.

Unoxidized, leached to very slightly calcareous, laminated silt underlies the clay bed #3. Organic material is preserved in the top meter or so of this unit, but is progressively more degraded with depth. There is a very weak soil structure overprinting the laminae which are more poorly expressed than the overlying lacustrine laminae. This unit, assigned to the Robein Silt, consists of loess and colluvial

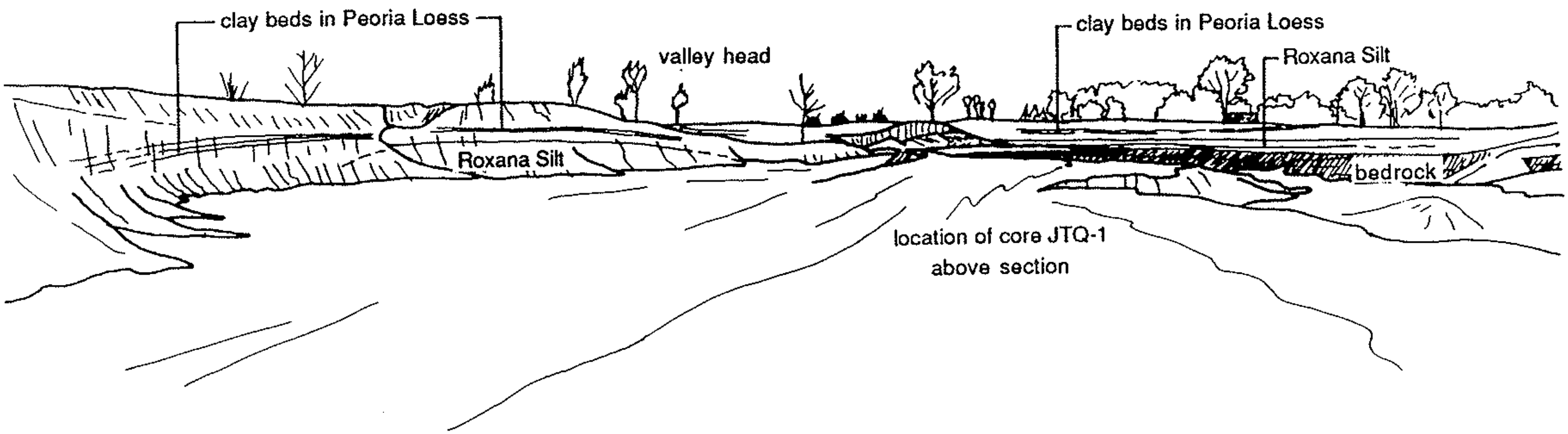

Figure 12. Sketch of exposures with clay beds in the Peoria Loess and location of core JTQ-1 above filled sinkhole at Jamestown Quarry.

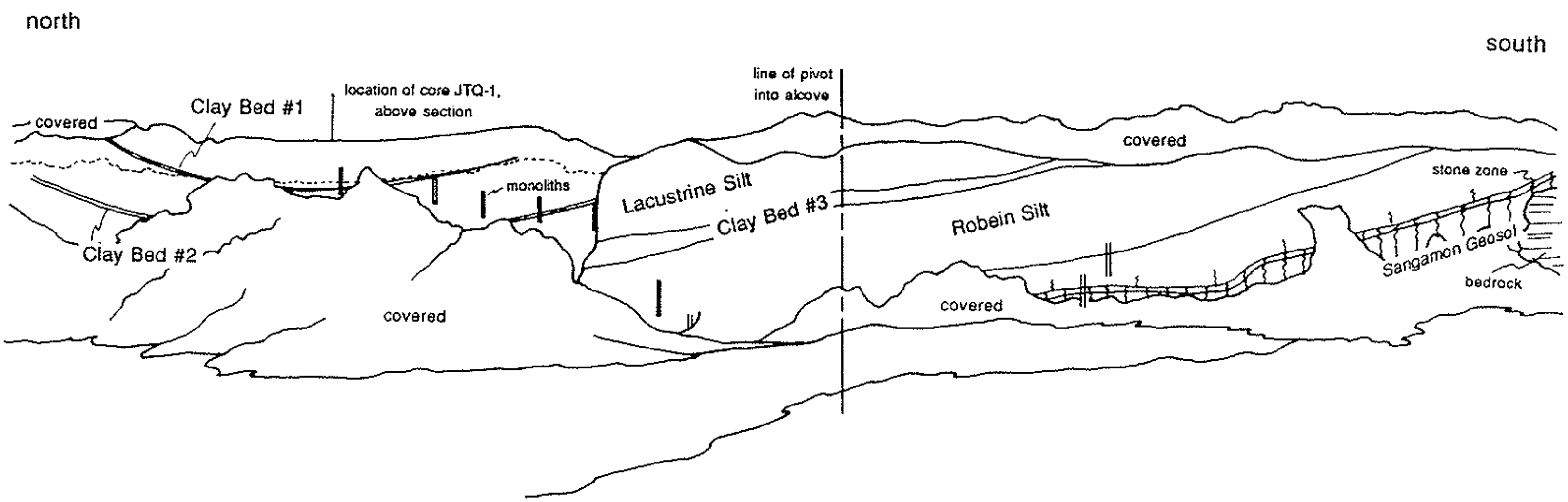

Figure 13. Sketch of section illustrating stratigraphy of sinkhole fill at Jamestown Quarry.

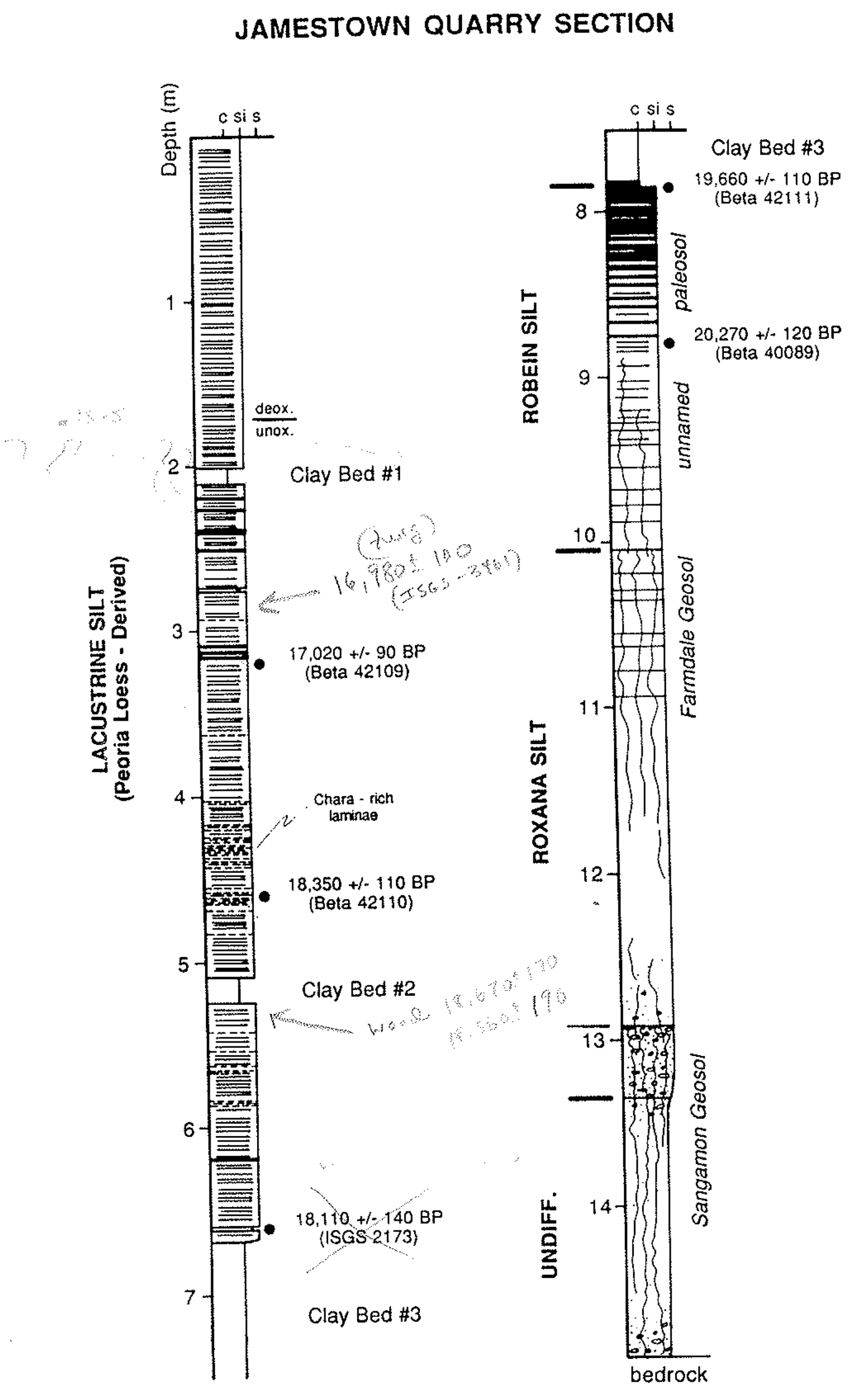

Figure 14. Sediment log, stratigraphy and radiocarbon ages of sinkhole fill at Jamestown Quarry. Section below the 10 m depth is taken from core JTQ-1.

accumulations of locally redeposited loess. Deposition of the oldest clay bed effectively sealed drainage through the sink and created a permanent lake in the basin. Moist conditions were also favored by a rising water table as the Mississippi River was actively aggrading its valley. The cumulic incipient poorly drained paleosol profile developed in the Robein Silt essentially was entombed with deposition of the oldest clay bed.

Robein Silt abruptly but conformably overlies the Roxana Silt and Farmdale Geosol which exhibits a similar very weak degree of soil structure overprinting poorly expressed thin beds. Towards the sink hole margin, the chroma of the Roxana Silt rapidly increases. At the base of the Roxana Silt is a silt diamicton (stone zone) which overlies the Sangamon Geosol. In core JTQ-1 taken above the axis of the sink, the Sangamon Geosol exhibits unoxidized colors and a cumulic profile whereas towards the margins, progressively higher chroma prevails.

There are five recently obtained radiocarbon ages from the section (Figure 14); four from Beta Analytic and one from the Illinois State Geological Survey. Radiocarbon ages were determined on *Picea* wood and other organic debris. Two additional samples are in the process of being assayed. The ISGS date is not in stratigraphic order with the other date series. Although it will not be discussed further at this time, it would be premature to reject this date during these early stages of analysis without additional cross-checks.

A radiocarbon age from the top of the Robein Silt immediately below the oldest clay bed indicates Mississippi River flooding and sealing of the sinkhole occurred about 19,660 ± 110 B.P. (Beta 42111) (Figure 14). The oldest radiocarbon age is 20,270 ± 120 B.P. and is about 1 m below this contact. The second flood episode occurred slightly before 18,350 ± 110 B.P. (Beta 42110) and the third not long after 17,020 ± 90 B.P. (Beta 42109). Extrapolation of sedimentation rates from the two younger ages yields an age of about 18,800 B.P. for the middle clay bed and an age of about 16,000 B.P. for the upper clay bed.

Thin and laterally continuous beds of clay in the Peoria Loess have been recorded at a number of other locations along the central Mississippi Valley and lower Illinois Valley (Table 8). Peoria Loess with clay beds occurs above older upland sediment assemblages beneath stepped surfaces and spurs, and less frequently above slackwater-flood sediments associated with the St. Charles Terrace Family.

Initially only one clay bed was recognized. It was identified as occurring at the base of Zone p-4 of the Peoria Loess, estimated to date to about 20,100 B.P. (McKay, 1977). Leighton (1965) suggested it was emplaced by the Gardena flood, marking the Gardena Substage. McKay (1977) interpreted the clay bed to have resulted from catastrophic flooding down the Mississippi Valley upon release of waters impounded in Lake Milan that marked the diversion of the Ancient Mississippi River to its current valley. Lake Milan, identified by laminated and bedded silt and sand, was created when advancing ice of the Lake Michigan Lobe blocked the Ancient Mississippi River, diverting waters to the Green River Lowland in northwestern Illinois (Shaffer, 1954). More recently, three clay beds commonly have been recognized, each usually separated by between 0.8 and 1.0 m of bedded to massive Peoria Loess (Hajic, 1990). They are found along the Mississippi Valley and lower Illinois Valley. As many as 10 clay beds have been identified over a lower St. Charles Terrace remnant in a tributary to the lower Illinois Valley.

The age of these clay beds temporally corresponds with a Mississippi flood plain aggrading to St. Charles Terrace levels and aggrading at markedly higher levels than today with correspondingly lower upland surfaces (ie. lacking the youngest increments of Peoria Loess). These altitudinal relationships suggest flooding that emplaced the clay beds, while certainly of appreciable magnitude relative to other floods at the time, may not necessarily have been catastrophic. Furthermore, multiplicity of clay beds spanning several thousand years detracts from the catastrophic drainage of Lake Milan hypothesis. By 16,000 B.P., the estimated age of the youngest clay bed at Jamestown Quarry, glacial ice had retreated a considerable distance from the Green River Lowlands thus excluding multiple episodes of lake filling and draining. Hajic (1990) had suggested that the clay beds in the lower Illinois Valley may have been related to the Kankakee Torrent, but the new radiocarbon ages suggest a lack of temporal correspondence.

The basis for Lake Milan has been the presence of extensive deposits of laminated and thin bedded silt and sand in the lowlands of northwestern Illinois. These are interpreted to have been deposited in a lake, filling the lowlands at the time of maximum glacial advance, around 20,000 B.P. (McKay, 1977; Shaffer, 1954) It is the opinion of this author that until definite evidence of deltas or shoreline features of Lake Milan can be identified, the existence of the lake should not be weighed too heavily. In other words, it is possible the silt and sand are fluvial in origin. There is some evidence to suggest that the Ancient Mississippi Valley, when it was flowing through the middle and lower Illinois Valleys, had aggraded to at or near its maximum level by about 20,000 B.P. (Hajic, 1990; Kerosotes, 1989; Miller, 1973); the Green River Lowlands may have already been filled with silt and sand at the time Lake Milan was postulated to have formed and begun infilling. This type of deposit may not have been unusual for a glacial-fed river known to have a large silt content.

Table 8. Altitude and location of clay beds in Peoria Loess.

Section or Core	Number of Clay Beds	Approximate Altitude m (ft)	Reference	Map Index
Jamestown Quarry	3	≈ 149.4 (490)	this paper	42
Williams Hollow	3	<151.8 (498), >149.7 (491)	Hajic, 1990	39
Greenbay Hollow	3	<152.7 (501), >151.2 (496)	Hajic, 1990	20
MTZ-3	10	<139.6 (458), >137.8 (452)	Hajic, 1990	25
Barton Landfill, mouth of Cahokia Creek	3	149.4 - 146.3 (490 - 480)	L. R. Follmer, personal communication	7
Canteen Creek	1	150.0 (492)	McKay, 1977; 1979 Follmer et al., 1979	8
Pleasant Grove School	1	149.4 (490)	Frye and Willman, 1970 McKay, 1977	30
G52	1	149.4 (490)	McKay, 1977	19
East Alton Vicinity (2 sections)	1	150.1 (495)	Leighton and Willman (1949)	14

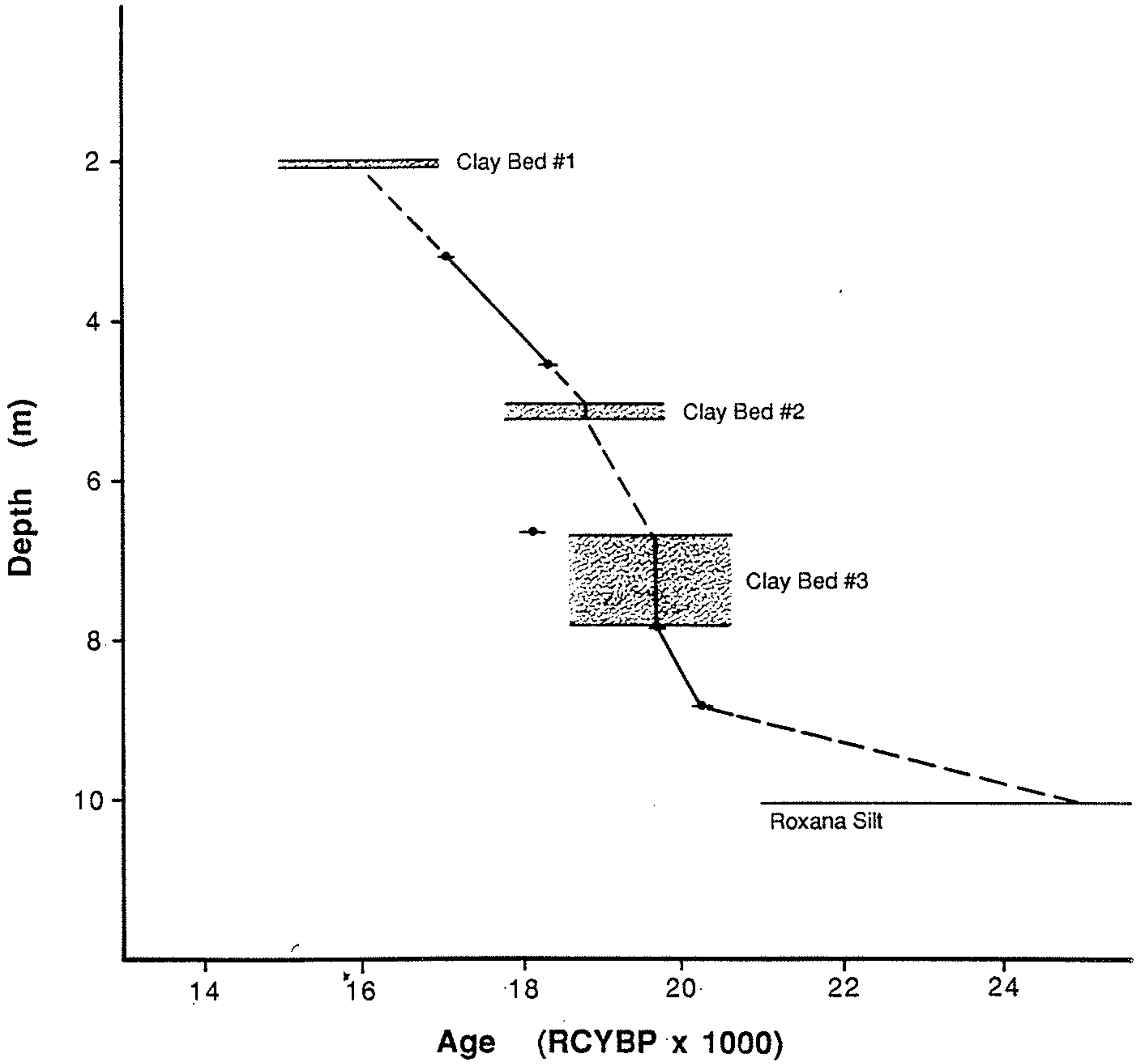

Figure 15. Preliminary plot of sedimentation rates for sinkhole infilling and age estimates on upper clay beds.

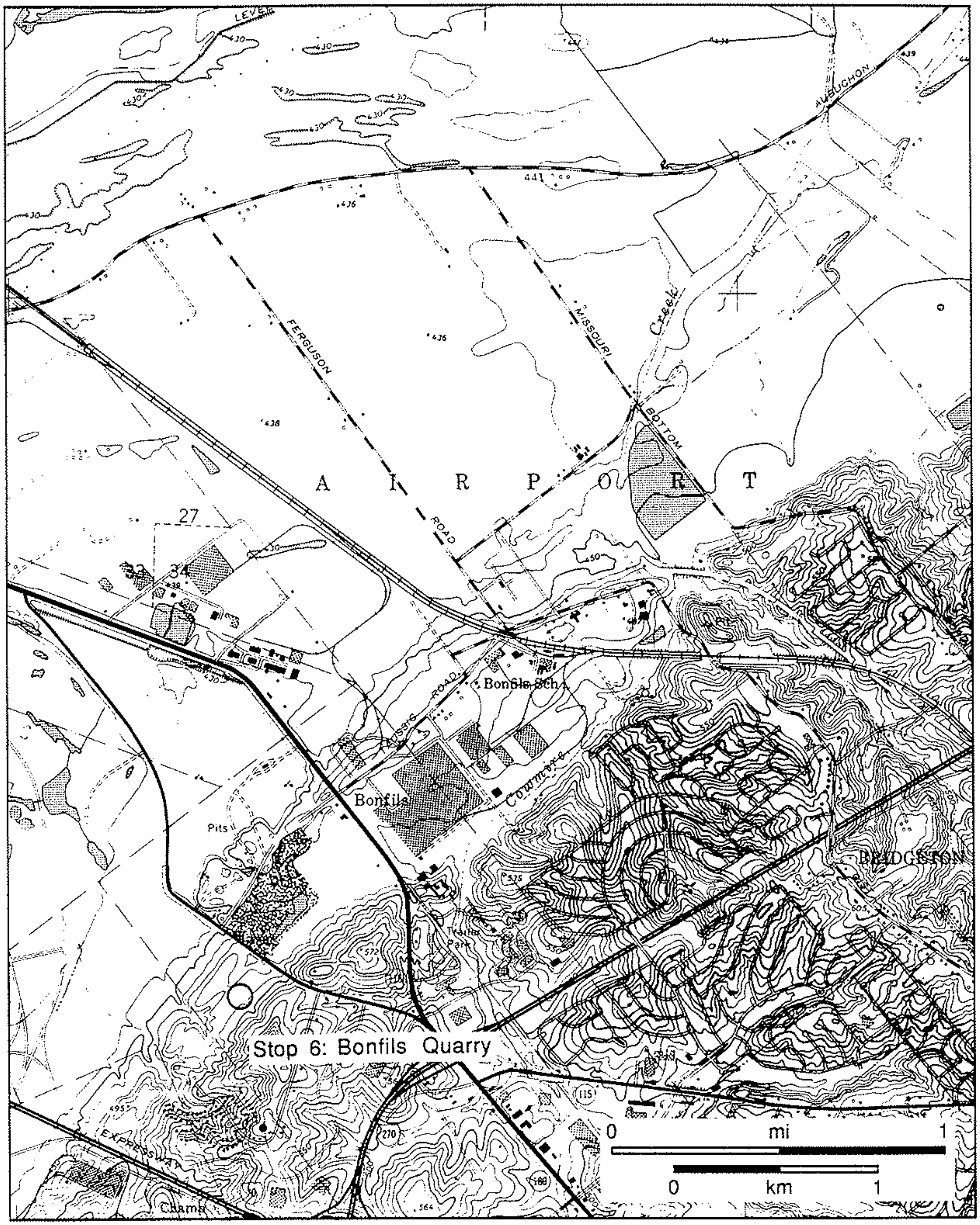

Figure 16. Location of Bonfils Quarry in the Missouri Valley. SW NW 3 T46N R5E, St. Charles, Missouri, 7.5' quadrangle.

STOP 6. BONFILS QUARRY

At this stop we will examine sediments below and related to the Bonfils Terrace, a St. Charles Terrace Family equivalent in the lower Missouri Valley across the river from St. Charles, Missouri. Radiocarbon ages and preliminary results of paleoenvironmental analyses (Miller, this volume) will be discussed. Ongoing removal of 'overburden' has exposed numerous sections, both in terrace deposits and the adjacent uplands. In the uplands, at least two, and possibly three loesses are present below the Peoria Loess.

Bonfils Quarry, operated by West Lake Quarry and Material Co., is situated on the east side of the Missouri Valley 4 mi (6.5 km) from the Mississippi Valley. The terrace remnant extends for 2.8 mi (4.5 km), is about 0.5 mi (0.8 km) wide at its widest, and has land surfaces ranging between 470 and 490 ft (143.3 and 149.4 m), with most of the area between 470 and 480 ft (143.3 and 146.3 m). This is about 40 ft (12.2 m) above the nearby flood plain that lies at about 435 ft (132.6 m). The Bonfils Terrace is flanked on the river side by a discontinuous, lower terrace, correlated to the Kingston Terrace at an altitude of about 440 to 450 ft (134.1 to 137.2 m).

First identified by Fenneman (1909; 1911) as a bedrock strath of Wisconsinan age overlain by loess, the Bonfils Terrace was considered an 'Early Mankato' terrace by Leighton and Willman (1949) and a 'Mankato' terrace by Flint and Deevey (1951). Goodfield (1965) examined exposures in a former quarry opened to the northeast along Taussig Road and interpreted the terrace as Wisconsinan on the basis of both stratigraphic criteria (Peoria Loess over alluvium) and radiocarbon ages from terrace - related alluvium reported in Rubin and Alexander (1958). The radiocarbon ages are 17,150 ± 600 B.P. (W-469) and 17,800 ± 600 B.P. (W-470). A third and often cited radiocarbon age from a log that came from the Bonfils Quarry area dated 12,148 ± 700 B.P. The location was revisited to test the validity of these ages.

Stratigraphy and section descriptions of Bonfils (St. Charles) Terrace - related deposits and deposits related to the lower terrace follow. Approximately 15.1 ft (4.6 m) of Peoria Loess abruptly but conformably overlies an unnamed alluvial unit below the terrace (Figure 17). The alluvial unit consists of massive to crudely bedded deoxidized silt that grades downward to laminated unoxidized and fossiliferous calcareous silt and then sand. The sand ranges from planar bedded to ripple cross-laminated with paleocurrent directions generally to the east and north. Small scours also are common. Lack of reddish brown clay, known to occur in contemporaneous backflood deposits, is absent from this unit. Discharge of the Missouri River was sufficient to preclude backflooding of its valley by the Mississippi River. The sand rests on bedrock and is reported by quarry operators to commonly have logs. However, some depressions in the limestone are filled with weathered clay suggesting the bedrock strath may be considerably older in age than Wisconsinan.

Wood collected from just above bedrock dated 17,540 ± 210 B.P. (ISGS-1811) and, from just below the weathering front above which organic matter is oxidized and altered, 17,050 ± 280 B.P. (ISGS-1790). These radiocarbon ages agree with the earlier reported ages. They do not correspond with the 12,148 ± 700 age, even though the dated material was reported to come from beneath a land surface some 50 ft (15.2 m) above the flood plain (Flint and Deevey, 1951). This date can be interpreted in several ways. It may simply be a bad date. It may actually have come from beneath the lower terrace at Bonfils (Goodfield, 1965) that is correlative with the Kingston Terrace. Or it may have come from a younger deposit filling a drainageway crossing the terrace. With such a degree of uncertainty, restraint is suggested in the use of this radiocarbon age.

Section:	Bonfils Quarry Section B-D composite
Location:	SW NW 3 46N 5E (St. Charles, Missouri, 7.5' quadrangle)
Landscape Position:	borrow cut into Bonfils Terrace (St. Charles Terrace Family, Cuivre level), within Missouri Valley
Altitude:	485 ft (147.8 m)
SCS Mapped Soil Series:	Ashton silt loam

Depth (m)	Horizon	Description
Peoria Loess		
0.00 - 4.60	C1	dark yellowish brown (10YR 4/4) to grayish brown (2.5Y 5/2) silt; massive; strongly effervescent; abrupt boundary.
unnamed alluvium		
St. Charles Terrace Family, Cuivre level		
4.60 - 8.30	2C2	olive brown (2.5Y 4/4) silt, few dark yellowish brown (10YR 3/6, 4/6) mottles; massive to thin bedded, poorly expressed; leached; few fine oxide concretions, possibly replaced organic matter; very gradual boundary.
8.30 - 9.60	3C3	grayish brown (2.5Y 5/2) silt; laminated, strongly to moderately expressed; leached; common fine oxide concretions, possibly replaced organic matter; abrupt irregular boundary, probably hydromorphic/weathering boundary.
9.60 - 11.45	4Cg1	very dark gray (5Y 3/1) to dark gray (5Y 4/1) silt to sandy loam; horizontal laminated, strongly expressed, with few discontinuous thick fine sand laminae, ripple-drift cross-laminated sets, and convoluted laminae near base; strongly effervescent down to leached; abundant uncarbonized Picea twigs and fine organic debris, including Picea cones, needles, and beetle parts; few snail shells; abrupt conformable boundary marked by silty clay laminae at top of next unit.
11.45 - 12.90	5Cg2	very dark gray (5Y 3/1) silt, loamy very fine sand, and fine sand, few laminae of black (5Y 2/1) silt; rhythmic graded beds of horizontal to ripple-drift cross-laminated sand to silt, or simply horizontal laminated sand to silt; towards base few beds of planar cross-stratified beds of sand; few small scours 5 to 20 cm deep with rip-up clasts in scour fill; occasional small ball and pillow structures and convoluted laminae; strongly effervescent; few twigs of *Picea* wood; paleocurrent: N71°E; abrupt unconformable boundary.
unnamed alluvium		
unnamed paleosol		
12.90 - 13.10	6Btb	variegated clay and silty clay; leached; discontinuously preserved in some shallow depressions on bedrock surface; abrupt unconformable boundary.
St. Louis Limestone		
unnamed bedrock bench		
13.10^{+}	7R	limestone

note: Bonfils Terrace of Fenneman (1909; 1911).

