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Late Quaternary Landscape Evolution in the South Fork of the Big Nemaha River Valley, Southeastern Nebraska and Northeastern Kansas

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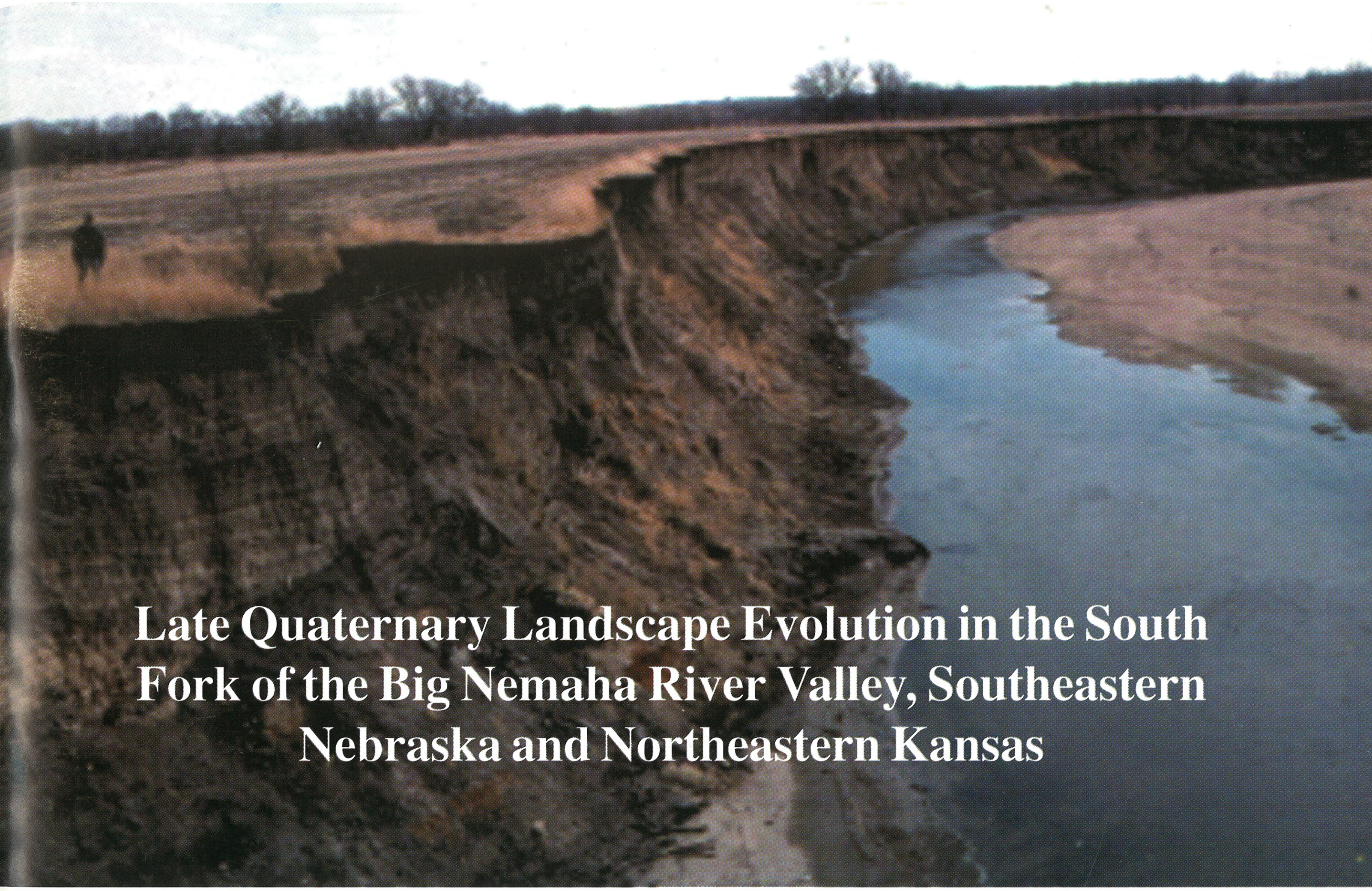

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Midwest Friends of the Pleistocene 47th Field Conference
June 2-4, 2000, Hiawatha, Kansas

Guidebook No. 11

Conservation and Survey Division
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(4)	1953	Northeastern Wisconsin	F.T. Thwaites
(5)	1954	Central Minnesota	H.E. Wright, Jr. and A.F. Schneider
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8	1957	South-central Indiana	W.D. Thornbury and W.J. Wayne
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Preface

In 1996, the Nebraska Archaeological Survey of the University of Nebraska State Museum, under the direction of Steve Holen, conducted an archaeological survey along the South Fork of the Big Nemaha River in southeastern Nebraska (fig. 1). One of the components of this survey was an intensive geomorphological investigation focusing on Holocene and late Wisconsinan landform sediment assemblages in the Nemaha valley. As project geomorphologist, it was my responsibility to determine the potential for buried archaeological materials and place the recorded cultural deposits in a geologic context. I quickly discovered that the South Fork of the Big Nemaha River offered a rare opportunity to develop a detailed Holocene and late Wisconsinan stratigraphic and paleoenvironmental record for a Midwestern drainage system.

During the 1950s, channelization projects on the lower South Fork of the Big Nemaha River initiated a wave of deep incision that quickly migrated up the valley. In many places, the channel incised to bedrock, exposing thick sections (> 10 m) of Holocene and late Wisconsinan valley fill. These sections are often hundreds of meters long and reveal crosscutting relationships of alluvial and colluvial deposits. In addition, organic mats consisting of plant macrofossils (seeds, stems and leaves, as well as accumulations of large pieces of wood) are exposed in the lower parts of most sections. With such an abundance of plant macrofossils, plus many charcoal-rich archaeological features, it was apparent that 1) radiocarbon dating could be used to establish a detailed late-Quaternary alluvial chronology for the stream, and 2) the region's late-Quaternary vegetative history could be reconstructed and used to infer climatic change. Hence, what began as a geoarchaeological investigation soon evolved into a multidisciplinary study that involved a number of specialists, including Richard Baker (University of Iowa; plant macrofossils), Glen Fredlund (University of Wisconsin-Milwaukee; pollen and phytoliths), Art Bettis (University of Iowa; Quaternary geology), Steve Holen (formerly University of Nebraska; archaeology), and me (University of Kansas; geomorphology and geoarchaeology). The purpose of this Midwest Friends of the Pleistocene field conference is to showcase the results of these efforts.

I want to thank the Nebraska State Historical Society for supporting our investigation. The Historical Society recognized the potential benefits of geological and paleoenvironmental studies for cultural resource management. Funding for much of the radiocarbon dating was provided through a National Science Foundation grant (Grant No. EAR-93-96391) awarded to Richard Baker and Art Bettis. I am indebted to Steve Holen (now with the Denver Museum of Natural History) and Dan Watson (University of Nebraska State Museum) for helping me in the field. Steve played an important role in coordinating the archaeological and geomorphological investigations, and Dan spent many hours using a transit to measure outcrops and determine the depths of radiocarbon samples.

Special thanks goes to Mark Kuzila, Director of the Conservation and Survey Division (Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln), for agreeing to publish the FOP guidebook. Charles Flowerday and support staff at the Conservation and Survey Division contributed editorial review and graphic support in helping prepare this guidebook. We are also indebted to Mr. and Mrs. Richard Farwell and Mr. and Mrs. Vaughn Koester for allowing us to work on their property and revisit it during the FOP field conference. Thanks also goes to Martin Marietta, Inc., for allowing our group to inspect outcrops in their DuBois quarry. Sam Fuller and Dennis Lippold of Martin Marietta were especially helpful in providing access to the quarry.

– Rolfe Mandel

ROAD LOG

DAY 1

mile	
0.0	Begin at the Hiawatha Inn parking lot, Hiawatha, Kansas.
0.1	Turn right (south) onto First Street.
0.15	Turn right (west) onto the U.S. Highway 36 ramp.
5.8	Notice the outcrop of Pennsylvanian limestone and shale on the left (south) side of the highway. Bedrock is shallow (< 3 m) in this area of the till plain.
8.7	Highway 36 crosses Spring Creek, a tributary of Walnut Creek, which in turn flows into the Big Nemaha River.
10.9	Enter the town of Fairview, Kansas. This community is on the divide between the Delaware River basin to the south and the Big Nemaha River basin to the north.
11.4	U.S. Highway 75, coming in from the south, joins Highway 36 at a T-intersection.Continue west on U.S. 36/75.
14.1	U.S. 36/75 crosses the upper Delaware River. Notice the Pennsylvanian bedrock exposed at shallow depths in cutbanks on the west side of the river. The first study to identify the DeForest Formation in Kansas focused on this area of the Delaware River valley (Mandel and others, 1991).
14.3	Turn right (north) on U.S. 75.
17.6	Enter the town of Sabetha, Kansas.
25.3	Cross Rock creek, a tributary of the South Fork of the Big Nemaha River.
25.4	Cross the Kansas-Nebraska state line.
26.7	Cross Honey Creek, a tributary of the South Fork of the Big Nemaha River.
30.4	Highway 75 descends into the South Fork of the Big Nemaha River valley. Notice the bedrock outcrops on both sides of the highway.
30.8	Cross the South Fork of the Big Nemaha River.
30.9	Turn right (east) onto gravel road.
31.0	**STOP 1.** Overview of the South Fork of the Big Nemaha River valley (fig. 2). After completing this stop, turn left (south) on Highway 75 and cross the South Fork of the Big Nemaha River.
31.4	Notice the shallow bedrock outcrop beneath the T-2 terrace on the right (west) side of the road.
32.4	Turn right (west) at Nebraska 8. The road rises onto the bluff overlooking the South Fork of the Big Nemaha River.
34.4	Cross Rattlesnake Creek. Notice the shallow bedrock in cutbanks on the north side of the road.
39.4	Nebraska 105, coming in from the north, joins Nebraska 8 at a T-intersection. Continue west on Nebraska 8.
40.5	Turn right (north) on gravel road.
41.6	Turn left (west) on gravel road.
42.2	**STOP 2.** "Old Bridge" Locality (fig. 2). After completing this stop, turn around and travel east on the gravel road.
42.8	At the T-intersection, turn right (south) on gravel road.
43.9	Stop sign. Turn right (west) on Nebraska 8.
45.5	Cross the South Fork of the Big Nemaha River. Kinters Ford Wildlife Management Area is on the right (north) side of the road immedi-

ately before we cross the bridge. Notice the high cutbanks on the west side of the channel. This stretch of the river was studied during the 1996 geoarchaeological survey and yielded much information on the Holocene stratigraphy and alluvial chronology of the Nemaha (Mandel, 1996). In addition, paleobotanical data have been gleaned from organic mats in the lower parts of the sections. A summary of this information is presented in the guidebook.

47.9 Stop sign at T-intersection with Nebraska 50. Turn left (south) onto Nebraska 50.

48.9 Enter the town of DuBois, Nebraska.

49.2 Turn left (east) onto Elm Street.

50.2 Turn left (north) onto dirt road.

50.5 **STOP 3.** High terrace (T-2) of the South Fork of the Big Nemaha River (fig. 2). Notice the prominent scarp that separates the T-2 terrace from the broad T-1 terrace to the east. Participants will have an opportunity to inspect core taken on the T-2 terrace. After completing this stop, turn around and travel south on the dirt road.

50.8 Stop sign. Turn right (west) on gravel road.

51.8 LUNCH STOP. DuBois Community Park on right (north) side of Elm Street. After lunch, turn around and travel east on Elm Street.

53.2 Cross the South Fork of the Big Nemaha River. Notice the deeply entrenched channel on both sides of the bridge. On the north side, thick deposits of the Honey Creek Member are exposed along the west bank. Notice stratified Camp Creek Member deposits in abandoned channels cut across the Honey Creek Member. On the south side of the bridge, bedrock is exposed in the channel of the Nemaha. High cutbanks visible to the south will be inspected at Stop 4.

53.6 Turn right (south) on gravel road. The road follows the bluff line. To the right (west), notice the gentle slope descending to the valley floor of the Nemaha.

54.1 **STOP 4.** Richard Farwell Locality (fig. 2). Walk down dirt road to the valley floor of the Nemaha. After completing this stop, turn around and travel north on the gravel road.

54.6 At T-intersection, turn left (west) on gravel road.

56.4 Stop sign. Turn right (north) onto Nebraska 50.

57.7 Turn right (east) on Nebraska 8.

60.1 Cross the South Fork of the Big Nemaha River. Kinters Ford Wildlife Management Area is on the left (north) side of the road immediately after we cross the bridge.

66.8 Turn left (north) on gravel road.

67.4 Road descends the scarp separating the T-2 and T-1 terraces of the South Fork of the Big Nemaha River.

68.5 Road crosses the abandoned channel of the Nemaha. This segment of the river was abandoned as part of the channel-straightening project conducted by the U.S. Army Corps of Engineers.

69.1 **STOP 5.** Miles alluvial fan (fig. 2). After completing this stop, turn around and travel south on the gravel road.

71.4 Stop sign. Turn left (east) on Nebraska 8.

74.3 Stop sign. Turn right (south) and return to Hiawatha Inn.

DAY 2

mile

0.0 Begin at the Hiawatha Inn parking lot, Hiawatha, Kansas.

0.1 Turn right (south) onto First Street.

0.15 Turn right (west) onto the U.S. Highway 36 ramp.

11.4 U.S. Highway 75, coming in from the south, joins Highway 36 at a T-intersection. Continue west on U.S. 36/75.

14.3 Turn right (north) on U.S. 75.

17.5 Turn right (east) into the borrow pit. **STOP 6** (fig. 2). After completing this stop, turn right onto Highway 75 and continue north through Sabetha.

32.4 Flashing yellow light. Turn left (west) onto Nebraska 8.

44.5 Stop sign at T-intersection with Nebraska 50. Turn left (south) onto Nebraska 50.

45.5 Enter the town of DuBois, Nebraska.

45.8 Turn left (east) onto Elm Street.

47.2 Cross the South Fork of the Big Nemaha River.

47.6 Turn right (south) on gravel road.

48.1 Enter the Martin-Marietta rock quarry. **STOP 7** (fig. 2). After completing this stop, turn around and travel north on the gravel road.

48.6 At T-intersection, turn left (west) on gravel road.

50.4 Stop sign. Turn left (south) onto Nebraska 50.

52.9 Nebraska-Kansas state line. Nebraska 50 becomes Kansas 63. Notice the South Fork of the Big Nemaha River to the left (east). The river is flowing north out of its headwater area near Seneca, Kansas.

56.1 Cross Turkey Creek. Looking to the right (west), notice the large size of Turkey Creek valley relative to the small size of the stream. This is a good example of an under-fit stream.

63.6 Stop sign at T-intersection with U.S. Highway 36. The town of Seneca is to the right (west). Turn left (east).

64.0 Cross the South Fork of the Big Nemaha River. Notice that the channel is not deeply incised at this locality.

64.4 Turn right (south) onto Kansas 63.

65.0 Pull into the Vitt borrow pit. **STOP 8** (fig. 2). This is the last stop. Some vans will return to the Hiawatha Inn.

Introduction

Most studies of late-Quaternary landscapes and stratigraphy in Nebraska have focused on the western and central parts of the state (for example, Brice, 1964; Diffendal and Corner, 1983; Ahlbrandt and others, 1983; May, 1986, 1989; Swinehart, 1989; Swinehart and Diffendal, 1989; Martin, 1990; Loope and others, 1995; Maat and Johnson, 1996; Mason and others, 1997; Muhs and others, 1999). We are just beginning to expand the database for eastern Nebraska through interdisciplinary studies that have involved geologists, pedologists, paleobotanists, and archaeologists. The purpose of this field trip is to present the results of a recent interdisciplinary study of late Quaternary landscape evolution in the South Fork of the Big Nemaha River valley of southeastern Nebraska and northeastern Kansas (fig. 1). We have established a detailed alluvial stratigraphic and paleoecological record spanning the past 40,000 years. Although the Holocene alluvial stratigraphic record will be the showcase of the field trip, outcrops of late Wisconsinan loess, colluvium, and alluvium will be examined. In addition, Pre-Illinoian till will be examined at two localities. We intend to demonstrate that the relatively subtle landscape of southeastern Nebraska and northeastern Kansas harbors an extremely complex late-Quaternary stratigraphic record that is a product of dynamic processes.

On the first day, we will consider modern stream entrenchment in the South Fork of the Big Nemaha River valley as a framework for interpretation of the longer-term processes resulting in the geometry and distribution of Holocene alluvial stratigraphic units. We will focus on the alluvial stratigraphy of the South Fork of the Big Nemaha River valley and emphasize that there is a distinctive, easily recognized sequence of alluvial fills that can be traced up and down the valley and from valley to valley across the region. These fills comprise the DeForest Formation, a lithostratigraphic unit that was first recognized in the Loess Hills of western Iowa. We will demonstrate that the members of the DeForest Formation are distinguishable on the basis of gross lithologic characteristics and that unconformities between the members, although aiding in interpretation of the stratigraphic units, are not necessary to distinguish the members. We will place the stratigraphic record against the backdrop of a detailed alluvial chronology. Intensive radiocarbon dating of organic materials associated with the alluvial fills reveals that the members of the DeForest Formation have predictable ages in the segment of the valley that was studied. We will also consider paleoenvironmental information gleaned from the analysis of pollen, phytoliths, and plant macrofossils recovered from the alluvial fills. In addition, we will explain how the archaeological record is related to the sequence of alluvial fills.

Although the Holocene stratigraphic record will be the centerpiece of the first day, stops will also be made at localities with thick late Wisconsinan deposits. We will focus on colluvial and alluvial facies of the Severance Formation and demonstrate relationships among late Wisconsinan deposits in different landscape positions. Two stops will feature organic-rich alluvium at the base of the Severance Formation, and we will describe the plant macrofossils recovered from these deposits. At the final stop of the day, we will examine a Farmdalian peat buried beneath late Wisconsinan alluvium that underlies a Holocene alluvial fan. Peat localities are rare in the central Great Plains, and this stop will feature interpretations of the pollen assemblage and plant macrofossils associated with the peat.

The second day of the field conference will focus on Pre-Illinoian tills in northeastern Kansas. These tills are patchy in the study area, but they form an important component of the Quaternary landscape. Our discussion will focus on the stratigraphy of an exposure of the Independence Formation and the properties of a truncated weathering profile developed in the deposits. At a second stop, we will examine and discuss an exposure of the Sangamon Geosol, the most regionally extensive Quaternary pedostratigraphic unit in North America.

Location and Environmental Setting

The South Fork of the Big Nemaha River and its tributaries drain an area of about 896 km^2 in Richardson and Pawnee counties of southeastern Nebraska and Nemaha County of northeastern Kansas. The South Fork and North Fork of the Big Nemaha River join about 2 km southeast of Salem, Nebraska, forming the Big Nemaha River, which flows east to the Missouri River (fig. 1).

The natural vegetation of southeastern Nebraska and northeastern Kansas is tallgrass prairie interspersed with deciduous forests (Kuchler, 1964; Sautter, 1976, p. 69; Kaul and Rolfsmeier, 1993). The prairies are dominated by big bluestem *(Andropogon gerardii)*, little bluestem *(Andropogon scoparius)*, Indian grass *(Sorghastrum nutans)*, and switchgrass *(Panicum virgatum)*. Upland deciduous forests are dominated by black walnut *(Juglans nigra)*, bur oak *(Quercus macrocarpa)*, white oak *(Q. alba)*, black oak *(Q. velutina),* shagbark hickory *(Carya ovata)*, bitternut hickory *(C. cordiformis)*, and green ash *(Fraxinus pennsylvanica)*. Gallery forests along streams are dominated by cottonwood *(Populus deltoides)*, black willow *(Salix nigra)*, hackberry *(Celtis occidentalis)*, and American elm *(Ulmus americana)*.

The climate of southeastern Nebraska and northeastern Kansas is continental; the summers are hot, and the winters are cold. Mean annual precipitation for the region ranges from about 76 to 86 cm (Lawson and others, 1977). More than 70 percent of the annual precipitation occurs during the months of April through September. This period of high precipitation is largely a result of frontal activity. Maritime polar (mP) and continental polar (cP) air masses that flow into the region during late spring and early summer often converge with warm, moist, maritime tropical (mT) air flowing north from the Gulf of Mexico. The overrunning of mP and cP air by warmer mT air often produces intense rainfalls of short duration along the zone of convergence. Convectional thunderstorms during the late summer months may also produce heavy rainfalls.

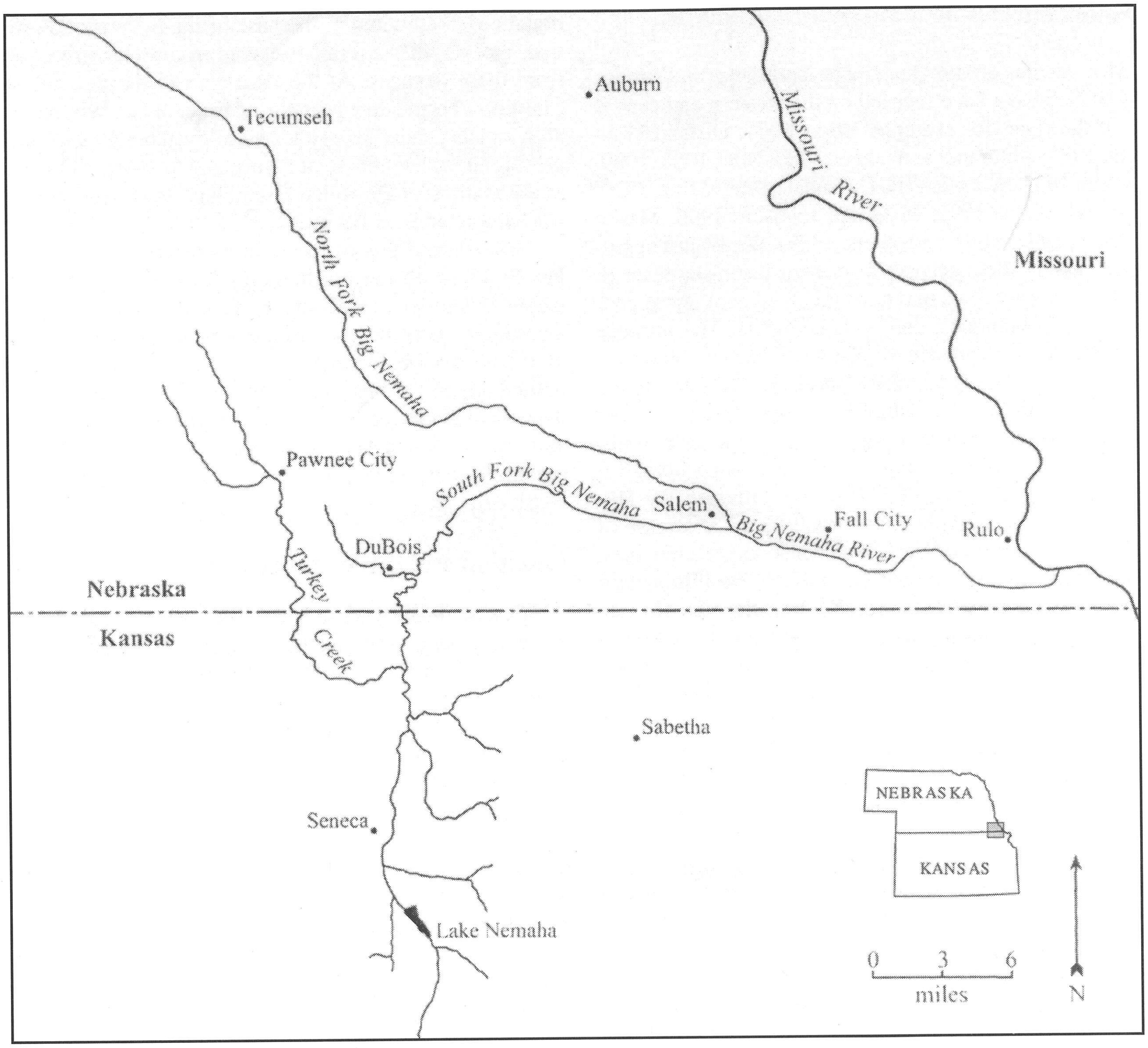


Fig. 1. The Big Nemaha River drainage network in southeastern Nebraska and northeastern Kansas.