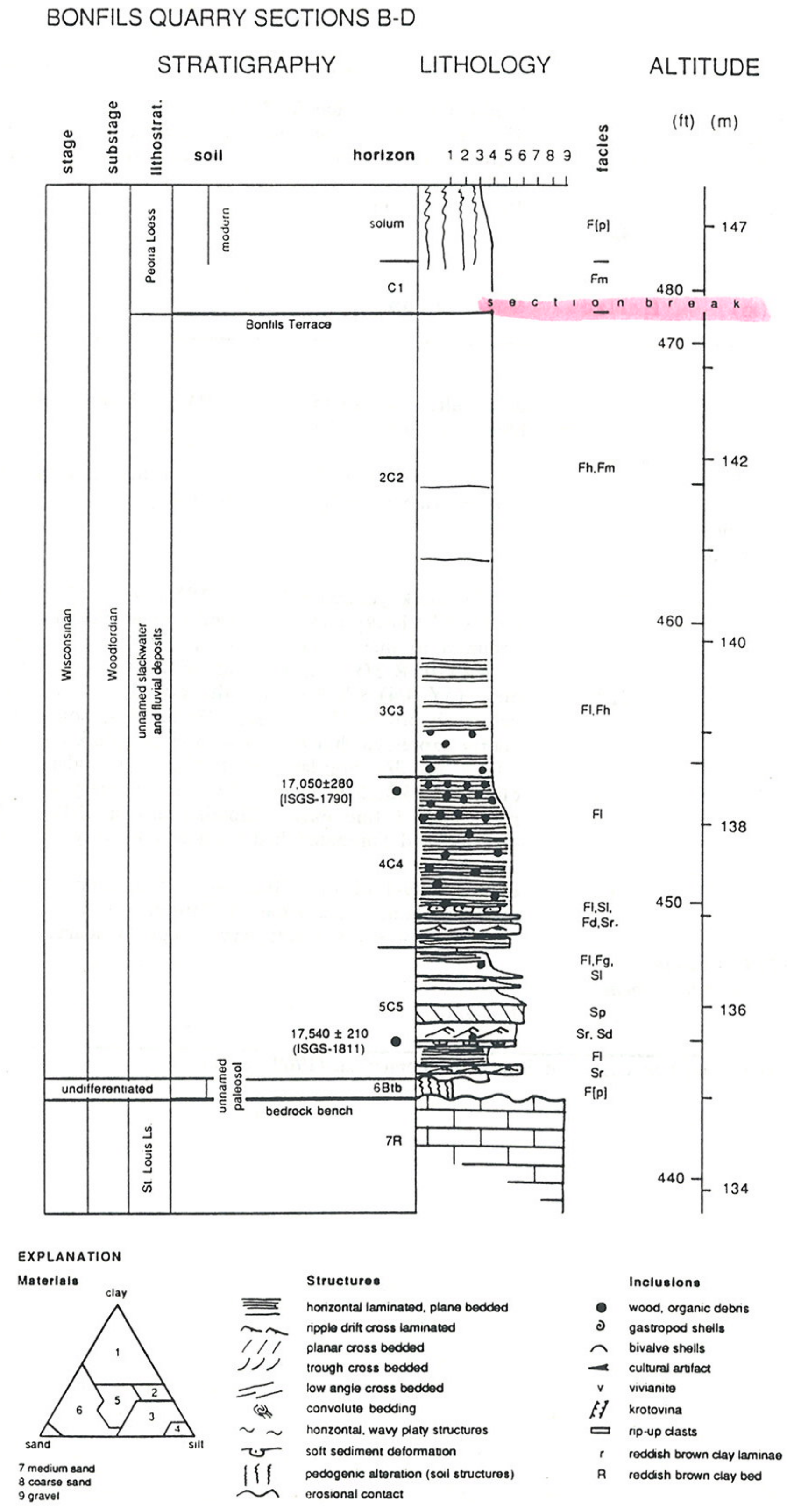

Figure 17. Stratigraphy and sediment log of the Bonfils (St. Charles) Terrace sediment assemblage, Bonfils Quarry, lower Missouri River Valley.

Section:	Bonfils Quarry Section A (BQ-A)
Location:	SW NW 3 46N 5E (St. Charles, Missouri, 7.5' quadrangle)
Landscape Position:	borrow cut into unnamed low terrace 1 (Kingston Terrace), within Missouri Valley
Altitude:	455 ft (138.7 m)
SCS Mapped Soil Series:	Freeburg silt loam

Depth (m)	Horizon	Description
Peyton Colluvium		
0.00 - 1.00	C	dark yellowish brown (10YR 4/4) silt loam; massive to weak subangular blocky; friable; leached; clear boundary.
Peoria Loess (?) or unnamed alluvium		
1.00 - 1.50	2Ab	very dark brown (10YR 2/2) silt loam; moderate fine angular and subangular blocky; friable; leached; clear boundary.
unnamed alluvium		
unnamed paleosol		
Kingston Terrace		
1.50 - 2.00	3Bt	mottled dark yellowish brown (10YR 4/4, 4/6) and brown to dark brown (10YR 4/3) heavy clay loam; moderate medium to coarse subangular blocky, common to many thin to moderately thick dark and very dark grayish brown (10YR 3/3, 3/2) argillans; leached; clear boundary.
2.00 - 2.85	3BCt	olive (5Y 4/4) silt loam to silty clay loam, many medium and fine dark yellowish brown (10YR 3/6, 4/6) mottles; coarse subangular blocky over poorly expressed thin beds, common thin dark and very dark grayish brown (10YR 3/3, 3/2) argillans; leached; clear boundary.
2.85 - 3.85	4C1	olive (5Y 4/3, 5/3) coarse silt, silt and very fine sand, silty clay, many medium and fine dark yellowish brown (10YR 3/6, 4/6) mottles; thin massive and laminated beds; leached to very slightly effervescent; abrupt boundary.
3.85 - 4.05	5C2	cobble gravel of local limestone slabs with olive (5Y 4/3) sandy loam matrix, common coarse dark yellowish brown (10YR 4/6) mottles; matrix is very slightly effervescent; very abrupt boundary.
St. Louis Limestone		
unnamed bedrock bench		
4.05^{+}	6R	limestone

note: Unnamed low terrace at Bonfils of Fenneman (1909; 1911).

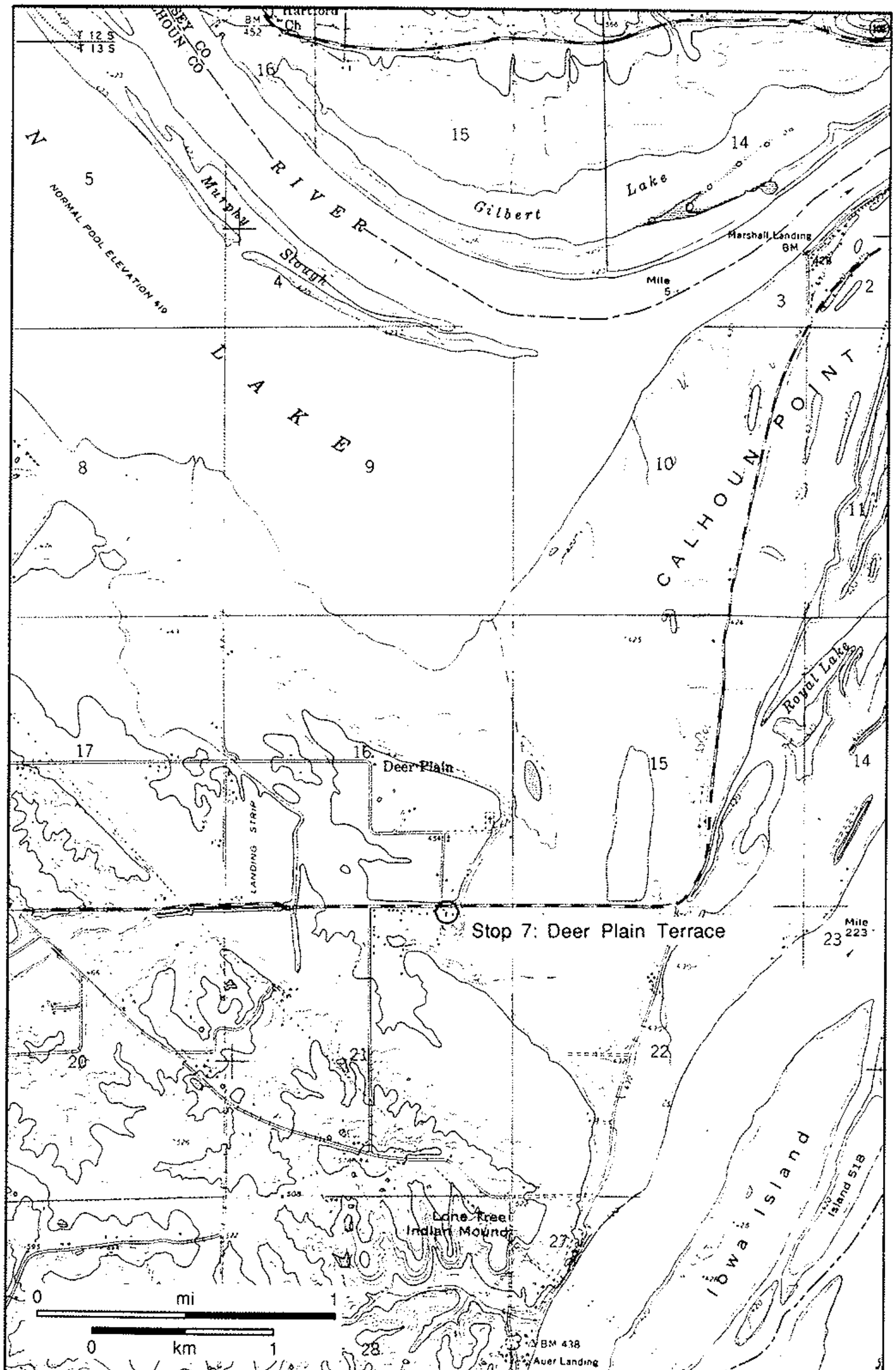

Figure 18. Location of the assembly point for Day 2 on the Deer Plain (Savanna) Terrace. NW NE NE 21 T13S R1W, Brussels, Illinois 7.5' quadrangle.

DAY 2

STOP 7. DEER PLAIN (SAVANNA) TERRACE

We rendezvous for Day 2 at the community of Deer Plain, Illinois, overlooking the Deer Plain (Savanna) Terrace escarpment into the Illinois and Mississippi Valleys (Figure 18). Our purpose at this stop is to assemble the group on this side of the Mississippi River and briefly discuss the terrace sediment assemblage, origin and age. The Deer Plain Terrace was defined and described by Rubey (1952) in both lower Illinois and nearby Mississippi Valleys on either side of Calhoun County, Illinois. The Deer Plain Terrace was recognized as correlative with the Savanna Terrace by Flock (1983).

The terrace lies at an altitude of 455 ft (138.7 m), about 30 ft (9.1 m) above the Illinois Valley flood plain. Those arriving via the Brussels Ferry crossed a series of Mississippi River bars swept across the mouth of the Illinois Valley; they eclipse 430 ft (131.1 m) in places. On both east and west sides of the Illinois Valley the terrace abuts against bedrock valley walls or older upland deposits. The terrace exhibits reverse slopes in Mississippi Valley tributaries relative to tributary gradients. It lacks a significant loess mantle which helps distinguish it from St. Charles terraces, although on remnants in the Mississippi Valley low dunes are common.

Surface morphology in the lower Illinois Valley closely reflects formational processes. A sandy beach ridge that crosses the terrace width forms a sharp morphologic and pedologic boundary (Figure 19). North of the ridge the terrace is flat and featureless, except for several intermittent ponds and broad swales on larger remnants. Here it is underlain by a lacustrine laminated clay over a lacustrine laminated silt (Figures 20 and 21). The silt and lowest clay increments have Lake Superior Basin source reddish brown clay laminae that are found tens of kilometers up the Illinois Valley. South of the boundary low eolian dunes mantle the surface and overlie surficial beds of silt with few clay laminae, including reddish brown clay, that in turn overlie sands that comprise the sediment dam (Figures 20 and 22). Mapped terrace soil series (Lilly, 1989) parallel the morphologic dichotomy (Figure 19). North of the beach ridge, Darwin silty clay, Booker clay, and Okaw silt loam are mapped. Coarser-textured Plainfield sand and Colp silt loam are mapped to the south. The latter incorporates reddish brown clay laminae in its solum.

Rubey (1952) concluded the Deer Plain (Savanna) Terrace resulted from "abnormally high flood stages of an ancient Mississippi River" that built a "deltalike" deposit in the mouth of the Illinois Valley "with virtual ponding and backwater for many miles up the lower part of the Illinois River". This, he argued, was compatible with the notable reverse gradient of the terrace in the Illinois Valley and his observations of deposits rapidly and progressively becoming finer upvalley. Alternatively, Butzer (1977) judged the reverse gradient problematical and hypothesized the marked reverse slope of the terrace may have developed erosionally "during successively lower stages of river level". The silt and clay were interpreted as alluvial overbank deposits. Flock (1983) accounted for the lengthy extent of reddish brown clay in near surface deposits down the Mississippi Valley by suggesting it resulted from a large magnitude flood from proglacial lakes to the north. Lithofacies, facies relationships, and sediment geometry verify Rubeys hypothesized origin for terrace-related deposits, although whether abnormally large (catastrophic) magnitude floods were necessary is questionable (Hajic, 1985; 1986; 1990).

Hajic (1990) also supplied radiocarbon ages for terrace-related sediment and incision that left the Deer Plain (Savanna) level as a terrace (Table 5). Radiocarbon ages and upvalley relationships of reddish brown clay indicate Mississippi Valley aggradation and construction of a sediment dam in the mouth of the Illinois and other valleys was nearly complete by about 13,300 - 13,400 B.P. Flock (1983) erroneously applied several of the Illinois Valley radiocarbon ages (ISGS-894, -875, -900) from basal lacustrine silt in the lower Illinois Valley to suggest aggradation to the Savanna Terrace level in the Mississippi Valley and its tributaries began, rather than ended, around 13,100 B.P. When taken in the proper context, however, the ages indicate most Mississippi Valley aggradation related to the Savanna Terrace was completed before about 13,400 B.P. The age of the base of the Savanna Terrace sediment assemblage near the mouth of the Illinois Valley remains uncertain, but probably post-dates incision during the Kankakee Torrent, sometime between 16,000 and 15,500 B.P. (Hajic, 1990), and definitely post-dates 17,000 B.P., the youngest radiocarbon age on the St. Charles Terrace Family.

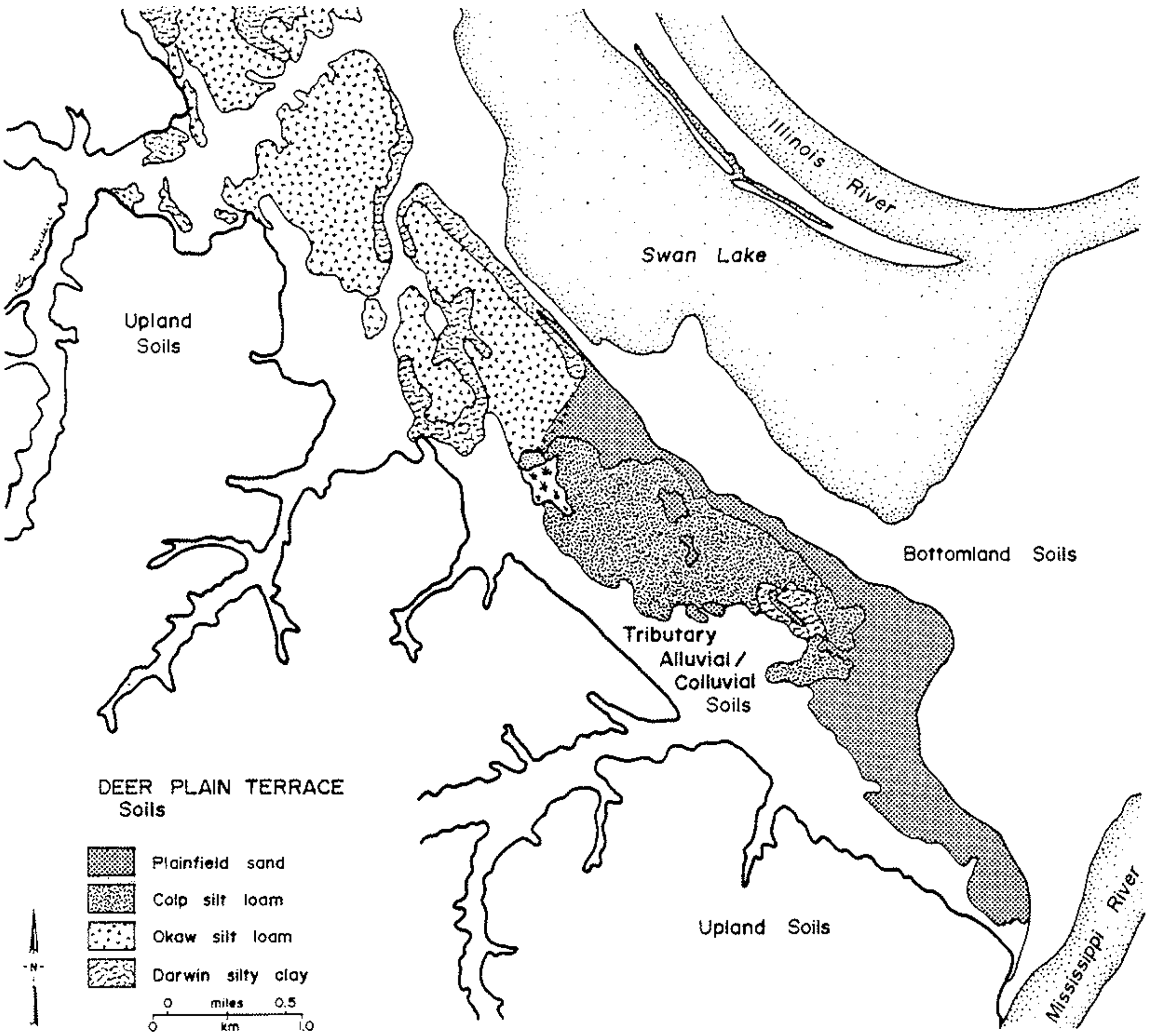

Figure 19. Soil-geomorphic discontinuity on the Deer Plain (Savanna) Terrace in the lower Illinois Valley. Soil series mapped by Lilly (1989).

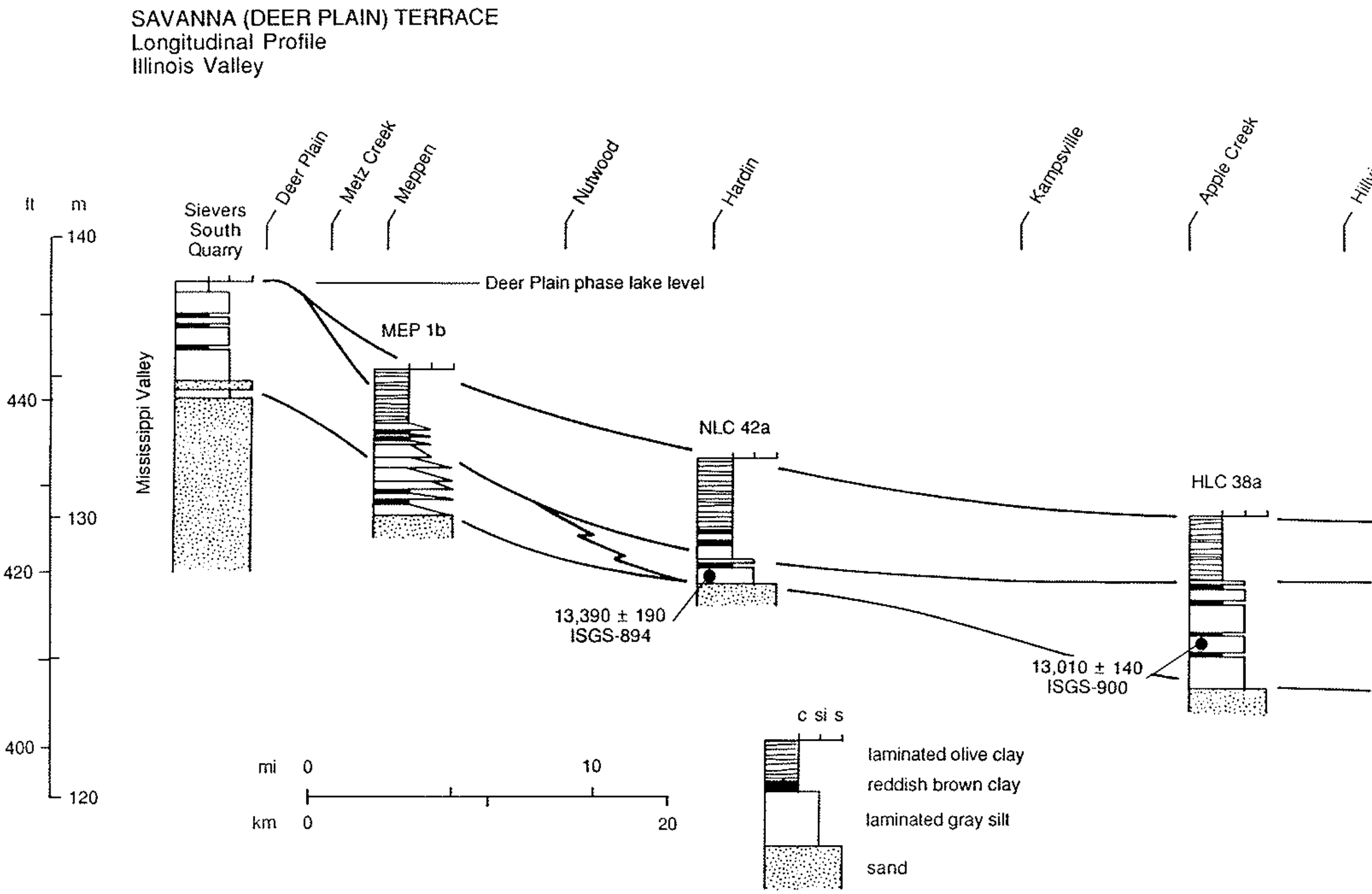

Figure 20. Longitudinal profile of the Deer Plain Terrace sediment assemblage illustrating lithofacies, lithofacies relationships, and reddish brown clay.

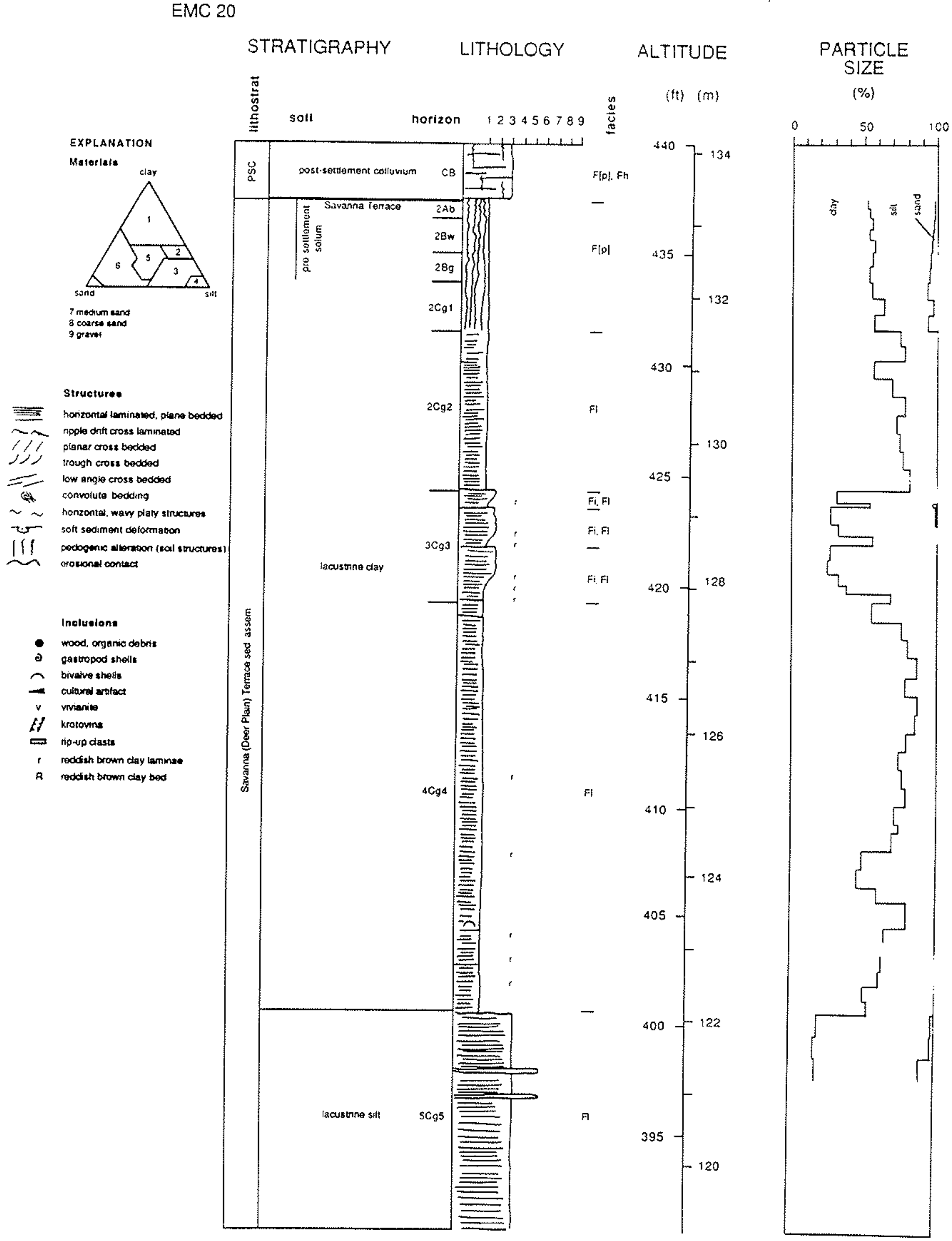

Figure 21. Lacustrine facies and stratigraphy of the Deer Plain (Savanna) Terrace sediment assemblage in the lower Illinois Valley, core EMC-20.