Bedrock Geology

Pennsylvanian and Permian marine and near-marine rocks crop out and significantly influence landscape form and processes in the field trip area. Exposed rocks in the area are primarily limestone and shale of the Shawnee, Wabaunsee and Admire (Upper Pennsylvanian-Virgilian Stage) and Council Grove groups (Permian) (Pabian and Diffendal, 1991). Cyclic sedimentation, produced by marine regressions and transgressions, is well expressed in these rocks. Individual cycles are referred to as a "cyclothem" and ideally consist of a gray to green (locally red) sandy non-marine shale overlain by marine limestone, then black marine shale (deep, anoxic water), then gray shale grading upward to crossbedded and laminated limestone (shallowing marine) (Heckel, 1977). The cycles have been interpreted to reflect sedimentation controlled by glacioeustatic sea level changes produced by glaciation on the Southern Hemisphere supercontinent Gondwanaland (Crowell, 1978; Veevers and Powell, 1978). Bedrock geology in this area is complicated by structure associated with the Humbolt Fault Zone, a complex zone of faults and steep dips that has been active since the Paleozoic (Burchett and Arrigo, 1978).

Physiography and Quaternary Geology

The South Fork of the Big Nemaha River basin is in Fenneman's (1931) Glaciated Central Lowlands region of the Great Plains physiographic province. During the Pre-Illinoian episode of the Pleistocene, the area was covered by continental ice sheets that extended as far south as the Kansas River in northeastern Kansas. Glaciers buried pre-glacial stream valleys, cut new valley segments, and leveled cuesta-form uplands. Pro- and post-glacial streams subsequently dissected the drift plain, leaving glacial deposits high in the landscape. Hence, this region is often referred to as the Dissected Till Plains (Sautter, 1976, p. 69; Schoewe, 1949).

Quaternary landscapes in southeastern Nebraska and northeastern Kansas are products of a host of glacial, periglacial, and interglacial geomorphic processes. In many areas, Pennsylvanian and Permian bedrock units control landscape form. The advance of continental glaciers into the region during the early Pleistocene left a complex stratigraphic record. This record indicates that the glaciers covered parts of southeastern Nebraska and northeastern Kansas on more than two occasions during the Pleistocene, and there were at least seven glacial advances across the nearby Till Plain of southern Iowa (Boellstorff 1978a, 1978b; Hallberg and Boellstorff, 1978; Hallberg, 1986). Glacial drift, as well as Pleistocene alluvium and loess, have been documented in southeastern Nebraska (see Reed and Dreeszen 1965; Mandel and Bettis, 1995). Paleosols within these deposits mark episodes of landscape stability, and erosion surfaces indicate former episodes of landscape instability. Thus, the complexity of the Quaternary stratigraphy within the region is a result of a varied geologic history.

Pleistocene Stratigraphy

The Pleistocene stratigraphy of the Dissected Till Plains beyond the Wisconsinan and Illinoian glacial limits is based on a framework of Pre-Illinoian glacial tills and intercalated volcanic ashes and younger loesses. These deposits are regional in extent and thus provide references to which more localized fluvial and colluvial units can be stratigraphically related. By the mid-20th century, the region's Pleistocene stratigraphic sequence consisted of the classic North American glacial and interglacial stages: Nebraskan, Aftonian, Kansan, Yarmouthian, Illinoian, Sangamonian, and Wisconsinan. Glacial stages (Nebraskan and Kansan in this area) were marked by single till formations, along with associated stratified glaciogenic or periglacial sediments; interglacial stages were marked by paleosols, gumbo tills, or other evidence of weathering (Condra and others, 1950; Frye and Leonard, 1952, 1953). The glacial deposits were correlated regionally by reference to the Pearlette volcanic ash bed (Reed, 1948), which was inferred to be early Yarmouth (Frye and others, 1948) or late Kansan in age (Frye and Leonard, 1957; Hibbard, 1958; Reed and Dreeszen, 1965). Stratigraphic separation of the Kansan and Nebraskan tills was based solely on relationships to buried soil (weathering profile) "markers." During the 1960s and 1970s, work in Nebraska, Kansas, and Iowa demonstrated the inadequacy of the classical two-till, one-ash stratigraphy (Reed and Dreeszen, 1965; Dort, 1966; Bayne, 1968; Boellstorff, 1978a; Hallberg, 1980). Bollestorff (1978a and b) and Hallberg and Boellstorff (1978) demonstrated that classic correlations of the glacial sequence were grossly in error and that a much more complex sequence of glacial and interglacial deposits was present. In order to avoid further confusion with preexisting terminology and correlations, Quaternary deposits older than Illinoian are now referred to as Pre-Illinoian stages undifferentiated (Hallberg and others, 1980).

Deposits associated with at least two and as many as five Pre-Illinoian glacial episodes have been described from localities in northeastern Kansas (Frye and Leonard, 1952; Dort, 1966, 1985; Bayne and others, 1971; Aber, 1988, 1991). Two diamictons are commonly recognized in Kansas. The lower diamicton has been called the Nebraskan, Nickerson, Iowa Point, or lower Kansan till, and the upper diamicton has been called Kansan, Cedar Bluffs, or upper Kansan. Recently, Aber (1991) proposed the Independence Formation to include all these glacial diamictons and stratified sediments associated with them. The presence of a weathering profile in the lower diamicton at some localities (Bayne, 1968; Bayne and others, 1971) indicates a minimum of two Pre-Illinoian episode glaciations separated by nonglacial conditions, during which the weathering profile developed.

The Independence Formation's age is constrained by paleomagnetic, radiometric, and biostratigraphic studies. Studies of the remnant magnetism of glacial diamictons in Kansas have found that all exhibit normal polarity (Aber, 1991). This suggests that they accumulated during the Bruhns chron (after 0.72 Ma B.P.), or less likely the Jarmillo subchron (1.0-0.9 Ma B.P.). Lava Creek B volcanic ash (0.62 Ma B.P.) has been found in a terrace fill interpreted as postdating glaciation along the north wall of the Kansas River valley near De Soto in Leavenworth County, Kansas (Geil, 1987), thus providing a maximum limiting age. Martin and Schultz (1985) have assigned the Walthena Local Fauna, collected from beneath an Independence Formation diamicton in Doniphan County, Kansas, to the Sappan subprovince of the Irvingtonian Provincial Land Mammal Age. Sappan faunas in sections with radiometric control all predate 1.2 Ma B.P. The available evidence constrains Independence Formation diamictons and associated stratified sediments to the period between about 0.62 and 0.78 Ma B. P., during marine oxygen isotope stages 16-18.

The interfluves and Pleistocene terraces in southeastern Nebraska and northeastern Kansas are mantled by late-Quaternary loess. At least three stratigraphically superposed loesses are present in the South Fork of the Big Nemaha River basin: the Loveland, Gilman Canyon, and Peoria. The Loveland Loess is the most widespread pre-Wisconsinan loess in the Midcontinent. It is typically yellowish-brown or reddish-brown eolian silt that reddens (as a result of weathering) toward the top of the unit. Regional stratigraphic relationships suggest that the Loveland Loess in southeastern Nebraska is Illinoian in age, and that the Sangamon paleosol developed in the upper part of the unit is buried by Wisconsinan deposits. Thermoluminescence (TL) dating at the Loveland paratype section in western Iowa indicates that the Loveland Loess was deposited from 135 to 140 ka B.P. (Forman and others, 1992; Maat and Johnson, 1996). The upper part of the Loveland Loess is weathered to the Sangamon Geosol. This pedostratigraphic unit is usually well expressed and its color ranges from a vivid to pale reddish-brown. Constraining TL and radiocarbon ages indicate that the period of pedogenesis could have extended from about 120 to 55 ka B.P. (isotope stages 5d to 3). At some localities, the Sangamon Geosol represents several soils welded together to form a "pedocomplex" that may represent formation over a longer time span (Schultz and Tanner, 1957; Fredlund and others, 1985; Morrison, 1987).

The Gilman Canyon Formation was first described in south-central Nebraska (Reed and Dreeszen, 1965). This is the earliest Wisconsinan loess and is in the stratigraphic position of the Pisgah Formation in western Iowa (Bettis 1990) and the Roxana silt of the upper Mississippi River basin (Follmer, 1983; Leigh and Knox, 1993). The Gilman Canyon Formation is a dark, noncalcareous silt loam that has been modified by pedogenesis. In the field trip area, the Gilman Canyon Formation is usually thin (<1.5 m), and the soil developed into it is welded to the Sangamon Geosol. Radiocarbon and TL ages from the Gilman Canyon Formation range from about 40,000 yr B.P. at its base to 24,000 yr B.P. at the top (May and Souders, 1988; Johnson and others, 1990; Johnson and Zhaodong, 1993; Mandel and Bettis, 1995; Pye and others, 1995; Matt and Johnson, 1996; Muhs and others, 1999).

Peoria Loess, the dominant surficial deposit on uplands and Pleistocene terraces in the field trip area, overlies the Gilman Canyon and Severance formations and is typically a calcareous, massive, light yellowish tan to buff-colored silt loam. In the field trip area, the Peoria Loess is less than 3 m thick and usually noncalcareous as a result of post-depositional weathering. Radiocarbon ages from the Peoria Loess in the eastern Great Plains range from about 24,000-23,000 yr B.P. at its base to 13,000 yr B.P. near the top (Martin, 1993; Johnson and others, 1993; May and Holen, 1993; Mandel and Bettis, 1995).

The combined thickness of loess deposits in the South Fork of the Big Nemaha River basin is generally less than 4 m. In many areas of the Nemaha River basin, Loveland and Gilman Canyon Formation loesses have been eroded from the uplands and only a thin mantle (< 1 m) of Peoria Loess remains.

In the University of Nebraska (NU) State Museum's report on the geoarchaeology of the South Fork of the Big Nemaha River valley, Mandel (1996) noted that colluvial and alluvial facies of the Gilman Canyon Formation underlie Peoria Loess on slopes and the T-2 terrace, respectively. His interpretation was based on 1) the stratigraphic relationship of the colluvium and alluvium to the Peoria Loess; 2) the morphology of the paleosol developed in the colluvium and alluvium; and 3) the numerical age of the colluvium and alluvium. In this guidebook, colluvium and alluvium underlying the Peoria Loess on slopes and the T-2 terrace within the valley are referred to as colluvial and alluvial facies of the Severance Formation, an informal lithostratigraphic unit proposed for formal status. The type locality for the Severance Formation is in the Wolf River valley immediately west of the community of Severance in Doniphan County, northeastern Kansas. We have separated valley facies (colluvium and alluvium) of the Severance Formation from the upland facies (loess) of the Gilman Canyon Formation.

Holocene Stratigraphy

Deposits of fine-grained Holocene alluvium in the South Fork of the Big Nemaha River valley strongly resemble those of the DeForest Formation of western Iowa. This formation is a lithostratigraphic unit containing all fine-grained Holocene alluvium in Iowa (Bettis and Littke, 1987; Bettis, 1990, 1995). Recent studies have extended the DeForest Formation into southeastern Nebraska (Dillon, 1992; Mandel, 1994a, 1999; Mandel and Bettis, 1995), northwestern Missouri (Fosha and Mandel, 1991), and northeastern Kansas (Mandel and others, 1991; Mandel, 1994b) and adopted Iowa's lithostratigraphic nomenclature for Holocene alluvial and colluvial deposits. This approach is reasonable since lithostratigraphic units do not terminate at political boundaries (Mandel and Bettis, 1995). Hence, the Holocene alluvial deposits in the South Fork of the Big Nemaha River valley are included in the DeForest Formation (Mandel, 1996).

Daniels and others (1963) originally defined the DeForest Formation as a sequence of alluvial fills in small valleys of the Loess Hills of western Iowa. Subsequent studies of drainage basins in Iowa and adjacent parts of the Midwest have led to expansion and revision of the formation (Bettis, 1990, 1995; Fosha and Mandel, 1991; Dillon, 1992; Mandel and Bettis, 1992, 1995; Mandel, 1994a, 1994b, 1996, 1999; Bettis and others, 1996a). The DeForest Formation consists of eight formal members, one of which, the Honey Creek Member, is new (Bettis, 1990, 1995; Bettis and others, 1996a). Only five members of the formation, the Camp Creek, Roberts Creek, Honey Creek, Gunder, and Corrington, are present in the field trip area. The Camp Creek Member encompasses deposits formerly referred to as "post-settlement alluvium." This member consists of stratified to massive, calcareous to noncalcareous, very dark gray to brown silt loam to clay loam, though some deposits may consist of coarser sediment. It is inset into or unconformably overlies the Gunder, Corrington, Honey Creek, and Roberts Creek members, depending on the geomorphic setting and history of land use (Bettis, 1990; Bettis and others, 1996a). The thickness of the Camp Creek Member is extremely variable in the South Fork of the Big Nemaha River basin, ranging from a few centimeters to more than 6 m. Surface soils developed in the Camp Creek Member are Entisols and thin Mollisols with organically enriched A horizons grading to stratified parent materials (C horizons). The Camp Creek Member includes sediment that accumulated after about 500 yr B.P. (Bettis, 1990; Mandel and Bettis, 1992).

The Roberts Creek Member consists of dark-colored, clayey, silty, and loamy alluvium. In the South Fork of the Nemaha basin, this member occurs only as channel fills in small (< third-order) valleys, but it forms channel fills and thick flood drapes in larger valleys. The Roberts Creek Member can overlie a wide variety of deposits, including the Gunder and Corrington members, coarse-grained older alluvium, loess, and glacial diamicton (Bettis, 1990, 1995). Roberts Creek Member deposits usually occur beneath floodplains and low terraces in large valleys. The Roberts Creek Member is separated from the younger Camp Creek Member of the formation

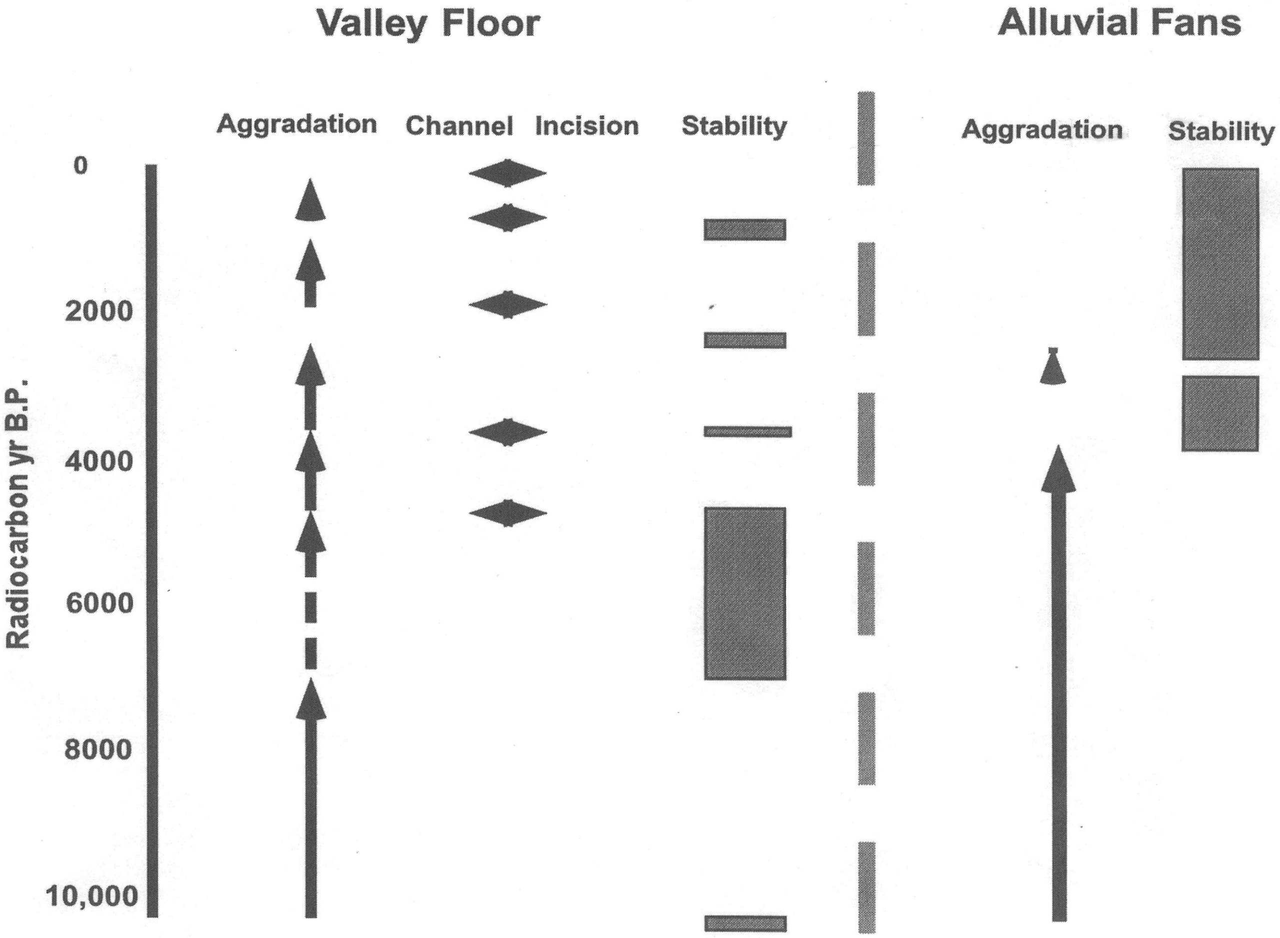


Fig. 26. Summary of the chronology of Holocene stream behavior in the study area. Arrows and arrow heads mark periods of aggradation; diamonds indicate shorter periods of degradation, and rectangles indicate stability. Ages are in uncalibrated radiocarbon years B.P., as in other figures.

Because the buried soils identified in the project area represent these surfaces, evidence for occupation would most likely be associated with them. It is important to note, however, that buried cultural deposits, even rich ones, also may be found in sediment that has not been modified by soil development (Hoyer 1980). Hence the presence or absence of buried soils cannot be used as the sole criterion for evaluating the potentials for buried cultural materials. The mere presence of Holocene deposits beneath a geomorphic surface offers some potential for buried cultural materials.

Our findings suggest that there is relatively low geologic potential for buried cultural deposits in valley fill beneath the T-2 terrace. This landform is mantled by a thin unit of Peoria Loess that was deposited sometime between ca. 20,000 and 12,000 yr B.P.

In contrast, there is high geologic potential for buried cultural deposits in valley fill beneath the T-1 terrace. However, the complex mosaic of deposits beneath the T-1 surface makes it difficult to predict the temporal and spatial patterns of such deposits. In places where it is preserved, the early Gunder Member may contain Paleoindian and Early and Middle Archaic deposits. At Kinters Ford, buried soils in the early Gunder Member date to about 7,000 and 4,800 yr B.P. Although no archaeological materials were found in these soils, a shallow buried soil developed in the upper part of the early Gunder Member at site 25PW64 (stop 4) contains late Middle Archaic cultural deposits.

At many localities in the study area, the late Gunder Member is laterally inset against the early Gunder Member or late Wisconsinan deposits. The late Gunder Member aggraded to the same level as the early Gunder Member; hence, both units underlie the T-1 surface. Cultural deposits dating to the Middle Archaic may be deeply buried in the late Gunder Member. However, there is greater potential for Late Archaic cultural deposits in association with buried soils in the upper part of the late Gunder Member. This potential was realized at sites 25PW63, 25PW65, and 25PW83. It is important to note that cultural deposits in the late Gunder Member are likely to represent short-term occupations, perhaps hunting camps, in a relatively unstable fluvial environment. Buried soils in the late Gunder Member are products of relatively short episodes of floodplain stability and were prone to frequent flooding. This type of setting would have been unfavorable for long-term human occupations, such as villages, that would have left a rich archaeological record.

Cultural materials dating to the Woodland period are likely to be deeply buried in the Honey Creek Member. This unit also occurs beneath the T-1 surface, and it contains a sequence of superposed buried soils. At site 25PW65 (stop 4), archaeological deposits dating to ca. 1,850 yr B.P. are associated with a buried soil 4.6-4.75 m below the T-1 surface. However, it is important to consider that the alluvium composing the Honey Creek Member accumulated rapidly, and the buried soils are products of short episodes (a few hundred to tens of years) of floodplain stability. Therefore, cultural deposits associated with the buried soils and the unweathered alluvium between them are likely to be sparse. A case in point is 25PW65, which is best described as an ephemeral site.

The results of this investigation suggest that there is low geologic potential for prehistoric cultural deposits beneath the modern floodplain complex (T-0) of the Nemaha River. Although the numerical age of T-0 fill is not well defined, much of it consists of the Camp Creek Member (<400 yr B.P). The presence of a weakly expressed surface soils (A-C profiles) on the modern floodplain indicates that this geomorphic surface is young. Also, bedding is well preserved at shallow depths, and no buried soils have been observed in the T-0 fill. Hence, floodplain aggradation has been fairly rapid over the past several hundred years.

There is high geologic potential for buried cultural deposits in alluvial fans that have developed where small streams flow out onto the valley floor of the Nemaha River. Unfortunately, good exposures of fan deposits are not common in the study area. However, based on evidence from the Miles alluvial fan, the evolution of Holocene fans was underway in the Nemaha River valley soon after ca. 10,500 yr B.P. and ceased soon after 3,000 yr B.P. It is important to note that alluvial fans often contain deeply buried cultural resources (see Hoyer, 1980; Bettis, 1990; Hajic, 1990; Mandel, 1995). Therefore, the fans in the Nemaha River valley should be targeted for deep, subsurface testing during future archaeological investigations.

The history of Holocene landscape evolution stored in the valley fill of the South Fork of the Big Nemaha River is complex and fragmentary; not all erosional or depositional events are preserved at one location or, necessarily, among several locations in the study area. Despite this problem, enough information is available to allow archaeologists to concentrate future testing in potentially productive areas. For example, a search for Late Archaic deposits should focus on the buried soils in the upper part of the late Gunder Member. These soils are easy to recognize and are useful stratigraphic markers in the late Holocene valley fill beneath the T-1 terrace. On the other hand, a search for Early and Middle Archaic materials should focus on the early Gunder Member beneath the T-1 terrace and on alluvial fans. Buried soils dating to the early Holocene are visible in cutbanks that have exposed the Corrington and early Gunder members. However, no archaeological survey is needed on the modern floodplain complex (T-0) of the Nemaha River. These low surfaces have been unstable geomorphic settings since the beginning of T-0 aggradation, and much of the T-0 fill appears to be too young (Camp Creek Member) to contain prehistoric cultural materials.

The three-dimensional landscape analysis used in the geoarchaeological survey of the South Fork of the Big Nemaha River valley yielded new information that helps explain certain aspects of the archaeological record in the survey area (Mandel, 1996). The results of that study strongly suggest that geologic processes have filtered the archaeological record. As geomorphic investigations continue in the Nemaha River valley, apparent gaps in the archaeological record may be filled and we may gain a better understanding of the relationship between people and the landscape.