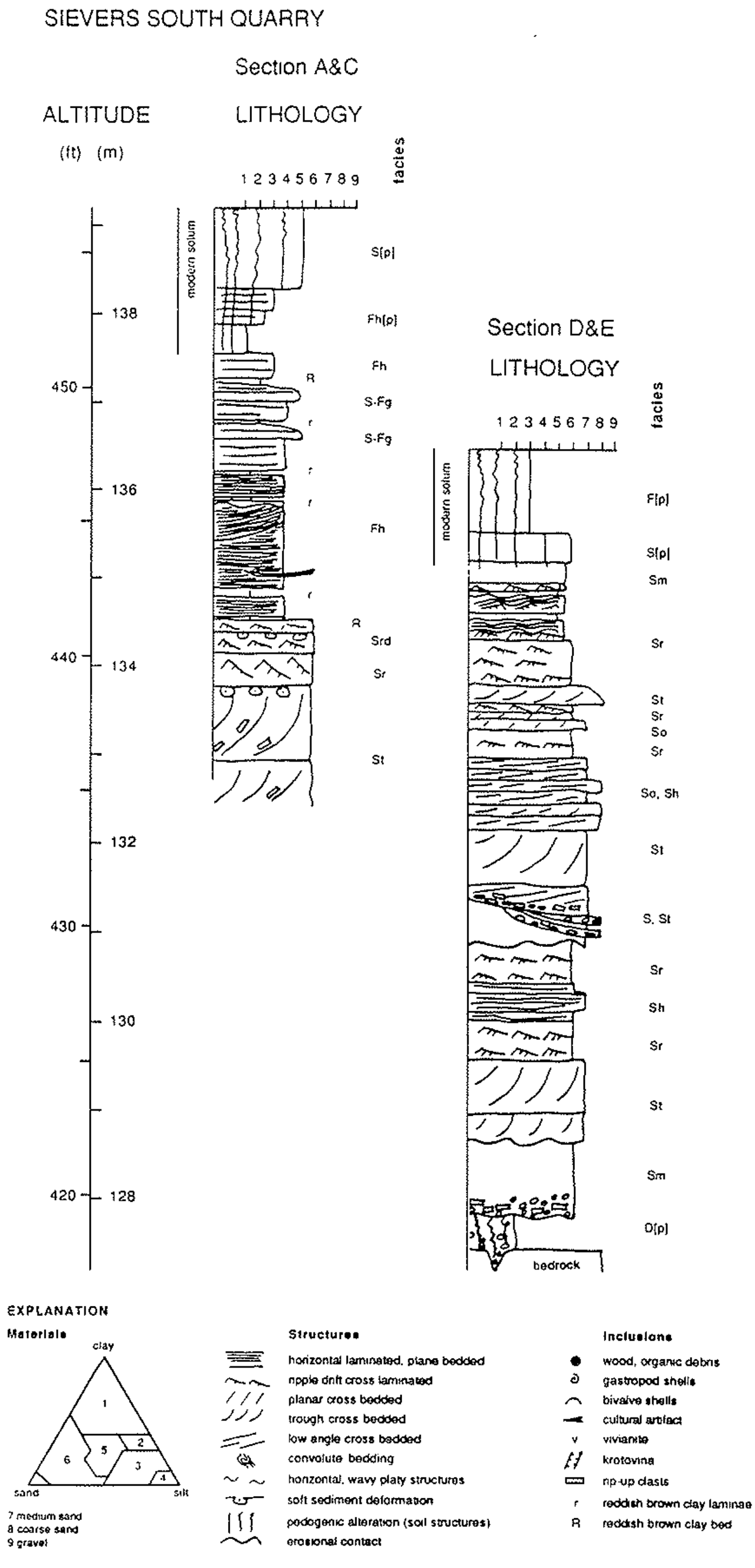

Figure 22. Sediment sequences and stratigraphy in glaciofluvial sediment dam related to the Deer Plain (Savanna) Terrace, Illinois Valley mouth, Sievers South Quarry at the junction of Illinois and Mississippi Valleys.

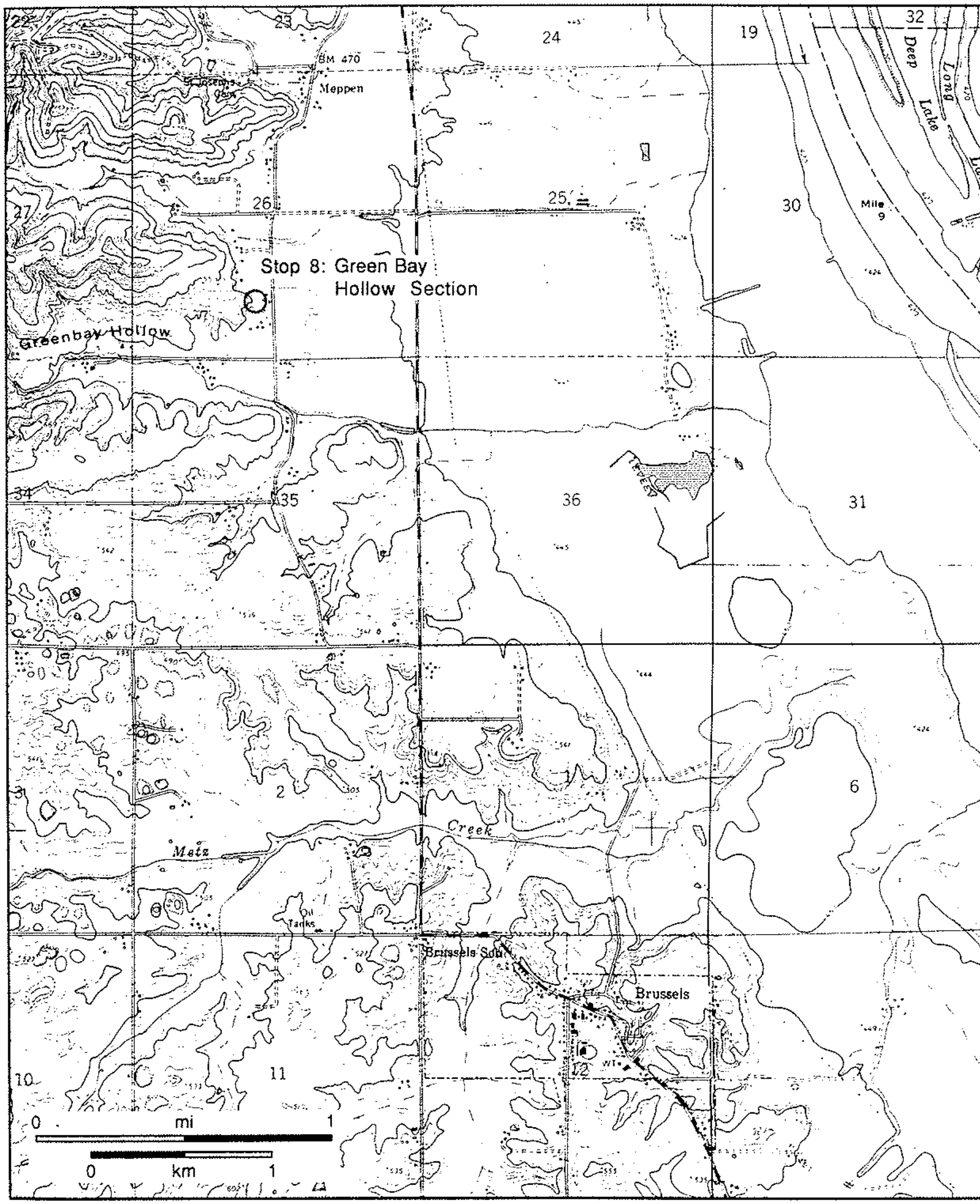

Figure 23. Location of the Greenbay Hollow Section, NE SE SW 26 T12S R2W, Brussels, Illinois, 7.5' quadrangle.

STOP 8. GREENBAY HOLLOW

At Greenbay Hollow we will examine in a series of sections and core the stratigraphy below a surface mapped by Rubey (1952) as the Brussels Terrace in its type area in the lower Illinois Valley. Wisconsinan loesses, including the three flood clay beds in the Peoria Loess, overlie multiple pre-Wisconsinan loesses and paleosols, but no obvious alluvium is present, except at the very base of the section. We will continue our discussion of the Brussels Terrace and examine landscape - stratigraphic relationships, and loess-paleosol stratigraphy and magnetic susceptibility.

Sections at Greenbay Hollow were exposed as borrow material was removed from a small spur where it descends from a gently sloping surface between 510 and 520 ft (155.4 and 158.5 m) (Figure 23). This dissected surface is preserved at and in the mouth of Greenbay Hollow which opens to the Illinois Valley in a reentrant in the bluffline. It rests about 70 ft (21.3 m) above the Deer Plain (Savanna) Terrace, 90 ft (27.4 m) above the Illinois River flood plain, and about 200 ft (61.0 m) below the local secondary drainage divide. Seaton silt loam is mapped on the higher levels of the surface and Sylvan silt loam is mapped on the spur projecting into the valley (Lilly, 1989). Both are greatly eroded. A broad, gently sloping alluvial fan that coalesces with a similar fan to the north is deposited in the embayment and overlies the Deer Plain (Savanna) Terrace which extends almost to the Illinois River. The Cap au Gres faulted flexure runs just south of the hollow in an east - west direction and the differing bedrock units on either side of the fold is reflected in the contrasting topography on either side of it. To the south, the St. Louis Limestone is pitted with sinkholes and some irregular drainages. To the north, well developed east - west oriented drainage networks are underlain by Burlington Limestone and other Mississippian limestones.

Exposed sections and cores taken on the surface of the spur and at the foot of the cuts, and at the location where the lower descending spur becomes buried by the alluvial fan, revealed 8.19 m of Peoria Loess with three flood clay beds over a weak Farmdale Geosol developed in Roxana Silt (Figure 24 and description). Relict oxide banding from groundwater activity is truncated by the modern hillslope. A "Late Sangamon" Geosol is developed in Loveland Silt that is about 10 ft (3.0 m) thick. Loveland Silt conformably overlies another well expressed paleosol developed in a heavy-textured silt unit that is 15.6 ft (4.77 m) thick. A second unnamed well expressed paleosol is developed in another heavy-textured silt that is 8. 3 ft (2.54 m) thick. About 1.5 ft (0.50 m) of crudely bedded silt and pebbly silt was at the base of the described core; the one taken for the field trip went deeper. Cores taken at the base of the cut where the Roxana Silt is at the base, and where the pre-borrow nose slope becomes buried by the alluvial fan reveal similar sequences and indicate former land surfaces represented by the paleosols sloped to the southeast. At the latter location, the Sangamon Geosol exhibited a particularly well drained profile with strong red colors. At this stage of investigation, the silt units below the Loveland Silt tentatively are interpreted as loesses, making a total of three pre-Wisconsinan loesses and paleosols.

There is no evidence below the surface in question to suggest it is a late Wisconsinan or even Illinoian alluvial terrace. The basis for the 510 and 520 ft (155.4 and 158.5 m) land surface is a combination of a pre-late Illinoian bedrock bench, local thicknesses of Wisconsinan and older loesses, and erosion associated with the 'Late Sangamon' Geosol and possibly older paleogeomorphic surfaces, not aggradation of alluvial sediment.

Cores taken on 510 and 520 ft (155.4 and 158.5 m) land surfaces in the Brussels vicinity in the Illinois Valley, mapped as Brussels Terrace, have yet to encounter stratified alluvial deposits. In the town of Brussels, Peoria Loess overlies Roxana Silt that in turn overlies the Sangamon Geosol developed in silt resting on a bedrock bench (Figure 25 and description). Coring in several sinkholes produced similar results, except soils reflected the more poorly drained conditions. Lack of a "Brussels Terrace" in the type area nullifies the utility of the "Brussels Terrace" and "Brussels Formation".

The problem with simply mapping "terraces" rather than doing some form of subsurface exploration is accentuated even more by comparing the Greenbay Hollow section with the Williams Hollow Section. Williams Hollow Section is located on the opposite side of the Illinois Valley directly across from Stop 8. Borrow activity exposed a longitudinal profile in a north - south oriented spur on the north side of the valley and a core was taken at the base of the section (Figure 26 and description). Land surface altitudes are comparable to those at Greenbay Hollow. Peoria Loess with three clay beds overlies just over 32.8 ft (10 m) of Roxana Silt that is sandy with depth. A thin "Late Sangamon" Geosol overlies fining upward alluvial flood plain deposits that rest on bedrock. Despite the similar geomorphic appearance of these surfaces, the stratigraphy contrasts greatly. There are a number of paleogeomorphic surfaces that could be responsible for the gross morphology

Core:	GBH-1 and GBH-3
Location:	NE SE SW 26 T12S R2W (Brussels 7.5' quadrangle)
Landscape Position:	cores taken on truncated spur on north side of Greenbay Hollow at its juncture with the Illinois Valley; GBH-1 taken on crest of spur immediately above borrow pit that makes a transverse cut through spur; GBH-3 taken from floor of borrow pit within 5 m of GBH-1
Altitude:	spur slopes southeast from 550 to 480 ft (167.6 to 146.3 m); top of GBH-1 ≈515 ft (157.0 m)
SCS Mapped Soil Series:	Sylvan silt loam

Depth (m)	Horizon	Description
(GBH-1)		
Peoria Loess		
modern solum		
0.00 - 0.22	Ap	silt; very dark brown (10YR 2/2) silt loam; weak crumb; strongly effervescent; abrupt boundary.
0.22 - 0.66	Bt1	silt; brown to dark brown (7.5YR 4/4) silty clay loam; moderate to strong fine and medium angular blocky, common very dark brown (10YR 2/2) argillans; firm; leached; clear boundary.
0.66 - 0.97	Bt2	silt; brown to dark brown (7.5YR 4/4) silty clay loam; moderate coarse subangular tending to prismatic, common very dark brown (10YR 2/2) argillans; firm; leached; gradual boundary.
0.97 - 1.52	Bt3	silt; dark yellowish brown (10YR 4/4) silty clay loam; weak coarse subangular blocky, few very dark brown (10YR 2/2) argillans; firm; leached; gradual boundary.
1.52 - 1.91	BC	silt; dark yellowish brown to olive brown (10YR - 2.5Y 4/4) silt loam to silt; weak coarse subangular blocky; friable; very slightly effervescent; gradual boundary.
1.91 - 6.55	C1	silt; olive brown (2.5Y 4/4, 4.5/4, 4/5) silt; massive, zones of horizontal and wavy platy structure at 2.40-3.10, 3.60-3.80, 4.70-5.10, 5.90-6.40, dark olive brown (2.5Y 3/4) clay beds at 3.10-3.14, 4.31-4.37, 5.36-5.41; friable; violently effervescent; 3.76-3.94 finely mottled grayish and olive brown (2.5Y 5/2, 4/4) and dark yellowish brown (10YR 5/6); very gradual boundary.
6.55 - 7.43	C2	silt; olive brown (2.5Y 4/4) down to dark yellowish brown (10YR 4/4) silt; massive; friable; strongly down to slightly effervescent; clear boundary.
colluvial facies		
7.43 - 7.90	C3	silt; dark yellowish brown (10YR 4/4) down to brown to dark brown (7.5YR 4/4) silt; massive; very slightly effervescent to leached
(GBH-3)		
7.90 - 8.19	C4	silt; brown (7.5YR 4.5/4) silt, slight increase in very fine sand, common medium dark yellowish brown (10YR 4.5/4) mottles; moderate medium platy; friable; slightly effervescent, few very fine secondary concretions; very few fine oxide stains; clear boundary.
Roxana Silt		
Farmdale Geosol		
8.19 - 8.57	2Bwb	silt; brown to strong brown (7.5YR 4/5) silt loam, common medium and fine dark yellowish brown (10YR 4/6) mottles; very weak subangular blocky; friable; leached with few very fine secondary carbonate concretions; few to common very fine and fine pores, few with oxide coatings; few fine charcoal fragments; clear boundary.

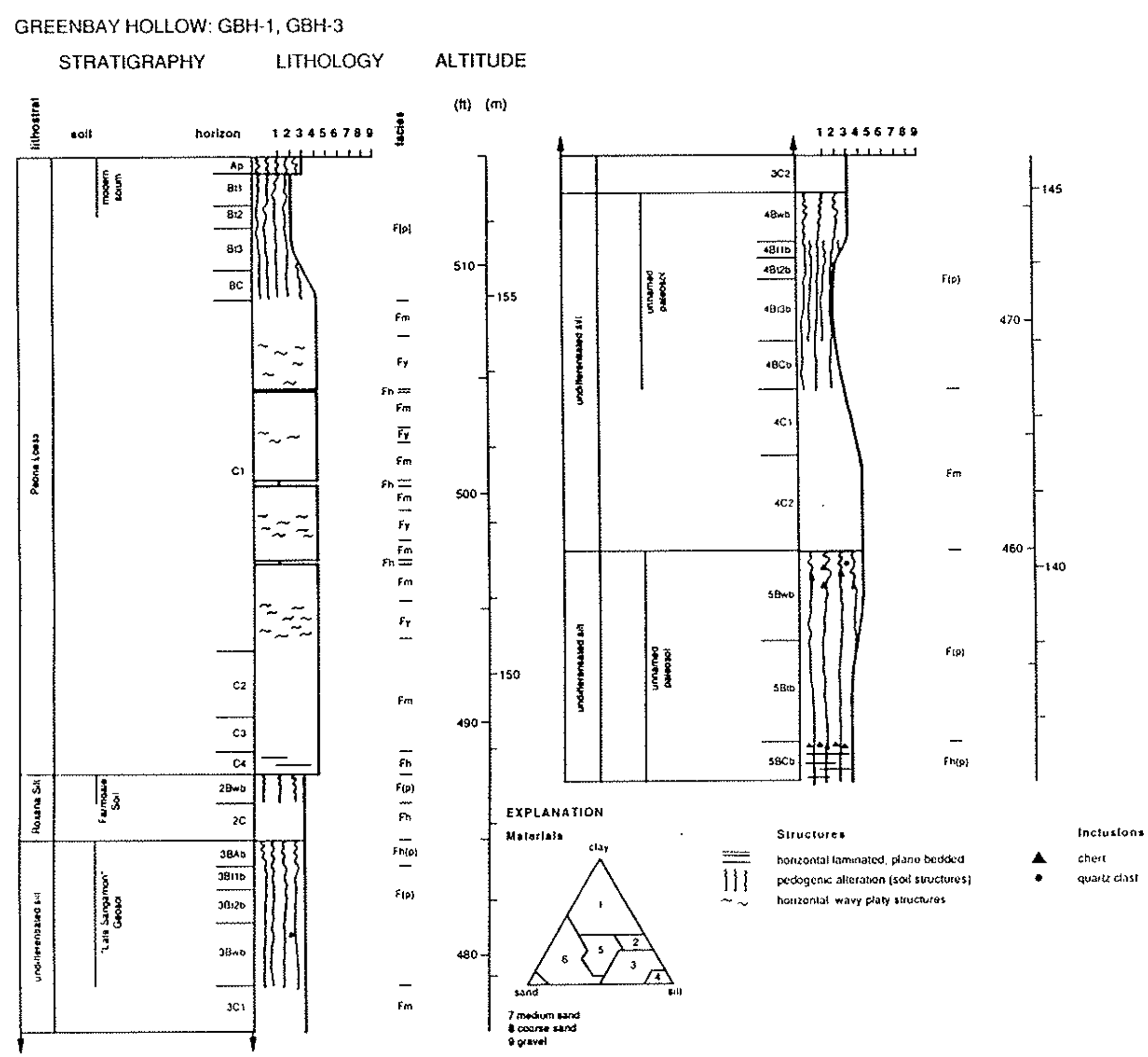

Figure 24. Stratigraphy and sediment log of cores GBH-1 and GBH-3, Greenbay Hollow Section.

8.57 - 9.05 2C silt; dark yellowish brown (10YR 4/4) silt loam, common medium dark yellowish brown (10YR 4/6) mottles and thin horizontal bands; moderate medium and coarse platy; friable; moderately effervescent, few very fine secondary carbonate concretions; few very fine and fine pores with oxide coatings; clear boundary.

undifferentiated silt
"Late Sangamon" Geosol

9.05 - 9.40 3BAb silt; brown to dark brown to dark yellowish brown (7.5YR - 10YR 4/4) silt loam, few medium and coarse dark yellowish brown (10YR 4/6) mottles; moderate fine angular blocky over weak platy grading down to weak medium columnar; friable; very slightly effervescent; few fine and medium pores; few small (<1 cm) voids with oxide stains; clear boundary.

9.40 - 9.70 3Bt1b silt; dark yellowish brown (10YR 4/4) silt loam, many medium and coarse dark yellowish brown (10YR 4/6) mottles; moderate medium columnar breaking to subangular blocky; friable to firm; leached, few very fine secondary carbonate concretions; common fine and medium pores with common thin (10YR 2/2) argillans and oxide coatings; few medium pores with fecal pellets; common small (<1 cm) voids with oxide and clay coatings; few discontinuous thin lenses with many fine chert pebbles and granules; clear boundary.

9.70 - 10.14 3Bt2b silt; dark yellowish brown (10YR 4/5) silt loam, many medium and coarse dark yellowish brown (10YR 4/6) mottles and common oxide stains; weak coarse subangular blocky; firm; leached, common secondary carbonate lining pores and voids; common fine and medium pores with common thin (10YR 2/2) argillans and oxide coatings; few medium pores and voids with fecal pellets; clear boundary.

10.14 - 10.96 3Bwb silt; dark yellowish brown (10YR 4/4.5) silt loam, one very fine chert pebble at 2.89; moderate coarse subangular blocky, common dark yellowish brown (10YR 4/4) argillans; firm; leached, few zones with voids with very fine dendritic pattern of secondary carbonate concretions; few fine pores with oxide coatings and secondary carbonate; abrupt boundary.

10.96 - 11.55 3C1 silt; brown to dark brown (7.5YR 4/4) down to dark yellowish brown (7.5 - 10YR 4/4) silt loam, sand content increases with depth, common fine and medium dark yellowish brown (10YR 4/5) mottles; massive; friable; leached, very few very fine secondary carbonate concretions; very few medium pores, few with oxide coatings; clear boundary.

11.55 - 12.04 3C2 silt; dark yellowish brown (10YR 4/4) silt loam; weak subangular blocky; oxide piping; gradual boundary

undifferentiated silt
unnamed paleosol

12.04 - 12.71 4Bwb silt; dark yellowish brown to olive brown (10YR - 2.5Y 4/5) heavy silt loam; massive to weak subangular blocky; firm; leached; very few fine pores; very few fine oxide concretions; abrupt boundary.

12.71 - 12.92 4Bt1b silt; finely mottled dark yellowish brown (10YR 4/4) and dark yellowish brown to olive brown (10YR - 2.5Y 4/5) heavy silt loam; moderate medium subangular blocky; firm; leached; common very fine, fine and medium pores, common thin very dark brown (10YR 2/2) argillans; abrupt boundary.

12.92 - 13.20 4Bt2b silt; mottled dark yellowish brown to olive brown (10YR - 2.5Y 4/5) and brown (7.5YR3.5/5) silty clay loam; moderate medium subangular blocky; firm; leached; common fine and medium pores, common thin very dark brown (10YR 2/2) argillans; many fine oxide concretions; clear boundary.

13.20 - 14.03 4Bt3b silt; brown to dark brown (7.5YR 4/4) silty clay loam, many fine and medium dark yellowish brown (10YR 4/5, 4/6) mottles; weak coarse subangular blocky; firm; leached; few fine and medium pores, common thin very dark brown (10YR 2/2) argillans; few fine oxide concretions and stains; clear boundary.

14.03 - 14.66 4BCb silt; brown to strong brown (7.5YR 4/5) silt loam, clay content decreases with depth, many medium and coarse dark yellowish brown (10YR 5/6) mottles; weak subangular blocky; friable; very slightly effervescent; few oxide stains; clear boundary.

14.66 - 15.54 4C1 silt; brown to strong brown (7.5YR 4/5) light silt loam; massive; friable; very slightly effervescent; very gradual boundary.

15.54 - 16.81	4C2	silt; brown to dark yellowish brown (8YR 4.5/4) silt, zone of coarse silt at 15.26-15.38 m, horizontal oxide banding common; massive; friable; leached; gradual boundary.
undifferentiated silt *unnamed paleosol*		
16.81 - 18.01	5Bwb	silt; brown to dark brown (7.5YR 4/4) silt, few chert and one quartz pebble near top of unit, many fine faint dark yellowish brown (10YR 3/4, 4/4) mottles; weak medium and coarse subangular blocky; friable; leached; common very fine oxide concretions and stains; gradual boundary.
18.01 - 19.35	5Btb	silt; finely mottled dark yellowish brown (10YR 4/4, 4/6) and brown to dark brown (7.5YR 4/2, 4/3, 4.5/3) silt loam; weak coarse subangular blocky; friable; leached; zones with fine oxide concretions and stains; few fine pores with thin to moderately thick (10YR 2/1) and (7.5YR 4/2) argillans; gradual boundary.
19.35 - 19.86	5BCb	silt; slightly yellower than dark yellowish brown (10YR 4/6, 5/6) silt loam, few pebbles in thin zone at top of unit; crude horizontal bedding, with fine reworked peds and rip-up clasts; leached; basal part with reticulate pattern of argillans or oxide lenses; base of core.

Core: BSL-3
Location: SW NW NW 7 13S 1W (Brussels 7.5' quadrangle)
Landscape Position: on truncated spur to Illinois Valley, broad flat at 520 ft, outskirts of Brussels, Illinois, 0.1 km west of Illinois Valley
Altitude: 520 ft
SCS Mapped Soil Series: not mapped

near Brussels

Depth (m)	Horizon	Description
Peoria Loess		
0.00 - 0.28	Ap	very dark grayish brown (10YR 3/2) silt loam; moderate crumb; friable; leached; abrupt boundary.
0.28 - 0.40	E	dark grayish brown (10YR 4/2) and light brownish gray (10YR 6/2) silt loam; weak fine subangular blocky; friable; leached; clear boundary.
0.40 - 0.62	Bw	brown to dark brown (7.5YR 4/4) silt loam to silty clay loam; moderate fine and medium subangular blocky; friable; leached; clear boundary.
0.62 - 1.58	Bt1	coarsely mottled brown to dark brown (7.5YR 4/4) and dark yellowish brown (10YR 4/4) silty clay loam; strong medium breaking to fine subangular blocky, many thin dark brown (7.5YR 4/3) argillans and common thin silans; firm; leached; few oxide dots; clear boundary.
1.58 - 1.90	Bt2	dark brown (10YR 3.5/4) silt loam to silt, few coarse dark yellowish brown (10YR 3/4) and fine light olive brown (2.5Y 5/4) mottles; weak coarse subangular blocky, few thin dark brown (7.5YR 4/3) argillans; firm to friable; leached; clear boundary.
1.90 - 2.51	CB	dark yellowish brown (10YR 4/4) silt; massive; friable; leached to slightly effervescent; yellowish brown (10YR 5/6) hydromorphic banding at top of horizon; clear to gradual boundary.
2.51 - 3.60	C1	light olive brown (2.5Y 5/4) silt, many fine grayish brown (2.5Y 5/2) mottles; alternating zones of wavy platy and massive; friable; strongly to violently effervescent, very few fine secondary carbonate concretions; gradual boundary.
3.60 - 5.18	C2	grayish brown (2.5Y 5/2) silt, few fine and medium light olive brown (2.5Y 5.5/6) mottles; alternating zones of moderate fine wavy and horizontal platy and massive; friable; strongly to violently effervescent, clear boundary.
5.18 - 5.62	C3	light olive brown (2.5Y 5/6) silt; strong fine wavy and horizontal platy to moderate medium and coarse horizontal platy; friable; strongly to violently effervescent, gradual boundary.

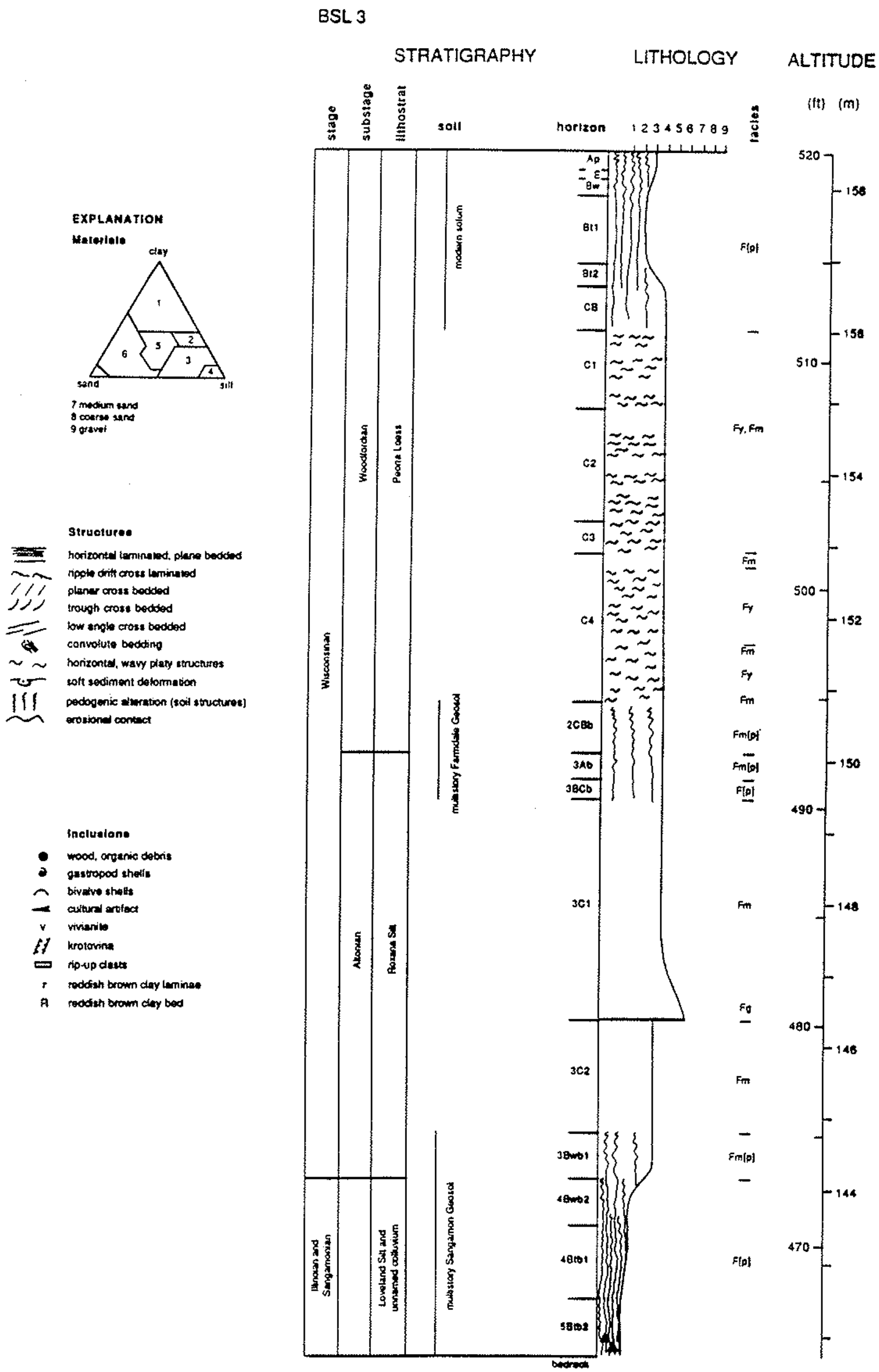

Figure 25. Stratigraphy and sediment log of core BSL-3, in Brussels, Illinois, type area for the Brussels Terrace.

5.62 - 7.70	C4	grayish to light olive brown (2.5Y 5/3) silt; strong fine to moderate fine and medium to weak medium and coarse wavy and horizontal platy, few thin massive zones; friable; strongly effervescent; abrupt boundary.
7.70 - 8.40	2CBb	brown (10YR 5/3) silt, very few fine dark yellowish brown (10YR 4/6) mottles; massive; friable; strongly effervescent; few fine pores Fe coatings; clear boundary.
Roxana Silt		
Farmdale Geosol		
8.40 - 8.76	3Ab	dark yellowish brown (10YR 4/4) to brown to dark brown (7.5YR 4/4) silt, few fine dark yellowish brown (10YR 4/6) mottles; massive; friable; very slightly effervescent; few to common fine pores; gradual boundary.
8.76 - 9.04	3BCb	dark brown (7.5YR 3.5/4) silt; weak coarse subangular blocky; friable; very slightly effervescent; common fine and medium vertical pores; clear boundary.
9.04 - 12.12	3C1	brown to dark brown (7.5YR 4/4) silt, 10.57-12.12 grades down to fine sandy loam; massive; friable; leached; very abrupt boundary.
12.12 - 13.70	3C2	brown to strong brown (7.5YR 5/5) light silt loam, few medium dark yellowish brown (10YR 3/4; 4/4) mottles; very massive; friable; leached; very gradual boundary.
13.70 - 14.33	3Bwb1	brown to strong brown (7.5YR 5/5) light silt loam; massive to weak subangular blocky; friable to firm; leached; few fine and medium pores with iron coatings; clear boundary.
Loveland Silt		
Sangamon Geosol		
14.33 - 14.98	4Bwb2	strong brown (7.5YR 4/6) heavy silty clay loam, few fine brown to dark brown (7.5YR 4/4) mottles; weak subangular blocky; very firm; leached; gradual boundary.
14.98 - 16.00	4Btb1	reddish brown to dark reddish brown (5YR 3.5/4) heavy silty clay loam, many fine and medium brown to dark brown (7.5YR 4/4) mottles; strong subangular blocky, many thin dark reddish brown (5YR (3/4) and few very dark gray (7.5YR 3/1) argillans; very firm; leached; very gradual boundary.
16.00 - 16.80	5Btb2	red to dark red (2.5YR 3.5/6) silty clay down to clay loam, few fine chert pebbles near base; moderate coarse subangular and angular blocky; very firm; leached; abrupt core refusal, probably on bedrock.

note: Type area for Brussels Terrace of Rubey (1952).

Section and Core:	Williams Hollow Borrow Pit; WH 1
Location:	E1/2 SE NE 4 T6N R13W
Landscape Position:	longitudinal section in truncated spur on north side of Williams Hollow, 0.7 km east of Illinois Valley, and core from floor of borrow pit
Altitude:	spur slopes south from 530 to 490 ft (161.5 to 149.4 m); top of core ≈475 ft (144.8 m)
SCS Mapped Soil Series:	Sylvan-Bold complex

Depth (m)	Horizon	Description (abbreviated for 0 - 11.20)
Peoria Loess		
modern solum		
0.00 - 0.80	solum	dark yellowish brown (10YR 4/4) silty clay loam; moderate subangular blocky; firm; leached; clear boundary.
0.80 - 3.25	C1	grayish brown (2.5Y 5/2) silt; massive; friable; jointed; strongly effervescent; clear to abrupt boundary.
clay bed		
Jules Soil (?)		
3.25 - 3.28	2C2	finely mottled grayish brown (2.5Y 5/2), (2.5Y 4/3), and (2.5Y 4/2) silt grading downslope (towards tributary creek) to thin clay bed; massive, bioturbated; friable; moderately effervescent; clear to abrupt boundary.

3.28 - 4.53	3C3	grayish brown (2.5Y 5/2) silt; faint horizontal bedding of massive beds; friable; moderately to strongly effervescent; abrupt boundary.
clay bed		
4.53 - 4.60	4C4	olive (5Y 4/4) clay; single thin bed, bioturbated; strongly effervescent, with secondary carbonate concretions; abrupt boundary.
4.60 - 5.63	5C5	grayish brown (2.5Y 5/2) silt; massive; friable; jointed, with several joints filled with clay associated with overlying clay bed; strongly effervescent; abrupt boundary.
clay bed		
5.63 - 5.65	6C6	olive (5Y 4/4) clay; single thin bed, bioturbated; strongly effervescent; with secondary carbonate concretions; abrupt boundary.
5.65 - 9.20	7C7	grayish brown (2.5Y 5/2) silt; massive; friable; jointed, with several joints filled with clay associated with middle clay bed (4.53-4.60); strongly to moderately effervescent; gradual boundary.
Roxana Silt		
Farmdale Geosol		
9.20 - 9.40	8Ab	dark yellowish brown (10YR 4/4) silt; massive; friable; few fine and medium filled pores; very slightly effervescent to leached; clear to abrupt boundary, becomes more abrupt in direction of noseslope of spur; few burrows within 0.3 m above and below contact.
9.40 - 9.85	8Bwb	brown (7.5YR 4/4) silt, with few fine dark yellowish brown (10YR 4/6) mottles; massive; friable; very slightly effervescent to leached; gradual boundary.
9.60 - 11.20	8C1	silt; slightly yellower than brown (7.5YR 4.5/4) silt, few coarse brown (7.5YR 4.5/3) mottles; massive; slightly effervescent (dolomitic).
(core WH-1)		
11.20 - 12.15	8C1	silt; slightly yellower than brown (7.5YR 4.5/4) silt, few coarse brown (7.5YR 4.5/3) mottles; weak coarse platy; slightly effervescent (dolomitic), few secondary carbonate linings in pores; few fine pores; gradual boundary.
12.15 - 13.35	8C2	silt; slightly yellower than brown (7.5YR 4.5/4) silt, few coarse brown (7.5YR 4.5/3) mottles; massive; slightly effervescent (dolomitic), very few secondary carbonate nodules < 2 cm, few secondary carbonate linings in pores; few fine pores; very gradual boundary.
13.35 - 15.13	8C3	silt; brown (7.5YR 4/4) coarse silt with some very fine sand; massive; very slightly effervescent (dolomitic), one large concretion at 2.10; gradual boundary.
15.13 - 15.57	9C4	sand; dark yellowish brown (10YR 4/3.5) loamy very fine sand grading up to silt, common fine very dark grayish brown (10YR 3/2) mottles; massive; very slightly effervescent (dolomitic); basal part of unit with burrows filled with underlying material; clear boundary.
15.57 - 15.70	9C5	sand; brown (7.5YR 4/4) very fine sandy loam; massive; very slightly effervescent (dolomitic); abrupt boundary.
15.70 - 15.78	10C6	silt; dark yellowish brown (10YR 4/5) silt loam, many fine very dark grayish brown (10YR 3/2) mottles, massive, single bed; very slightly effervescent (dolomitic); abrupt boundary.
unnamed paleosol		
15.78 - 16.85	11Bwb	silt; slightly yellower than brown (7.5YR 4.5/4) silt, with common medium faint dark yellowish brown (10YR 4/5) mottles; massive; very slightly effervescent (dolomitic) to leached; one fine chert pebble; abrupt boundary.
16.85 - 17.08	12C1	silt; dark brown to brown (7.5YR 4/2) silt; massive; leached; clear boundary.
17.08 - 17.66	12C2	silt; dark brown to brown (7.5YR 4/4) silt loam; massive; leached; very few coarse chert sand grains and fine chert pebbles; gradual boundary.
17.66 - 19.05	12C3	silt; brown to strong brown (7.5YR 4/5) silt loam; massive; leached; clear boundary.
colluvial facies		
unnamed paleosol		
19.05 - 19.64	13Bwb1	silt; dark yellowish brown (10YR 4/5) silt loam; weak coarse subangular blocky with few redeposited silt loam peds; leached; clear boundary.
19.64 - 19.84	14Bwb2	diamicton; dark yellowish brown (10YR 4/5) silt loam diamicton, with few very fine chert pebbles; weak coarse subangular blocky, with few redeposited silt loam peds; leached; abrupt boundary.

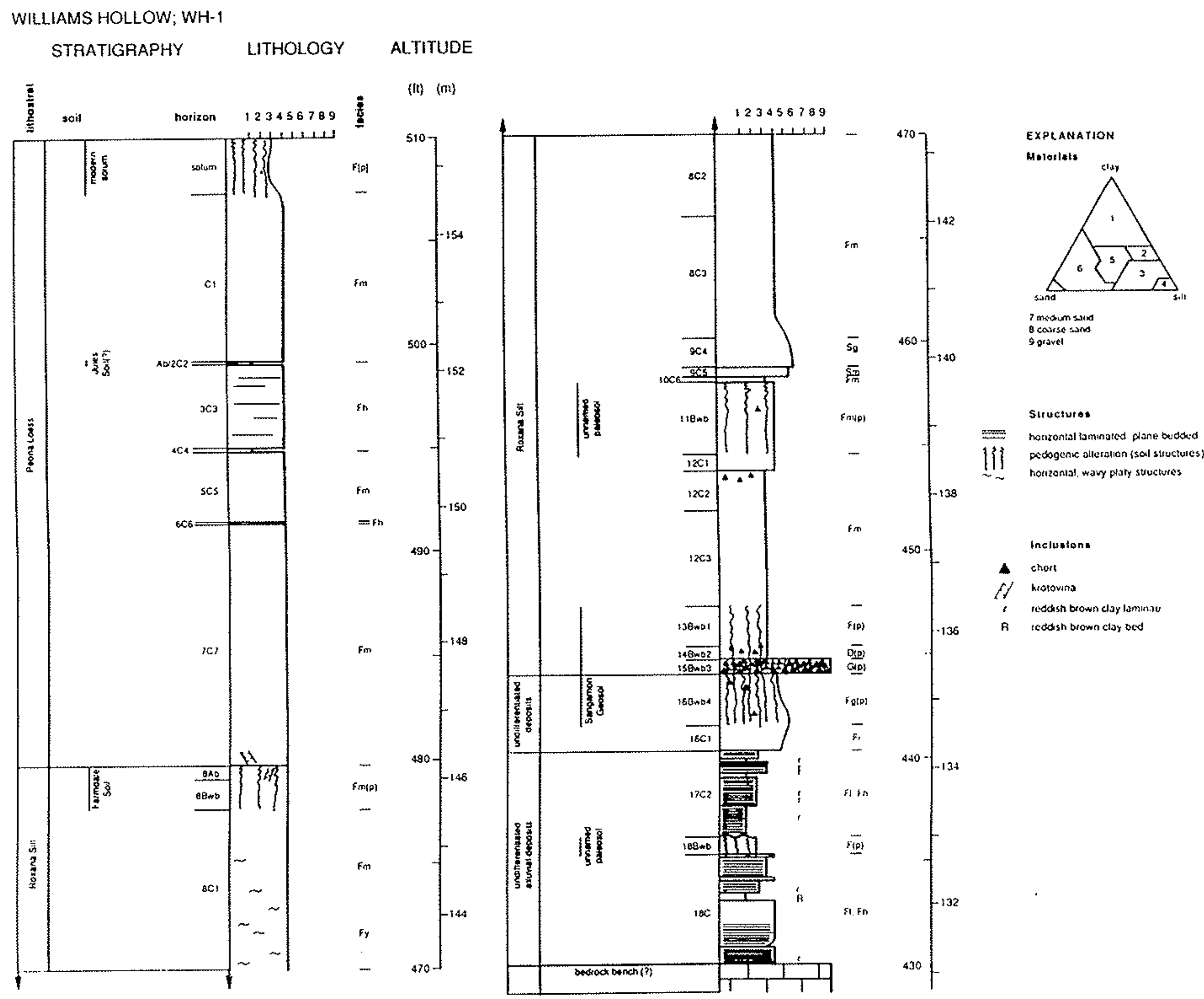

Figure 26. Stratigraphy and sediment log of the Williams Hollow Section and core WH-1.

19.84 - 20.05	15Bwb3	gravel; one bed of very fine to coarse chert gravel with a matrix of slightly yellower than brown to strong brown (7.5YR 5/4) silt loam, many oxide concretions < 4 mm diameter; leached; abrupt boundary.
undifferentiated sediments		
Sangamon Geosol		
20.05 - 20.80	16Bwb4	silt; slightly yellower than (7.5YR 4/5) very fine sandy loam grading up to silt loam (with noticeable fine sand and clay), with very few very fine chert pebbles and very coarse chert sand grains; with many coarse dark yellowish brown (10YR 4/6) and common coarse brown to strong brown (7.5YR 4/5) mottles, and many fine and medium black oxide concretions and stains; weak coarse subangular blocky; leached; clear boundary.
20.80 - 21.17	16C1	silt; light olive brown (2.5Y 5/4) silt grading up to very fine sandy loam, with many medium and coarse dark yellowish brown (10YR 4/6) mottles and few medium black oxide stains; graded with no soil structure; leached; abrupt boundary.
unnamed alluvial deposits (Sangamonian [?]), floodplain facies		
21.17 - 22.43	17C2	silt and clay; stratified (thin bedded to laminated) light olive brown (2.5Y 5/5) silt, grayish brown (2.5Y 5/2) silty clay loam, few laminae of brown to dark brown (7.5YR 4/4, 4/3) and reddish brown (5YR 4/4) silty clay; leached; very abrupt boundary.
unnamed paleosol		
22.43 - 22.69	18Bwb	silt; brown to strong brown (7.5YR 4/4, 4/3) silty clay loam, many fine dark yellowish brown (10YR 4/6) mottles; weak subangular blocky; leached to very slightly effervescent; very abrupt boundary.
22.69 - 24.27 ~80 ft. depth	18C	silt; laminated and thin bedded brown to strong brown (7.5YR 4/4) silty clay loam and grayish brown (2.5Y 5/2), light olive brown (2.5Y 5/4), and light yellowish brown (2.5Y 6/4) silt, few brown to strong brown (7.5YR 4/4) silty clay laminae; violently effervescent, some zones with abundant fine secondary carbonate concretions; base of core probably on bedrock.

395' bedrock (probably)

MAGNETIC SUSCEPTIBILITY INTERPRETATION OF GREEN BAY HOLLOW

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Magnetic susceptibility was measured on two separate cores (upper and lower) with a Bartington meter and probe. The factors and processes which control magnetic susceptibility are presented in a paper later in this guidebook.

In the upper core (see figure 27), the yellow-brown Peoria Loess contains a susceptibility minimum in its middle portion which is typical of many loess exposures in the region. When compared to the susceptibility record of the Peoria Loess at Thebes, Alexander County, Illinois, the small scale similarities are quite remarkable. High readings in the upper meter of the core may be due to the concentration and in-situ production of ferrimagnetic minerals during Modern soil formation. From 1.0 to 6.75 m, relatively unaltered, dolomitic Peoria Loess contains a primary signal with a minimum at about 4 m. Susceptibility minimums in the clay beds are, in part, primary and, in part, due to the formation of secondary carbonate. Susceptibility readings in the browner Roxana Silt (6.75 - 8.7 m) are generally higher than in the Peoria Loess, as found elsewhere in the region. This increase is probably primary; however, pedogenic processes during the Farmdalian may have had some effect. The A horizon of the Sangamon Geosol may have been reached at about 8.6 m. The highest magnetic susceptibility readings at Green Bay Hollow were found in the solum of the reddish-brown Sangamon Geosol in the field (this paleosol was below the limit of the upper core and above the lower core). High readings in the Sangamon Geosol may be due to the concentration of primary magnetite and/or the in-situ production of sub-micron ferrimagnetic minerals and the subsequent translocation of these minerals into the Bt horizon during the Sangamonian.

In the lower core (see figure 28), susceptibility readings are associated with textural and color changes. Gleyed silty clays and clays (3-7.75 m and 9.5-12 m) have very low susceptibilities. More oxidized, browner silt loams and silty clay loams (0-3 m and 7.75-9.5 m) have relatively higher susceptibilities. The cause for these variations may be lithologic, pedologic, or a combination. They are lithologic if the signal represents varying concentrations of primary magnetite - typically more abundant in coarser grain size fractions. They are pedogenic if magnetite was destroyed under the strongly reducing conditions present in the gleyed clays or if ferrimagnetic minerals were produced during soil forming intervals. In all likelihood, this signal represents a combination of processes, with the pedologic signal overprinting a lithologic signal.

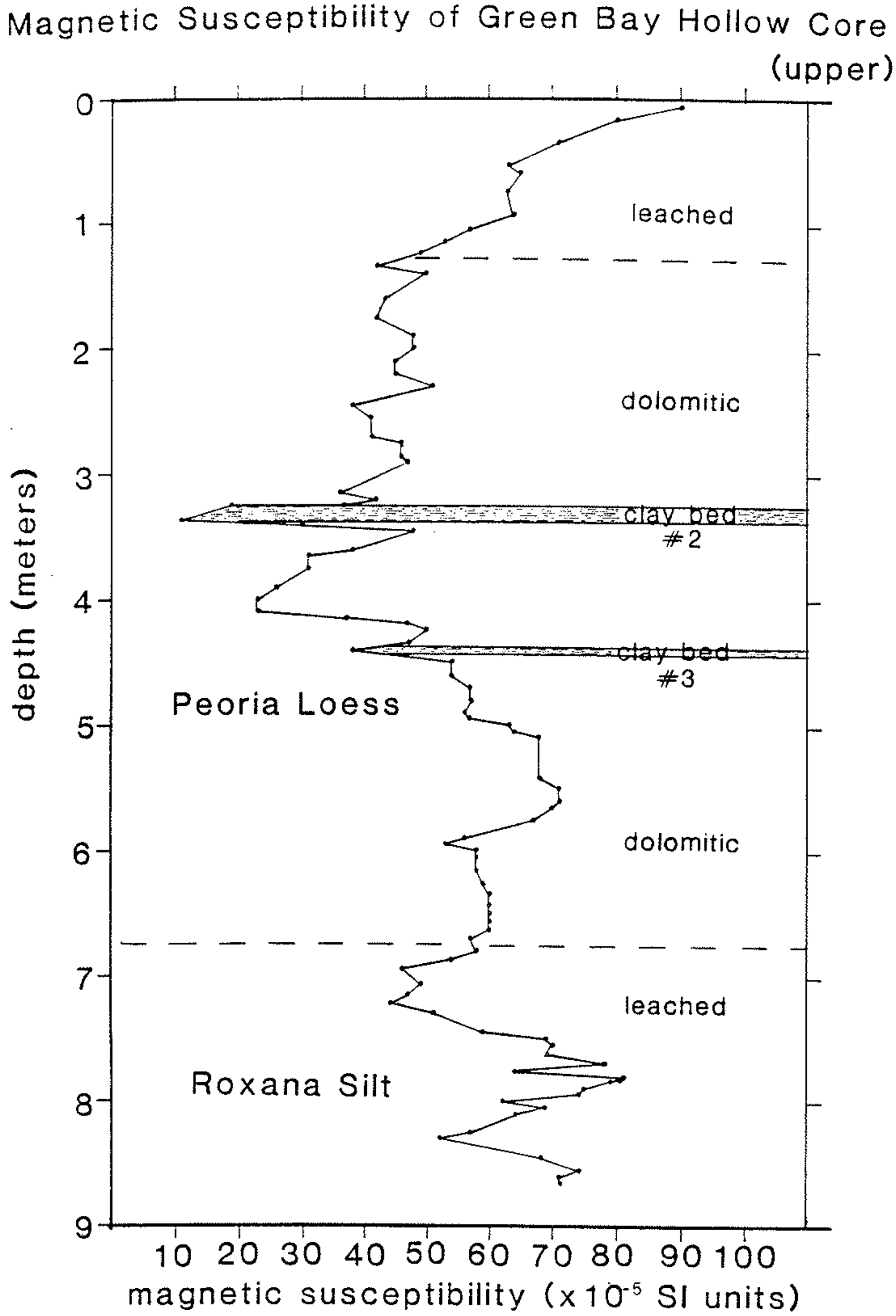

Figure 27. Magnetic susceptibility of Greenbay Hollow core GBH-1B, Peoria Loess and Roxana Silt.

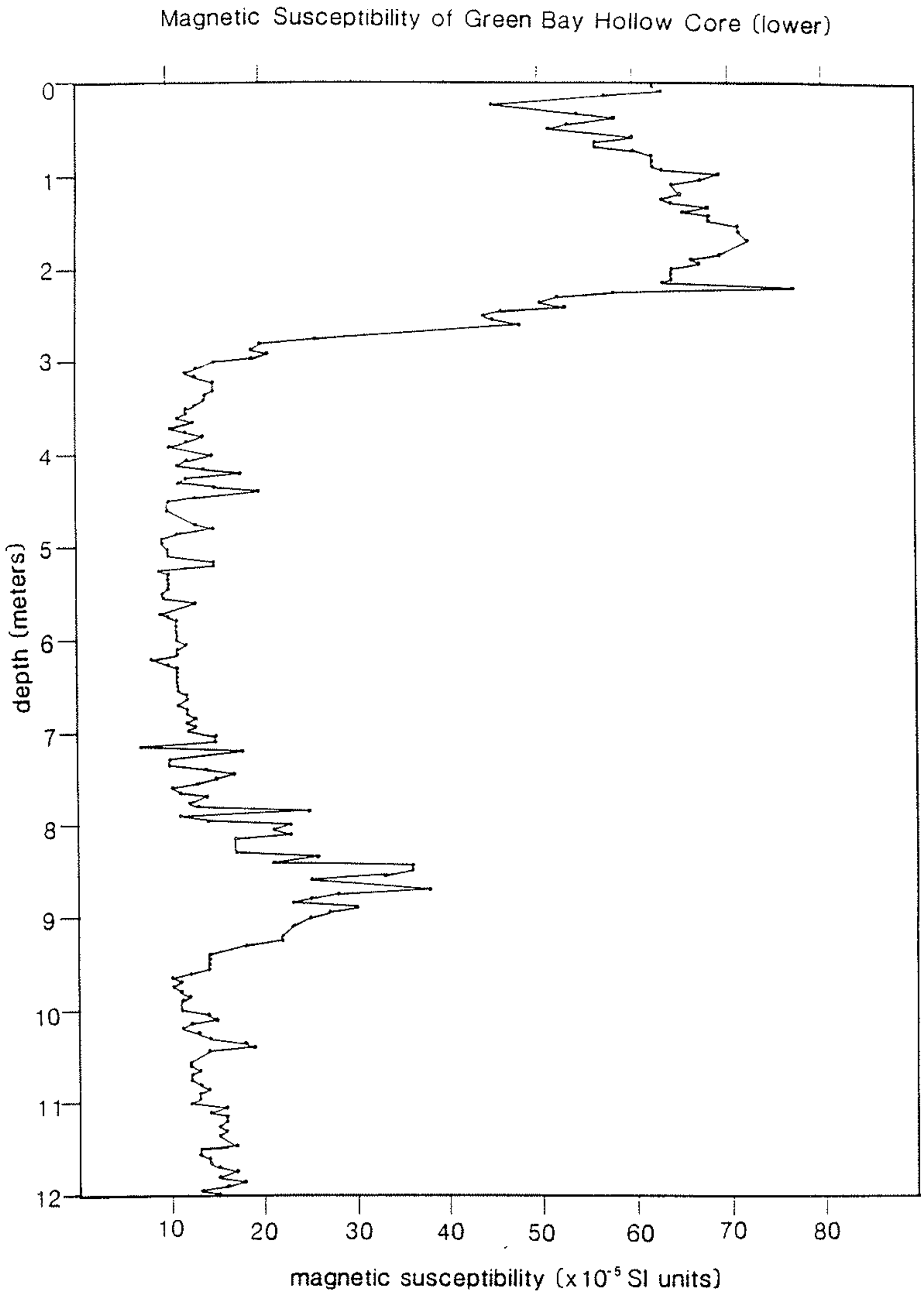

Figure 28. Magnetic susceptibility of Greenbay Hollow core GBH-3B, sub-Sangamon Geosol units.