Holocene Vegetational Change in Southeastern Nebraska

by Richard G. Baker and Glen G. Fredlund

Few paleobotanical records exist in the central Great Plains because bogs typically used for palynology are extremely rare. One of the few bogs is Muscotah Marsh in nearby northeastern Kansas. Although this record is excellent, it is incomplete and not well dated. It indicates that prairie was present throughout the Holocene, although some trees may have been present in the early Holocene. However, few details are revealed about the Holocene vegetation. Fluctuations in such cosmopolitan and weedy taxa as chenopods/amaranths, ragweed, sagebrush, and grass pollen are difficult to interpret (Grüger, 1973; Wright and others, 1985; Fredlund, 1995). The other closest sites with Holocene representation are the Cheyenne Bottoms in central Kansas, about 285 km southwest of our sites (and with an incomplete Holocene section), and lakes in the central Dakotas (for example, Laird and others, 1998) and northwestern Iowa (Van Zant, 1979), >500 km to the north and >400 km to the northeast, respectively.

When Mandel discovered that cutbanks of the South Fork of the Big Nemaha River contained abundant organic remains (Mandel, 1996), we were invited to use the techniques developed in northeastern Iowa (Baker and others, 1996, 1998) and western South Dakota (Fredlund and Tieszen, 1997) to investigate the vegetational history of the area. We collected approximately 1-liter samples in resealable plastic bags from several organic-rich zones near the base three large cutbanks along the South Fork of the Big Nemaha River near Dubois, Nebraska. These were collected by Mandel, Bettis, Baker, and Krieg, and subsampled by Baker for plant macrofossils and by Fredlund for phytoliths, pollen, and stable carbon isotopes. Samples were prepared for phytolith analysis by 1) removal of carbonates with HCl; 2) removal of clays with 0.1N sodium pyrophosphate; 3) oxidation of the residue

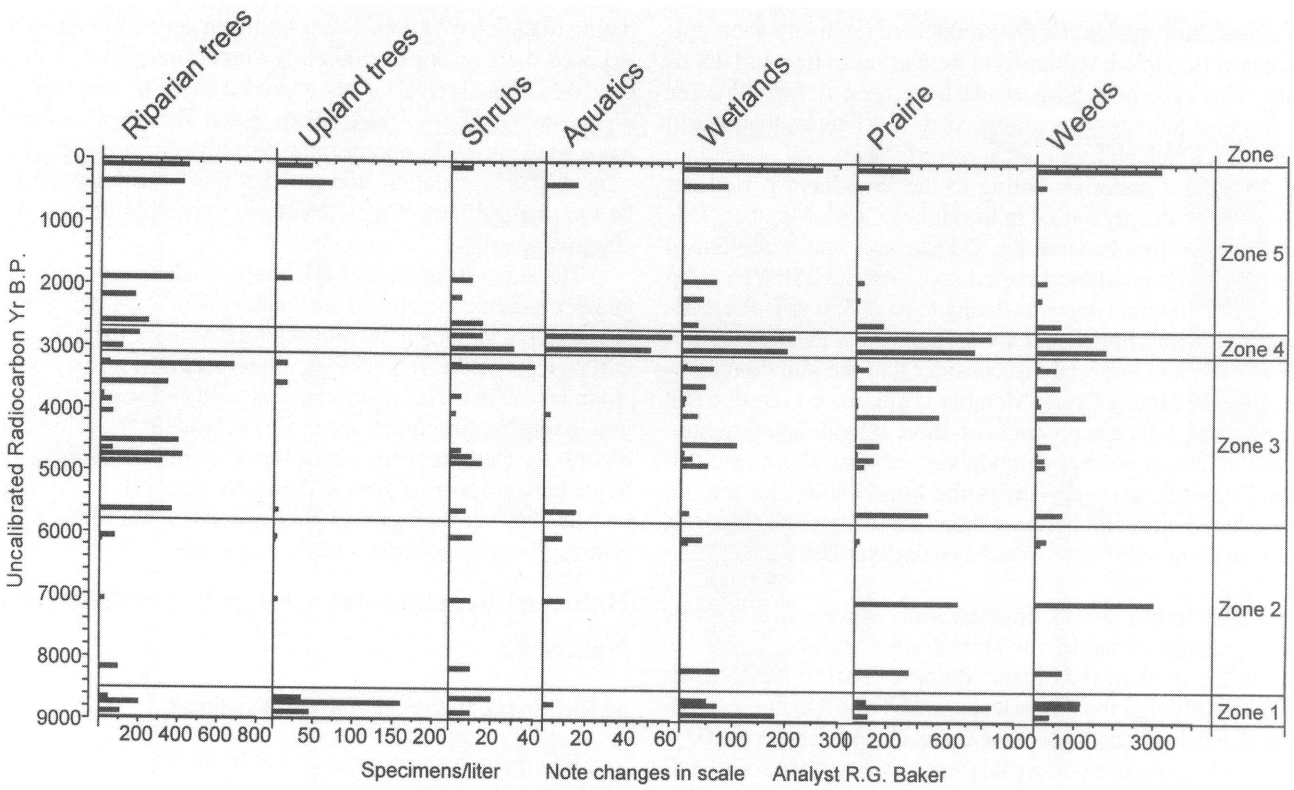


Fig. 27. Summary of plant macrofossils from cutbanks along the South Fork of the Big Nemaha River near DuBois, Nebraska.

with 30% hydrogen peroxide; and 4) isolation of biogenic silicates using heavy-liquid (ZnBr2 at 2.35 specific gravity) as described in Fredlund and Tieszen (1997). Pollen samples were processed using heavy liquid flotation (Johnson and Fredlund, 1985). Pollen and phytoliths were identified using reference materials at the Geography Department of the University of Wisconsin-Milwaukee. Plant macrofossils were washed through 0.5 and 0.1 mm sieves, picked by hand, and identified using the reference collection at the Geoscience Department of the University of Iowa.

The stable carbon isotope analyses of bulk organic matter were carried out at the Isotope Ratio Mass Spectrometer facility in the Biology Department at Augustana College, Sioux Falls, South Dakota, as described in Fredlund and Tieszen (1997). Pretreated samples were combusted in a Carlo Erba CHN analyzer coupled to an SIRA-10 Isotope Ratio Mass Spectrometer fitted with a special triple trap to isolate cryogenically and purify the CO_2. Lab standard and random replicates were run to ensure precision better than 0.2l. Isotopic ratios are expressed as per-mil deviations from the PDB standard.

The results of these studies are in Baker and others (2000) and Baker (2000). We provide a brief overview of the research here. Each sample is a snapshot of paleoecological conditions, and the samples are arranged in chronological order by their radiocarbon age (fig. 27). Five zones are recognized by visual inspection. Macrofossils in zone 1 (ca. 9,000 to 8,500 yr B.P. (all ages are in uncalibrated radiocarbon years B.P.) indicate that upland deciduous trees were present, but prairie, weedy, and wetland habitats were also well established. Zone 2 (ca. 8,500 to 5,800 yr B.P.) is sparsely represented, but upland trees disappeared, riparian trees and wetland plants were sparse, and weeds and prairie taxa fluctuated from low to high values. This interval was probably the warmest, driest part of the Holocene. Zone 3 (ca. 5,800 to 3,100 yr B.P.) had at least at times a rich riparian forest, along with well-developed prairies, disturbed habitats, and wetlands. This period was more moist but with intermittent droughts. Zone 4 (ca. 3,100 to 2,700 yr B.P.) has peaks in many prairie and weedy elements, whereas riparian forest elements nearly disappeared, suggesting another warm, dry interval. Zone 5 represents a return to somewhat less arid conditions and records a strong signature of introduced weeds in post-settlement time.

Phytoliths are represented by many morphotypes; several are characteristic in well-defined subgroups of grasses, whereas some are nearly ubiquitous. Fredlund and Tieszen (1997) worked with 10 morphotypes (not all shown on fig. 28) that allow the distinction between tall C_4 grasses (tallgrass prairie taxa), short C_4 grasses (tribe Chlorideae, of drier habitats) and C_3 grasses (cool-season grasses more common in northern prairies and in non-prairie environments). Saddles represent the Chloridoid group of C_4 grasses, including the short-grass prairie dominants. Panicoid types include the major C_4 tall-grass prairie grasses, and rondels and rectangles represent cool-season C_3 grasses.

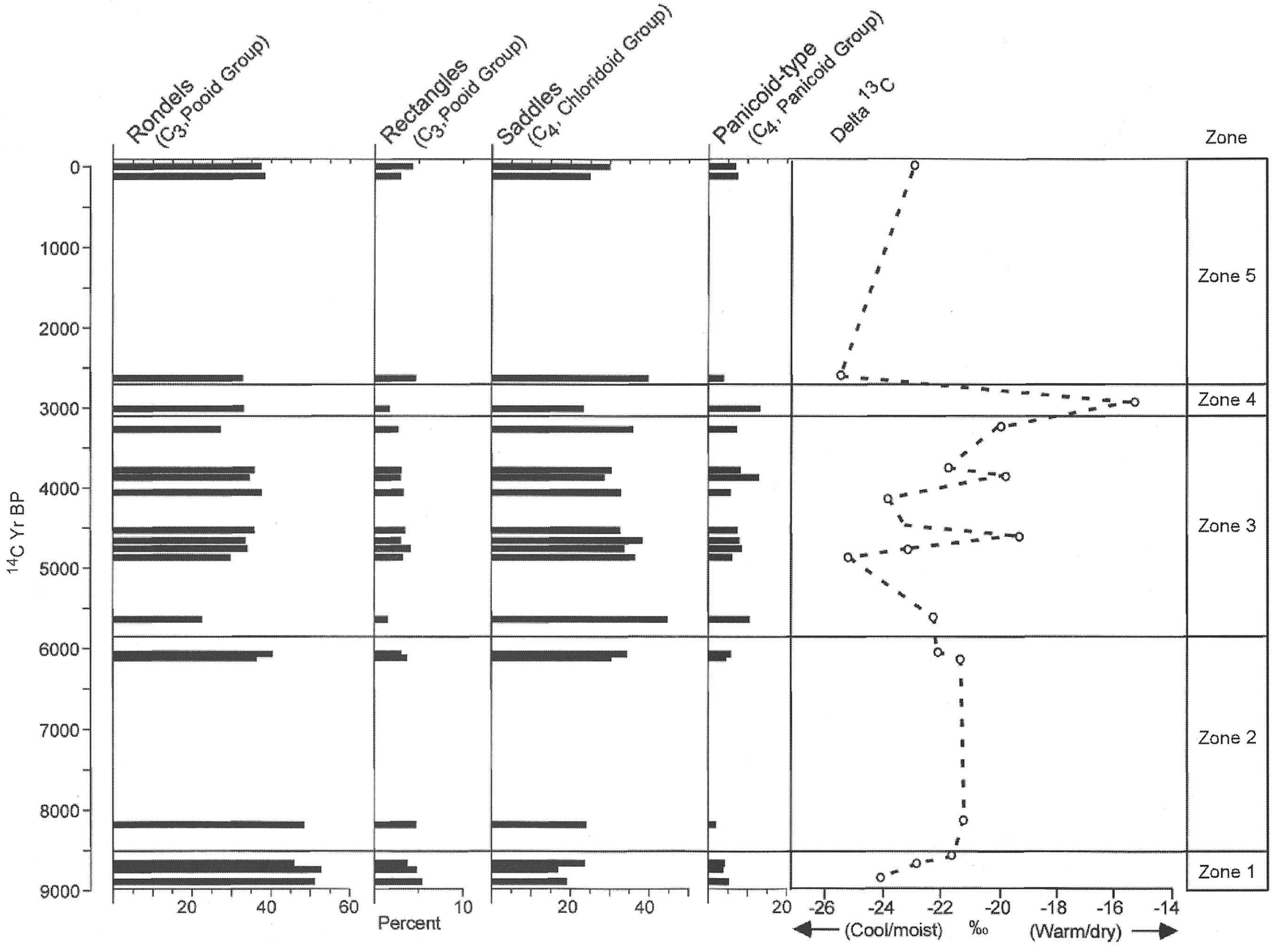


Fig. 28. Carbon isotopes and selected phytoliths from cutbanks along the South Fork of the Big Nemaha River near DuBois, Nebraska.

Rondel and rectangle types are most abundant in zone 1 (fig. 28), suggesting that cool-season grasses were prominent when deciduous trees reach their peak in the early Holocene. These types decrease to minima between ca. 6,000 and 5,000 yr B.P. and reach another low value about 3,000 yr B.P., when climate was thought to be warmer and drier. Saddles are lowest in zone 1, increase to peaks in the warm, dry intervals in mid-Holocene zones 2 and 3 and again in the late Holocene, about 3,300 and 2,600 yr B.P. They are inexplicably low in zone 4, which is considered to be warm and dry, and they also fall to low values in post-settlement times. Panicoid types reach peaks in zones 3 and 4 (ca. 6,000 to 2,600 yr B.P.) and are at lower levels above and below.

Carbon isotopic values are low, indicating cooler environments and a high proportion of C_3 plants, in the early Holocene zone 1, when deciduous trees were still present (fig. 28). They are higher in zone 2, but there is a large gap with no samples that covers most of that zone. They fluctuate in zone 3 from low to high values, and they reach a peak in zone 4, suggesting a high proportion of C_4 plants. The values reach their lowest values, ca. -26/mil, at the base of zone 5, and they are also low in the only other sample in zone 5 (in post-settlement sediments).

In summary, several lines of evidence indicate that deciduous forest remnants were present in the prairies of this area in eastern Nebraska until about 8,500 yr B.P. (uncalibrated radiocarbon). A warm, dry period followed from ca. 8,500 to 5,800 yr B.P. that is represented by only a few fossil localities. Fluctuating values of carbon isotopes and plant macrofossil groups suggest intermittent droughts in a generally cooler period from ca. 5,800 to 3,100 yr B.P., compared with the preceding one. During a short period between ca. 3,100 and 2,700 yr B.P., upland and most riparian trees completely disappeared, and prairie plants, weeds, and carbon isotopes reached high values. These changes are tentatively interpreted as a short warm, dry episode. Few samples are available from 2,700 yr B.P. to the present, but two low values of carbon isotopes and the return of arboreal macrofossils suggest a return to cooler conditions.

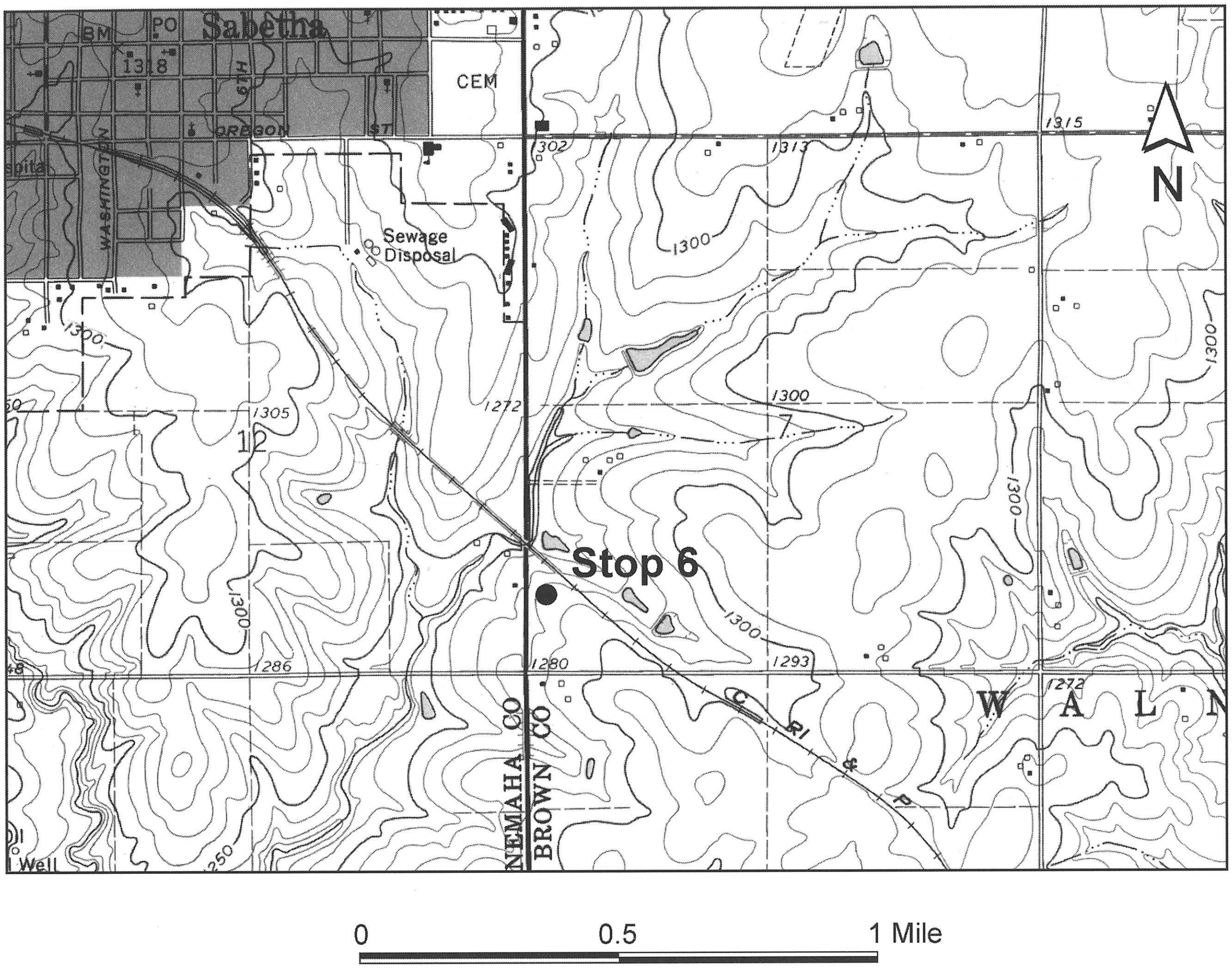


Fig. 29. Topographic map showing the location of stop 6.

Stop 6. Sabetha Borrow Pit

The Sabetha borrow pit (stop 6) is located on the south side of Sabetha, Kansas, a small community in northeastern Kansas (figs. 2 and 29). A borrow pit dug into the side of a hill exposes a 4-m-thick section of oxidized, unleached, Pre-Illinoian till (Independence Formation) overlain by a thin unit of silty colluvium. This brief stop provides an opportunity to examine the Sangamon Geosol developed in the upper part of the till. Our discussion will focus on 1) the properties of the Sangamon Geosol; 2) regional correlations of the Sangamon Geosol; and 3) the value of the Sangamon Geosol as a stratigraphic marker in the region.

Geosols (pedostratigraphic units) are laterally traceable buried soils on portions of past landscapes that have a known stratigraphic position (North American Commission on Stratigraphic Nomenclature, 1983). The overlying unit establishes the statigraphic position of a geosol. In the midcontinent, Wisconsinan loess and tills are regionally extensive tabular deposits whose stratigraphic position are well established. These deposits bury and thereby establish the stratigraphic position, of the Sangamon Geosol.

At the Sabetha borrow pit, silty colluvium (slope sediments) derived from Peoria Loess is the surficial deposit. The colluvium contains more sand and stones with depth and buries an erosional surface developed on the Sangamon Geosol. The presence of a modern soil with morphology similar to soils developed in Peoria Loess in the upper part of the colluvium suggests that the colluvium is a facies of the loess.

The Sangamon Geosol exposed in the section at stop 6 is a well-expressed, 1.9-m-thick, EB-Bt-BC soil profile developed in loamy pre-Illinoian glacial diamicton. The Bt horizon is strong brown (7.5YR hue) and has moderate to strong angular blocky soil structure with continuous argillans (clay coatings) on ped surfaces. Accumulations of secondary carbonate occur as soft masses and coatings along fractures in the diamicton below the solum. Properties of the Sangamon Geosol at the Sabetha pit are typical for well-drained examples of this pedostratigraphic unit in the eastern Great Plains and Midwest (Hall and Anderson, 2000).

by either a fluvial erosion surface or a hiatus marked by a buried soil. Weakly developed buried soils with A-C or A-Bw profiles are common in the Roberts Creek Member, but they are rarely traceable from one valley to another. In the South Fork of the Big Nemaha River basin, surface soils developed into the Roberts Creek Member are thick, dark-colored Mollisols. These soils are morphologically less well expressed and have darker colored B and C horizons than soils developed in the older Gunder and Corrington members. In large valleys, such as the South Fork of the Big Nemaha, the Roberts Creek Member ranges in age from ca. 3,000 to 500 yr. B.P. (Bettis, 1990, 1995; Mandel and Bettis, 1992).

The Gunder Member consists of oxidized, dominantly silty and loamy alluvium lacking a loess cover. Lower parts of this member may be reduced and/or coarse grained. Gunder Member deposits occur in valleys of all sizes and unconformably overlie coarse-grained and often organic-rich older alluvium, loess, glacial diamicton, or bedrock (Bettis, 1990, 1995). Younger members of the formation are separated from the Gunder Member by a fluvial erosion surface or a hiatus marked by a buried soil. In the Big Nemaha River basin, surface soils developed in the Gunder Member are thick Mollisols with brown or yellowish brown Bw or Bt horizons. Buried soils have been documented within the Gunder Member, but they are not widely traceable or useful as regional pedostratigraphic units. The Gunder Member ranges in age from about 10,500 yr. B.P. at its base to about 2,000 yr B.P. at its surface (Bettis, 1990, 1995; Mandel and Bettis, 1992). In large valleys, such as the South Fork of the Big Nemaha, the Gunder Member is often represented in two separate fills beneath the same terrace: a strongly oxidized fill dating from ca. 10,500 B.P. at its base to ca. 4,500-5,000 yr B.P. at its surface (early Gunder), and a moderately oxidized fill dating from ca. 4,500-4,700 yr B.P. at its base to ca. 2,000 yr B.P. at its surface (late Gunder).

The Honey Creek Member, which was first recognized in southeastern Nebraska and referred to as the Honey Creek Fill (Dillon, 1992), is a grayish brown to brown (10YR 3/1-5/3) silt loam that is massive in its upper part and has large-scale trough cross-bedding and epsilon cross-stratification near its base. The Honey Creek Member occurs as a channel fill in large- and intermediate-size streams (> fourth-order); it has not been observed in smaller drainage elements. It is inset into the early and late Gunder Member, but its stratigraphic position relative to the Roberts Creek Member is unclear. Surface soils developed in the Honey Creek Member are Mollisols with A-Bw profiles, and weakly expressed buried soils with A-C and A-Bw profiles are common in this unit. The Honey Creek Member accumulated between ca. 3,700 and 1,000 yr B.P. (Dillon, 1992; Mandel, 1996, 1999).

Corrington Member deposits underlie alluvial fans and colluvial aprons along valley margins. Alluvial fans are located where small streams (first- through third-order) enter large valleys. The Corrington Member is the most internally variable unit of the DeForest Formation and consists of very dark brown to yellowish brown oxidized loam and clay loam with interbedded lenses of sand and gravel (Bettis, 1990, 1995; Mandel and Bettis, 1992). The unit is stratified and often contains multiple buried soils. Surface soils developed into the Corrington Member are typically thick Mollisols with argillic (Bt) horizons, though some have cambic (Bw) horizons. The Corrington Member buries coarse-grained older alluvium, glacial diamicton, loess, or bedrock and can grade laterally into Gunder Member deposits. The Corrington Member accumulated between ca. 9,000 and 3,000 yr B.P. (Bettis, 1990; Mandel, 1995; Mandel and Bettis, 1992).