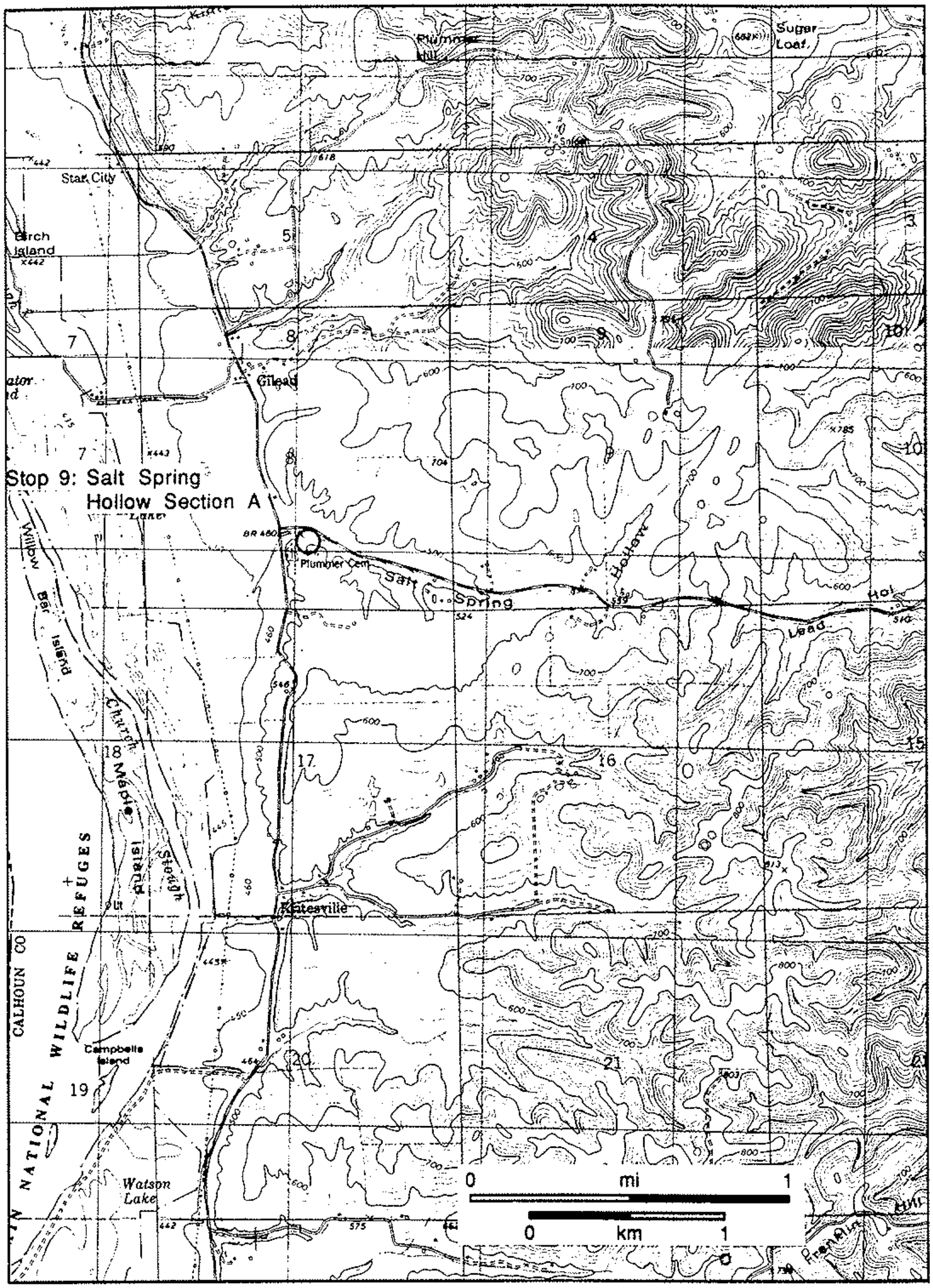

Figure 29. Location of Salt Spring Hollow Section, NW SW SE 8 T11S R2W, Foley, Missouri-Illinois, 7.5' quadrangle.

STOP 9. SALT SPRING HOLLOW

At this top we will view in section the sediment assemblage underlying a surface mapped as Brussels Terrace by Rubey (1952). We will see that there are indeed alluvial deposits below 520 ft land surfaces that clearly are responsible for the geomorphic expression of that surface in some places. There will also be additional radiocarbon and paleoenvironmental discussion. We will wrap up our discussion of the Brussels Terrace and Brussels Formation arguments, and review the central Mississippi Valley terrace chronology.

Salt Spring Hollow Section is a series cut banks where the local creek meandered into a 520 ft (158.5 m) surface. The surface is relatively extensive and flat, and can be found around the mouths of tributary valleys for some distance southward (Rubey, 1952). Excellent examples are visible north of the road at the mouth of Salt Spring Hollow. Upvalley these surfaces exhibit a nearly nil gradient, then apparently rise slightly. Upvalley, differentiation between this surface and low spurs that may be underlain by erosion surfaces is difficult without further subsurface work. Along this reach of the Mississippi Valley there is a highly dissected high-level surface that rises about 120 to 140 ft (36.6 to 42.7 m) above 520 ft (158.5 m) surface yet is still about 150 ft (45.7 m) below the major drainage divide. This high-level surface leads southward into the Batchtown Channel, a former Mississippi River channel, and our last stop is cut into a comparable surface.

Peoria Loess, at least 20 2 ft (6.15 m) thick, overlies the terrace surface (Figure 10). Pedogenically altered chert gravel and diamicton are at the base of the section; these deposits are widespread throughout the Calhoun County area. In this example they grade rapidly upward to pedogenically altered unoxidized overbank deposits that may be modified by a poorly drained Farmdale Geosol. In between are alluvial deposits that aggraded to the terrace level and were incised. These deposits consist of calcareous, unoxidized, fossiliferous, thin bedded and laminated slackwater silt that fines upward to a silty clay loam modified by incipient soil formation. Partially indurated nodules occur along the upper boundary of the soil. Abruptly overlying the soil are strongly laminated silt and some reddish brown clay laminae indicating at least some of these deposits were derived from the Mississippi Valley. The base of laminated deposits has undergone soft sediment deformation. Laminated strata rapidly grades upward to an unoxidized unleached silt with thin discontinuous fine sand lenses that may reflect local eolian dunes.

Radiocarbon ages from the unoxidized silt of 18,770 ± 310 B.P. (ISGS-1500) and 18,690 ± 610 B.P. (ISGS-1498) indicate a Woodfordian age. From a channel at the very base of a section several hundred meters upstream, there is an age of 19,200 ± 420 B.P. (ISGS-1789) indicating aggradation began at least this early (Table 5). Radiocarbon ages, a conformable contact with the Peoria Loess, and lack of Roxana Silt all indicate the terrace is late Wisconsinan in age, and not Illinoian.

The sediment assemblage underlying this terrace is unmistakably that of the "Brussels Formation" described by Rubey (1952) for this reach of the Mississippi Valley. Similar sediment assemblages were examined below several other 520 ft (158.5 m) land surfaces along this reach of the valley. The lack of similar deposits in the type area in the lower Illinois Valley and widespread presence in the Mississippi Valley leads to renaming of the terrace level after the town of Gilead, Calhoun County, Illinois, the closest town to Salt Spring Hollow where the terrace and associated deposits are well represented (Hajic, 1990). This level is the highest recognized in the St. Charles Terrace Family.

The age of the Gilead terrace level refutes the Illinoian ice or till dam hypothesis (Rubey, 1952; Leighton and Brophy, 1961; Goodfield, 1965) as cause for the Brussels Terrace and other correlative terraces. Furthermore, it negates the redefinition of the Brussels Terrace forwarded by Allen and Ward (1978). The late Wisconsinan age for the Gilead level does not nullify the possibility there are fragments of an Illinoian terrace, potentially at about the same altitude, in the Three Rivers Area (cf. O'Fallon Park Section of Rubey, 1952). Except for one core at Arrowhead Industrial Park where rhythmically bedded sediment is reported modified by the Sangamon Geosol (Allen and Ward, 1978), investigated terraces produced no evidence to support a lake behind an Illinoian glacial ice or till dam. In addition to the Arrowhead Industrial Park core, only four sections have been cited north of St. Louis where Roxana Silt buried, or Sangamon

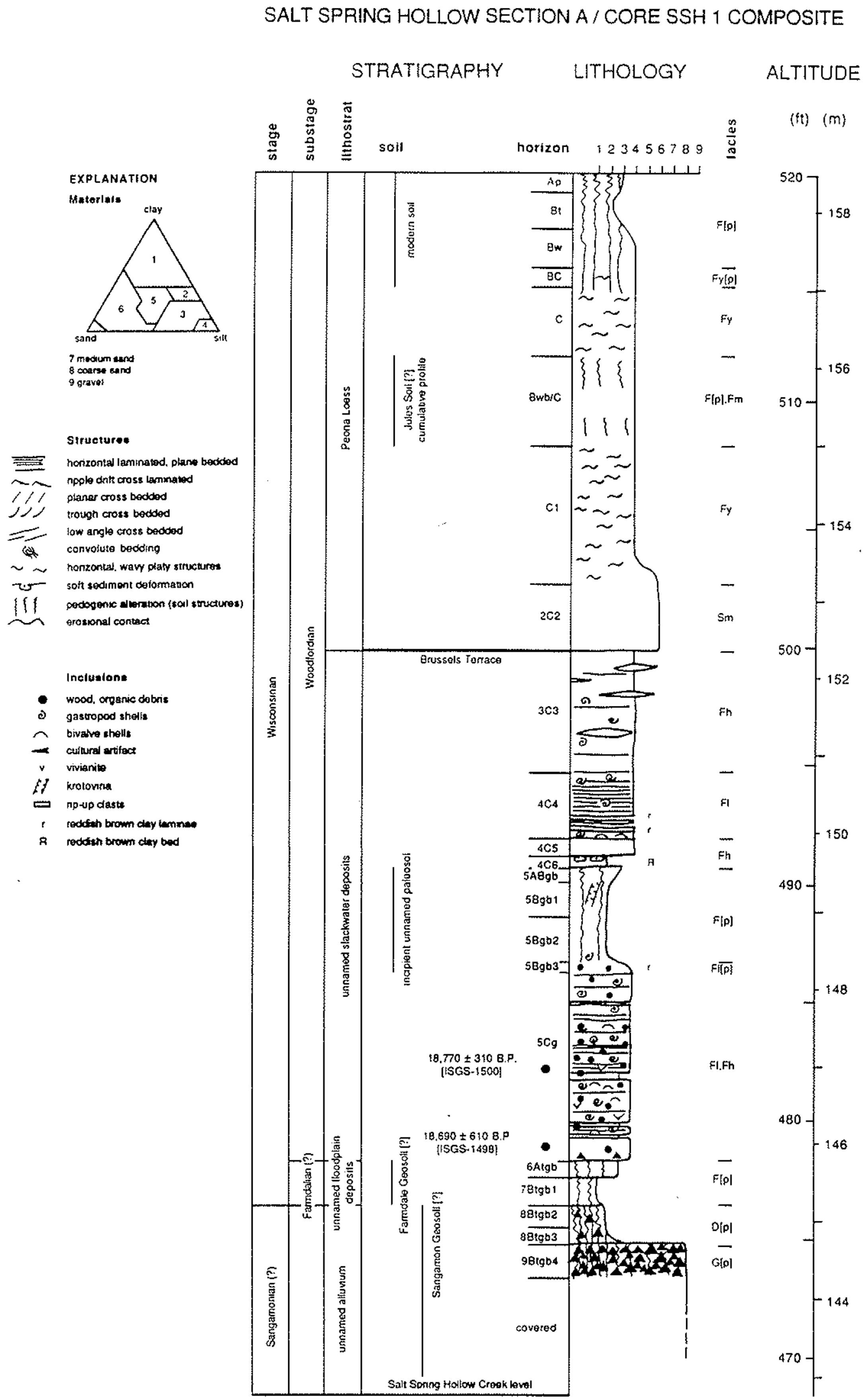

Figure 30. Stratigraphy and sediment logs of Salt Spring Hollow and the Brussels Terrace (St. Charles Terrace) sediment assemblage.

Section:	composite of Salt Spring Hollow Section A and core SSH-1
Location:	NW SW SE 8 T11S R2W (Foley 7.5' quadrangle)
Landscape Position:	cutbank, south side of creek, into broad terrace defined by 520 ft contour, in mouth of Salt Spring Hollow, 0.2 km east of Mississippi Valley
Altitude:	520 ft (158.5 m)
SCS Mapped Soil Series:	Seaton silt

Depth (m)	Horizon	Description
Peoria Loess		
modern solum		
0.00 - 0.24	Ap	silt; very dark brown (10YR 2/2) silt loam; moderate crumb; friable; leached; abrupt boundary.
0.24 - 0.72	Bt	silt; brown to dark brown (7.5YR 4/4) silty clay loam; moderate medium subangular blocky; firm; leached; clear boundary.
0.72 - 1.20	Bw	silt; dark yellowish brown (10YR 4/4) silt loam; weak coarse subangular blocky; friable; leached; clear boundary.
1.20 - 1.46	BC	silt; yellowish brown (10YR 5/4) silt; moderate fine platy; friable; leached; abrupt boundary.
1.46 - 2.36	C	silt; grayish to light olive brown (2.5Y 5/3) silt; strong fine platy; very friable; strongly effervescent; clear boundary.
Jules Soil (?)		
2.36 - 3.52	Bwb/C	silt; brown (10YR 5/3) down to grayish brown (10YR 5/2) silt, common medium and coarse dark yellowish brown (10YR 4/6) mottles; massive with zones of very weak coarse subangular blocky; friable; slightly effervescent, dolomitic; few medium vertical pores partially filled with silt; few hydromorphic bands at and near base; abrupt boundary.
3.52 - 5.29	C1	silt; grayish brown (2.5Y 5/2) silt, sand content increases with depth in lower half, common medium and coarse dark yellowish brown (10YR 4/6) mottles; strong medium wedge platy down to moderate medium and coarse wedge and horizontal platy; friable; violently down to strongly effervescent; clear boundary.
5.29 - 6.15	2C2	sand; dark yellowish brown (10YR 4/6) fine sand; massive to loose, single grain; abrupt boundary.
unnamed alluvium, slackwater facies		
Brussels Terrace (St. Charles Terrace Group, Gilead Level)		
6.15 - 7.71	3C3	silt; light olive brown (2.5Y 5/6, 5/4) silt, common olive brown (2.5Y 4/6) and olive yellow (2.5Y 6/6) fine sand lenses up to 0.05 m thick, many medium and coarse grayish brown (2.5Y 5/2) mottles; thin to medium bedded, poorly expressed; friable; violently effervescent, few fine secondary carbonate nodules; common gastropods; gradual boundary.
7.71 - 8.56	4C4	silt; light olive brown (2.5Y 5/4) and dark yellowish brown (10YR 4/6) silt and dark brown to brown (7.5YR 4/4) silty clay loam, common medium grayish brown (2.5Y 5/2) and dark yellowish brown (10YR 3/6) mottles; thickly laminated to thinly bedded, horizontal to very slightly wavy, strongly expressed; friable; violently effervescent; few gastropods; clear boundary.
8.56 - 8.79	4C5	silt; light olive brown (2.5Y 5/4) silt, many medium light olive brown (2.5Y 5/6) mottles and few fine and medium dark yellowish brown (10YR 4/6) mottles; single thin bed, thins to west, highly distorted; friable; violently effervescent, common secondary carbonate nodules; common gastropods, few large bivalves at basal contact; abrupt and highly irregular boundary.
8.79 - 8.94	4C6	clay; dark brown to brown (7.5YR 4/4) silty clay and silty clay loam; single thin bed, thickens to west, highly distorted; firm; violently effervescent; clear to abrupt smooth boundary.
unnamed paleosol		
8.94 - 9.12	5ABgb	silt; dark gray (5Y 4/1) surficially weathered to brown (10YR 4.5/3) silt loam, common thin dark yellowish brown (10YR 3/6) iron coatings and few thin grayish brown (2.5Y 5/2) silans; moderate medium subangular blocky; friable; violently effervescent; few bivalves, gastropods and zones of shell

		"hash"; common coarse burrows filled with dark brown (7.5YR 3/4) silty clay loam; clear boundary.
9.12 - 9.57	5Bgb1	silt; dark gray (5Y 4/1) surficially weathered to dark yellowish brown (10YR 3.5/4) silty clay loam, many thin dark yellowish brown (10YR 3/6) iron coatings; moderate medium breaking to fine subangular blocky; firm; violently effervescent; many very fine, fine and medium pores with many thin to moderately thick iron linings; clear boundary marked by dark gray (5Y 4/1) and gray (5Y 5/1) silty clay loam, massive, very firm, "nodules" up to 0.20 m long surrounded by slightly stronger oxidized zones.
9.57 - 10.15	5Bgb2	silt; dark gray (5Y 4/1) silty clay loam, many thin dark yellowish brown (10YR 3/6) iron coatings; moderate medium subangular blocky; firm; violently effervescent; common very fine, fine and medium pores with many thin to moderately thick iron linings; common pieces decomposed organic matter; few gastropods; clear boundary.
10.15 - 10.28	5Bgb3	silt; dark gray (N 4/0) silty clay loam to silt loam at base; strong medium breaking to fine subangular blocky, continuous thin dark yellowish brown (10YR 3/6) iron coatings; very firm; violently effervescent; very few fine pores; common fine uncarbonized organic matter pieces; few gastropods; clear boundary.
10.28 - 12.70	5Cg	silt; dark gray (5Y 4/1), dark greenish gray (5GY 4/1), and dark gray to dark brown (7.5YR 4/1; upper half only) silt and silt loam, some silty clay loam, very few pebbles in lower 0.40 m; laminated to thin bedded, horizontal to slightly wavy, moderately expressed, one area bedding dips steeply (up to 21^0) upvalley; strongly to violently effervescent; common to abundant fine uncarbonized organic matter, including needles, seeds, moss, and insect parts, with zones of common coarse pieces of *Picea* wood; common gastropods; few to common bivalves in lower 1/2; very abrupt boundary.
unnamed alluvium, floodplain overbank facies (?)		
Farmdale Geosol (?)		
12.70 - 12.92	6Atgb	silt; olive gray (5Y 5/2) heavy silt loam, very few pebbles within 0.05 m of lower contact; moderate medium to fine angular blocky, common thin very dark grayish brown (2.5Y 3/2) argillans; firm to friable; very slightly effervescent; very abrupt boundary; pinches out to the east.
unnamed alluvium		
multistory paleosol, Sangamon (?) or Yarmouth (?)		
12.92 - 13.27	7Btgb1	clay; dark greenish gray (5GY 4/1 to 5BG 4/1 at base) silty clay, very few chert pebbles in upper 0.05 m and at upper contact; moderate coarse to medium subangular blocky, common moderately thick dark yellowish brown (10YR 3/4, 3/6) and few thin olive gray (5Y 4/2) argillans; very firm; very slightly effervescent, few fine secondary carbonate nodules; very few pieces of wood in upper 0.10 m; common slickensides; gradual boundary.
13.27 - 13.57	8Btgb2	diamicton; dark greenish gray (5G 4/1 to 5BG 4/1) silty clay loam to silty clay diamicton, very few fine chert pebbles; moderate coarse to medium subangular and angular blocky, many thin olive gray (5Y 4/2) and dark yellowish brown (10YR 3/4) argillans and iron coatings; firm; leached, few fine secondary carbonate nodules; clear boundary.
13.57 - 13.79	8Btgb3	diamicton; olive gray to olive (5Y 4/2.5) silty clay diamicton, common very fine and fine chert pebbles, many fine and medium dark yellowish brown (10YR 3/4) mottles; moderate coarse subangular blocky and angular blocky, many moderately thick to thick dark yellowish brown (10YR 3/6) argillans and iron coatings; firm; leached; abrupt boundary.
13.79 - 14.22^+	9Btgb4	gravel; very fine and fine chert gravel with olive gray (5Y 5/2) silty clay loam matrix, many fine light olive brown (2.5Y 5/4) mottles; moderate angular blocky with continuous thin to thick dark yellowish brown (10YR 3/4, 3/6) argillans and iron coatings; firm; leached; base not exposed.
14.22 - 15.72		covered to creek level.

notes: In SSH-1, unit between 6.15 and 7.71 is 3.00 m thick.

Geosol modified, sediments of the "Brussels Formation" (two each by Rubey [1952] and Leighton and Brophy [1961]; no locations or descriptions supplied).

Goodfield's (1965) attempt at correlation of higher terraces in the region was hampered by having to account for his relatively high Chain of Rocks Terrace by an awkward hypothesis involving large-scale mixing of floodplain and Altonian valley train sediments (Table 2). Such reasoning was required because radiocarbon samples yielding Altonian ages were given credence over sedimentology and stratigraphy at the Chain of Rocks Section. The simplest explanation, judging from Goodfields section description and proximity to other recognized outcrops of Illinoian diamicton (Leverett, 1899; Robertson, 1938; others), is that "till-like" material in the section, from which the dated wood was recovered, is indeed an Illinoian diamicton, thus suggesting the alternative interpretation that the radiocarbon age estimates are in error. To date, no other evidence of an Altonian age floodplain has been identified definitively, and the Altonian Roxana Silt is commonly found at considerably lower altitudes along principal valleys in the Three Rivers Area. This assessment does not exclude the possibility that the top of sand and gravel immediately overlying diamicton at the Chain of Rocks Section marks a buried terrace. Unfortunately, description of the Chain of Rocks cut does not explicitly state whether Roxana Silt is present over the sand and gravel, thus leaving to question whether the coarse sediments are Illinoian proglacial or supra-glacial, Sangamonian, or potentially much younger fluvial or glaciofluvial deposits.

In addition to the Brussels Terrace along the west side of Calhoun County, the Gilead level likely encompasses the Flourissant Basin Terrace. Descriptions provided by Goodfield (1965) of sections and cores from the floor of the Flourissant Basin give no indication that the Roxana Silt is present immediately below Peoria Loess. The basin's latest episode of infilling was probably coincident with aggradation to the Gilead or Cuivre level. Unnamed high terrace remnants in lower Missouri Valley tributaries (Goodfield, 1965) probably correspond with remnants mapped by Robertson (1938) as Cuivre Terrace in some of the same tributaries and are most likely part of the Gilead level. Beouf Terrace (Robertson, 1938) rests at higher altitudes and therefore probably pre-dates the Gilead level. Lack of stratification and the presence of coarse erratics suggest it may be related to a pre-Wisconsinan erosion surface.

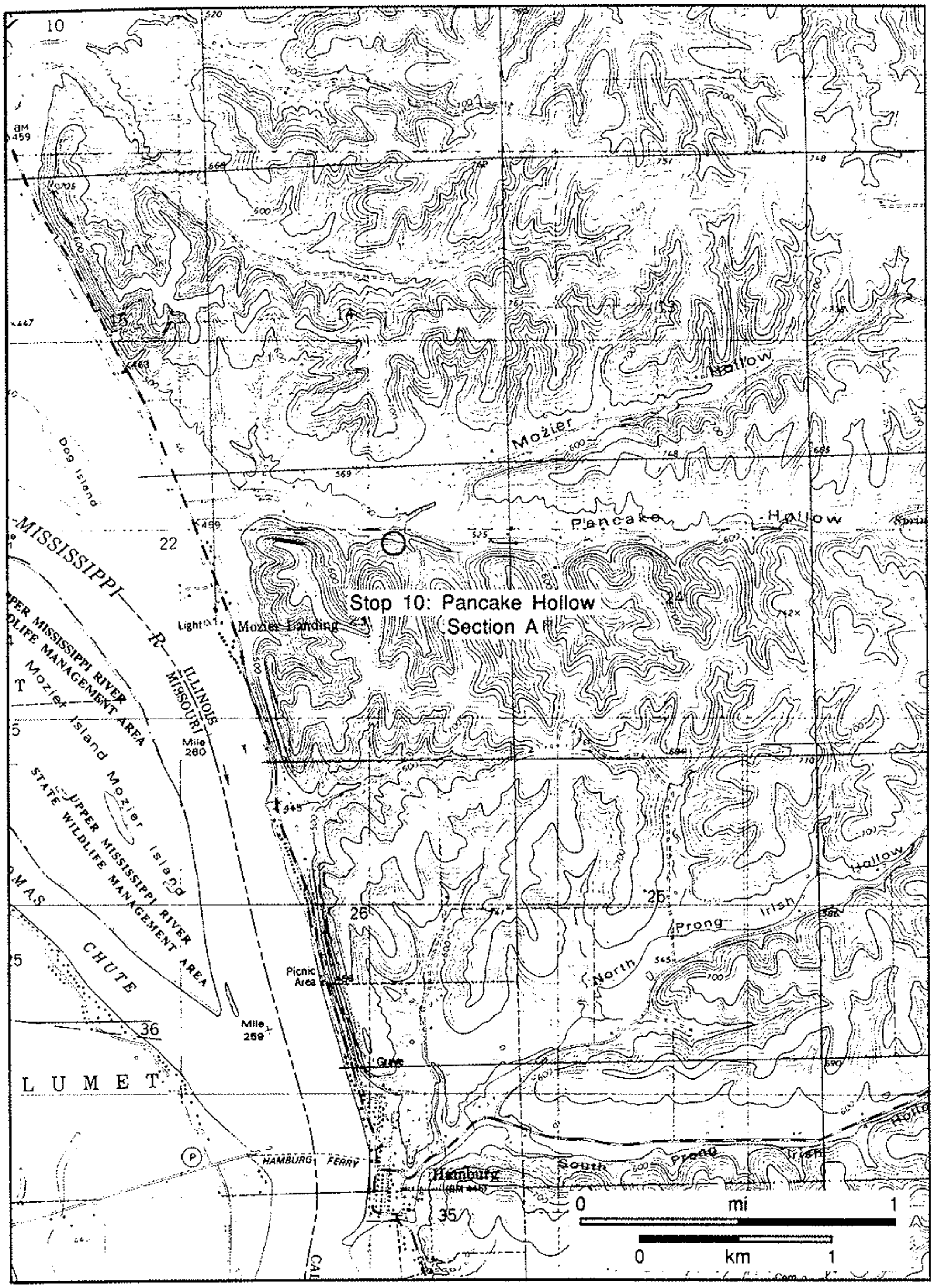

Figure 31. Location of the Pancake Hollow Section, NE SW NE 23 T9S R3W, Pleasant Dale Valley 7.5' quadrangle.

STOP 10. PANCAKE HOLLOW

Reprinted from: Quaternary records of southwestern Illinois and adjacent Missouri, Illinois State Guidebook 23

INTRODUCTION

Pancake Hollow Section 1, 1 km east of the Mississippi Valley at the junction of Mozier and Pancake hollows (Fig. 31), is a previously undescribed cutbank exposure. It formed in 1982 when Pancake Hollow Creek undercut its south bank. This is the first reported exposure in unglaciated west-central Illinois of multiple pre-Wisconsinan silts of loessial origin with intervening paleosols. The roughly 15 m cut exposes at least two, and possibly four, pre-Wisconsinan paleosols and four silt-dominated loess or loess-derived deposits. All of these deposits are below relatively high level tributary creek chert gravels, Loveland Silt, Sangamon Soil, Roxana Silt, Farmdale Soil, and Peoria Loess. All deposits are continuous across the outcrop. The section was described and sampled in November, 1985, although investigations of this section and other cutbank exposures to the east are still in early stages.

LANDSCAPE POSITION

Deposits exposed at Pancake Hollow Section 1 are associated with a remnant of a high level surface that slopes toward the hollow axis from about 170 to 180 m (560 to 600 ft). This high level surface locally forms a dissected bench up to 1.5 km wide, typically at about 188 m (620 ft), along the east side of the Mississippi Valley south of Pancake Hollow. Drainage divides in the area are at about 224 m (740 ft) and the nearby Mississippi Valley flood basin is at about 132 m (435 ft). To the south, the surface forms a dissected bedrock-walled valley that Rubey (1952) called the "Batchtown channel". The outlet of the "Batchtown channel" is obscured south of the Cap au Gres faulted flexure, an east-west trending monoclinal fold with downthrown side to the south, where the landscape contrasts sharply with that north of the fault.