Stratigraphic Nomenclature

by Jeremy S. Dillon, Rolfe D. Mandel, and E. Arthur Bettis III

In this guidebook, late Quaternary alluvial deposits are assigned to two lithostratigraphic units: the DeForest and Severance formations. Alluvium can present challenges with regard to stratigraphic nomenclature, and some researchers may object to the use of lithostratigraphy in alluvial settings. The following discussion addresses stratigraphic nomenclature and presents arguments for using lithostratigraphy instead of allostratigraphy and chronostratigraphy in the South Fork of the Big Nemaha River valley.

According to Article 22 of the North American Stratigraphic Code, a lithostratigraphic unit is

> ...a defined body of sedimentary, extrusive igneous, metasedimentary, or metavolcanic strata which is distinguished and delimited on the basis of lithic characteristics and stratigraphic position. A lithostratigraphic unit generally conforms to the Law of Superposition and commonly is stratified and tabular in form (North American Commission on Stratigraphic Nomenclature, 1983, p. 855).

The Code states that a lithostratigraphic unit is not required to be cemented or lithified. Clay, till, and other unconsolidated materials are given as examples of deposits that may be assigned lithostratigraphic status. Critical to the recognition of a lithostratigraphic unit is the nature of "lithic characteristics." Article 24 of the Stratigraphic Code defines lithic characteristics as

> ...chemical and mineralogical composition, texture, and such supplementary features as color, primary sedimentary or volcanic structures, fossils (viewed as rock-forming particles), or other organic content (coal, oil shale) (North American Commission on Stratigraphic Nomenclature, 1983, p. 855).

As noted earlier, the DeForest Formation consists of eight formal members. Each member is recognized on the basis of color (mostly reflecting variations in iron oxide and organic matter content), internal bedding styles, and stratigraphic position. Radiocarbon ages and the morphology of soils developed in the upper parts of the units are not criteria for defining a lithostratigraphic unit, but these data confirm that consistent alluvial stratigraphic relationships extend across regions.

Problems arise with the laterally discontinuous nature of alluvium. Because the DeForest Formation is composed of valley fill sediments, the deposits are not connected from basin to basin. Therefore, one can argue that Holocene alluvial deposits in widely separated drainage basins are formed from different parent materials and should be considered separate stratigraphic bodies. However, any laterally extensive lithologic unit, such as the Peoria Loess, probably includes sediment from a variety of sources (for example, Muhs and Bettis, 2000). Furthermore, one can argue that elements of a regional drainage are ultimately interconnected. The important feature of the DeForest Formation is that deposits with the same internal, lithic characteristics are traceable from basin to basin. Laterally traceable boundaries are not required since the units are recognized by internally consistent, objectively mappable lithic criteria.

Some workers have applied allostratigraphy to Holocene alluvium. Article 58 of the North American Stratigraphic Code defines an allostratigraphic unit as "...a mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities" (North American Commission on Stratigraphic Nomenclature, 1983, p. 855). The discussion of allostratigraphic units centers on deposits of similar lithology bounded by discontinuities that can be traced laterally. If the bounding discontinuities cannot be traced laterally, the Code states that "...they must be extended geographically on the basis of objective correlation of internal properties of the deposits other than lithology, topographic position, numerical ages, or relative-age criteria" (North American Commission on Stratigraphic Nomenclature, 1983, p. 867). Superposed till bodies, valley-fill sediments composed of repeating facies, and terrace gravels are used as examples of candidates for allostratigraphy.

Autin (1992) provided an excellent example of the use of allostratigraphy for fluvial deposits. He recognizes three alloformations based on unconformable boundaries, landscape morphology, and relative pedogeneic development. Similar lithofacies are identified in all units. However, each alloformation represents a discrete landform sediment assemblage formed during a separate period of time (Autin, 1992). Hence, brown silt, gray silt, and sand facies are included in each alloformation and not recognized as individual lithic units. This approach has created a consistent, logical model for deposits in the Amitee River of southeastern Louisiana (Autin, 1992).

Members of the DeForest Formation rarely occur as individual terrace fills that can be mapped by topography. In the eastern Great Plains and Midwest, one broad geomorphic surface often dominates the valley floors of streams, and three or four members of the DeForest Formation may underlie this surface. Furthermore, individual members are separated by discontinuities that are evidenced by changes in color and primary sedimentary structures. These are internal lithic characteristics, and differentiation based on these criteria fits the definition of a lithostratigraphic unit. As the code states, "unconformities, where recognizable objectively on lithic criteria, are ideal boundaries for lithostratigraphic units" (North American Commission on Stratigraphic Nomenclature, 1983, p. 856). This distinction would seem to be a deliberate contrast to allostratigraphic units composed of similar facies separated by recognizable discontinuities.

It is important to note that each member of the DeForest Formation is usually composed of multiple fills. Within each member, the individual fills are lithologically similar and are recognized by weakly formed soils or erosional disconformities. These lithologically similar beds would suggest allostratigraphy. However, the disconformities and weak soils are rarely traceable beyond individual exposures. Furthermore, the individual fills that comprise a member, while internally similar, are easily distinguished from those of adjacent or nearby members on the basis of color and bedding style. Once again, lithic characteristics are the primary criteria for recognition and identification.

In addition, using allostratigraphy to recognize cut-and-fill episodes would result in a plethora of local stratigraphic units. One would have to decide between lumping the fills into one undifferentiated unit, making general correlations based on radiocarbon age (that is, early, middle, or late Holocene), or attempting to group the units of similar lithology. The first two approaches tend to obscure important details concerning fluvial processes, and the latter approach is lithostratigraphy.

Finally, in situations where the numerical ages of Holocene deposits are known because of intensive radiocarbon dating, one is tempted to apply chronostratigraphy to these deposits. However, detailed radiocarbon chronologies have demonstrated that Holocene alluvial fills are diachronous, even within individual basins (for example, Bettis, 1990; Mandel, 1992, 1995). Hence chronostratigraphy is problematic in stream valleys.

We concede that there are problems and limitations in the application of lithostratigraphy to Holocene alluvium. Sometimes it is not easy to recognize individual members due to reducing conditions (gleization), poor exposures, and local facies variation. However, use of the DeForest Formation has yielded consistent stratigraphic and chronologic relationships across a broad region. This has led to many advances in our understanding of Holocene paleogeography and of processes and driving forces in fluvial systems. As the North American Commission on Stratigraphic Nomenclature (1983, p. 847) pointed out, "The objective of a system of classification is to promote unambiguous communication in a manner not so restrictive as to inhibit scientific progress." We have tried to follow their guidance.

Landform Sediment Assemblages

The South Fork of the Big Nemaha River valley is a complex mosaic of landform sediment assemblages produced by late Quaternary fluvial, eolian, and gravitational processes. The landscape has been subjected to periods of stability, evidenced by soil development, and instability, evidenced by floodplain aggradation, stream entrenchment (resulting in terrace formation), and alluvial/colluvial fan development. The following discussion briefly describes the different landform sediment assemblages that were identified and studied in the Nemaha Valley. Landform sediment assemblages are landforms and underlying genetically related packages of sediment and associated soils (Bettis and others, 1996b).

The valley floor of the South Fork of the Big Nemaha River is 1-2 km wide in the area of DuBois, Nebraska, and consists of two landform sediment assemblages: an alluvial terrace (T-1) and a modern floodplain complex (T-0). The T-1 terrace is a paired geomorphic surface that dominates the valley floor. It has a gently sloping tread and subtle alluvial features, including natural levees, meander scars, and flood chutes. The T-1 surface represents the former floodplain that was abandoned as the river underwent a period of deep entrenchment during the last century. Channel entrenchment left the T-1 surface 8-12 m above the modern channel.

There is a series of unpaired, discontinuous surfaces within the entrenched channel of the river. These surfaces, along with active bar deposits, form the floodplain complex (T-0). As an active floodplain, it is flooded frequently and at fairly consistent recurrence intervals.

Alluvial fans and colluvial aprons occur along the margins of the valley floor of the South Fork of the Big Nemaha River and its major tributaries. The fans have developed where small, ephemeral streams join the large valleys of the trunk streams. Most of the fans grade to the T-1 surface.

Remnants of a loess-mantled terrace (T-2) are common on both sides of the South Fork of the Big Nemaha River. The T-2 surface is relatively flat and featureless and is elevated 9-12 m above the T-1 surface. Alluvial terraces higher than T-2 are present, but they have not been investigated.

Day 1

Stop 1. Highway 75 Crossing

At this stop, we will examine the geomorphology of the South Fork of the Big Nemaha River valley (figs. 2 and 3). This locality also provides an opportunity to see how the U.S. Army Corps of Engineers has modified the Nemaha. Before it was channelized, the Nemaha flowed in a shallow, meandering channel on the north side of the valley floor; it now flows in a deep, straight channel in the middle of the valley floor (fig. 3).

The T-1 terrace is the lowest geomorphic surface and dominates the valley floor at stop 1. This valley landscape is representative of the lower South Fork of the Big Nemaha River and will be seen at other stops during the field trip. A prominent scarp on the south side of the valley floor separates the T-1 terrace from a high alluvial terrace. The surface of the high terrace is 10-12 m above the valley floor and has been deeply dissected by gullies. Valley fill underlying the high terrace is only 2-3 m thick and mantles a strath cut on bedrock. The bedrock is exposed in the face of the scarp and in the roadcut where Highway 75 South rises off the valley floor.

Oil wells in the vicinity of stop 1 are part of the 680-acre Dawson Field, which was opened in 1941. The Dawson Field was part of a larger oil play in Richardson County in 1940 and 1941 (Carlson, 1989). At its peak in 1955, the field had 13 wells producing 117,481 barrels (Reed and Johnston, 1975). In 1991, the field's four producing wells yielded 1,700 barrels (Carlson and Newell, 1997). Oil in this Forest City Basin field is contained in a structural trap (anticline) and is drawn from three zones at depths of between 655 and 990 m: the Hunton Dolomite (Devonian); carbonate facies of the Maquoketa Formation (Upper Ordovician); and the Simpson Group's St. Peter Sandstone (Lower/Middle Ordovician).

Stop 2. Old Bridge Locality – Entrenched Stream Processes and Stratigraphy

The Old Bridge locality is located about 13 km upstream from stop 1 (figs. 2 and 4). A 400-m long cutbank on the east side of the South Fork of the Big Nemaha River exposes a complex sequence of alluvial deposits beneath the T-1 terrace (fig. 5). A small surface scatter of fire-cracked rock (FCR) was recorded at the top of the cutbank, and a large, basin-shaped archaeological feature consisting of FCR was observed eroding out of the cutbank at a depth of 100-150 cm below the T-1 surface (Holen and others, 1996, p. 158). Unfortunately, this site (25RH121) did not yield diagnostic artifacts, and the basin-shaped feature did not contain sufficient amounts of charcoal for conventional radiocarbon dating. However, organic mats and many pieces of wood, including large tree trunks, were found in the lower part of the cutbank (Mandel, 1996, p. 40-41). The abundant floral material provided opportunities for radiocarbon dating and plant-macrofossil analysis. Radiocarbon ages determined on plant material at this locality helped us establish an alluvial chronology for the Nemaha, and radiocarbon control of the floral record was crucial for reconstructing Holocene bioclimatic change. The alluvial chronology and floral record will be discussed later in the guidebook.

The following discussion is in two parts. In the first part, we consider the processes that produced the entrenched channel of the Nemaha. This is an important consideration because stream entrenchment is the rule, not the exception, in southeastern Nebraska. The second part of the discussion focuses on the stratigraphy exposed in the banks at stop 2.

Processes of Channel Entrenchment

Entrenched streams pass through several developmental stages that are characterized by different bank and bed stabilities and overall channel appearance (Heede, 1974; Bradford and others, 1978; Bettis and Thompson, 1982; Simon, 1995). Several developmental stages are evident along the length of an entrenched channel at a point in time, and a channel cross-section passes through the sequence of stages with time. A six-stage classification scheme for these stages developed in Tennessee (Simon, 1995) is applicable in the South Fork of the Big Nemaha River valley. The stages are as follows:

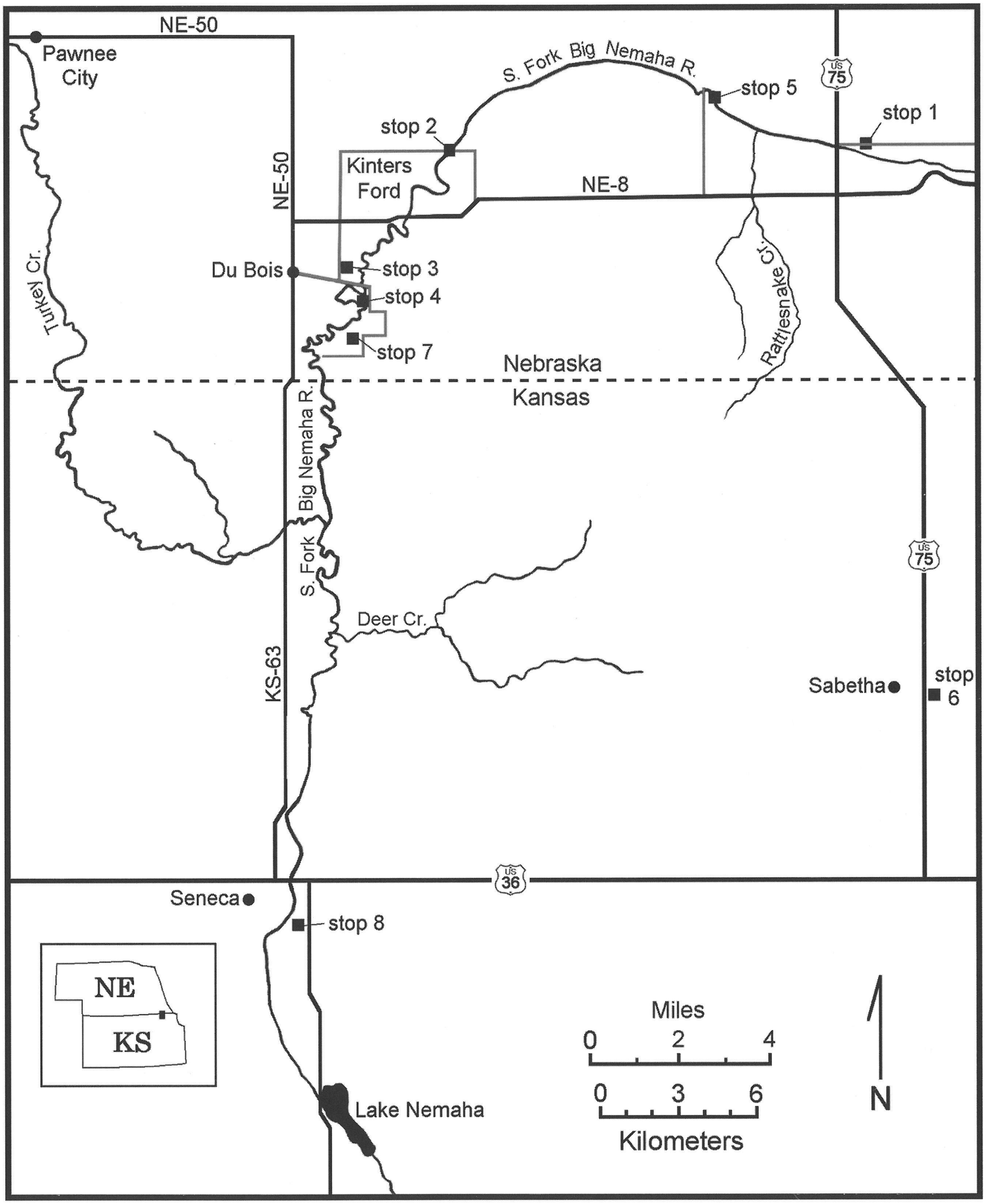


Fig. 2. Midwest Friends of the Pleistocene field-trip stops, 2000.

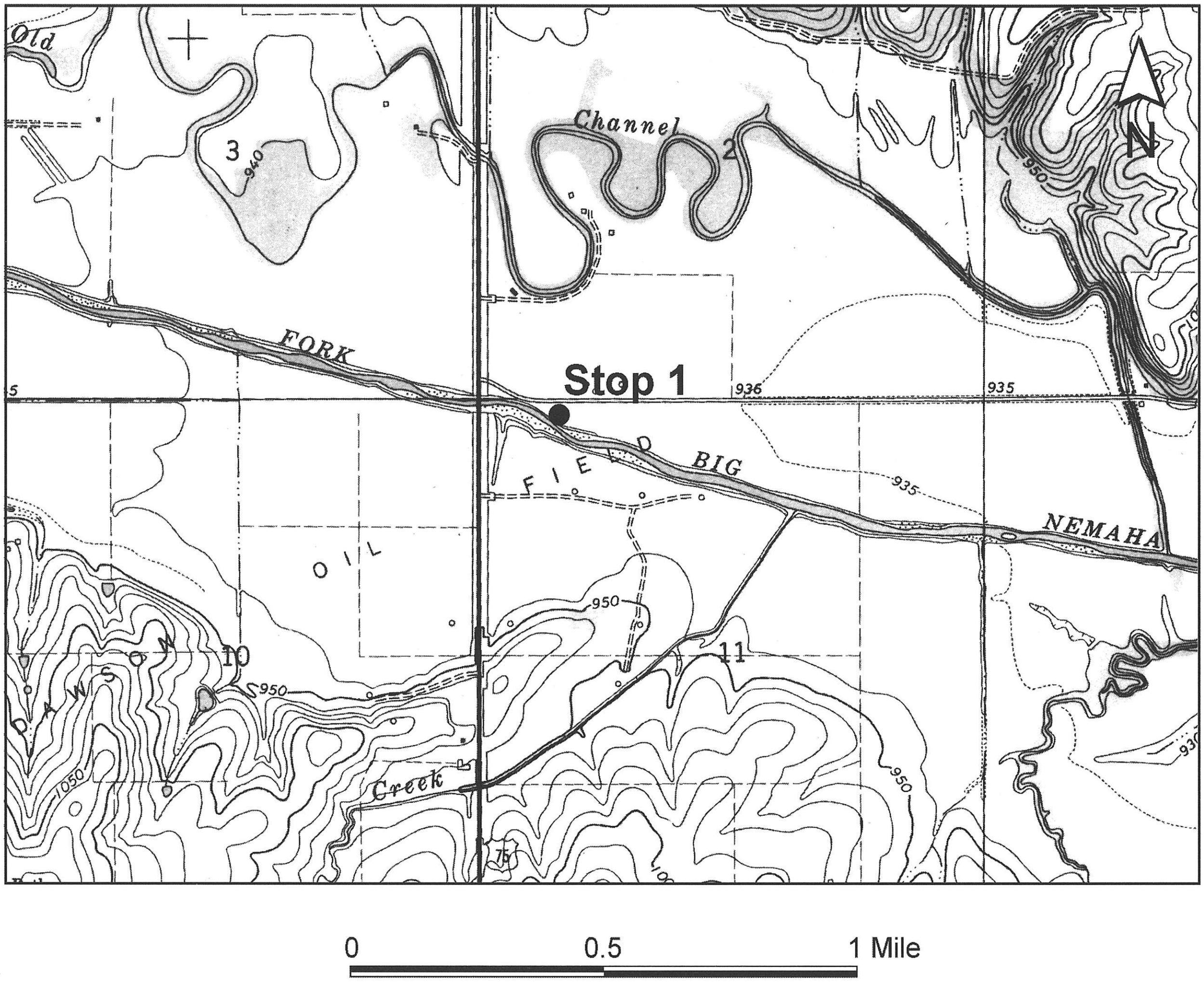


Fig. 3. Topographic map showing the location of stop 1.

Stage I: Stable vegetated banks lacking an entrenched channel. This is the initial condition of channels in southeastern Nebraska and northeastern Kansas prior to an entrenchment cycle.

Stage II: Human-modified. Channelization and/or straightening occurs primarily in large and moderate-size valleys in the region. This lowers local base level and increases stream power. This stage is unique to the post-settlement period.

Stage III: Degradation. This can occur in human-altered reaches as the modified channels adjust to gradient and sediment-supply changes (Daniels and Jordan, 1966; Schumm and others, 1988) or in upstream reaches as knickpoints move headward in response to lower base level downstream. Degradation by undercutting and pop-out failure further increases bank height (Bradford and others, 1978). During this stage, banks are steep and the width-to-depth ratio of the entrenched channel is small. Stage III is represented along many reaches of the South Fork of the Big Nemaha River in southeastern Nebraska and in some reaches of the river in northeastern Kansas.

Stage IV: Threshold. Entrenchment slows relative to stage III, but knickpoints may migrate up the entrenched channel. Banks are still unstable and significant widening begins to occur. Shallow planar (slab) failures are dominant, sometimes followed by deep-seated rotational slumps in some areas (van der Poel and others, 1986). Most bank failure by mass wasting occurs in the spring following snowmelt and heavy rains. These conditions foster bank failure by adding weight (load) to the top of the bank, increasing shear stress, and by increasing pore pressure in the bank materials, thereby decreasing shear strength. As long as streamflow is able to transport debris from mass wasting, this stage continues and further channel widening occurs. Stage IV is well represented along much of the South Fork of the Nemaha River in Nebraska.

Stage V: Aggradation. When more debris enters the channel than the stream can transport, aggradation begins. Chan-

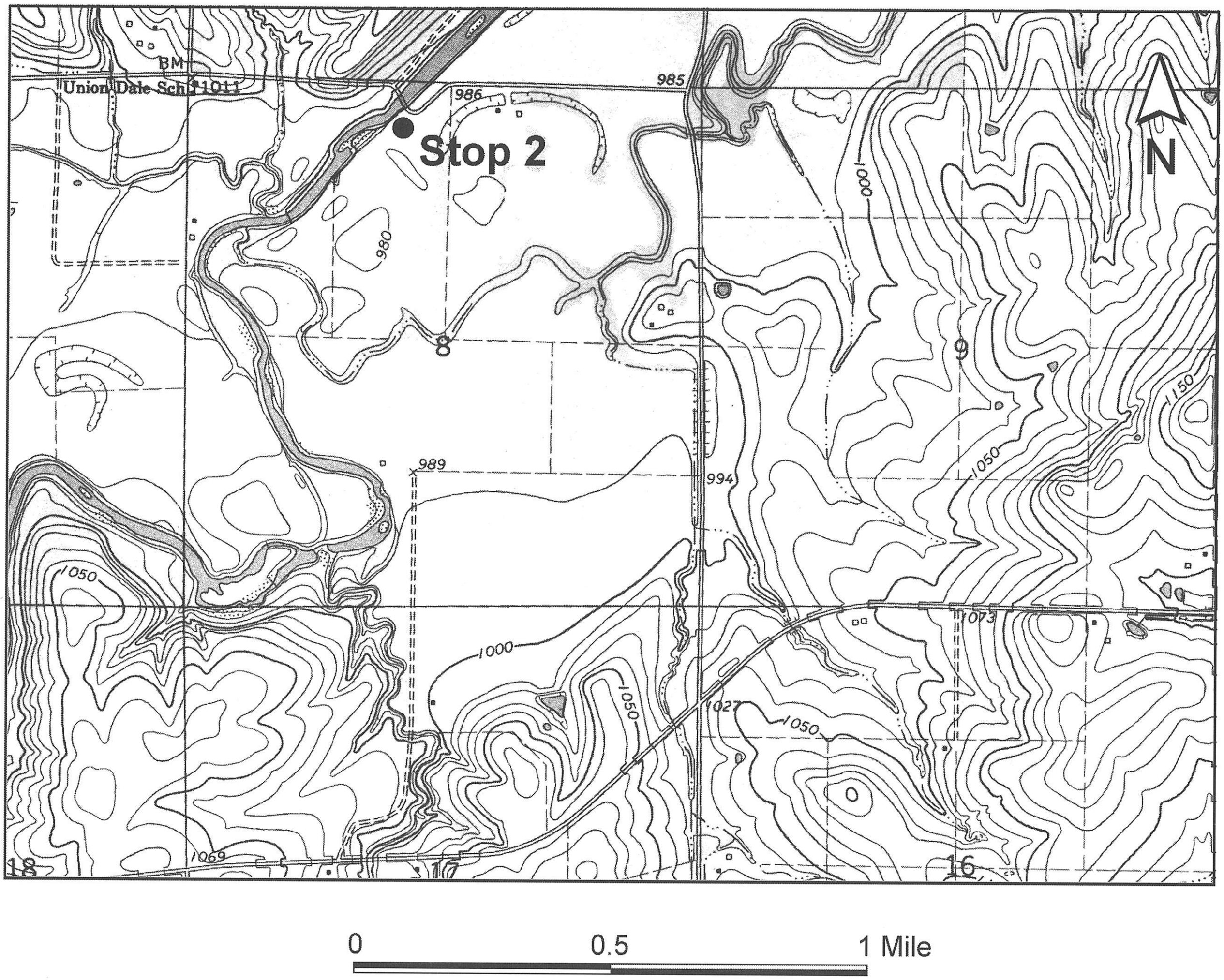


Fig. 4. Topographic map showing the location of stop 2.

nel reaches lower in the drainage network begin to aggrade first because gradients are lower there. Rotational slumps at the end of stage IV significantly lower bank angles, and aggradation lowers bank height. These two processes acting together result in bank stability.

Stage VI: Restabilization. Mass wasting decreases, and vegetation becomes established on the banks, promoting further aggradation and moving the system back toward stage I. In southeastern Nebraska and northeastern Kansas, stages V and VI often take place concurrently.

Stratigraphy

Three members of the DeForest Formation are exposed in the cutbank at stop 2: Gunder, Honey Creek, and Camp Creek (fig. 5). The following observations of the stratigraphic units were made in 1996 and may vary somewhat from what is exposed at the time of the field trip.

The Honey Creek Member is the dominant unit exposed in the cutbank and is represented by two thick fills and several thin fills (fig. 5). At this locality, the oldest Honey Creek fill is at the upstream (southwest) end of the cutbank, and a younger Honey Creek fill composes a large part of the downstream (northeast) segment of the exposure. The younger fill is laterally inset against and draped over the older fill (fig. 5).

The two, thick Honey Creek Member fills consist of grayish brown silt loam with faint planar bedding grading downward to trough cross-bedded grayish brown and brown loam, fine sandy loam, sand, and sandy gravel. The trough cross-bedded alluvium is interbedded with very dark gray loam and sand containing abundant plant macrofossils. The upper 2-3 m of both fills consist of massive, grayish brown silt loam.

Mollisols with A-Bw-C profiles are developed in the upper parts of the Honey Creek Member. The soil at the top of the older fill is mantled by a thin increment of fine-grained alluvium that is an overbank facies of the younger fill (fig. 5). Prehistoric cultural deposits, including burned-rock features, are in the upper 30 cm of the thick A horizon of this buried soil. However, no radiocarbon-datable materials or diagnostic artifacts were found in the cultural zone.

Although the upper 7 to 8 m of Honey Creek Member alluvium exposed at the Old Bridge locality lack organic remains, the basal parts of both fills are rich in plant macrofos-

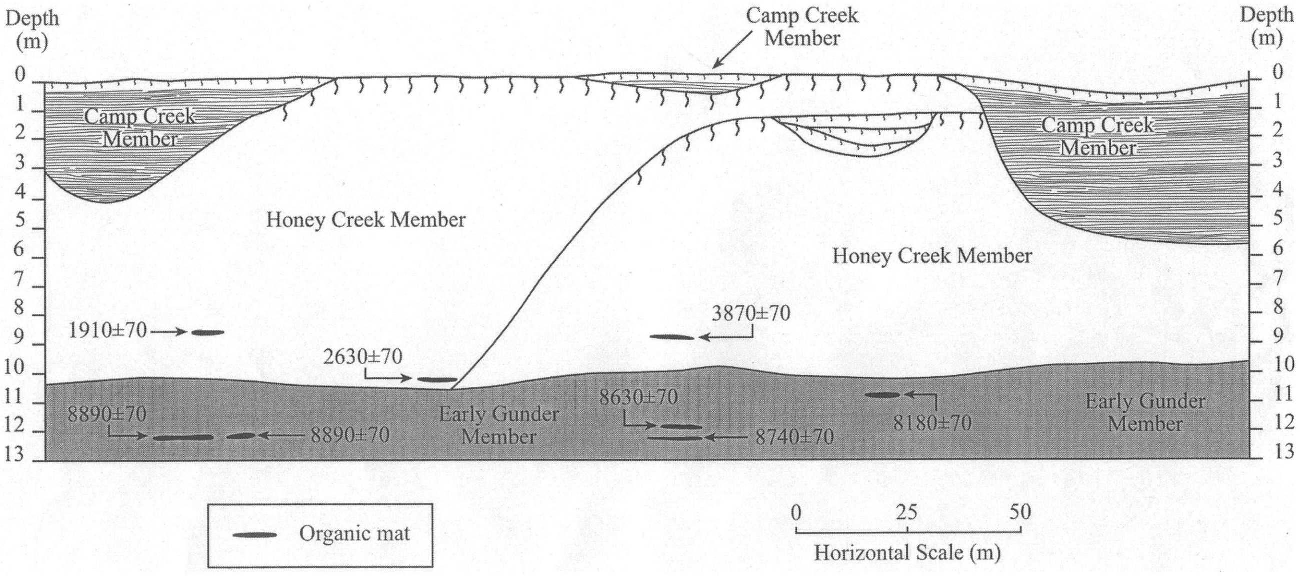


Fig. 5. The outcrop along the east bank of the South Fork of the Big Nemaha River at stop 2.

sils. A radiocarbon age of 3,870±70 yr B.P. (ISGS-3429) was determined on wood from an organic mat near the base of the older Honey Creek fill (fig. 5). Wood recovered from dark gray organic-rich sand 3.4 m above the base of the younger fill (figs. 5 and 6) yielded a radiocarbon age of 1,910±70 yr B.P. (ISGS-3424), and a radiocarbon age of 2,630±70 yr B.P. (ISGS-3437) was determined on wood at the base of this fill (fig. 5).

Approximately 200 m upstream from the abandoned bridge at stop 2, three superposed deposits with lithologies characteristic of the Honey Creek Member occupy a shallow paleochannel cut in the oldest Honey Creek Member fill at this locality (fig. 5). The absence of sand and gravel in the paleochannel suggests that it is a former flood chute. The sequence of deposits indicates that the trough-shaped, scoured-out channel was initially filled up by sets of thin beds, conforming, in general, to the shape of the channel. In a later phase, this trough-shaped channel with its conformable beds was partially eroded away, and a new younger trough was produced and filled up by bedded Honey Creek Member alluvium. This process was repeated one more time, resulting in the development of channel-fill cross-bedding.

At the far upstream and downstream ends of the exposure, the Camp Creek Member is the uppermost unit and occupies deep channels cut in the Honey Creek Member fills (fig. 5). The channel fills have properties typical of the Camp Creek Member, including well-expressed stratification at shallow depths and weak surface-soil development (A-C profile).

The early Gunder Member is the lowest exposed alluvial unit in the section (fig. 5). Upper parts of the unit have been eroded by episodes of entrenchment preceding aggradation of the overlying fills of the Honey Creek Member. Across most of the section, the early Gunder Member consists of a thin zone (< 1 m thick) of oxidized loam and fine sandy loam above a reduced, dark gray (gleyed) silty clay. Organic mats and large pieces of wood are common in the reduced Gunder Member alluvium. At a sampling locality near the downstream (northeast) end of the exposure, two separate pieces of wood were collected from organic mats in the upper 20 cm of the gray, reduced Gunder Member alluvium (fig. 5). Both samples yielded a radiocarbon age of 8,890±70 yr B.P. (ISGS-3426 and ISGS-3427). Wood from an organic mat in the upper 22 cm of the reduced alluvium at a sampling locality about 125 m upstream from the northeast end of the cutbank yielded a radiocarbon age of 8,630±70 yr B.P. (ISGS-3436) (fig. 5). At the same sampling locality, a piece of wood recovered from an organic-rich zone 54-65 cm below the surface of the reduced alluvium yielded a radiocarbon age of 8,740±70 yr B.P. At the southwestern-most sampling locality, wood collected from the upper 21 cm of the dark-gray alluvium yielded a radiocarbon age of 8,180±70 yr B.P. (ISGS-3431) (fig. 5). Hence, the early Gunder Member becomes progressively younger from northeast to southwest along this exposure.

Kinters Ford Wildlife Management Area

Kinters Ford Wildlife Management Area is located about 2 km downstream from the Old Bridge locality (fig. 2). Kinters Ford yielded information that is crucial to our interpretation of the Holocene alluvial-stratigraphic record in the Nemaha River valley. Unfortunately, logistical problems preclude visiting Kinters Ford during the Friends of the Pleistocene field trip. Given the significance of this locality, a brief summary of our findings is presented below.

At Kinters Ford, valley fill beneath the T-1 terrace is exposed in long, high cutbanks on the west and north sides of the South Fork of the Big Nemaha River. Although few archaeological deposits were found in the cutbanks during the 1996 geoarchaeological survey (Mandel, 1996), deeply

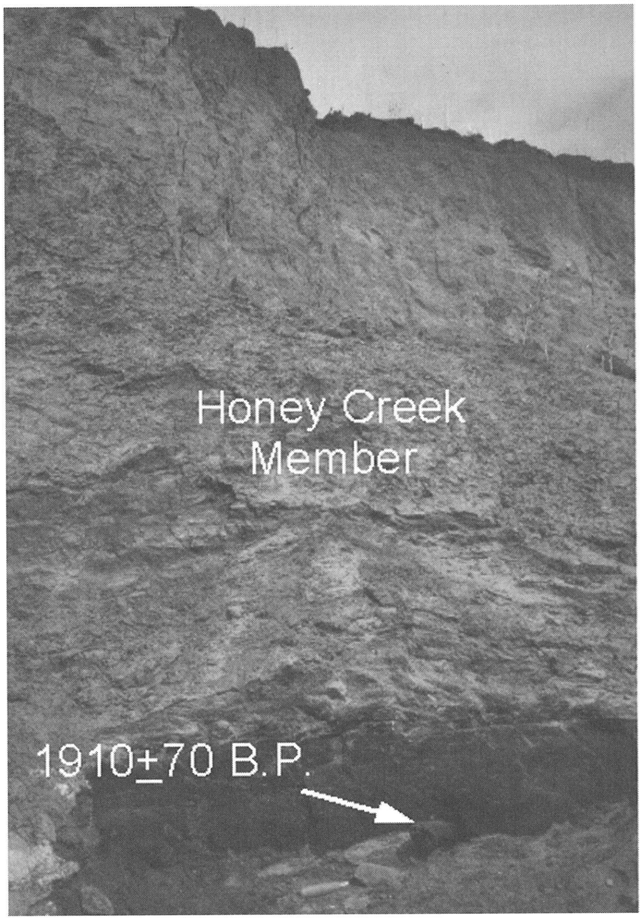


Fig. 6. Photograph of organic-rich alluvium in the lower part of the Honey Creek Member at the Old Bridge Locality (stop 2). The radiocarbon age was determined on a piece of wood (see arrow).

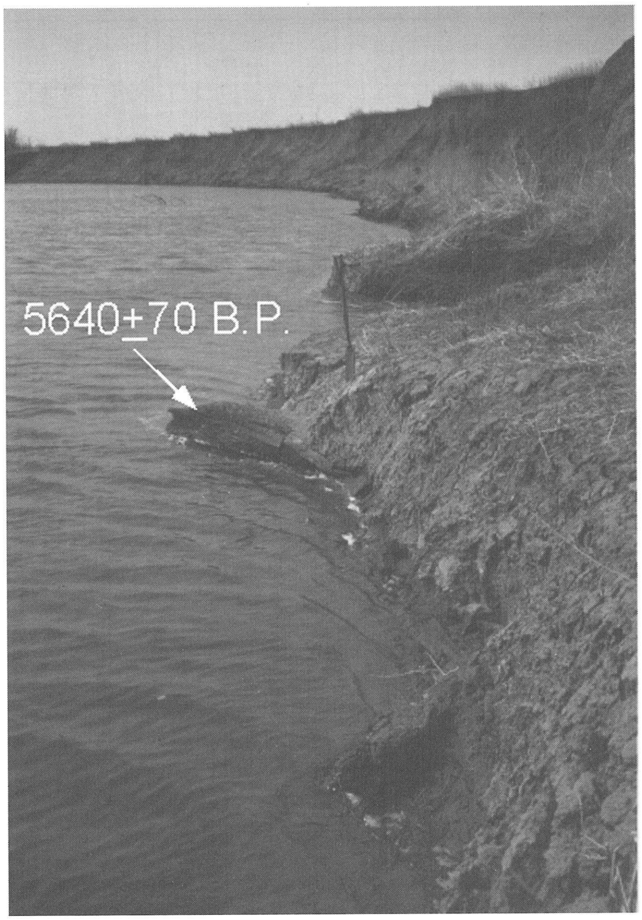


Fig. 7. Photograph of a log in the Early Gunder Member. The radiocarbon age was determined on wood from the outer 2 cm of the log.

buried wood and organic mats were discovered at many places along the river.

Reduced, dark gray, early Gunder Member deposits are exposed in the lower 50-100 cm of most cutbanks at Kinters Ford. The depth to the top of these reduced deposits ranges from about 6.9 to 7.7 m below the T-1 surface. Organic mats and large pieces of wood, including entire tree trunks, are common in and above the reduction zone (fig. 7). Plant macrofossils collected from reduced early Gunder Member deposits at two separate sections along a 400-m long cutbank yielded radiocarbon ages of 6,120±70 yr B.P. (ISGS-3405) and 6,070±70 yr B.P. Organic mats 2-3 m above the reduced alluvium were dated to 5,640±70 yr B.P. (ISGS-3401) and 4,870 yr B.P. (ISGS-3398).

There are striking similarities between the stratigraphy at Kinters Ford and the Old Bridge locality (stop 2). Specifically, in most of the sections at Kinters Ford, late Holocene deposits truncate the early Gunder Member. For example, in a section where the Honey Creek Member overlies the early Gunder Member, twigs from an organic mat near the base of the Honey Creek Member yielded a radiocarbon age of 2,800±70 yr B.P. (ISGS-3403). A piece of wood from an organic mat in reduced early Gunder Member alluvium 41 cm below the organic mat in the Honey Creek Member yielded a radiocarbon age of 6,120±70 yr B.P. (ISGS-3405). At another section, wood collected at the base of the Honey Creek Member yielded a radiocarbon age of 3,010±70 yr B.P. (ISGS-3404). Twigs from an organic mat in reduced early Gunder Member alluvium 40 cm below the wood sample from the Honey Creek Member yielded a radiocarbon age of 6,120±70 yr B.P. (ISGS-3405).

At one locality in the Kinters Ford Wildlife Management Area, a thick Roberts Creek Member channel fill truncates the late and early Gunder members. Wood from the bottom of the channel fill yielded a radiocarbon age of 3,270±70 yr B.P. (ISGS-3399). About 50 m downstream from the Roberts Creek Member channel fill, a series of thick, laterally inset Honey Creek Member channel fills overlie bedrock; the early and late Gunder Members have been completely cut out. Each channel fill is massive in its upper part and has large-scale trough cross-bedding and epsilon cross-stratification near its base. Wood collected from the bottom of the Honey Creek Member channel fills yielded radiocarbon ages of 3,780±70 (ISGS-3402), 3,300±70 (ISGS-3446), and 2,190±70 yr B.P.

(ISGS-3452). The youngest Honey Creek channel fill is truncated by Camp Creek Member alluvium composing a channel fill that is nearly 7 m thick. Wood collected from the bottom of the Camp Creek Member channel fill yielded a radiocarbon age of 370±70 yr B.P. (ISGS-3453).

Although the early Gunder Member generally occurs beneath late Holocene deposits at Kinters Ford, the top of this stratigraphic unit forms the T-1 surface in a 30-m long cutbank at the northern end of the wildlife management area. Unlike the gray and light brown late Holocene deposits, the early Gunder Member is strongly oxidized to a depth of 6-7 m below the T-1 surface. Also, there are two buried soils (soils 2 and 3) with thick A horizons developed in the upper 4 m of the early Gunder Member. Organic carbon from the upper 10 cm of soils 2 and 3 yielded radiocarbon ages of 4,780±110 (Tx-8942) and 7,070±70 yr B.P. (Tx-8943), respectively.

Based on the inspection of more than 2,000 horizontal meters of cutbank at Kinters Ford, the tops of the Honey Creek and late Gunder members form most of the T-1 surface (Mandel, 1996). The stratigraphic record indicates that in nearly all of this area, the upper 6-7 m of the early Gunder Member has been stripped off as a result of entrenchment, lateral channel migration, and channel widening during the late Holocene. This pattern is repeated at stop 4 and elsewhere in the South Fork of the Big Nemaha River valley.

Stop 3. Koester Site

At this stop, we will examine a core taken from the Koester archaeological site (25PW58) in the South Fork of the Big Nemaha River valley near DuBois (figs. 2 and 8). The site is named after the landowner, Vaughn Koester, who allowed the NU State Museum to conduct test excavations on this property in 1996. The results of the archaeological investigation will be discussed, but the stop will focus primarily on the stratigraphy exposed in the core. By comparing the stratigraphy at 25PW58 with the stratigraphy viewed in exposures at stops 4 and 7, we intend to demonstrate relationships among late Wisconsinan deposits in different landscape positions, that is, terraces versus colluvial aprons.

The Koester site is on the T-2 terrace, which is 3 to 4 m above the adjacent T-1 surface. The heaviest concentration of cultural material is on the east side of the unimproved county road, and extends across the flat tread of the terrace to the top of the scarp that separates T-2 from T-1. In this area, there is a rich surface assemblage of lithic debris, tools, and fire-cracked rock, and a smaller amount of ceramic material. Several aspects of the archaeological record at 25PW58 are noteworthy. The chipped-stone debris is interesting because it largely consists of exotic material derived from glacial till and river cobbles, even though massive outcrops of high-quality Permian chert are only a few kilometers from the site. Middle Archaic and Woodland projectile points and a few undiagnostic pottery sherds were found during the archaeological investigation (Holen and others, 1996). Diagnostic Archaic artifacts are represented by three projectile points: two resembling Big Sandy notched points and one that is somewhat similar to Munkers Creek points or possibly to Middle or Late Archaic Stone Square stemmed points. Diagnostic Woodland artifacts are represented by two projectile points: a small, Late Woodland corner-notched point, and a thick, crude, medium-sized point with an expanding base and shallow, indistinct side-notches. The medium-sized point somewhat resembles Steuben and Rice side-notched points (Holen and others, 1996). The pottery sherds, which are heavily tempered with angular sand, are probably Woodland (ca. 1,900 to 500 yr B.P.), but could be Late Prehistoric (500-200 yr B.P.). The archaeological assemblage indicates that the T-2 surface has been relatively stable and has not witnessed alluvial sedimentation during most of the Holocene.

In 1996, a 4 m-long core was taken at the Koester site (Mandel, 1996). This core revealed a thin mantle of Peoria Loess above a thick paleosol developed at the top of oxidized, upward-fining late Quaternary alluvium (fig. 9). The upward-fining sediment was initially described as an alluvial facies of the Gilman Canyon Formation (Mandel, 1996). However, in this guidebook, the alluvium is referred to as the Severance Formation.

The Peoria Loess is 1-2 m thick across the Koester site and is the parent material for a surface soil with an A-Bt-BC profile (table 1). In some places, the argillic (Bt) horizon is immediately below the plow zone because most of the A horizon has been stripped off by agriculturally related erosion. The Bt horizon is 53-cm thick and is dark brown (10YR 4/3, dry), noncalcareous heavy silty clay loam. Based on observations with a hand lens, there are common, distinct, continuous, dark brown clay films on ped faces in the Bt horizon. An abrupt boundary separates the yellowish brown (10YR 5/4, dry) BC horizon of the surface soil from the underlying paleosol developed in the Severance Formation.

The buried paleosol is noncalcareous and has a strongly expressed Bt-BC profile; the A horizon was stripped off by erosion before the paleosol was buried. The truncated 2Btb horizon (2Bt1b + 2Bt2b) is 154-cm thick and is dark brown (7.5YR 4/4, dry) to strong brown (7.5YR 4/6, dry) silty clay loam. There are common to few discontinuous dark brown (7.5YR 3/3, dry) clay films and a few pale brown (10YR 6/3, dry) silt coats (silans) on the ped faces. Yellowish brown (10YR 5/4, dry) fine loam composing the 2BCb horizon grades downward to yellowish brown coarse loam interbedded with fine sandy loam and silty clay loam in the 2C horizon. There are common fine, soft and hard, dark concretions (iron and manganese oxides) in the paleosol and upper 50 cm of the 2C horizon. At stops 4 and 7, we will examine radiocarbon-dated soils with similar morphology and stratigraphic position beneath the Peoria Loess.

Stop 4. Farwell Locality

The Farwell locality is in the South Fork of the Big Nemaha River valley about 1.5 km southeast of the town of DuBois (figs. 2 and 8). The county road shown immediately east of stop 4 in figure 8 was cut out by the river and has been replaced by a road that crosses the upper side-slopes of the valley wall.

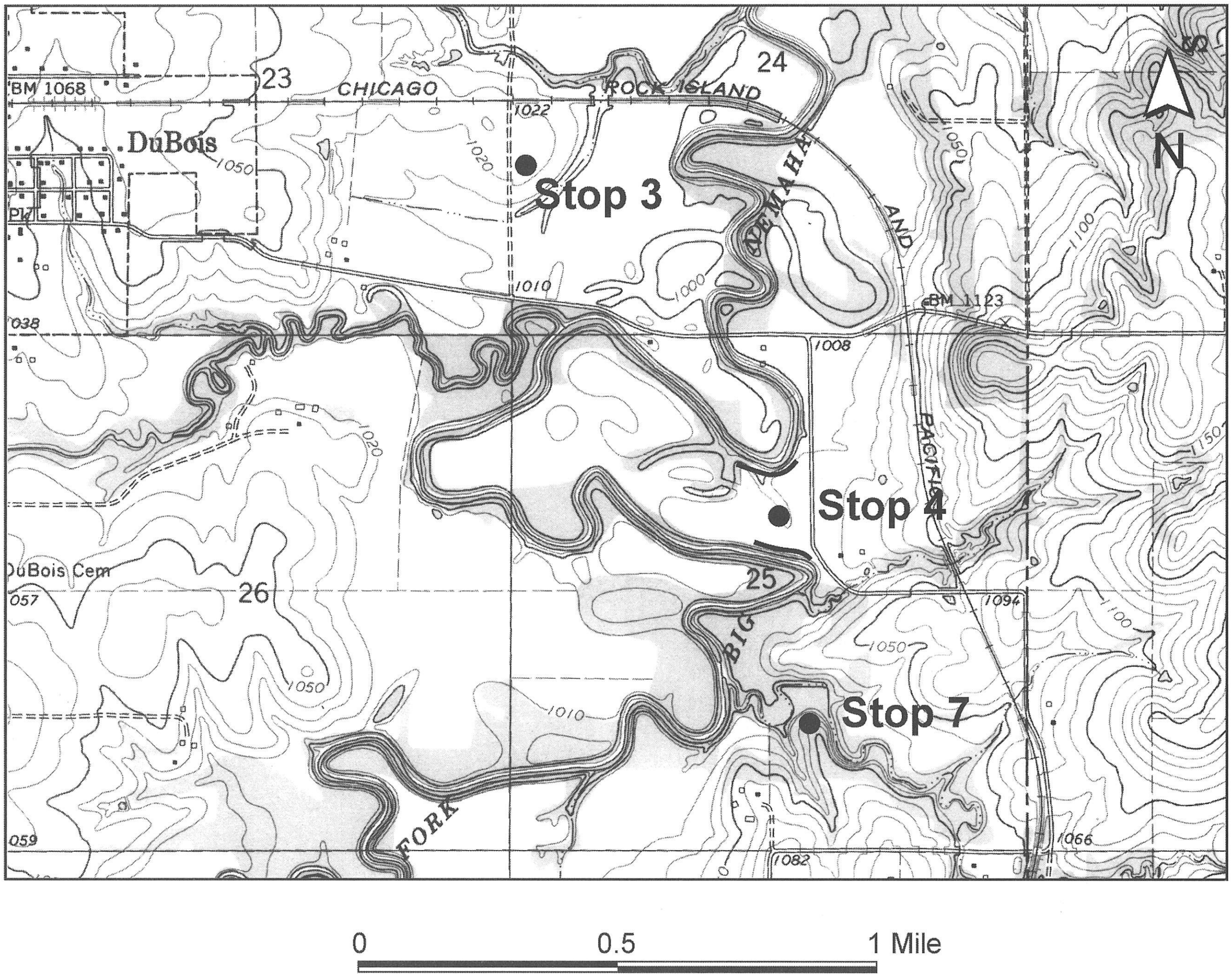


Fig. 8. Topographic map showing the locations of stops 3, 4, and 7.