DESCRIPTION AND INTERPRETATION

At the base of the section (Fig. 32), Unit 1 is a leached dark yellowish-brown to dark brown silty clay loam diamicton that grades upward to a pebbly silty clay loam with decreasing pebble frequency. Pebbles also rapidly decrease in frequency near and below creek level. Clasts are subangular to angular chert and can be in excess of 0.40 m in diameter. Sand content (about 4 %, primarily consisting of chert) and a ratio of very coarse (31-63 um) to coarse silt (16-31 um) of about 1.1 $\pm$ 0.1 remain nearly uniform throughout the unit. The unit is at least 2.73 m thick; its base is not exposed at this section but to the east, Unit 1 overlies the Hannibal Shale.

The entire unit is pedogenically altered with strong soil expression; it exhibits subangular and angular blocky soil structure, a Bt horizon roughly centered on the zone with the largest frequency of chert clasts, large oxide concretions up to

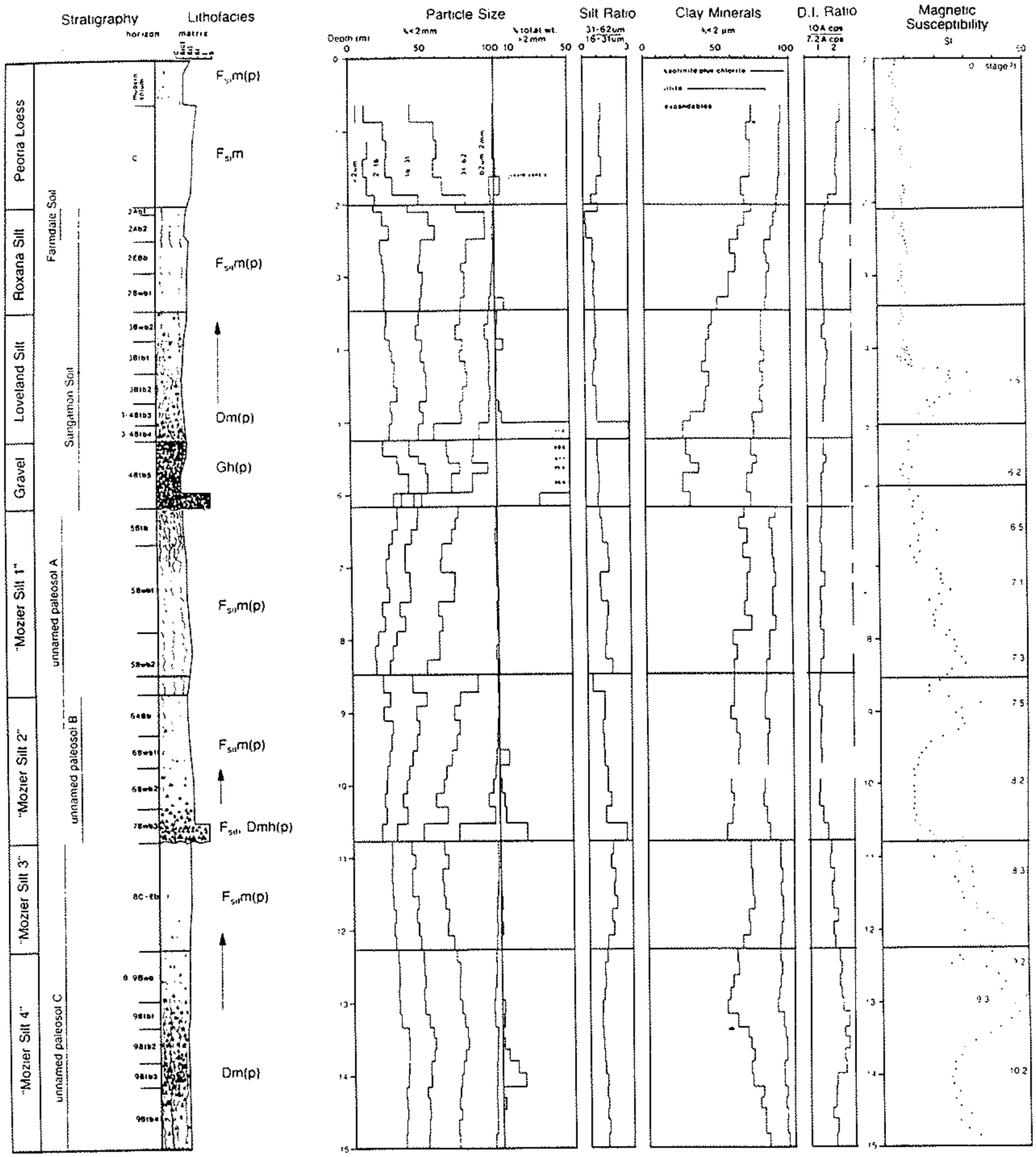

Figure 32. Sediment log, particle size, clay mineral, and magnetic susceptibility data for the Pancake Hollow Section.

3 cm in diameter, and many pores. The apparent decrease in percent expandable clays centered slightly above the Bt maximum is a result of weathering and is reflected in the Heterogeneous Swelling Index (HSI). Clay mineralogy (<2 um) averages 79% expandables, 15% illite and 6% kaolinite plus chlorite in the lower 0.85 m of the sampled unit where clay mineralogy apparently is least altered by weathering.

The diamicton facies of Unit 1 are interpreted as colluvium and the upsection decreases in pebbles, in part, may reflect initial eolian influx of the overlying silt. Unit 1 differs markedly from the relatively thick, strongly oxidized, cherty clay diamicton weathering mantle. The material, often referred to as "residuum", is commonly found on upland divides overlying bedrock and underlying Wisconsinan loesses in Calhoun County. The matrix of Unit 1 is texturally and clay mineralogically similar to loess, implying it is probably loess derived with further implications that the original eolian deposit records a glacial interval. The strong degree of soil expression, similar to both Sangamon and modern soils, suggests the paleosol developed during at least one interglacial interval.

Unit 2 is a 1.5 m thick unbedded, primarily leached yellowish to olive brown heavy silt loam. Krotovina 2-3 cm in diameter in the uppermost part of the profile are filled with sediment from the overlying unit. Sand content is small, and along with clay content, decreases slightly upward. The silt ratio is nearly uniform, averaging about 1.7, with appreciably greater very coarse silt content than Unit 1. Unit 2 conformably overlies Unit 1, grading downward into it; the gradual boundary is reflected in transition zones of the very coarse silt component, very coarse to coarse silt ratio, clay mineral percentages, and occasional very fine chert pebbles in the lower part of Unit 2. Similar to Unit 1, it contains abundant expandable clay minerals and relatively small amounts of illite and kaolinite plus chlorite. The composition is nearly identical to the clay mineral composition of the Peoria Loess. Expandable clay minerals and kaolinite plus chlorite average 8% less and 3% more, respectively, than the least altered clay mineral assemblage of Unit 1.

The massive character and uniform silt-dominated texture of Unit 2 suggest that it is a loess. Larger silt ratios than Unit 1 and clay mineral differences indicate that Unit 2 was not derived from Unit 1 but rather is a distinct deposit. The gradual boundary between the two units suggests that the rate of Unit 2 deposition initially was relatively slow creating a cumulative profile with pedogenic mixing. Unit 2 was modified by pedogenic processes related to a younger upper solum of the underlying soil. Unit 2 loess signifies a second glacial interval.

Unit 3 and Unit 4 are both fining upward sequences, leached and pedogenically altered to varying degrees. The lower sequence, Unit 3, 2.04 m thick, unconformably overlies Unit 2 and consists of a basal bed of crudely stratified brown sandy loam diamicton, silt loam and pebbly silt loam. To the west this bed thins and exhibits a sharper contact. It is overlain by three crudely defined massive beds of silt loam and heavy silt loam with few chert pebbles decreasing upwards. Sand content decreases rapidly upward.

The upper sequence, Unit 4, is a 2.55 m dark yellowish brown silt loam that grades up to silty clay loam and exhibits no visible bedding. The boundary with Unit 3 is clear to gradual. There is negligible sand throughout. Very coarse silt, reaching 40%, decreases as clay increases upward. Silt ratios are similar to Unit 3 but are more variable. Few fine chert pebbles occur in the uppermost 0.30 m as do krotovina filled with sediments from overlying units. The entire unit is modified by the lower horizons of an erosionally truncated soil. The base of the Bt horizon of this soil is preserved but the weathering is not reflected in the HSI.

Clay mineral content of Units 3 and 4 is again dominated by expandables, but they comprise a lesser fraction than in underlying Units 1 and 2, as kaolinite content is greater. Within Unit 4, approximately 0.85 m from its base, there is an abrupt but slight change in relative clay mineral frequencies. Expandable clay minerals increase while kaolinite plus chlorite decrease to a lesser degree.

Unit 3 is interpreted as a fluvial and/or colluvial deposit that was eventually swamped by loess accumulation. The abrupt basal erosional contact suggests some initial fluvial activity. Chert pebbles in the silty matrix suggest colluviation or fluvial overbank deposition. Pedogenic alteration of the entire unit indicates either relatively slow loess accumulation with concomitant soil formation, or modification by the soil in Unit 4.

Unit 4 is interpreted as a loess based upon grain size, clay mineralogy and its massive character. Some colluvial additions at the top of the sequence are suggested by the presence of a few chert clasts. Clay mineral similarities and the lack of a strong soil at the top of Unit 3 suggest that Units 3 and 4 are closely related. Along with the strongly developed soil in Unit 4, they represent at least one glacial interval followed by at least one interglacial.

Crude thin beds of Unit 5, consisting of chert pebbles and cobbles and containing relatively small amounts of leached sand and fines, unconformably overlie Unit 4. Beds range from 0.10 to 0.27 m thick and have a cumulative thickness of about 0.95 m. Beta horizon development modifies the whole unit; it is enriched with translocated clay related to development of the Sangamon Soil in sediment immediately overlying Unit 5. In addition, a later generation of calcareous silans occurs sporadically.

Unit 5 is interpreted as alluvium; it is texturally similar to local modern stream bedloads and bars while the crude bedding and general lack of matrix argue against a colluvial origin.

At Pancake Hollow the overlying unit is in the stratigraphic position of the Illinoian Loveland Silt. It is a leached silty clay loam diamicton grading up to a pebbly silty clay loam that probably overlies Unit 5 conformably. Sand content is nearly uniform, pebbles generally decrease in frequency upward, and silt ratios, except for the basal sample, are uniformly small throughout. The entire unit is modified by pedogenic processes; Bw and Bt horizonation is expressed downward through the unit. Expandable clay minerals show an apparent decrease in percent downward and the HSI was unmeasurable reflecting the increase in intensity of weathering.

The diamicton comprising Unit 5 is interpreted to be a colluvial facies of Loveland Silt, possibly with an initial alluvial overbank component. The uppermost chert pebbles and associated slight increase in sand content may be pedisediment reflecting the complex interaction of slope processes and soil formation. The soil is interpreted to be the Sangamon Soil.

Loveland Silt is conformably overlain by a 1.86 m increment of leached, dark brown to dark yellowish brown silt interpreted to be Wisconsinan Roxana Silt. At Pancake Hollow there are two Roxana Silt components. The lower is a heavy silt loam with sand decreasing upward. It is modified pedogenically and is interpreted to be the upper horizons of the Sangamon Soil. The upper component primarily is a massive, light silty clay loam to heavy silt loam with little very coarse silt and negligible sand. It is modified by the Farmdale Soil. Roxana Silt is overlain by up to 5.0 m of Peoria Loess, the upper part of which has been modified by pedogenesis related to the modern soil at the ground surface. Color change at the Roxana Silt-Peoria Loess contact is abrupt but textural and clay mineralogical trends across the boundary suggest there máy be some minor pedogenic mixing. Peoria Loess is an unleached light silt loam to silt primarily consisting of very coarse and coarse silt. Banding may reflect original bedding to some degree, but is prmarily due to different weathering zones. Secondary carbonate nodules are common towards the base of the Peoria Loess. The base of the modern soil Bt horizon is abrupt. The abrupt change likely represents the contact of a slip plane due to mass movement of the overlying pedogenically altered material.

DISCUSSION

There is evidence at Pancake Hollow for a minimum of 5 pre-Wisconsinan glacial intervals (loess-derived silt in Unit 1, loesses of Units 2, 3, and 4, and loess-derived silt in the Loveland) and 3 interglacial soil-forming intervals, not including the 2 weaker soils developed in Units 2 and 3. The truncated Bt horizon in the upper part of Unit 4 probably represents a distinct pre-Sangamonian interglacial soil-forming interval. Clay mineralogy and the HSI indicate translocation of weathered clay during the Sangamonian did not cross the boundary between Units 4 and 5. Furthermore, if the fluvial interpretation of Unit 5 is correct, these deposits must predate the Sangamonian because Sangamon Soil is developed in deposits at lower altitudes along tributary valley slopes in the area. Also, the relative altitude of the Sangamonian Ancient Iowa River flowing in the Mississippi Valley was considerably lower than the river to which Unit 5 was graded.

At this early stage of investigation, possible regional correlations are speculative at best; the geographic extent of pre-Wisconsinan loesses and paleosols, except for the Sangamon Soil, is not well know. Further complications arise from the present lack of any direct link to till units, erosional gaps in the record, and the potential complexity of the paleosols. Nevertheless, Pancake Hollow is not unique and other sections with multiple Illinoian and older loesses and paleosols hold promise for development of a regional stratigraphy.

Within the "Batchtown channel" Rubey (1952) identified crudely bedded outwash gravel and sand that he related to pre-Illinoian ("Kansan") glaciation in Missouri with an ice margin in the Mississippi Valley. This coarse deposit is overlain by a 3-4 m thick paleosol in strongly weathered, locally gravelly, sandy clay which in turn is overlain by brown clayey silt "that is indistiguishable from loess". Water wells in the channel indicate that over 20 m of unlithified deposits overlie bedrock. Field reconnaissance has identified mutliple silts in cutbanks around the town of Batchtown. Based upon similar landscape positions, altitudes, and general degree of weathering, the basal paleosol at Pancake Hollow and the paleosol in the "Batchtown channel" described by Rubey likey are correlative.

If the "Kansan" drift in the "Batchtown channel" and on the uplands in nearby Missouri is the youngest pre-Illinoian drift, correlative with the Wolf Creek Formation defined in Iowa (Hallberg, 1980), then the basal paleosol at Pancake Hollow is probably the Yarmouth Soil. If the basal paleosol is the Yarmouth Soil, then Units 2 through 5 belong to the Loveland Silt by definition (Willman and Frye, 1970). Alternatively, the till may correlate with the older Alburnett Formation (Hallberg, 1980) and the basal soil would be pre-Yarmouthian. In either case, the paleosol indicates a pre-Illinoian Ancient Iowa River Valley floor at a relative altitude probably no higher than the modern Mississippi Valley.

Exploratory cores at and south of the Cap au Gres fault on the east side of Calhoun County indicate that at least part of the pre-Woodfordian landscape is developed on multiple pre-Sangamon silts, similar to those exposed in Pancake Hollow, and possibly deposited in the lee of bedrock highs to the west and north. It is probable that one or more of the loesses at Pancake Hollow correlate to the Burdick, Maryville, or Chinatown silts examined at Stop #4 (McKay, this volume; 1979).

Pancake Hollow illustrates the complexities that can arise from the interaction of loess accumulation, colluviation and pedogenic processes. The proximity of the section to the uplands explains why colluviation was a significant and at times dominating process. The next cutbank to the east (Pancake Hollow Section 2) was even closer to the uplands and exhibits a larger colluvial component. The pattern exhibited by the Loveland Silt colluvial facies, Sangamon Soil, Roxana Silt and Farmdale Soil is repeated by the soil and deposits of Units 1 and 2, and to some degree, the roots of the soil at the top of Unit 4. Colluviation is followed and probably accompanied by interglacial soil formation. The contact with the overlying loess is gradual with varying degrees of pedogenic mixing and physical reworking. With relatively thin or slow loess deposition as the next glacial cycle begins, further soil formation modifies the loess and appears as an over thickened upper solum associated with the Bt horizon of the underlying interglacial soil.

REFERENCES

Hallberg, G. R., 1980, Pleistocene stratigraphy in east-central Iowa: Iowa Geological Survey Technical Information Series, Number 10.

McKay, E. D., III, 1979, Stratigraphy of Wisconsinan and older loesses in south-western Illinois: Illinois State Geological Survey Guidebook Series 14, p. 37-67.

Rubey, W. W., 1952, Geology and mineral resources of the Hardin and Brussels quadrangles (in Illinois): United States Geological Survey Professional Paper 218.

Willman, H. B., and Frye, J. C., 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey Bulletin 94.

MAGNETIC SUSCEPTIBILITY INTERPRETATION OF PANCAKE HOLLOW SECTION

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Magnetic susceptibility was measured in the field with a portable Bartington meter and probe. Each susceptibility data point (see figure 33) is an average of three lateral readings.

Low susceptibility readings in the Peoria Loess and Roxana Silt are associated with gleying. Under reducing conditions, primary magnetite in the loess has been dissolved or transformed into weakly magnetic iron oxides. Typical values for nongleyed Wisconsinan loesses in the region are five to ten times higher (see the Magnetic Susceptibility Interpretation of Green Bay Hollow and the contributing paper later in this guidebook).

High readings in the Loveland Silt are associated with reddish or purplish hues in the Bt horizon of the Sangamon Geosol. The higher readings could be the result of the formation of very fine-grained magnetite and/or maghemite and the subsequent translocation of these minerals in the fine clay fraction. The good drainage of this paleosol would have been conducive to the in-situ production of ferrimagnetic minerals during the Sangamonian.

Low readings in the gravelly beds are to be expected, due to the abundance of chert and the scarcity of ferrimagnetic minerals in locally derived sediments. Low readings in the upper portion of Mozier Silt 1 and in Mozier Silt 2 are associated with the clay-rich sediments (silty clay loam). Primary magnetite would be less common in the clay fraction than in the silt fraction, so these low readings may be lithogenic, in part. However, since the clay-rich sediments are poorly drained, they tend to be gleyed, moreso than the silt-rich sediments. The reducing conditions associated with gleying could result in the weathering of magnetite as Paleosols A and B developed. The upper portion of Mozier Silt 1 could have been gleyed during the Sangamonian or even recent times.

High susceptibilities in lower Mozier Silt 1, Mozier Silt 3, and Mozier Silt 4 occur in silt-rich sediments (more "loess-like") with little or no gravel. Their readings are higher probably because there was more primary magnetite in these deposits and also because these coarser-textured sediments remained moderately well drained and did not experience intense reducing conditions. Lower readings in the middle of Mozier Silt 4 are associated with an increase in chert gravel.

Susceptibility trends in figure 33 are extremely similar to those measured by George Kukla in 1987 at the same section with a similar meter and probe (see figure 32). Further study may provide insights as to the lithologic and pedologic origins of the susceptibility trends. Magnetic susceptiblity may also prove to be useful as a correlation tool for the Mozier Silt units.

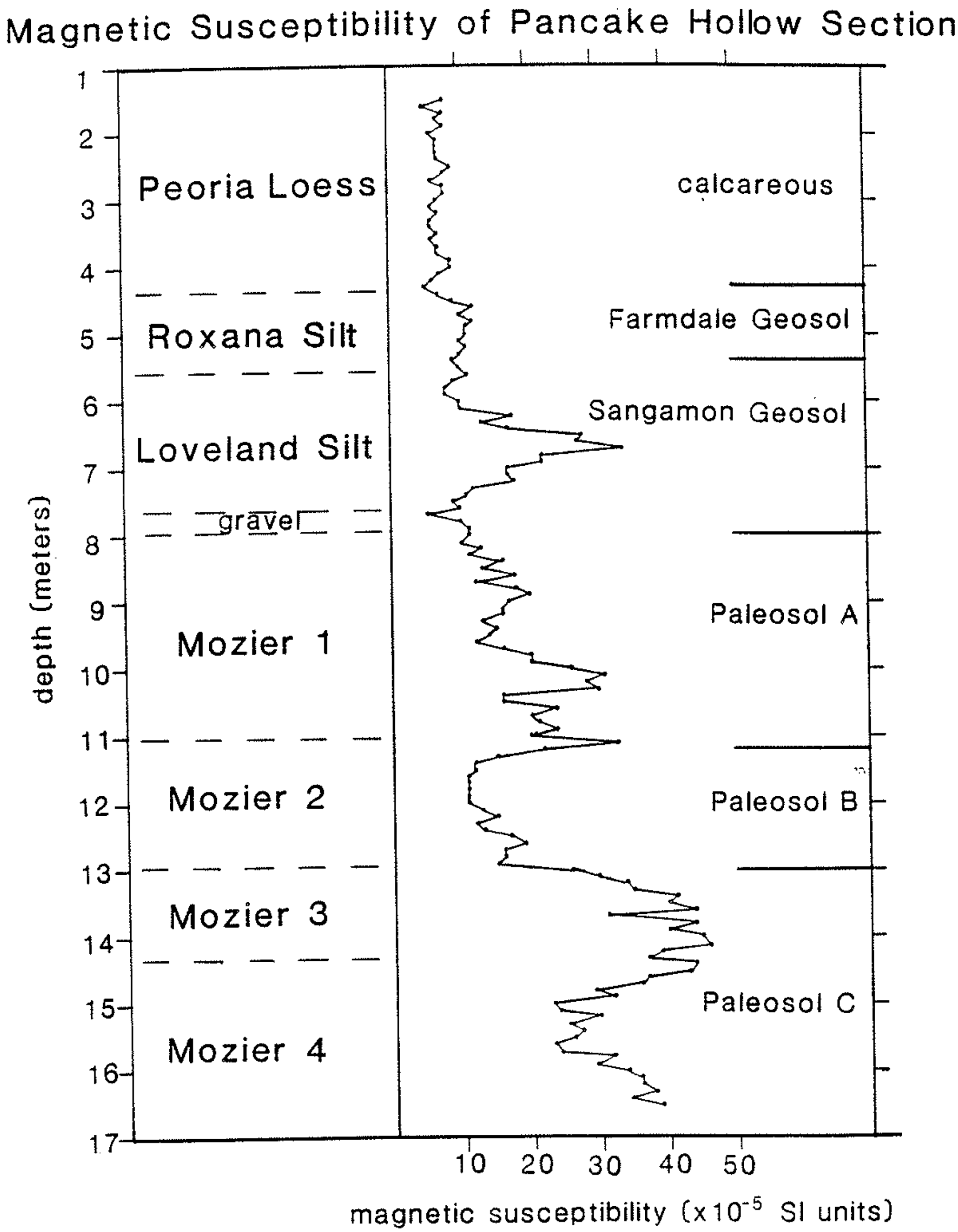

Figure 33. Magnetic susceptibility of Pancake Hollow Section.

REFERENCES CITED

Allen, W.H., Jr., and Ward, R.A. 1978. The Brussels Formation - A stratigraphic re-appraisal. In, *Quaternary Soils*, Mahaney, W.C. (ed.), p. 167-185. Geo Abstracts, Norwich England.

Anderson, R.C. 1968. Drainage evolution in the Rock Island area, western Illinois, and eastern Iowa In, The Quaternary of Illinois, Bergstrom, R.E. (ed.), p. 11-18. University of Illinois, College of Agriculture, Urbana.

Bettis, E.A., III. 1988. Quaternary history, stratigraphy, geomorphology, and pedology. In, *Archaeology and Geomorphology in Pools 17 & 18, Upper Mississippi River*, Benn, D.W., Bettis, E.A., III, and Vogel, R.C., p. 18-91. Center for Archaeological Research, Southwest Missouri State University, Springfield.

Bettis, E.A., III, and Hallberg, G.R. 1985. The Savanna (Zwingle) Terrace and "red clays" in the Upper Mississippi River valley: stratigraphy and chronology. In, *Pleistocene Geology and Evolution of the Upper Mississippi Valley: A Working Conference, Abstracts and Field Trip Guide*, Lively, R.S. (coord.), p. 41-43. Minnesota Geological Survey, St. Paul.

Bicki, T.J. 1981. Geomorphology, stratigraphy, and soil development in the Iowa and Cedar River valleys in southeastern Iowa. Unpublished Ph.D. dissertation, Iowa State University, Ames, 338 p.

Butzer, K.W. 1977. Geomorphology of the lower Illinois Valley as a spatial-temporal context for the Koster Archaic Site. Illinois State Museum Reports of Investigations 34, 60 p.

Clayton, L. 1983. Chronology of Lake Agassiz drainage to Lake Superior. In, *Glacial Lake Agassiz*, Teller, J.T. and Clayton, L. (eds.), p. 290-307. Geological Association of Canada Special Paper 26.

Clayton, L. and Moran, S.R. 1982. Chronology of late Wisconsinan glaciation in middle North America. Quaternary Science Reviews 1: 55-82.

Drushel, J.A. 1911. Studies in glacial geology in St. Louis and vicinity. St. Louis Academy of Science Transactions 20: 27-36.

Eschman, D.F. and Mickelson, D.M. 1986. Correlation of glacial deposits of the Huron, Lake Michigan and Green Bay Lobes in Michigan and Wisconsinan. In, *Quaternary Glaciations in the Northern Hemisphere*, Sibrava, V., Bowen, D.Q., and Richmond, G.M. (eds.), p. 53-58. Quaternary Science Reviews 5.

Esling, S.P. 1984. Quaternary stratigraphy of the lower Iowa and Cedar River Valleys, southeast Iowa. Unpublished Ph.D. dissertation, University of Iowa, Iowa City, 451 p.

Fenneman, N.M. 1909. Physiography of the St. Louis area. Illinois State Geological Survey Bulletin 12, 83 p.

Fenneman, N.M. 1911. Geology and mineral resources of the St. Louis quadrangle, Missouri - Illinois. United States Geological Survey Bulletin 438, 73 p.

Fenton, M.M., Moran, S.R., Teller, J.T., and Clayton, L. 1983. Quaternary stratigraphy and history in the southern part of the Lake Agassiz basin. In, *Glacial Lake Agassiz*, Teller, J.T. and Clayton, L. (eds.), p. 49-74. Geological Association of Canada Special Paper 26.

Flint, R.F. and Deevey, E.S. 1951. Radiocarbon dating of Late-Pleistocene events. American Journal of Science 249: 257-300.

Flock, M.A. 1983. The late Wisconsinan Savanna Terrace in tributaries to the upper Mississippi River. Quaternary Research 20:2: 165-176.

Frye, J.C. 1961. Fluvial deposition and the glacial cycle. Journal of Geology 69:5: 600-603.

Frye, J.C., Glass, H.D., and Willman, H.B. 1968. Mineral zonation of Woodfordian loesses of Illinois. Illinois State Geological Survey Circular 427, 44 p.

Frye, J.C. and Willman, H.B. 1963a. Loess stratigraphy, Wisconsinan classification and accretion-gleys in central western Illinois. Illinois State Geological Survey Guidebook Series 5, 36 p.

Frye, J.C. and Willman, H.B. 1963b. Development of Wisconsinan classification in Illinois related to radiocarbon chronology. Geological Society of America Bulletin 74:4: 501-506.

Goodfield, A.G. 1965. Pleistocene and surficial geology of the city of St. Louis and the adjacent St. Louis county, Missouri. Unpublished Ph.D. dissertation, University of Illinois, Urbana, 185 p.

Graham, R.W. 1986. Stratified cultural and faunal horizons at Kimmswick, Missouri. In, *Quaternary records of southwestern Illiinois and adjacent Missouri.* Illinois State Geological Survey Guidebook 23: 57-68.

Hajic, E.R. 1985 Terminal Pleistocene events in the Mississippi Valley near St. Louis as inferred from Illinois Valley geology. In, *Pleistocene Geology and Evolution of the Upper Mississippi Valley: A Working Conference, Abstracts and Field Trip Guide*, Lively, R.S. (coord.), p. 49-52. Minnesota Geological Survey, St. Paul.