At this stop, we will examine a reach of entrenched channel and discuss the Holocene and late Wisconsinan stratigraphic units exposed in a series of extensive cutbanks. Our discussion will focus on 1) the lithologic properties and stratigraphic relationships of the units; 2) surface and buried soils developed in the units; 3) radiocarbon ages obtained on materials from the units; and 4) stratified archaeological deposits in the Honey Creek and late Gunder members.

The Farwell locality is named after the landowner, Richard Farwell. In 1996, the NU State Museum conducted archaeological testing at three sites on this property: 25PW63, 25PW64 and 25PW65. Based on the testing results, these sites were included in a proposed nomination for classification in the National Register of Historic Places (NRHP) Archaeological District (Peterson and others, 1996). The sites have buried Middle Archaic, Late Archaic, and/or Woodland components, with the oldest evidence of human occupation dating to ca. 4,600 yr B.P.

At the Farwell locality, the valley floor is nearly 2 km wide and dominated by the T-1 terrace; only a small area of the modern floodplain (T-0) is present on the west side of the river, and there is a remnant of the T-2 terrace on the east side of the valley floor. The T-1 terrace is not flat or featureless; subtle depressions mark the positions of flood chutes and abandoned channels.

The South Fork of the Big Nemaha River has cut through the late-Quaternary valley fill and is flowing on bedrock at the Farwell locality. Recent lateral migration of the channel has created long, high cutbanks on both sides of the neck of a large meander loop (fig. 8). These cutbanks provide opportunities to examine stratigraphic relationships among four members of the DeForest Formation: Gunder, Roberts Creek, Honey Creek, and Camp Creek. Also, stratigraphic relationships between the DeForest Formation and late Wisconsinan deposits can be viewed in some cutbanks at this locality. In addition, organic-rich zones are common at the bottom of the

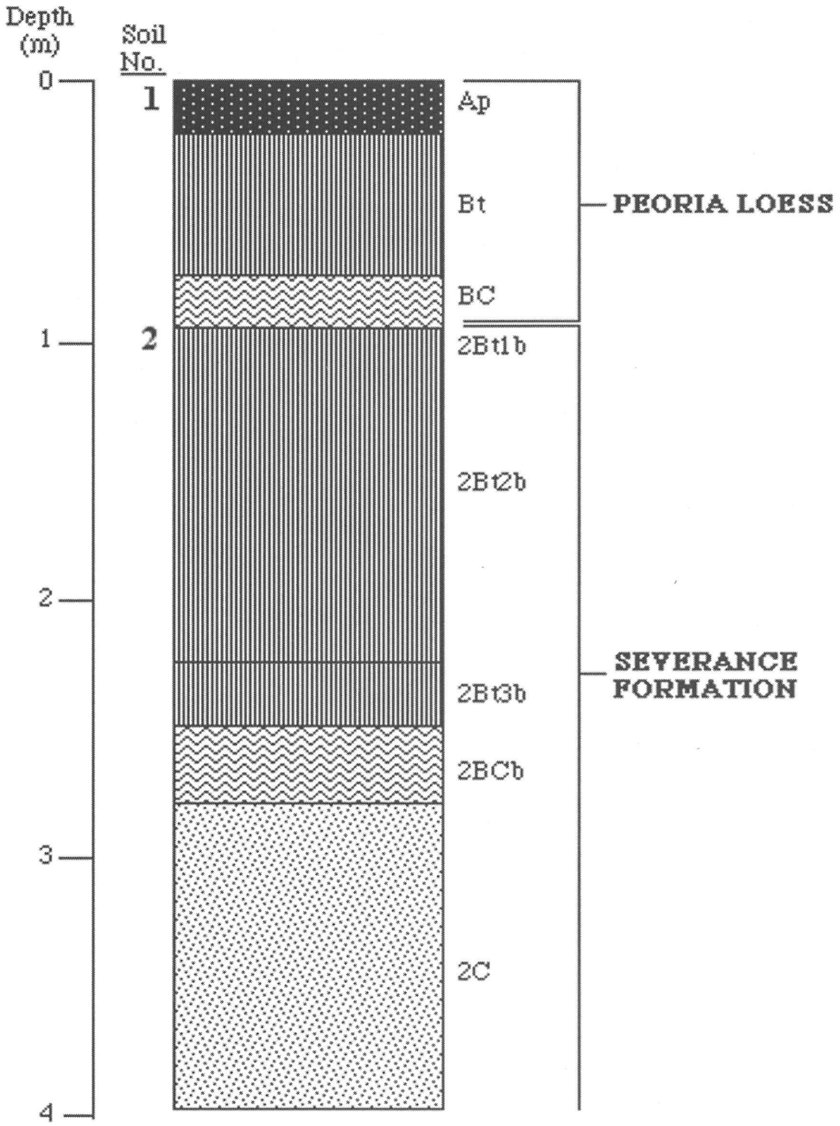


Fig. 9. Stratigraphic profile for core at site 25PW58, T-2 terrace, stop 3.

cutbanks, and archaeological features containing charcoal are associated with buried soils in the upper 2-3 m of the valley fill. Radiocarbon ages determined on wood, small plant fragments, and charcoal provide the basis for a numerical chronology of late-Quaternary degradation, aggradation, and landscape stability in this part of the South Fork of the Big Nemaha River valley.

We will inspect cutbanks at several points along the river at the Farwell locality. Our tour begins at site 25PW65 on the south side of the meander neck (fig. 10). Then we will walk north across the meander neck to examine cutbanks at sites 25PW64 and 25PW63.

Figure 11 is a diagram of the cutbank at site 25PW65 showing the distribution of Holocene and late Wisconsinan alluvial fills beneath the valley floor. Although the modern geomorphic surface is relatively featureless across most of the site, the alluvial stratigraphy is complex because of multiple episodes of cutting and filling during the late Holocene. In addition, aggradation was punctuated with many short episodes of landscape stability and pedogenesis; hence the alluvial stratigraphy is further complicated by superposed buried soils (fig. 11).

At the eastern end of site 25PW65, the late Gunder Member is laterally inset against and draped over the Severance Formation (fig. 11). The lateral contact between the late Gunder Member and Severance Formation has been masked by pedogenesis near the land surface, but at greater depth the contact is abrupt. We will examine a section (profile SF-1 in fig. 11) with a 90-cm-thick unit of late Holocene alluvium (late Gunder Member) overlying alluvial facies of the Severance Formation. A surface soil with a moderately expressed A-Bw profile is developed in the late Gunder Member (table 2 and fig. 12). Lithic artifacts are common in the plow zone, and a burned-rock feature was recorded at a depth of 40-45 cm. A clear boundary separates the late Gunder Member from a paleosol developed in the Severance Formation. The paleosol has a thick, strongly expressed Bt-BCt profile; the A horizon was stripped off before the soil was buried by late Gunder Member deposits. Pedologic features of the paleosol include strong-to-moderate prismatic structure parting to

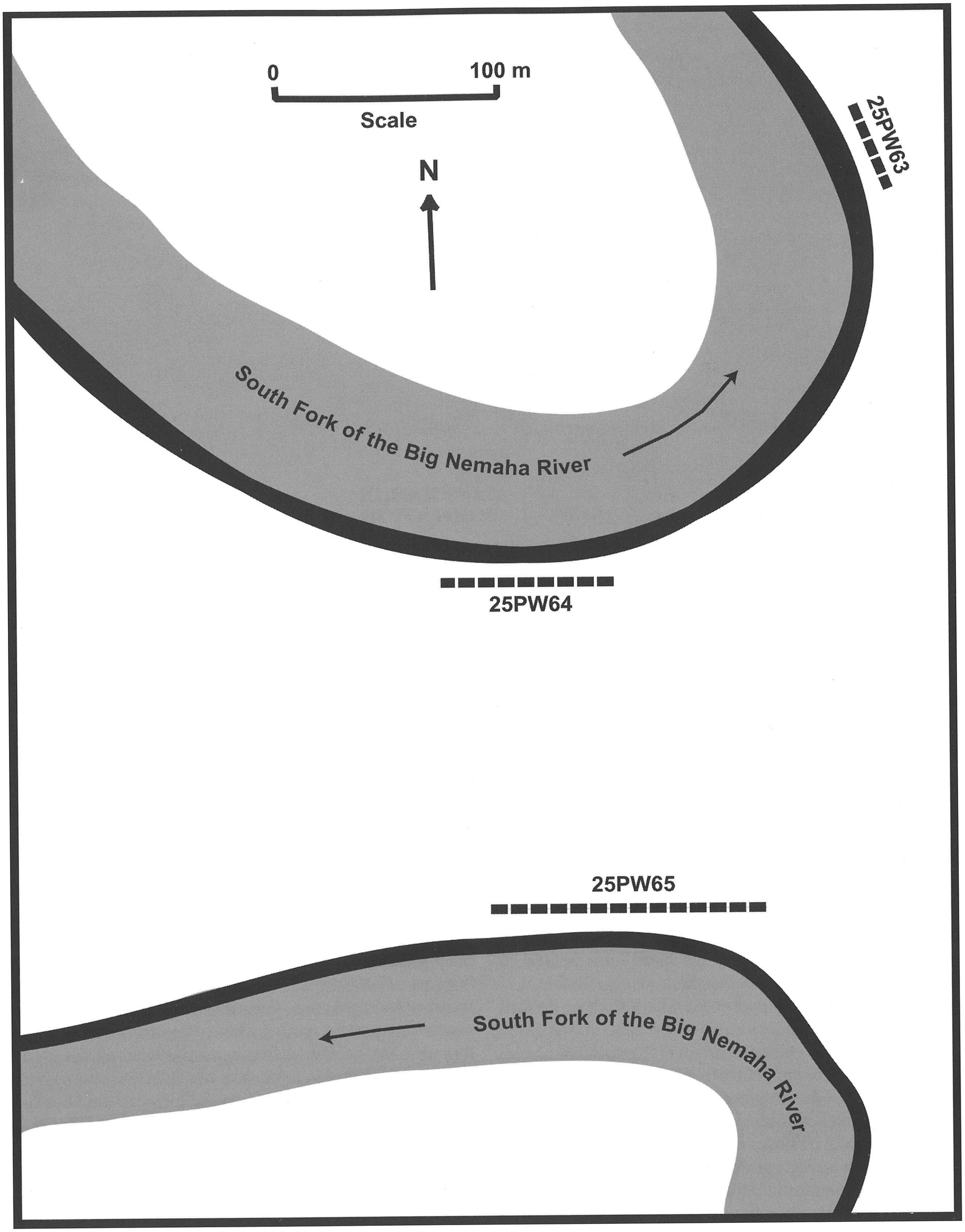


Fig. 10. Plan view of the Farwell locality (stop 4) showing the locations of sites 25PW63, 25PW64, and 25PW65. Bold black line indicates cutbanks

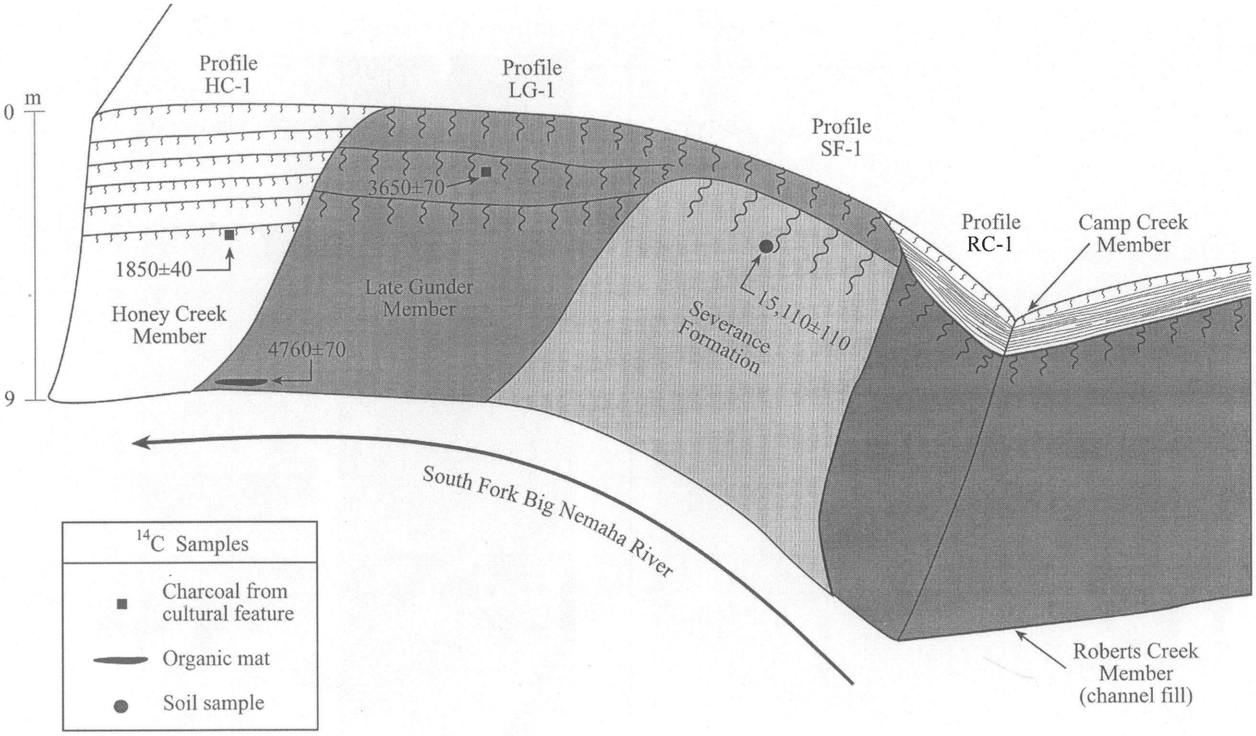


Fig. 11 (above). The outcrops along the north and east banks of the South Fork of the Big Nemaha River at site 25PW65 (stop 4).

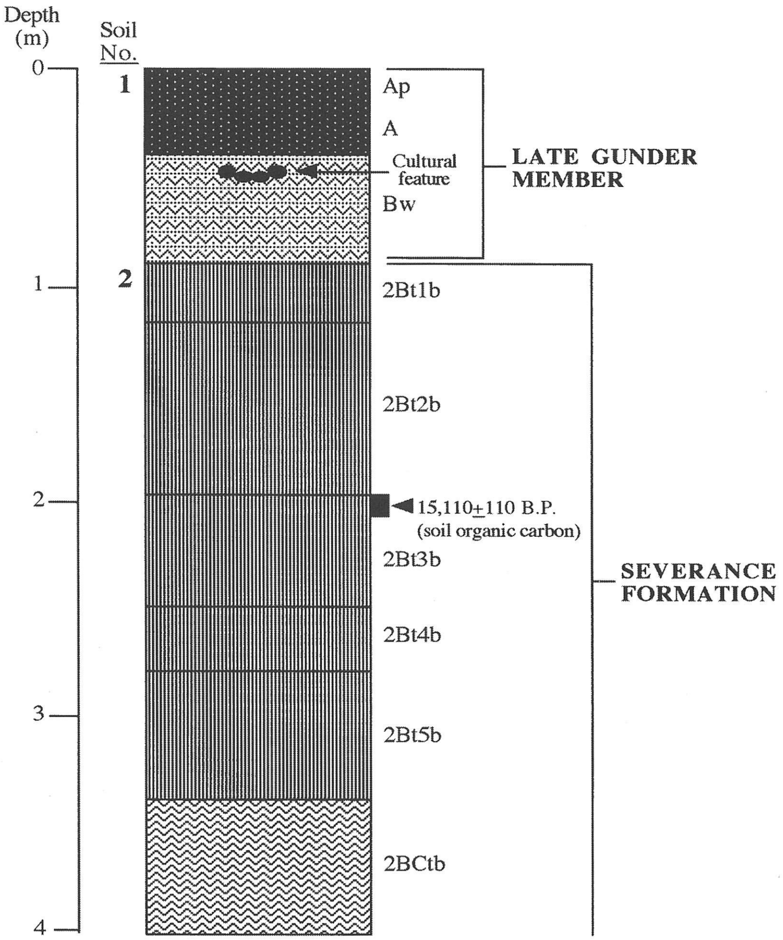


Fig. 12 (left). Stratigraphic section for profile SF-1 at site 25PW65, Farwell locality, stop 4.

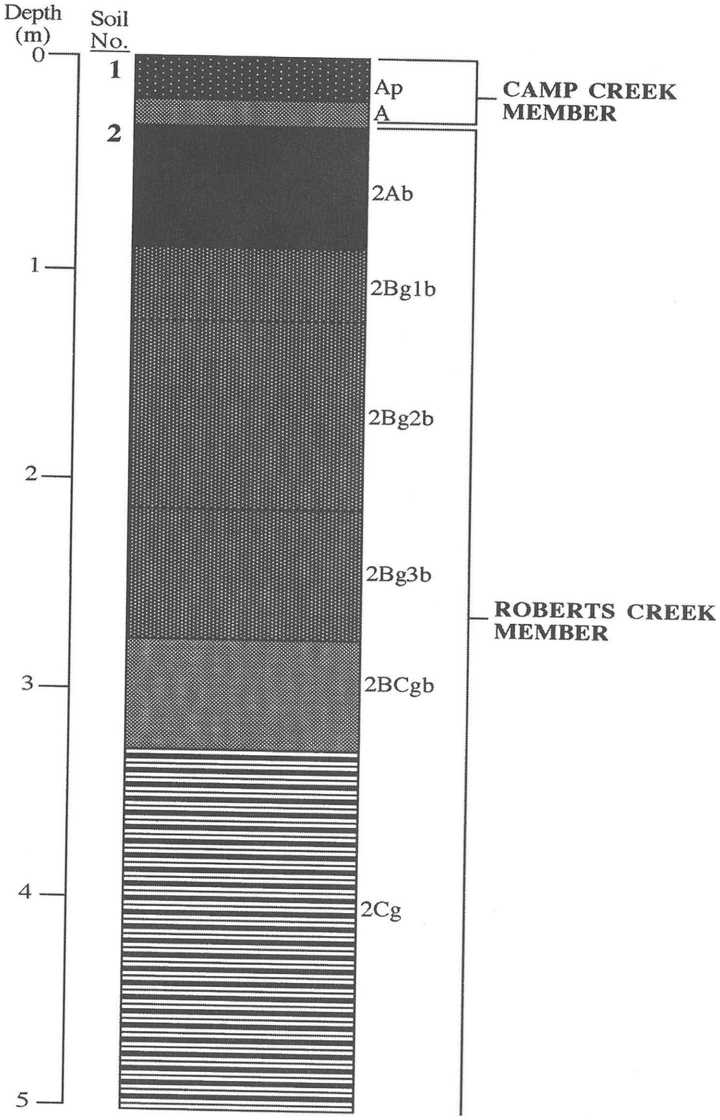


Fig. 13. Stratigraphic section for profile RC-1 at site 25PW65, Farwell locality, stop 4.

strong-to-moderate angular blocky structure; continuous and discontinuous clay films on ped faces; iron and manganese oxide concretions and stains; and strong mottling. Sand content increases with depth in the Severance Formation, and fine gravel is common near the bottom of this unit. Humates from a bulk soil sample collected from the upper 10 cm of the 2Bt3b horizon (200-210 cm below surface) yielded a radiocarbon age of 15,110±110 yr B.P. (ISGS-4468). Given its shallow depth, the paleosol probably has been contaminated by younger carbon (roots, modern humates, etc.); hence, ca. 15,100 yr B.P. should be considered a minimum age for burial of the paleosol.

One of the interesting aspects of profile SF-1 is the eroded surface of the Severance Formation. We do not know how much of the Severance Formation was stripped off or when this erosion event occurred. In fact, there may have been multiple episodes of erosion. The absence of Peoria Loess at this locality suggests that at least one erosional event occurred sometime after ca. 12,000 yr B.P.

A channel fill consisting of the Camp Creek and Roberts Creek members completely cuts out the Severance Formation along the southern edge of the site (fig. 11). In profile RC-1, the Camp Creek Member is only 33 cm thick and has been affected by plowing and modern soil development (Ap-A soil profile) (fig. 13). The Roberts Creek Member consists of dark-colored, fine-grained alluvium. A soil developed in the upper 3 m of the Roberts Creek Member has an A-Bg-BCg profile (table 3). This soil is less well drained than any of the other soils exposed in the cutbank at 25PW65. Heavy silty clay loam composing the 2Ab and 2Bgb horizons grades downward into a light silty clay loam 2BCgb horizon. Soil colors range from very dark gray (10YR 3/1, dry) to dark grayish brown (10YR 4/2, dry). The 2Cg horizon consists of stratified grayish brown (10YR 5/2, dry) silt loam and loam interbedded with very dark grayish brown (10YR 3/2, dry) silty clay loam.