Hajic, E.R. 1986. The late Wisconsinan Deer Plain Terrace in the lower Illinois River Valley. In, *Quaternary Records of Southwestern Illinois and Adjacent Missouri*, Graham, R.W., Styles, B.W., Saunders, J.J., Wiant, M.D., McKay, E.D., Styles, T.R., and Hajic, E.R., p. 80-89. American Quaternary Association, Ninth Biennial Meeting, Field Guide, Urbana.

Hajic, E.R. 1987a. Geoenvironmental context for archeological sites in the lower Illinois River Valley. Center for American Archeology, Contract Archeology Program, Report of Investigations 184, p.78.

Hajic, E.R. 1990. Late Pleistocene and Holocene landscape evolution, depositional subsystems, and stratigraphy in the lower Illinois River Valley and adjacent central Mississippi River Valley. Unpublished PhD dissertation. Department of Geology, University of Illinois, Urbana, Illinois. 301 p.

Hallberg, G.R. and Kemmis, T.J. 1986. Stratigraphy and correlation of the glacial deposits of the Des Moines and James Lobes and adjacent areas in North Dakota, South Dakota, Minnesota, and Iowa. In, *Quaternary Glaciations in the Northern Hemisphere*, Sibrava, V., Bowen, D.Q., and Richmond, G.M. (eds.), p. 65-68. Quaternary Science Reviews 5.

Kehew, A.E. 1982. Catastrophic flood hypothesis for the origin of the Souris spillway, Saskatchewan and North Dakota. Geological Society of America Bulletin 93: 1051-1058.

Kehew, A.E., and Clayton, L. 1983. Late Wisconsinan floods and development of the Souris-Pembina spillway system in Saskatchewan, North Dakota, and Manitoba. In, *Glacial Lake Agassiz*, Teller, J.T. and Clayton, L. (eds.), p. 187-209. Geological Association of Canada Special Paper 26.

Kehew, A.E. and Lord, M.L. 1986. Origin and large-scale erosional features of glacial-lake spillways in the northern Great Plains. Geological Society of America Bulletin 97: 162-177.

Kemmis, T.J., Quade, D.J., and Bettis, E.A., III. 1985. Stratigraphy and sedimentology of distal late Wisconsinan valley train terraces in north-central Iowa (abstr.). Geological Society of America, North Central Section, Abstracts with Programs, p. 295.

Kerasotes, M.L. 1989. Woodfordian stratigraphy and glacial geology in the upper Illinois Valley region, north central Illinois. Unpublished M.S. thesis. University of Illinois, Urbana.

King, J.E. and Allen, W.H., Jr. 1977. A Holocene vegetation record from the Mississippi River valley, southeastern Missouri. Quaternary Research 8: 307-323.

Leighton, M.M. 1965. The stratigraphic succession of Wisconsin loess in the Upper Mississippi River Valley. Journal of Geology 73:2: 323-345.

Leighton, M.M. and Brophy, J.A. 1961. Illinoian glaciation in Illinois. Journal of Geology 69:1: 1-31.

Leighton, M.M. and Willman, H.B. 1949. Late Cenozoic geology of Mississippi Valley. Itinerary, 2nd Biennial State Geologists Field Conference, Illinois State Geological Survey, 86 p.

Leverett, F. 1899. The Illinois glacial lobe. United States Geological Survey Monograph XXXVIII, Washington, p. 817.

Lilly, M. 1989. Soil survey of Calhoun County, Illinois. United States Department of Agriculture, Soil Conservation Service, Urbana.

Lineback, J.A. 1979. The status of the Illinoian glacial stage. Illinois State Geological Survey Guidebook 13: 69-78.

Liu, C.L., Riley, K.M., and Coleman, D.D. 1986. Illinois State Geo'ogical Survey Radiocarbon Dates VIII. Radiocarbon 28:1: 78-109.

Matsch, C.L. and Schneider, A.F. 1986. Stratigraphy and correlation of the glacial deposits of the glacial lobe complex in Minnesota and northwestern Wisconsinan. In, *Quaternary Glaciations in the Northern Hemisphere*, Sibrava, V., Bowen, D.Q., and Richmond, G.M. (eds.), p. 59-64. Quaternary Science Reviews 5.

McKay, E.D. 1977. Stratigraphy and zonation of Wisconsinan loesses in southwestern Illinois. Unpublished Ph.D. dissertation, University of Illinois, Urbana, 242 p.

McKay, E.D. 1979. Stratigraphy of Wisconsinan and older loesses in southwestern Illinois. In, *43rd Annual Tri-State Geological Field Conference*, p. 37-67. Illinois State Geological Survey Guidebook 14.

Miller, J.A. 1973. Quaternary history of the Sangamon River drainage system, central Illinois. Illinois State Museum Reports of Investigations 27, 36 p.

Munson, P.J. 1971. An archaeological survey of the Wood River Terrace and adjacent bottoms and bluffs in Madison county, Illinois. Illinois State Museum Report of Investigations 21: 1-17.

Nott, J.A. 1981. Pleistocene stratigraphy and landscape evolution in the Long and Crooked Creek drainage basins of southeast Iowa. Unpublished M.S. thesis, University of Iowa, Iowa City, 227 p.

Peltier, L.C. 1951. Late Wisconsin terraces and soils near St. Louis, Missouri (abstr.). Geological Society of America Bulletin 62: 1558.

Robertson, P. 1936. Some problems of the Middle Mississippi River region during Pleistocene time. Unpublished Ph.D. dissertation, Washington University, St. Louis, 143 p.

Rubey, W.W. 1952. Geology and mineral resources of the Hardin and Brussels quadrangles (in Illinois). United States Geological Survey Professional Paper 218, 179 p.

Rubin, M. and Alexander, C. 1958. United States Geological Survey radiocarbon dates IV. Science 127:3313: 1476-1487.

Ruhe, R.V. and Prior, J.C. 1970. Pleistocene Lake Calvin. Geological Society of America Bulletin 81: 919-923.

Shaffer, P.R. 1954. Extension of Tazewell glacial substage of western Illinois into eastern Iowa. Geological Society of America Bulletin 65: 443-456.

Shaw, E.W. 1915. Newly discovered beds of extinct lakes in southern and western Illinois and adjacent states. Illinois State Geological Survey Bulletin 20. Urbana, p. 139-157.

Teller, J.T. 1987. Proglacial lakes and the southern margin of the Laurentide Ice Sheet. In, *The Geology of North America, Vol. K-3, North America and Adjacent Oceans During the Last Deglaciation*, Ruddiman, W.F. and Wright, H.E., Jr. (eds.), p. 39-70. Geological Society of America, Boulder.

Tummons, R.L. 1982. Soil Survey of St. Charles County, Missouri. United States Department Agriculture, Soil Conservation Service, and Missouri Agricultural Experiment Station, 157 p.

Wermeyer, R.A. 1955. Pleistocene deposits of the St. Louis area. Unpublished M.S. thesis, Washington University, St. Louis.

Wiant, M.D., Hajic, E.R. and Styles, T.R. 1983. Napoleon Hollow and Koster site stratigraphy: Implications for Holocene landscape evolution and studies of Archaic Period settlement patterns in the lower Illinois River Valley. In, *Archaic Hunters and Gatherers in the American Midwest*, Phillips, J.L. and Brown, J.A. (eds.), p. 147-164. Academic Press, New York.

Willman, H.B. and Frye, J.C. 1970. Pleistocene stratigraphy of Illinois. Illinois State Geological Survey Bulletin 94, 204 p.

Wright, H.E. 1964. Wisconsin glaciation of Minnesota. Friends of the Pleistocene, Midwest Section, Guidebook for 15th Annual Field Conference, Minnesota Geological Survey and Department of Geology, University of Minnesota.

Wright, H.E. 1972. Quaternary history of Minnesota. In, *Geology of Minnesota: A Centennial Volume*, Sims, P.K. and Morey, G.B. (eds.), p. 515-578. Minnesota Geological Survey, St. Paul.

PRELIMINARY SURVEY OF OSTRACODES FROM JAMESTOWN QUARRY

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Introduction

An 11-m thick sequence of lacustrine sediments exposed at Jamestown Quarry was described and sampled for several physical and biological records including: particle-size distribution, semi-quantitative mineralogy of the <2 μm fraction, molluscs, insects, pollen and plant macrofossils. Ostracodes occur in a 5.5 m -thick sequence from about 1.7 to 7.2 m depth (see Figure 13, Hajic, 1991) deposited from about 19.6 to 16.0 (est.) ka. We present a prelimnary list of the ostracode fauna, and interpretation of paleoenvironments based on the relative abundance of ostracode species.

Ostracodes are bivalved microcrustaceans that occur in almost all aquatic environments. Fossil ostracodes have been used to reconstruct paleolimnologic parameters (such as water chemistry, water temperature, etc.) using data on the environmental requirements of modern ostracodes (e.g., Forester, 1987; Smith, 1991). Moreover, ostracode shells yield numerical ages (generally radiocarbon assays by accelerator-mass spectrometry) or environmental isotopes (C, O; e.g., Colman et al., 1990). The taxonomy of the ostracode species found at Jamestown Quarry are discussed in Hoff (1942), Furtos (1933), and Delorme (1970a,b).

Methods

Approximately 100 grams of sediment were subsampled from 6 cm-thick channel samples. Ostracodes were disaggregated following the procedures in Colman et al. (1990). Abundance profiles of ostracode species, and shell concentration per gram of dry sediment are expected results. We present prelimanry results below based on the scanning of several samples.

Results

Table 1 lists the ostracode fauna from Jamestown Quarry. All species indicate shallow littoral to sublittoral water depths. Candona stagnalis, Candona crogmaniana, and Paracandona euplectella indicate that the lake environment was controlled by groundwater discharge (i.e., relatively constant water temperatures, water chemistry and water depth). A stable lake environment is also indicated by the absence of limnocytherid ostracodes. Collectively, the assemblage indicates dilute water with total dissolved solids of less than 250 to 300 mg/L just at or below calcite saturation. The water temperature was cool, but not cold. Candona ohioensis, Candona paraohioensis, and Cyclocypris ovum collectively occur today in southern Canada and northern United States with mean July temperatures of about 17 ^{o}C (Forester et al., 1989), 9 ^{o}C cooler than the mean July temperature, 26 ^{o}C, at St. Charles, Missouri. The cool water temperature implied from above is supported by the lack of cold water taxa, such as Candona subtriangulata (Forester et al., 1989).

Clay bed #3 contains little or no ostracodes. The lower 0.5 m of clay bed #3 is barren of ostracodes, but the upper 0.6 m contains rare, broken and discolored ostracode shells, especially in a zone from 7.2 to 7.3 m depth. Shell abundance is variable upwards through the remaining ostracode-bearing interval. Shells are not present in clay beds #2 and #1. Ostracodes appear to be most abundant in uniform sediment with little or no fragments of organic matter. Ostracode shell abundance is neither positively correlated to layers with abundant, conspcuous fragments of Chara, nor with layers containing abundant molluscs.

Conclusions

The ostracode fauna indicate that the lake at Jamestown Quarry from ca. 19.6 to 16.0 (est.) ka. was shallow and permanent. Lake water input was dominated by groundwater discharge that provided stable and dilute (<300 mg/L TDS) water. Collectively, the ostracodes occurred in a cool, shallow lake that might be found today in southern Canada or the northern United States with mean July temperatures of about 17 ^{o}C.

Table 1. Ostracode taxa identified and relative abundance from subsamples at depths of 2.26-2.32 and 3.28-3.34 m at Jamestown Quarry. Depths correspond to the sediment log in Hajic (1991).

Taxon	Relative Abundance
Candona crogmaniana	common to abundant
Candona ohioensis	rare
Candona paraohioensis	rare to common
Candona stagnalis	common
Paracandona euplectella	rare
Cyclocypris ampla	common
Cyclocypris laevis	absent to abundant
Cyclocypris ovum	rare to common
Cypridopsis vidua	rare to common
Cypria sp.??	rare

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References Cited

Colman, S. M., Jones, G. A,, Forester, R. M., and Foster, D. S., 1990, Holocene paleoclimatic evidence and sedimentation rates from a core in southwestern Lake Michigan: Journal of Paleolimnology, v. 4, pp. 269-284.

Delorme, L. D., 1970a, Freshwater ostracodes of Canada. Part II. Subfamily Cypridopsinae and Herpetocypridinae, and family Cyclocyprididae: Canadian Journal of Zoology, v. 48, pp. 253-266.

Delorme, L. D., 1970b, Freshwater ostracodes of Canada. Part III. Family Candonidae: Canadian Journal of Zoology, v. 48, pp. 1099-1127.

Forester, R.M., 1987, Late Quaternary paleoclimate records from lacustrine ostracodes, in, W. F. Ruddiman and H. E. Wright, Jr. (eds.) North Amercia and Adjacent Oceans During the Last Deglaciation, The Geology of North America, Volume K-3, The Geological Society of America, Boulder, Colorado, pp. 261-276.

Forester, R.M., Delorme, L.D., and Ager, T.A., 1989, A lacustrine record of late Holocene climate change from south-central Alaska: Geophysical Monograph 55, pp. 33-40.

Furtos, N. C., 1933, The ostracoda of Ohio: Ohio Biological Survey Bulletin 29, vol. V, no. 6, pp. 411-524.

Hajic, E.R., 1991, Quaternary deposits and landforms, confluence region of the Mississippi, Missouri, and Illinois Rivers, Missouri and Illinois: Outwash terraces and terrace problems. Guidebook, Midwest Friends of the Pleistocene, 38th Annual Field Conference.

Hoff, C. C., 1942, The ostracods of Illinois, Their Biology and Taxonomy: Illinois Biological Monographs, nos. 1-2, pp. 1-196.

Smith, A. J., 1991, Lacustrine ostracodes as paleohydrochemical indicators in Holocene lake records of the North-Central U.S.: unpublished Ph.D. dissertation, Brown University.

ANALYSIS OF MOLLUSCS FROM THE JAMESTOWN AND BONFILS QUARRIES

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Introduction

Molluscan faunas have long been known from late Wisconsinan sediments of the Missouri-Mississippi River valleys of Missouri (Pauken, 1969; Hubricht, 1964; 1985). Most of these reported assemblages are from loess deposits of the area and usually are not associated with radiocarbon dates. This report is based on the study of two radiocarbon dated molluscan sequences collected from Jamestown and Bonfils quarries. Radiocarbon dates from several horizons suggest that the Bonfils Molluscan assemblages accumulated between 17,000 to 17,500 Y.B.P. The radiocarbon ages from four horizons at the Jamestown Quarry indicate the age of the molluscs to be between 20,270 ± 120 and 17,020 ± 90 Y.B.P.

Faunal Composition and Analysis

Preliminary examination of the sediments sampled at the Jamestown Quarry for mollusc indicate that they are dominated by aquatic taxa in terms fro both individual abundances and the number of species. Molluscs were present in 7 of the 11 samples examined. Fifteen of the 18 taxa identified to species from these collections (Table 1) live in aquatic habitats. Although none of these taxa are limited to permanent lentic water, the combination of species favors a lentic rather than lotic habitat as the probable depositional site.

Cold-water species represented by Fossaria Decampi, Pisidium conventus, Pisidium ventricosum, Pisidium ferrugineum and Pisidium millium form a prominent part of the mollescan assemblages. Published ambient air temperature isotherm values associated with the geogrpahic ranges of these species (Clarke, 1973, Table 2) imply a July mean temperature of between 13 ^{O}C to 17 ^{O}C at the time the fossils were living. The average July temperature at St. Charles, Missouri is now about 26 ^{O}C. Some members from this cold-water assemblage were identified in all but the 5.61 - 5.64 m and 8.92 - 8.98 m interval samples (Table 1).

The three species of terrestrial snails, Vertigo elatior, Vertigo modesta, and Nesovitrea electrina are represented by 5 individuals. These taxa are common in the loess deposits of this age that accumulated on the valley slope and upland. they probably represent material washed into the depositional basin as slope wash from these valley slope sites.

The Bonfils Quarry molluscan fauna is a striking contrast to the Jamestown Quarry assemblage. The fauna is dominated by small hygrophilic terrestrial taxa (Vertigo, Columella, Carychium, Euconulus) which are commonly encountered in Late Wisconsinan loess depsits of the region. Only three, Fossaria exigua, Bakerilymnaea dalli, and Pisidium ventricosum, of the 19 species identified from the Bonfils Quarry, are found in aquatic habitats (Table 2).

The presence of vesicular lime nodules that encrust some of the terrestrial shells, coupled with the small species taht favor wet to damp habitats, invite speculation that there was probably a spring or seep near the site of deposition. The spring or seep may have sustained a small pool that provided suitable habitat for the aquatic taxa that are most abundant in the Lower and Middle units. The general reduction in molluscan abundances in the Upper unit may indicate drying of the water supply to the seep or spring.

The Bonfils assemblage includes several extraliminal terrestrial species that are no longer living in this region of the Midwest. These include Hendersonia occulta, which now approaches the area in northeastern Iowa in Dubuque and Clayton counties (Latitude 42^{O} 31' North). Vertigo modesta and Collumella alticola now reach the southern limits of their range in the midcontinent area between latitudes 48 and 45 North, well to the north of the study site. Vertigo elatior, and Discus cronkhitei, do not occur in Missouri but reach the southern margin of their range in this region farther to the north in Iowa and Illinois (Hubricht, 1985).

The southern range limit of these northern species is believed to be controlled bythe high summer temperatures, whereas species with distributions that now include the study area appear to be constrained by the length and severity of the winter. Based on these distribution-patterns the terrestrial molluscs from the Bonfils Quarry probably lived at a time that combined summer-month temperatures (June - August) of about 17 ^{O}C, similar to what now occurs along the north shore of Lake Superior (NOAA, 1979) with a frost-free growing season of about 130 days, similar to that which now occurs along the north shore of Lake Huron (Fremlin, 1974: 51-52).

Conclusions

Although the molluscan faunal components from the Jamestown and Bonfils quarries differ significantly in terms of environments represented, they both contain "cool" extraliminal species that imply cooler summer temperatures at the time they lived. Both assemblages suggest summer temperatures that may have been about 9 °C cooler than now occur in the area.

Table 1. Molluscs identified from the Jamestown Quarry by stratigraphic interval.

Taxon	Depth (m)						
Aquatic	3.08-3.17	4.33-4.42	4.57-4.64	5.61-5.64	6.50-6.60	8.62-8.72	8.92-8.98
Armiger crista		X	X		X		X*
Fossaria decampi		X	X		X		
Gyraulus parvus	X	X	X		X		
Gyraulus deflectus	X				X		
Gyraulus sp.						X	X
Helisoma trivolvis		X			X		
Helisoma anceps	X						
Helisoma sp.			X				X
Lymnaea stagnalis		X	X		X		
Musculium sp.		X	X				
Physa sp.	X	X	X				
Pisidium compressum	X	X		X	X		
Pisidium conventus	X	X			X	cf.	
Pisidium ferrugineum			X				
Pisidium milium					X		
Pisidium ventricosum		X	X		X		
Pisidium sp.				X			cf.
Valvata sincera		X	X			X	
Valvata tricarinata	X	X	X	X		X	
Terrestrial							
Catinella sp.						X	
Nesovitrea electrina			X				
Vertigo elatior			X				
Vertigo modesta		X					

Table 2. Molluscan taxa identified and abundance counts from three horizons (LOW = lower; MID = middle; UP = upper) at Bonfils Quarry. The numerals under the Habitat column refer to the following: 1) Hygrophilic; moist situations in leaf mold, under sticks and debris; shaded areas not far from water, 2) Moist areas under leaf litter, logs, among tall marsh grass, 3) woodland and shrubs; shaded areas on valley slopes, 4) ephemeral small stream, pond, slough or marsh, 5) Small bodies of water on floodplain; no significant seasonal drying; with dense stands of submerged aquatic vegetation, 6) Perennial, non-stagnant water bodies: slow to moderate current; areas of still water; shallow spots with soft sand or mud substrate.

Taxon	Horizon			Habitat
	LOW	MID	UP	
Carychium exile	22	16	14	1,2
Catinella sp.	3	0	0	?
Columella alticola	7	20	10	1,2
Deroceras laeve	6	2	0	1,2
Discus cronkhitei	1	10	9	1,2
Euconulus fulvus	13	7	6	1,2
Bakerilymnaea dalli	0	0	8	4,5,6
Fossaria exigua	29	49	0	4,5,6
Haplotrema concavum	0	4	2	2,3
Hendersonia occulta	0	0	3	2,3
Nesovitrea electrina	6	25	6	2
Pisidium ventricosum	0	2/2	0	5,6
Punctum minutissimum	9	14	7	2
Stenotrema sp.	1	0	0	?
Stenotema leai	0	1	0	2,3
Succinea ovalis	0	2	0	1
Triodopsis multilineata	1	2	0	2,3
Vertigo elatior	22	42	9	1
Vertigo hubrichti	0	7	0	?1
Vertigo modesta	14	43	34	2,3
Zonitoides cf. Z. nitidus	0	0	1	2

References Cited

Clarke, A.H., 1973, The freshwater Mollusca of the Canadian Interior Basin: Malacologia, 13:1-510.

Fremlin, G. (editor), 1974, The national atlas of Canada. 267 pp. MacMillan of Canada, Toronto.

Hubricht, L., 1964, Some Pleistocene land snail records from Missouri and Illinois: Sterkiana, 13:7-17.

National Ocianic and Atmospheric Association (NOAA), 1979, World weather records, 1961-1970, Vol. 1, North America, 290 pp. National climatic Center, Asheville, North Carolina.

Pauken, R.J., 1969, A population study of the Pleistocene molluscan faunas in loess of the Missouri River Basin in Missouri: Unpublished PhD. Dissertation, University of Missouri - Columbia. 192 pp.

MAGNETIC SUSCEPTIBILITY: ITS APPLICATION TO MIDWESTERN LOESS/PALEOSOL SEQUENCES

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Introduction

Magnetic susceptibility is a powerful tool which is increasingly being used, not only in characterizing and correlating surficial materials, but also in understanding the geologic and pedologic processes which the materials have undergone. To date, lateral and vertical variations in susceptibilty have been used in various disciplines to characterize soil forming processes, to trace sediment sources, to study erosional processes, and to help correlate lithostratigraphic units. In China, magnetic susceptibility has been used to correlate their extensive loess/paleosol record to the marine oxygen isotope record (Kukla, 1989). In Midwestern loess units, susceptibility may be a reliable indicator of provenance, paleowind intensity, or distance from the loess source. In the paleosols, the susceptibility signal may provide insight as to the conditions present during soil formation. Susceptibility trends also show promise for local or regional correlation of loess units. The possibility of correlations to the marine oxygen isotope record needs to be explored further, but does show promise at particular exposures.

The interpretation of susceptibility data trends should always be made with respect to field observations and traditional laboratory methods. Additionally, since the susceptibility of a substance is somewhat dependent upon the sizes and shapes of strongly magnetic minerals, as well as their concentrations, susceptibility measurements are most useful when analyzed in conjunction with laboratory studies which characterize these minerals.

Definition

Magnetic susceptibility is defined as the ratio of induced magnetization in a volume of material to the intensity of the magnetic field applied to that volume. Its value is, therefore, dimensionless. When measured in the laboratory, susceptibility is sometimes expressed on a per unit mass basis. This type of susceptibility is termed mass susceptibility and is equal to magnetic susceptibility (also called volume susceptibility) divided by the bulk density of the material. With either mass susceptibility or volume susceptibility, it is also necessary to specify whether the numerical value is in the cgs or SI system of units. A value in the SI system on the same material would be four pi times larger than a value in the cgs system of units.

Variables Affecting Magnetic Susceptibility

The magnetic susceptibility of a material is directly related to its magnetic mineralogy, their respective concentrations, their grain sizes, and, to a lesser extent, their grain shapes. Bulk density is an additional factor which can affect volume susceptibility. Water content can affect mass susceptibilities.

Magnetic Mineralogy

Although all minerals are somewhat affected by the application of a magnetic field, magnetite ($Fe_2^{3+}Fe^{2+}O_4$), titanomagnetites (in the solid solution series between magnetite and ulvospinel - $Fe_2^{3+}Ti^{4+}O_4$), and/or maghemite ($Fe_2^{3+}O_3$) typically control the bulk of the susceptibility signal in surficial materials. The extremely large susceptibility of these ferrimagnetic minerals is in part due to their atomic structure and in part due to the presence of iron atoms (which have four unpaired electrons in the 3d electron shell). Magnetites (including the titanomagnetites) have an inverse spinel structure so that two out of every three of the magnetic moments line up in one direction and the third is oppositely aligned. Maghemites have a somewhat defective inverse spinel structure and their magnetic susceptibility is somewhat less than that of pure magnetite. In addition to lattice defects, susceptibility is also affected by isomorphic substitutions. For instance, the susceptibility of the titanomagnetites generally decreases with increased titanium substitution.

Diamagnetic materials (such as water, orthoclase, calcite, kaolinite, and gold) possess extremely small, negative susceptibilities due to the cancelling out of the electron spin and electron orbital components of the magnetic moment. Paramagnetic materials (such as air, lepidocrocite, ferrihydrite, muscovite, dolomite, and platinum) have very small but positive susceptibilities, because electron and orbital spins each contribute only small magnetic moments. In antiferromagnetic minerals (such as hematite, goethite, and ilmenite), electron spins alternate atom by atom so that the adjacent atomic magnetic moments align themselves in opposite directions and tend to cancel themselves out. The resulting susceptibility is small and positive, but typically somewhat larger than that of paramagnetic materials. Ferromagnetic materials (such as elemental iron, nickel and cobalt) attain very high susceptibilities but are not found in natural surficial materials, with the exception of meteorites, because of their instability in an oxygen-rich environment.

Concentrations

When the other variables (magnetic mineralogy, grain size, grain shape) are held constant, the magnetic susceptibility of a substance is linearly proportional to the concentrations of the contributing minerals (verified with magnetite in Illinois loess by Jones and Beavers, 1964). The susceptibility of a material is often controlled by the concentrations of a very minor percentage of ferrimagnetic magnetites and maghemites. Preliminary studies of relatively unaltered Midwestern loesses indicate that they contain approximately 0.05% to 0.35% magnetite in their silt fractions. Only when ferrimagnetic minerals are in very low concentrations, will ilmenite, hematite, goethite, or lepidocrocite play a significant role.

Grain Size

The size of strongly magnetic grains can also contribute to the susceptibility signal. In particular, when magnetic grains are smaller than about 0.02 µm, thermal randomization acts to flip the magnetization direction of the entire magnetic grain from one axis to another. This causes magnetic domains in grains to become thermally unstable and in the presence of an external magnetic field, the grain's magnetic moment will align more frequently in the direction of the applied field. This behavior is called superparamagnetic and as a result, the susceptibility of magnetic grains smaller than about 0.02 µm can be significantly larger than for an equivalent volume or mass of larger grain sizes. Superparamagnetic grains of magnetite are not common in relatively unaltered loess (C or CB horizons of a soil profile), but are not uncommon as secondary minerals in modern and buried soil solums. The relative significance of superparamagnetic minerals in Midwestern Quaternary loesses and paleosols is yet to be determined; however, it does seem to play a significant role in the paleosols of the Chinese loess record (Maher and Thompson, 1991).

Grain Shape

The shape of strongly magnetic grains can also affect magnetic susceptibility. Magnetic theory indicates that the less elongate a grain is, the lower the induced magnetization (Mullins, 1977). As a result, needle shaped magnetite grains will have higher susceptibilities than an equivalent volume or mass of spherical magnetite grains. The role of grain shape is probably very minimal in relatively unaltered loess, but may play more of a role in soil solums.

Density

Variable densities within a material can affect volume susceptibility, but will not effect mass susceptibility. From preliminary studies, many variations in the volume susceptibility of loesses, laterally and vertically, do not seem to correlate well with density changes in the loess. Most susceptibility variations are much more abrupt and distinctive than the typical density variations within loess. Despite this, a method for correcting the volume susceptibility for minor changes in the bulk dry density of the loess is being investigated. Pedologic processes (pedoturbation, weathering, translocations) are probably responsible for most of the variations in density. In deeply buried sediments, compaction may also cause slight density increases. Variations in density due solely to variations in water content would not contribute to volume susceptibility variations.