The soil developed in the Roberts Creek Member is a good example of a cumulative soil. With these soils, there are influxes of parent material while pedogenesis is occurring (Nikiforoff, 1949). Consequently, the A horizon builds up with the accumulating parent material, and the material in the former A horizon eventually becomes a B horizon. Hence, slow sedi-

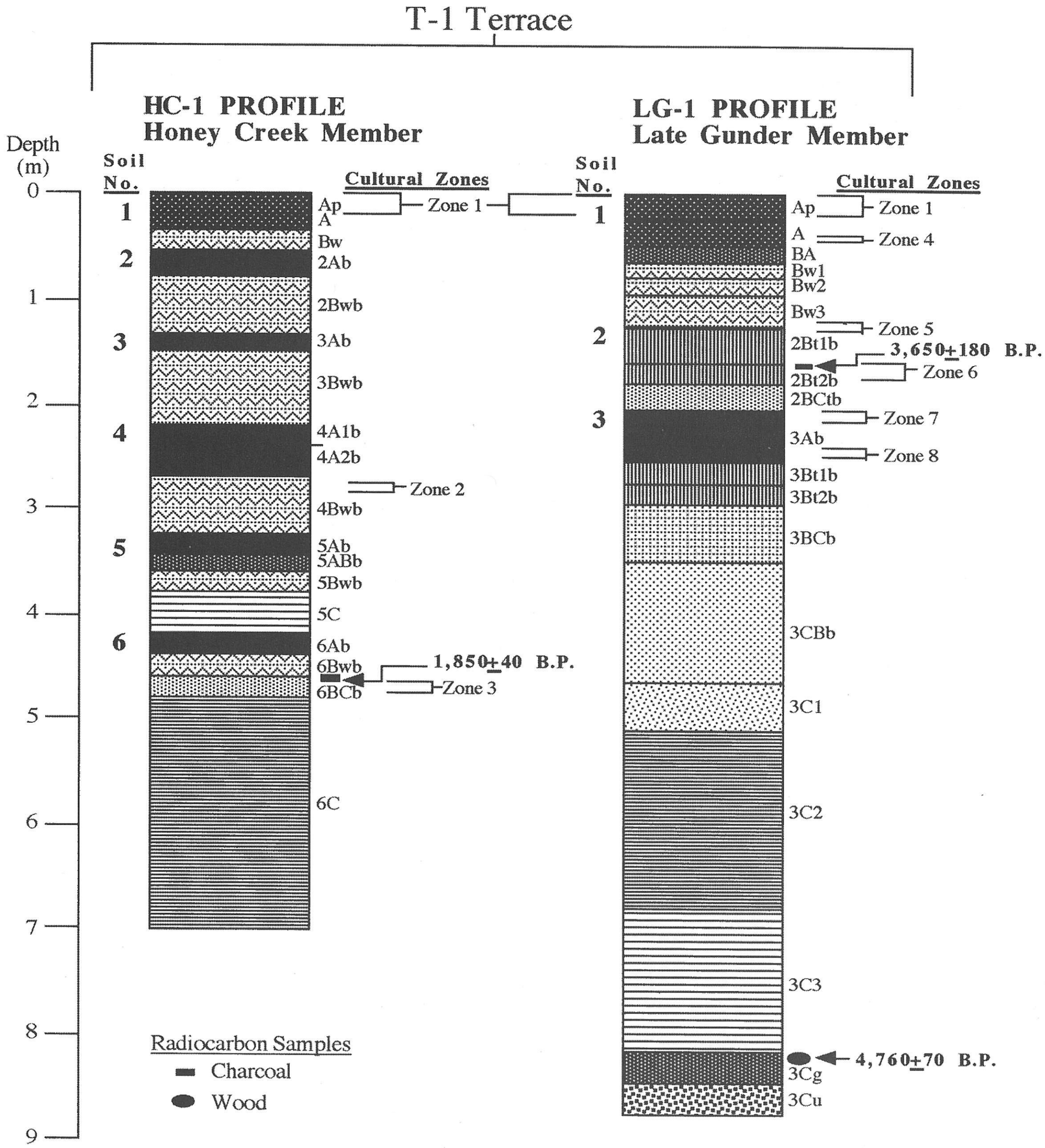


Fig. 14. Stratigraphic section for profile LG-1 and HC-1 at site 25PW65, Farwell locality, stop 4.

mentation and simultaneous soil development account for the overthickened 2Ab horizon in the Roberts Creek Member. This horizon thickened with the accumulation of organic-rich alluvium, a process that typically forms the Roberts Creek Member. Because cumulative soils have parent material continuously added to their surfaces, their features are partly sedimentologic and partly pedogenic (Birkeland 1999, p. 166).

After examining the Roberts Creek Member, we will focus on the main area of site 25PW65 along the south-facing segment of the cutbank. This archaeological site is stratified and consists of eight cultural zones. The cultural zones are numbered consecutively from youngest, zone 1, to oldest, zone 8 (fig. 14). Five of the seven buried cultural zones are in the late Gunder Member, and two are in the Honey Creek Member. Cultural zone 1 is in the plow zone and extends across the late Gunder and Honey Creek members.

At site 25PW65, the upper 121 cm of the late Gunder Member consists of very dark grayish brown (10YR 3/2, dry) silt loam coarsening downward to brown (10YR 5/3, dry) loam. The surface soil at the top of the late Gunder Member is a Mollisol with an A-BA-Bw profile (table 4). Two cultural zones are within the surface soil: zone 1 at a depth of 0-20 cm (Ap horizon), and zone 4 at a depth of 40-45 cm (lower part of the A horizon) (fig. 14).

There is a truncated buried soil (soil 2) with a Bt-BCt profile at a depth of 121-200 cm below the surface of the late Gunder Member (fig. 14). Dark grayish brown (10YR 4/2, dry) silty clay loam composing the 2Btb horizon grades downward to brown (10YR 5/3, dry) silt loam in the 2BCtb horizon. Two cultural zones are within soil 2: zone 5 at a depth of 121-127 cm (upper part of the 2Bt1b horizon), and zone 6 at a depth of 160-175 cm (2Bt2b horizon). Zone 6 has the greatest quantity of fire-cracked rock, charcoal, and burned earth com-

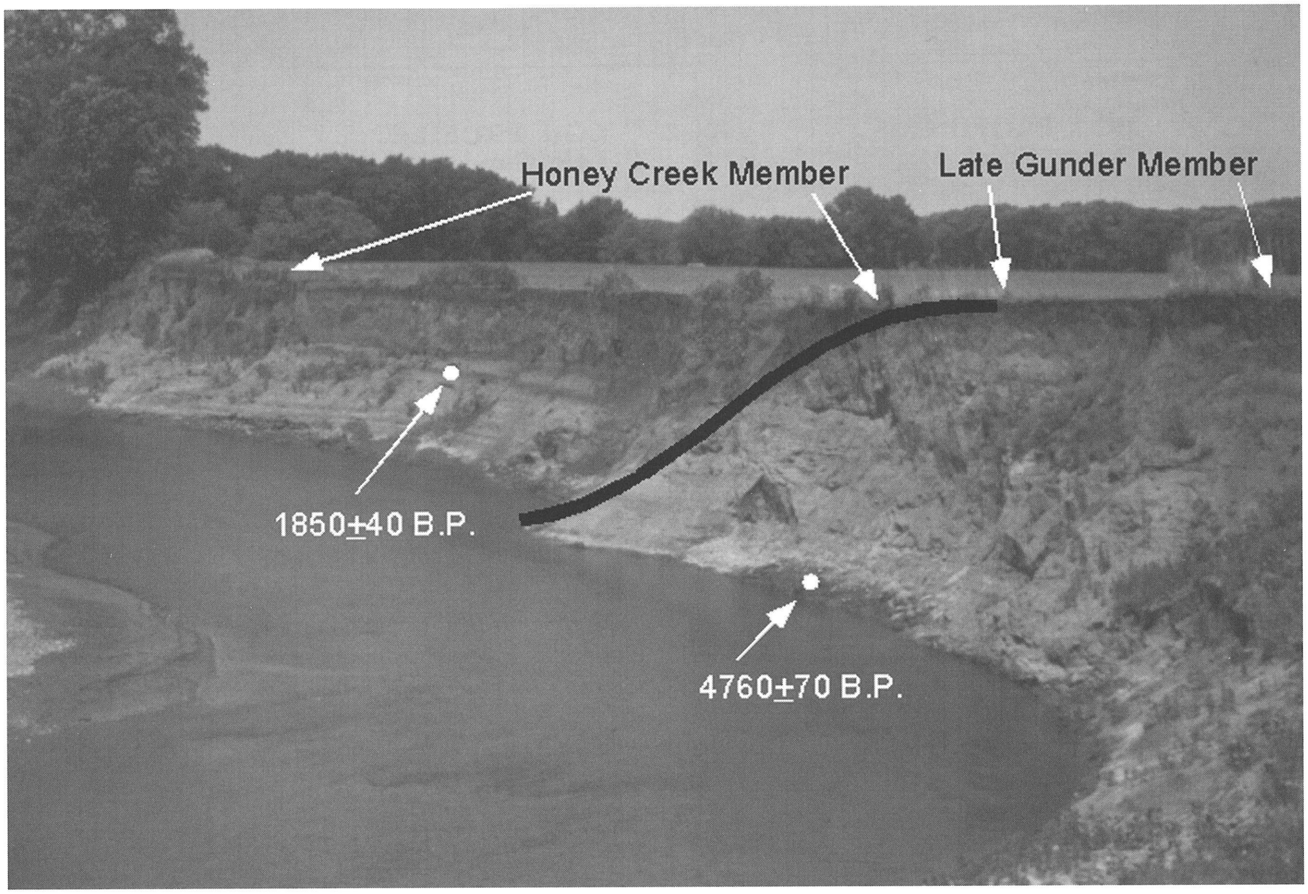


Fig. 15. Photograph of the north bank of the South Fork of the Big Nemaha River at site 25PW65 (stop 4) showing the Honey Creek Member laterally inset against the late Gunder Member.

pared to the other cultural zones in the late Gunder Member, but only a few chert artifacts were found in this archaeological horizon. Charcoal from zone 6 yielded a radiocarbon age of 3,650±180 yr B.P. (Tx-9016); hence it dates to the Late Archaic period.

A second buried soil (soil 3) is at a depth 200-465 cm below the surface of the late Gunder Member. Soil 3 has a well-expressed A-Bt-BC-CB profile (table 4). The 3Ab horizon is 50-cm thick and is a dark gray (10YR 4/1, dry) silty clay loam. The 3Btb horizon (3Bt1b + 3Bt2b) is 45 cm thick and consists of dark brown silty clay loam grading downward to brown (10YR 5/3, dry) silt loam. Cultural zones 7 and 8 are in the upper and lower 10 cm of the 3Ab horizon, respectively. Both of these cultural zones consist of fire-cracked rocks and diffuse flecks of charcoal. Soil 3 merges with soil 2 towards the east end of the cutbank.

The late Gunder Member is stratified below a depth of 510 cm, and the alluvium coarsens downward from silt loam in the 3C1 horizon to sand and gravel in the lower 30 cm of the 3C3 horizon. Coarse-grained channel deposits at the bottom of the section are interbedded with dark gray (2.5Y 4/1, dry), organic-rich silty clay loam and clay loam. Wood from an organic-rich bed about 75 cm above the bedrock contact yielded a radiocarbon age of 4,760±70 yr B.P. (ISGS-3414).

The Honey Creek Member is laterally inset against the late Gunder Member at 25PW65 (figs. 11 and 15). The surfaces of these two units are separated by a gently sloping, 40-cm high scarp. The lateral contact between the Honey Creek and late Gunder Member has been slightly blurred by pedogenesis near the land surface, but at greater depth the contact is abrupt. The Honey Creek Member consists of an 8.6-m thick package of horizontally stratified, silty alluvium. There are five buried soils in this unit (fig. 14 and table 5). Each of these soils has a weakly expressed A-Bw profile developed at the top of an upward-fining sequence. The upward-fining sequences account for finer textures in the A horizons (silty clay loam) compared to the Bw horizons (silt loam).

Three cultural zones are present in the Honey Creek Member (fig. 14). Zone 1, which is in the Ap horizon of the modern surface soil, yielded fire-cracked rock, lithic debitage, and Nebraska Phase pottery. The pottery dates to ca. 1,000-800 yr B.P. Zone 2 is in the lower part of soil 4 at a depth of 275 cm below the surface of the Honey Creek Member. Only one artifact was found in zone 2: an oval-shaped slab of limestone. The slab is 20 cm long, 12 cm wide and 2 cm thick, and its surface is rough and appears to have been heated. Burned earth and a few small pieces of charcoal were found in the sediment surrounding the slab. Zone 3 is in the lower

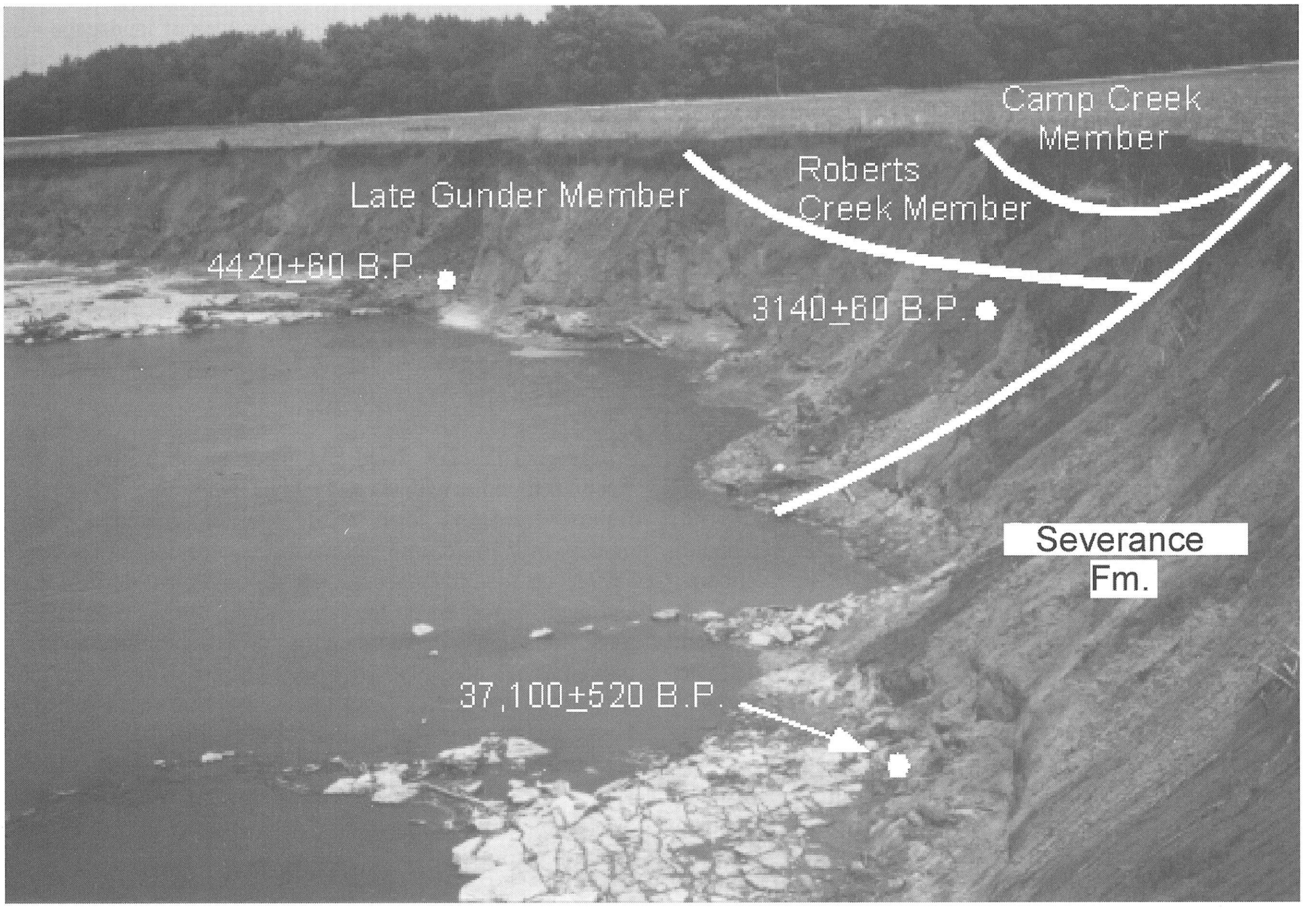


Fig. 16. Photograph of the east bank of the South Fork of the Big Nemaha River at site 25PW63 (stop 4).

part of soil 6 at a depth of 460-475 cm below the surface of the Honey Creek Member. During the geomorphological investigation, fire-cracked rock, a small basin-shaped feature (feature 1), burned earth, and many small pieces of charcoal were recorded in zone 3 (Mandel, 1996). Charcoal recovered from feature 1 yielded a radiocarbon age of 1,850±40 yr B.P. (Tx-9013).

A suite of three radiocarbon ages, combined with relative ages inferred from diagnostic artifacts, provide the basis for a late-Holocene alluvial chronology at site 25PW65. Aggradation of the late Gunder Member began around 4,700 yr B.P. and continued until sometime after ca. 3,650 yr B.P. Initially, alluviation was rapid, with 6 m of alluvium accumulating in about 1,000 years. However, alluviation slowed soon before 3,650 yr B.P. and was punctuated by two episodes of soil development. Aggradation of the late Gunder Member ceased soon after ca. 3,650 yr B.P., and a surface soil developed in this stratigraphic unit. Deep entrenchment of the channel occurred sometime before ca. 1,850 yr B.P. and was followed by rapid aggradation of the Honey Creek Member. Aggradation of the Honey Creek Member was punctuated by five brief episodes of stability and soil development between ca. 1,850 yr B.P. and 1,000-800 yr B.P. The presence of Nebraska Phase pottery at the top of the Honey Creek Member indicates that the surface of this unit has been stable since at least 1,000-800 yr B.P.

After completing our discussion at 25PW65, we will walk north across the meander neck and inspect thick deposits of Holocene and late Wisconsinan alluvium exposed in a steep, 350-m long cutbank (fig. 16). The T-1 surface is relatively flat and featureless adjacent to this cutbank, but it gently rises to the east as it approaches a colluvial apron at the foot of the valley wall. To the north, a subtle swale marks the position of a gully fill that trends east-west across the T-1 surface. On the west side of the Nemaha River, the channel has cut into valley fill beneath the modern floodplain (T-0), exposing a 4-m thick section of stratified, fine-grained alluvium in the cutbank. Wood recovered from the base of this cutbank yielded a "modern" radiocarbon age (ISGS-3415), meaning too young to yield a numerical date.

The complexity of the alluvial stratigraphy on the south side of the meander neck is repeated and amplified on the north side of the meander neck. In order to sort out this complexity, we will focus on cutbanks at two archaeological sites: 25PW63 and 25PW64 (fig. 10). We will also examine a cutbank between the two sites.

Site 25PW63 is a stratified prehistoric occupation on the east bank of the South Fork of the Big Nemaha River (fig. 10). Three members of the DeForest Formation are exposed in the cutbank at this site: Camp Creek, Roberts Creek, and late Gunder. Together, these units form an 8-m thick package of Holocene alluvium.

The Camp Creek and Roberts Creek members fill a shallow channel (flood chute) cut in the late Gunder Member (figs. 16 and 17). The Camp Creek Member at the top of the profile is only 26-cm thick (fig. 18 and table 6). Although this unit has been modified by soil development (Ap-AC profile), sedimentary features have not been completely destroyed. The coarse platy structure of the AC horizon is a product of planar bedding within the body of sediment.

The Camp Creek Member overlies a 1.15-m thick unit of organic-rich alluvium typical of the Roberts Creek Member. Two soils are developed in the Roberts Creek Member: a thin A horizon (soil 2) above an A-ABt profile (soil 3). Soil 3 has a thick, cumulic A horizon consisting of very dark gray (10YR 3/1, dry) silt loam (3A1b) and very dark grayish brown (10YR 3/2, dry) light silty clay loam (3A2b). The 3ABtb horizon is 21 cm thick and is very dark grayish brown (10YR 3/2, dry) silty clay loam. Soil 3 is welded onto a soil (soil 4) developed in the upper part of the late Gunder Member; hence, a gradual boundary separates the Roberts Creek and late Gunder members.

The late Gunder Member composes most of the section at site 25PW63 (fig. 17). There are four soils (soils 4, 5, 6 and 7) developed in this stratigraphic unit (fig. 18). The 4Btb horizon is 35-cm thick and is dark brown (10YR 4/3, dry) silty clay loam. Stratified silt loam and silty clay loam composing the 4C horizon overlie a prominent soil (soil 5) with an At-Bt profile. A small burned-rock feature (feature 1) and many large pieces of wood charcoal were found in the upper 10 cm of the 5Atb horizon (Mandel, 1996, p. 34). Charcoal from feature 1 yielded a radiocarbon age of 3,140±60 yr B.P. (Tx-9015). Soil 6 is at a depth of 305-320 cm and consists of a Btg horizon developed in a clayey flood drape. The flood drape overlies an At-Bt-BC profile (soil 7) that is 320-430 cm below the T-1 surface. Brown (10YR 5/3, dry) sandy loam in the lower part of the 7C horizon fines upward to very dark grayish brown (10YR 3/2, dry) silty clay in the 7Atb horizon. Burned earth, small flecks of charcoal, and one fire-cracked rock were observed in the upper 25 cm of the 7Atb horizon (Mandel, 1996, p. 34).

Coarse-grained lateral accretion deposits at the base of the late Gunder Member are interbedded with fine-grained, organic-rich alluvium and dense organic mats. The organic mats contain limb-size pieces of wood and smaller plant material, including stems, leaves, and seeds. Wood from an organic mat at a depth of 650-670 cm yielded a radiocarbon age of 4,060±60 yr B.P. (ISGS-3416). The deepest organic mat is at a depth of 730-765 cm and lies directly on bedrock. During the 1996 geoarchaeological survey, two human bones, a femur and an ulna, were found in the deepest organic mat (see Peterson and others, 1996, p. 193). A small piece of wood from the upper part of the mat yielded a radiocarbon age of 4,420±60 (Tx-9017). The stratigraphic context of the bones and plant materials indicated that they accumulated together in or immediately adjacent to the late Gunder channel and were quickly buried beneath sand and gravel (Mandel, 1996, p. 34-35).

Radiocarbon ages indicate that most of the sediment composing the late Gunder Member at 25PW63 accumulated between ca. 4,400 and 3,100 yr B.P. Aggradation of the late Gunder was interrupted by four episodes of landscape stability and soil development. Soils 7 and 6 developed sometime between ca. 4,000 and 3,100 yr B.P., and development of soil 5 was underway by at least ca. 3,100 yr B.P.

Although all of the buried soils in the late Gunder Member at 25PW63 have Bt horizons, they are not products of long episodes of pedogenesis. This interpretation is supported by the radiocarbon chronology. Approximately 5 m of alluvium accumulated and three soils developed over a period of about 900 years. The high clay contents of most of the B horizons of the buried soils are attributed to the deposition of clay-rich alluvium and not to in-situ clay formation. Also, some of the clay films on peds and in pores may be flood coating instead of true argillans. Unlike argillans, which largely consist of fine clay, flood coatings consist of all clay-size fractions together with silt and humus (Brammer, 1971). Also, flood coatings can form in 2 to 3 years, whereas argillans usually take more time to develop. According to Brammer (1971), the material that composes flood coats is derived from sediment deposited on the land surface during floods. This material is translocated when the soil is submerged and in a reduced state, possibly under hydraulic pressure. It also may be washed down deep cracks in the soil during wet periods. Unfortunately, the distinction between flood coatings and argillans could not always be made in the field (Mandel, 1996). Hence, the suffix "t" was used whenever clay coatings were observed in soil horizons and does not imply the presence of an argillic horizon.

The late Gunder Member was buried by Roberts Creek Member deposits sometime after ca. 3,100 yr B.P. Aggradation appears to have been slow but steady during the past 3,000 years; soils in the Roberts Creek Member are characterized by thick, dark, cumulic A horizons. Historic floods emplaced a thin veneer of alluvium (Camp Creek Member) on top of the Roberts Creek Member.