Processes Influencing Magnetic Susceptibility

There are a variety of processes which can help explain the distributions, sizes, and shapes of strongly magnetic minerals within a soil or sediment. In general, one is faced with the problem of distinguishing between lithogenic susceptibility variations and pedogenic (diagenetic) susceptibility variations (Figure 1).

Lithogenic Processes

Lithogenic susceptibility variations are inherited from primary minerals in the sediment. These variations are dependent upon the mode, energy, and distance of sediment transportation, as well as the provenance. Lithogenic processes account for the bulk of the susceptibility variations in relatively unaltered sediments (C or D horizons). In loess/paleosol sequences, these processes include the provenance of the glacial silt, the wind intensities during depositional events, and the distance that the silt was blown from the source area, typically the floodplain of a Pleistocene river.

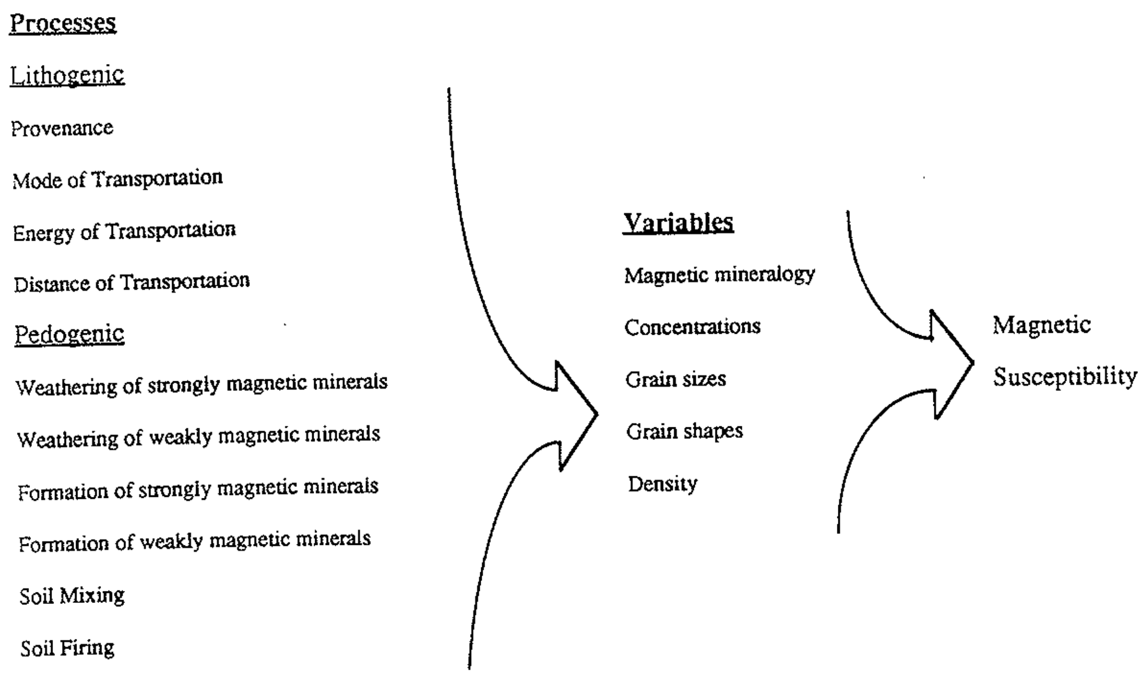


Figure 1. Relationships among processes, variables, and magnetic susceptibility.

Provenance variations in loess of the Midwest would be the result of varying susceptibilities of the silt in each of the major rivers (Ohio, Wabash, Illinois, Mississippi, Missouri, and Platte) which carried the meltwaters of the major continental glaciers. Ultimately, provenance would relate to the types of bedrock or sediments which were incorporated into the Laurentide Ice Sheet.

Variations in wind intensities also could produce a primary susceptibility signal in unaltered loesses. Stronger winds would be more apt to carry heavy minerals such as magnetite and could be responsible for abrupt increases in susceptibilty. This effect of density fractionation was shown to be significant in loess derived from the Tanana River floodplain near Fairbanks, Alaska (Beget et al, 1990). As one might predict, the susceptibility increases in this loess correlated well with a coarsening of the particle size distribution in bulk samples of the loess.

Also due to density fractionation, susceptibility will decrease with increasing distances from the loess source. Magnetite, along with other heavy minerals, will tend to settle to the ground at a faster rate than the more prevalent light minerals in glacial silts. In theory, the decrease in susceptibility in loess deposited farther from the bluffs should correspond to a decrease in the particle size of the loess and to changes in the heavy mineralogy.

Pedogenic (Diagenetic) Processes

Pedogenic (or diagenetic) susceptibility variations in surficial sediments or soils are those variations which are brought about by near surface processes after deposition. These processes may act to dissolve, transform, neoform, or translocate weakly magnetic or strongly magnetic minerals in the A, B, and, to a lesser extent, the C horizons of soils. Both magnetite and maghemite commonly control the susceptibility signal in soil solums and they are present in a wide range of concentrations and grain sizes. Grain shapes may also be somewhat variable. Magnetic susceptibility values in soils are much less uniform than values in unaltered sediments; on a small scale due to such features as mottles and clay skins, and on a larger scale due to the degree of soil development and the degree of soil drainage.

Because of the relative resistance of magnetite to weathering, it is not unusual for this mineral to be concentrated upon the weathering of weakly magnetic minerals, such as carbonates, feldspars, and amphiboles. This process would result in a susceptibility increase proportional to the increased concentration of magnetite. Similarly, susceptibility can decrease by the dilution of magnetite with the in-situ production of organic matter or secondary carbonate in soils.

Although magnetite generally is resistant, it can be rapidly destroyed in reducing environments or can be transformed into weakly magnetic iron oxides under strongly acidic weathering conditions. Under reducing conditions, iron oxides (which comprise a large fraction of the reducible components in soils) act as a sink for the electrons produced by the metabolic reactions of plants and microorganisms. Iron subsequently becomes transformed relatively rapidly from the oxidized form to the reduced form. In the mobile form, iron may leach out of the system, but often may stay in the system due to poor drainage. Dissolution of grains does seem to be linked to the biochemical effects of gleying and is most effective on very small grain sizes (Maher, 1986).

A study by R.R. Anand and R.J. Gilkes (1984) has given firm evidence for the weathering of sand-sized magnetite to hematite pseudomorphs (martite) under oxidizing conditions. This weathering has occurred in a saprolite developed in adamellite in Southwestern Australia. Oxidation of the magnetite commonly begins along its octahedral (111) planes and proceeds from the surfaces and edges of the grain towards the center. From early experiments of artificial oxidation of magnetite to martite, magnetite derived from igneous and metamorphic rocks was determined to be more resistant to weathering than sedimentary magnetite of the slightly distorted type (Gruner, 1926). It is also well known that grains of smaller diameter will tend to weather faster because of their large surface free energy and their large surface area to volume ratio. In addition to weathering to hematite, it may also be possible for magnetite to transform into goethite or lepidocrocite. Presumably, the transformation of magnetite into any one of these weakly magnetic iron oxides would result in a decrease in magnetic susceptibility.

The in-situ formation of very fine clay-sized magnetite and/or maghemite is a globally widespread phenomena in well-drained, organic-rich surface horizons of soils developed into a variety of parent materials (Le Borgne, 1955; Neumeister and Peschel, 1968; Vadyunina et al, 1972). Often, it is disputed whether these secondary ferrimagnetic minerals are formed inorganically, organically, or by the action of soil firing. Based upon the morphology of the secondary minerals and isomorphic substitutions, it is sometimes possible to distinguish between ferrimagnetic minerals produced by the three mechanisms - bu these interpretations are often disputed. Laboratory experiments have shown that magnetite, of 0.01-0.07 mm mean diameter, can be synthesized inorganically in the lab by the controlled oxidation of Fe^{2+} solutions at typical soil forming conditions (Taylor, Maher, and Self, 1987). However, similar-sized magnetite can also be produced by soil bacteria, intracellularly and extracellularly (Fassbinder et al, 1990). The third alternative is that susceptibility enhancements in the upper solum of soils may be related to soil firing events. Under the high temperatures and reducing conditions present in the soil during forest or grassland fires, weakly magnetic iron oxides, such as hematite, may be reduced to magnetite and subsequently oxidized to maghemite upon cooling as air enters the system (Le Borgne, 1960). The amount of susceptibility enhancement is dependent upon such factors as the amount of iron in the upper solum, soil porosity, soil conductivity, litter layer depth, and soil temperature attained during firing (Maher, 1986). In areas of recent fires, the resulting susceptibility enhancement attained is very dramatic and is confined to the uppermost few centimeters of the A or O horizon. In order to explain more common gradual susceptibility enhancements of soils, which often extend down into the upper B horizon, one must rely on soil mixing processes to distribute the secondary ferrimagnetic minerals in a consistent manner (Le Borgne, 1960).

Magnetic Susceptibility Trends in Midwestern Loess/Paleosol Sequences of Quaternary Age

The forthcoming discussion is in part based upon reconnaissance field studies of magnetic susceptibility at the following exposures:

Missouri River Loess: Loveland Paratype Section, several other exposures in Pottawattamie County, Ruhe's Railroad Cut #36, Earlham Quarry, and South Turkey Creek, Iowa, Randolf Section, exposure near Miami, Riverview Quarry, North Stone Quarry, Bonfils Quarry, and Jamestown Quarry, Missouri.

Upper Mississippi River Loess: several exposures in Adams County and Pike County, near Lomax, Coal Creek, and Pancake Hollow, Illinois; Hegary and Boise, Wisconsin.

Illinois-Sangamon River Loess: Farm Creek section, several exposures in Cass County, Florence Quarry, Green Bay Hollow, Illinois.

Middle Mississippi River Loess (between St. Louis and Cairo): I-270 and Bluff Road, Pleasant Grove School Section, Drury Inn Section, Powdermill Creek Section, Thebes Road Cut, Thebes Core, Lone Star Quarry, Moses Gravel Pit, Illinois.

Lower Mississippi/Ohio River Loess (south of Cairo): Wittsburg Quarry and Bledsoe Section (Crowley's Ridge), Arkansas.

Wabash River Loess: Patoka Section and exposures near Petersburg, Indiana.

The magnetic susceptibility of the Peoria Loess ranges from $3x10^{-5}$ (SI units) in gleyed loess at Athens Quarry, up to $159x10^{-5}$ in portions of the coarse-textured loess at the Randolf Section (just north of Kansas City, Missouri). Where the Peoria Loess is thick, silt loam textured (but not too coarse), and relatively unaltered, retaining its characteristic yellow-brown color, its susceptibility is almost always in the range between $30x10^{-5}$ and $80x10^{-5}$. It is very common for the susceptibility of the Peoria Loess to decrease upward from the Roxana Loess/ Peoria Loess stratigraphic boundary. Based upon detailed measurements at some of the exposures with the most continuous records (Athens Quarry, Florence Quarry, Green Bay Hollow, Thebes, Crowley's Ridge sections), it seems that this susceptibility minimum in the middle portions of the Peoria Loess is a primary signal - probably reflecting lower concentrations of silt-sized magnetite in glacial meltwater sediments.

Susceptibilities in the Roxana Loess range from $6x10^{-5}$ in gleyed loess at Athens Quarry to $115x10^{-5}$ in the A horizon of a well-drained, organic-rich Farmdale Geosol at Wittsburg Quarry. Where the Roxana Loess is thick, silt loam textured, relatively unaltered, and retains its characteristic brown to reddish-brown color, its susceptibility values fall in the range between $50x10^{-5}$ to $90x10^{-5}$. As a rule, when the Peoria Loess and Roxana Loess are present in the same section, the Roxana Loess has the higher susceptibility. This is also a primary signal, at least in part.

Susceptibilities in the Loveland Loess (Illinoian Stage) range from as low as $8x10^{-5}$ in the Bg horizon of the Sangamon Geosol at the Coal Creek Section to readings in the 100's $x10^{-5}$ in the A horizon of the Sangamon Geosol at both Ruhe's Railroad Cut #36 and Bonfils Quarry. Where the Loveland Loess is thick, silt loam textured, relatively unaltered, and retains its "Peoria-like" yellow-brown color (Moses Gravel Pit, Wittsburg Quarry, Bledsoe Section, Thebes, Loveland Paratype Section, Bonfils Quarry), its susceptibility is generally between $40x10^{-5}$ and $70x10^{-5}$ - similar to values found in relatively unaltered Peoria Loess.

In Pre-Illinoian loesses, susceptibilities range from $5x10^{-5}$ in the Bt horizon of the Yarmouth Geosol at Wittsburg Quarry to readings in the 80's $x10^{-5}$ in the A horizon of the Yarmouth Geosol at Thebes. This fourth loess unit is not thick enough to determine typical susceptibility values in the relatively unaltered state at any of the exposures visited.

Whereas the magnetic susceptibility signal in relatively unaltered loesses is dominantly controlled by varying concentrations of silt-sized magnetite grains, secondary magnetite and maghemite of much finer grain size can play a role in soil solums. Soil forming processes during Yarmouthian, Sangamonian, Farmdalian, and Holocene times may have acted to increase susceptibility to some extent due to the concentration of magnetite by the weathering of carbonates and feldspars or by porosity reduction. However, significant susceptibility increases in the upper solums of modern and buried soils cannot be explained simply by the concentration of primary magnetite. These increases are interpreted to be caused by the secondary formation of very fine-grained magnetite or maghemite. These ferrimagnetic minerals may be of inorganic or organic origin or may be produced during soil firing events. Whatever the mechanism, these minerals likely formed during an interglacial or interstadial stage when land surface was no more than about one meter above and when the soil was well-drained and organic-rich. In the loess/paleosol sequences visited, these susceptibility enhancements are found in the upper horizons of weakly to moderately developed paleosols with good paleodrainage.

In strongly developed soils or in poorly drained soils, processes may act to transform or to destroy magnetite due to very acidic or very reducing conditions. In the gleyed horizons of poorly drained soils, susceptibilities become lower with more intense gleying, due to the dissolution or transformation of magnetite. The magnetic susceptibility of strongly gleyed paleosols and loesses is very low, ranging from $3x10^{-5}$ to $20x10^{-5}$. In strongly developed, moderately drained Sangamon and Yarmouth Geosols, it is typical for magnetic susceptibility to drop off sharply in the Bt horizon to values between $20x10^{-5}$ and $50x10^{-5}$. This decrease in susceptibility is due to slight gleying and/or the transformation of magnetite to hematite, goethite, or lepidocrocite under a strongly acidic weathering environment.

As one proceeds away from the bluffs of the major Pleistocene rivers, there is often a predictable and significant decrease in the susceptibility of loesses and paleosols. The cause for this is probably threefold. First, soils developed in thick loess near the bluff are often more weakly developed, due to the erosional character of the bluffs, so that ferrimagnetic minerals would be more apt to form in-situ rather than be weathered. Second, soils near the highly dissected bluff areas are often much better drained when compared to soils developed on the flat, loess veneered Illinoian and Pre-Illinoian till plains. Again, near the bluff, ferrimagnetic minerals would be more apt to form in-situ rather than be dissolved or transformed under reducing conditions. Third, there also is probably a primary difference in magnetite concentrations as one proceeds "downwind" from the bluff due to density fractionation of the heavy minerals. Coarse-textured loess and "sandy" loess near the bluffs do seem to have much higher magnetic susceptibilities and these susceptibilities tend to vary with grain size variations in the loess. In unglaciated landscapes with a thick loess blanket, the third argument will still hold, but the first two arguments become less relevant because landscapes at all distances from the bluff are highly dissected.

As one proceeds further west, the proportion of well-drained and less strongly developed paleosols increases as the climate becomes drier. Likewise, the proportion of paleosols with susceptibility enhancements also increases due to the more favorable conditions for the in-situ production of ferrimagnetic minerals. Towards the east and south, a greater proportion of paleosols have a susceptibility minimum in their Bt or Bg horizon due to more intense weathering or due to poor drainage. Perhaps it may be possible in the future to correlate loess/paleosol sequences in Nebraska, Kansas, Iowa, or Missouri to the marine oxygen isotope record with the help of magnetic susceptibility measurements. The susceptibility record of these loess/paleosol sequences may follow a similar trend to the loess/paleosol record in China, with higher readings in the paleosols and lower readings in the relatively unaltered loesses.

Conclusion

It is apparent that the concentrations and grain sizes of strongly magnetic minerals are quite sensitive to changes in lithologic or pedologic environments. Magnetic susceptibility devices can detect these magnetic minerals in concentrations and grain sizes far below what can be detected by non-magnetic methods.

Primary variations in susceptibility are detectable within relatively unaltered loess. This primary signal is largely inherited from varying concentrations of silt-sized magnetite in the loess and its oscillations may be related to provenance, paleowind intensities, or distance from the loess source. The Peoria and Loveland loesses have similar ranges of susceptibility values. The middle portion of the Peoria Loess commonly contains a susceptibility minimum. The Roxana Loess generally has a higher susceptibility than either the Peoria or Loveland loesses in comparable stages of alteration.

Pedogenic processes can act to increase magnetic susceptibility in the upper horizons of well-drained, organic-rich soils and to decrease susceptibility in the strongly developed B horizons or in the gleyed horizons of moderately drained to poorly drained soils. Very fine-grained secondary maghemite and/or magnetite plays a role in the susceptibility enhanced horizons of soils. The susceptibility in the solums of modern and buried soils is more spatially variable
than the measurements in relatively unaltered loess.

In the future, magnetic susceptibility should prove to be useful in characterizing and correlating (locally, regionally, and globally) loess/paleosol sequences of the Midwest.

References Cited

Anand, R.R., and Gilkes, R.J., 1984, Mineralogical and Chemical Properties of Weathered Magnetite Grains from a Lateritic Saprolite, Journal of Soil Science, v.35, p.559-567.

Beget, J.E., Stone, D.B., and Hawkins, D.B., 1990, Paleoclimatic Forcing of Magnetic Susceptibility Variations in Alaskan Loess during the Late Quaternary, Geology, v.18, p.40-43.

Fassbinder, W.E., Stanjek, H., and Vali, H., 1990, Occurrence of Magnetic Bacteria in Soil, Nature, v.343, p.161-163.

Gruner, J.W., 1926, Magnetite-Martite-Hematite, Economic Geology, v.21, p.375-393.

Jones, R.L. and Beavers, A.H., 1964, A Technique for Magnetic Susceptibility Determinations of Soil Materials, Soil Science Society of America Proceedings, v.28, p.47-49.

Kukla, G. and An, Z.S., 1989, Loess Stratigraphy in Central China, Paleogeography, Paleoclimatology, and Paleoecology, v.72, p.203-225.

Le Borgne, E., 1955, Susceptibilite Magnetique Anomale du Sol Superficiel, Annales de Geophysique, v.11, p.399-419.

Le Borgne, E., 1960, Influence de Feu sur les Proprietes Magnetiques du Sol et sur celles Schiste at du Granite, Annales de Geophysique, v.16, p.159-195.

Maher, B.A., 1986, Characterization of Soils by Mineral Magnetic Measurements, Physics of the Earth and Planetary Interiors, v.42, p.76-92.

Maher, B.A. and Thompson, R., 1991, Mineral Magnetic Record of the Chinese Loess and Paleosols, Geology, v.19, p.3-6.

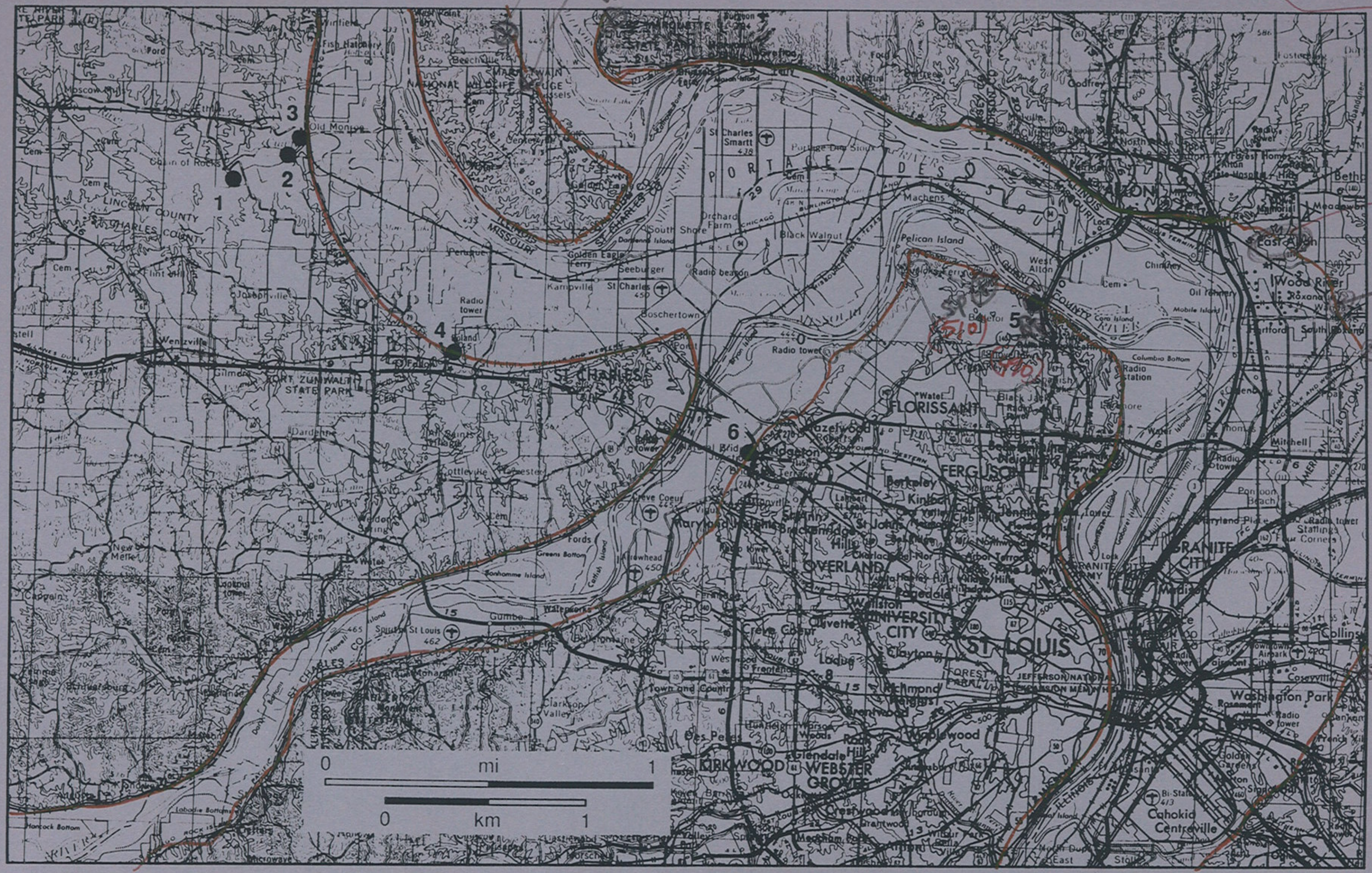
Mullins, C.E., 1977, Magnetic Susceptibility of the Soil and its Significance in Soil Science - A Review, Journal of Soil Science, v.28, p.223-246.

Neumeister, H. and Peschel, G., 1968, The Magnetic Susceptibility of Soils and Pleistocene Sediments in the Neighborhood of Leipzig, Albrecht-Thaer-Archiv, v.12, p.1055-1072.

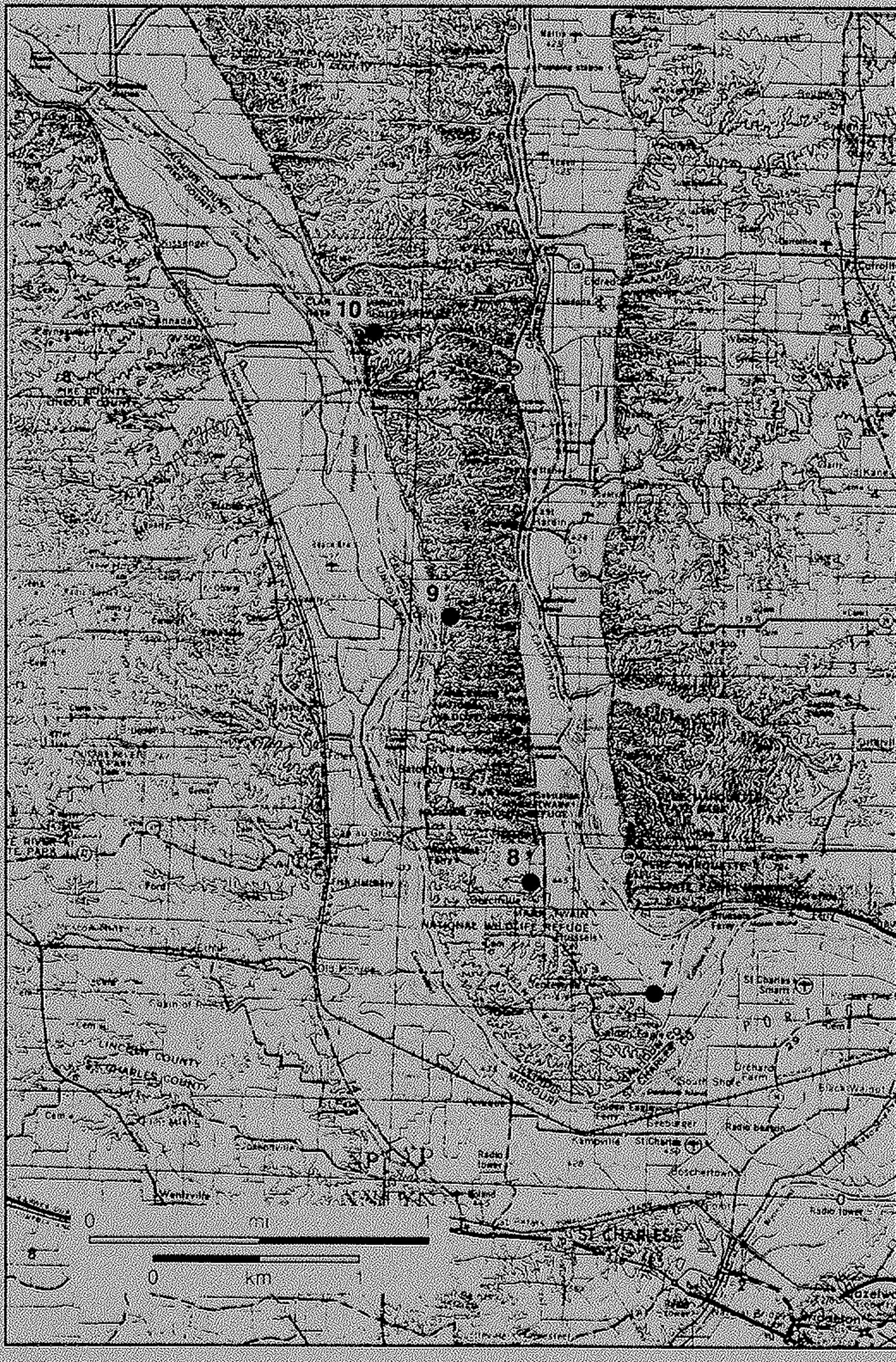
Taylor, R.M., Maher, B.A., and Self, P.G., 1987, Magnetite in Soils: I. The Synthesis of Single-Domain and Superparamagnetic Magnetite, Clay Minerals, v.22, p.411-422.

Vadyunina, A.F., and Babanin, V.F., 1972, Magnetic Susceptibility of Some Soils in the U.S.S.R., Soviet Soil Science, v.4, p.588-599.

Clay Beds in Peoria Silt



Field trip route DAY 1



Field trip route DAY 2