The package of Holocene units at 25PW63 is laterally inset against late-Wisconsinan valley fill along the southern edge of the site (fig. 17). The late-Wisconsinan sediments are contained in two stratigraphic units: a 2.8-m thick upper unit of Peoria Loess overlying a 6.2-m thick lower unit consisting of oxidized, upward-fining alluvium typical of the Severance Formation (fig. 19). The surface soil developed in the Peoria Loess has a thick, strongly expressed A-Bt-Bt profile. An abrupt boundary separates the Peoria Loess from a truncated paleosol developed in the Severance Formation. This paleosol has a thick, well-expressed Bt-BC profile. Pedologic features of the paleosol include strong-to-moderate prismatic structure parting to strong-to-moderate angular blocky structure; continuous and discontinuous clay films on ped faces; iron and manganese oxide concretions and stains; and strong mottling. The 2C horizon is stratified and consists of loamy sand grading downward to cobbly gravel. There are zones of iron-cemented pebbly and cobbly sand below a depth of 6.4 m, and laminated beds of gray, reduced, fine sandy loam and loamy fine sand are common in the lower meter of the alluvial fill. The reduced sediments at the base of the Severance Formation contain plant fragments and flecks of charcoal. A fragment of a prairie plant yielded an AMS radiocarbon age

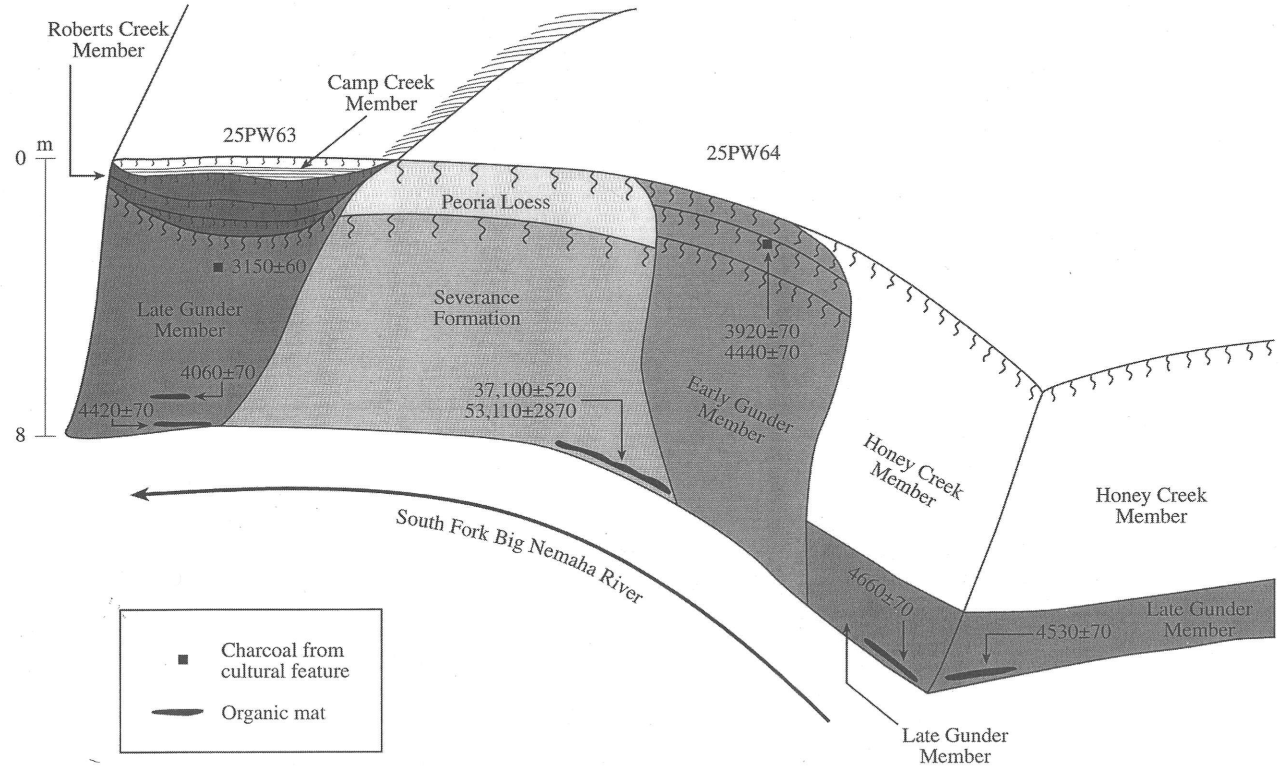


Fig. 17 (above). The outcrops along the east and south banks of the South Fork of the Big Nemaha River at sites 25PW63 and 25PW64 (stop 4).

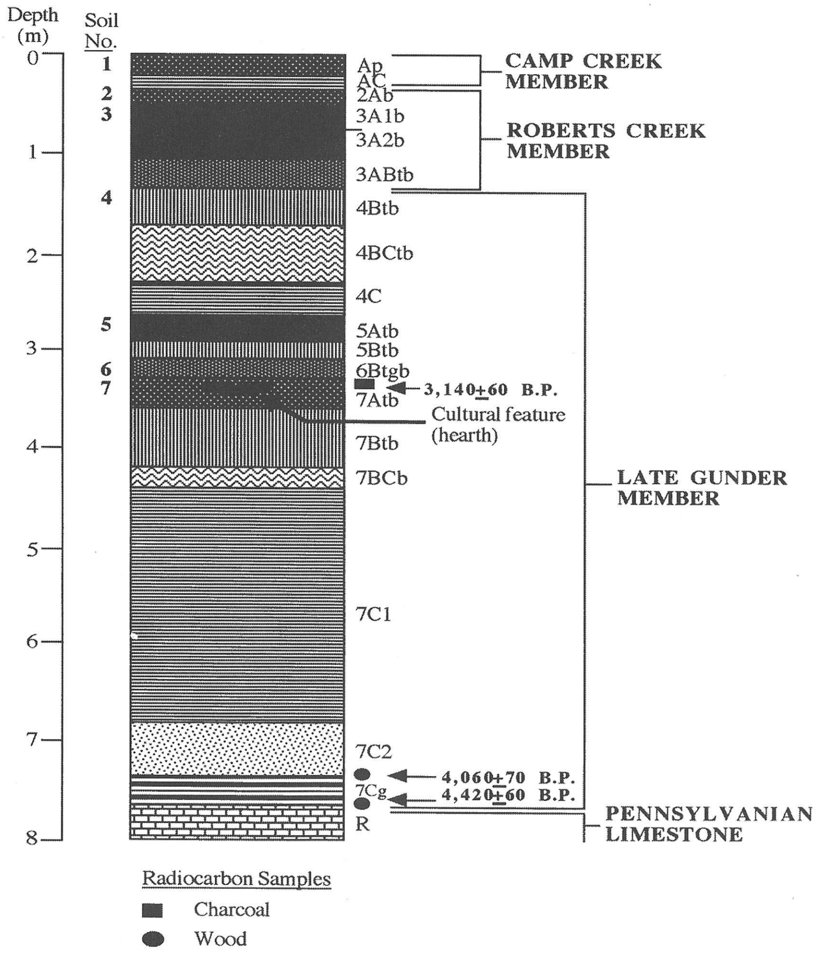


Figure 18 (left). Stratigraphic section for the cutbank at site 25PW63, Farwell locality, stop 4.

Fig. 19. Stratigraphic section for the segment of the cutbank between sites 25PW63 and 25PW64, Farwell locality, stop 4.

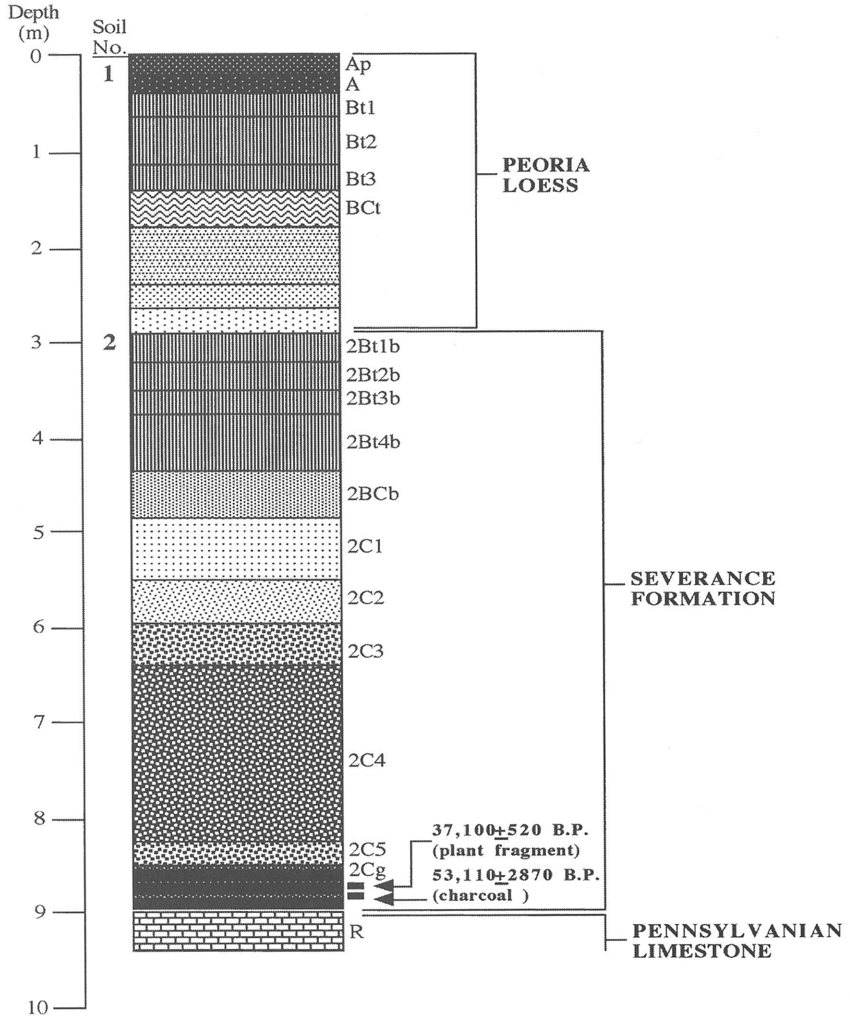
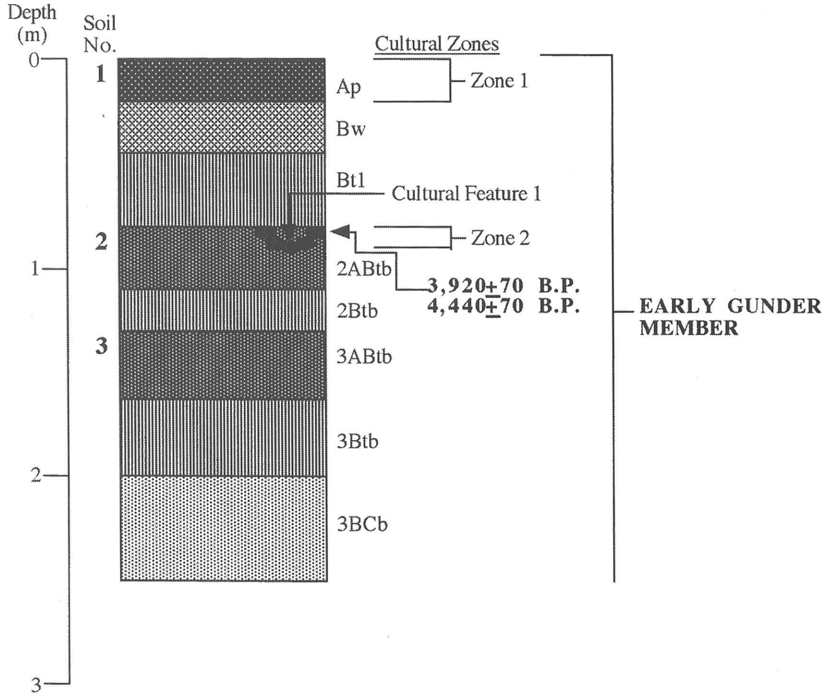


Fig. 20. Stratigraphic section for the cutbank at site 25PW64, Farwell locality, stop 4.



of 37,100±520 yr B.P. (NSRL-3619, CAMS-41681), and a small piece of charcoal yielded an AMS radiocarbon age of 53,110±2870 yr B.P. (CAMS-33983). We are inclined to reject the age determined on the charcoal because a twig recovered from a gray, organic-rich zone near the base of the Severance Formation at the Martin Marietta Quarry (see stop 7) yielded a radiocarbon age of 33,257±1096 (ISGS A-0020).

According to Dr. Richard Baker, the reduced sediment at the base of the Severance Formation is dominated by macrofossils of prairie and weedy species, which is interesting given the radiocarbon age of ca. 37,100 yr B.P. Based on his analysis, the prairie species include dropseed *(Sporobolus asper)*, Indian grass *(Sorhastrum nutans)*, beard tongue *(Penstemon sp.)*, sunflower *(Helianthus sp.)*, and big and little bluestem *(Andropogon gerardii* and *Andropogon scoparius)*. Weeds include amaranth *(Amaranthus sp.)*, ragweed *(Ambrosia psilostachya* type), chenopod *(Chenopodium spp.)*, plantain *(Plantago aristata* type), and catchfly *(Silene antirrhina)*. Baker also documented a few wetland and aquatic species, but no macrofossils of trees were found. The complete absence of trees in the cutbank sequences is rare, even in the Holocene. Baker concluded that the upland vegetation was prairie at ca. 37,100 yr B.P.

The Peoria Loess and Severance Formation are exposed in the sharp bend of the cutbank where the river turns from east to north, but they are completely cut out by Holocene alluvial deposits in the area of site 25PW64 (fig. 17). This site is a multi-component prehistoric occupation located on the south bank of the Nemaha about 100 m upstream from 25PW63. Archaeological materials, including fire-cracked rocks and chert flakes, were found in the plow zone and at a depth of 78 cm below the T-1 surface. The only diagnostic artifact recovered from the site was a full-grooved ax typical of the Middle Archaic period (Peterson and others, 1996, p. 194).

The section at 25PW64 largely consists of oxidized alluvium typical of the Gunder Member. However, unlike the section at 25PW63, most of the Gunder alluvium at 25PW64 predates the late Holocene; hence, it is referred to as early Gunder.

Three depositional units compose the upper 2.5 m of the early Gunder Member at 25PW64 (fig. 20). The upper unit is 44-cm thick and consists of silty alluvium that has been greatly modified by pedogenesis. The surface soil in this unit has an A-Bw-Bt profile (table 7). The argillic (Bt) horizon is 34-cm thick and is brown (10YR 5/3, dry) silty clay loam with moderate structure and distinct, nearly continuous clay films on the ped faces. The clay films extend down into the underlying buried soil (soil 2); hence, the surface soil is welded to the buried soil.

Soil 2 has an ABt-Bt profile (fig. 20 and table 7). Fire-cracked rocks were found in the upper 5cm of the 2ABtb horizon, and a basin-shaped feature (feature 1) extends from surface of this horizon down into the 2Btb horizon. Wood charcoal from feature 1 yielded two radiocarbon ages: 4,440±70 yr B.P. (Tx-8952) and 3,920±70 (Beta-95298). The 500-yr difference in the two ages may be attributed to several factors, including the age of the trees that were the source of the charcoal, contamination of the charcoal by modern rootlets, and the analytical procedures used by the two radiocarbon laboratories. Soil 2 is welded to a buried soil (soil 3) beneath it.

Soil 3 has an ABt-Bt-BC profile. Dark brown (10YR 4/3, dry) silty clay loam in the 3Btb horizon grades downward to brown (10YR 5/3, dry) silt loam in the 3BCb horizon. No archaeological materials were found in soil 3.

On the western edge of 25PW64, late Gunder Member deposits are exposed in the lower 1-2 m of the section. The late Gunder Member is laterally inset against the early Gunder Member and truncated by Honey Creek Member deposits that fill a paleochannel (fig. 16). Wood from organic mats at the bottom of the late Gunder channel yielded radiocarbon ages of 4,530±70 yr B.P. and 4,660±70 yr B.P. These ages are consistent with the age of wood recovered from the bottom of the late Gunder channel at 25PW63.

The radiocarbon dating indicates that most of the alluvium exposed in the section at 25PW63 is greater than 4,500 yr old. Also, the ages and stratigraphy suggest that Archaic people were camped near the entrenched channel of the South Fork of the Big Nemaha River at ca. 4,500-4,000 yr B.P.

Stop 5. Miles Alluvial Fan

The Miles alluvial fan is located 8 km downstream from the Old Bridge locality (stop 2) (figs. 2 and 21). This fan developed at the mouth of an unnamed intermittent stream that flows into the South Fork of the Big Nemaha River. The channel of the Nemaha is along the north side of the valley wall and is cutting into the midsection of the fan. This has resulted in the development of a steep cutbank that exposes a thick section of fan and floodplain deposits (fig. 22). In addition, a Farmdalian peat is exposed at the bottom of the cutbank (figs. 22 and 23).

Approximately 100 m downstream from the Miles fan, stratified late Wisconsinan alluvium is exposed in a cutbank. This alluvium contains wood and other plant macrofossils, including white spruce *(Picea glauca)* cones. Two separate wood samples, both *Picea*, yielded radiocarbon ages of 19,920±240 (ISGS-4681) and 20,290±120 yr B.P. (ISGS-4680). These ages are statistically the same.

Based on its lithology, the Miles fan is composed of the Corrington Member of the DeForest Formation. The fan deposits are oxidized and consist of multiple upward-fining sequences. Two buried soils are developed in the fan: soil 2 at a depth of 130 cm and soil 3 at a depth of 360 cm (figs. 22 and 23). Humates from the upper 10 cm of soils 2 and 3 yielded radiocarbon ages of 3,130±50 yr B.P. (Tx-8945) and 10,450±120 yr B.P. (Tx-8944), respectively.

The alluvium below soil 3 is distinctly stratified and consists of fine-grained, late-Wisconsinan floodplain deposits. A razor-sharp boundary separates these deposits from a 1-m thick peat that is 9.9-10.7 m below the surface of the alluvial fan. Peat samples collected at depths of 9.9-10.1 m, 10.3-10.4 m, and 10.6-10.7 m yielded radiocarbon ages of 23,490±310 yr B.P. (Tx-8946), 24,640±410 yr B.P. (Tx-8947), and 27,580±550 yr B.P. (Tx-8948), respectively. The peat grades downward into a 75-100 cm thick unit of gray, organic-rich, pebbly clay loam.

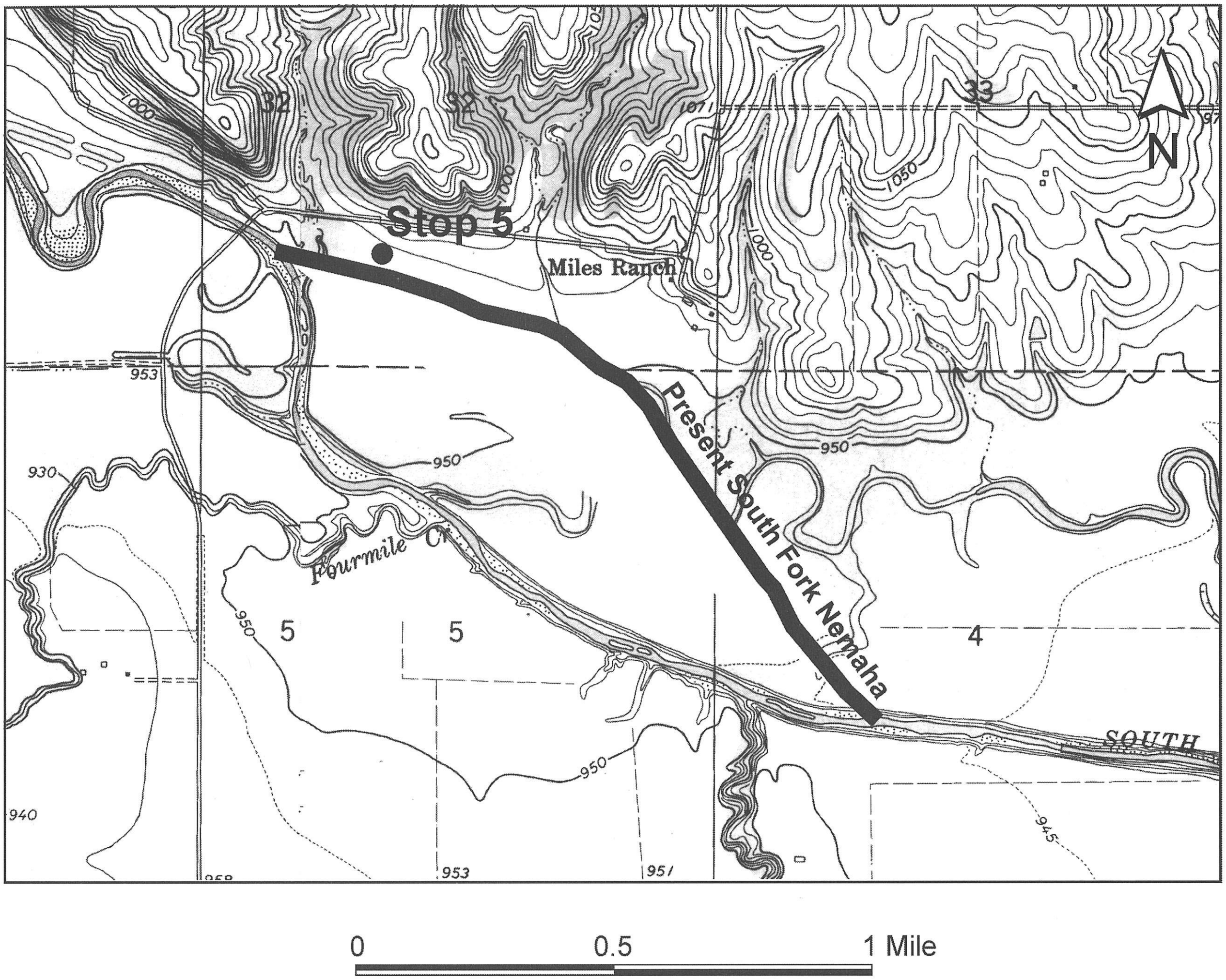
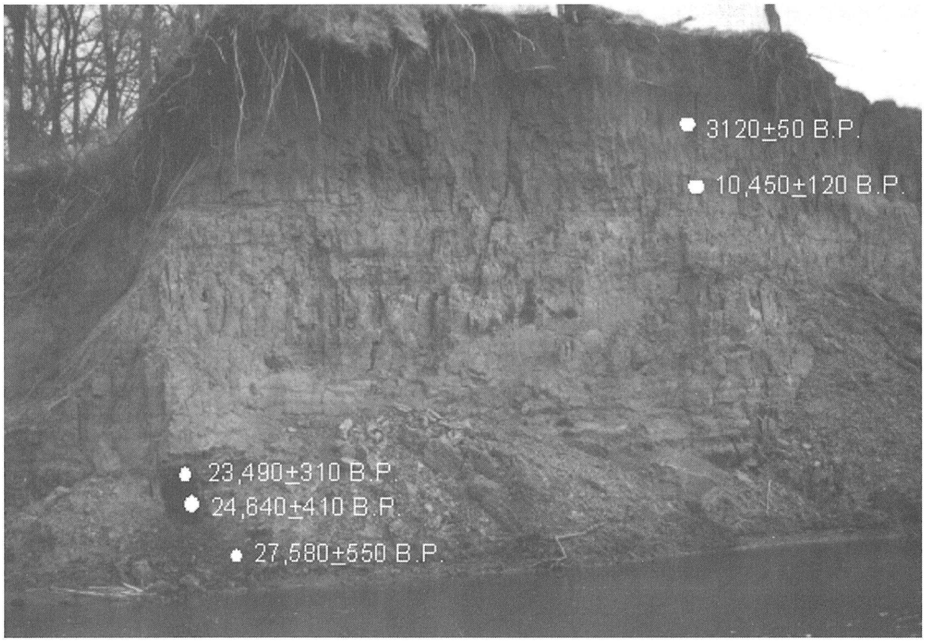


Fig. 21 (above). Topographic map showing the location of stop 5.

Fig. 22 (right). Photograph of the section at the Miles alluvial fan (stop 5). Note the dark peat at the bottom of the section.



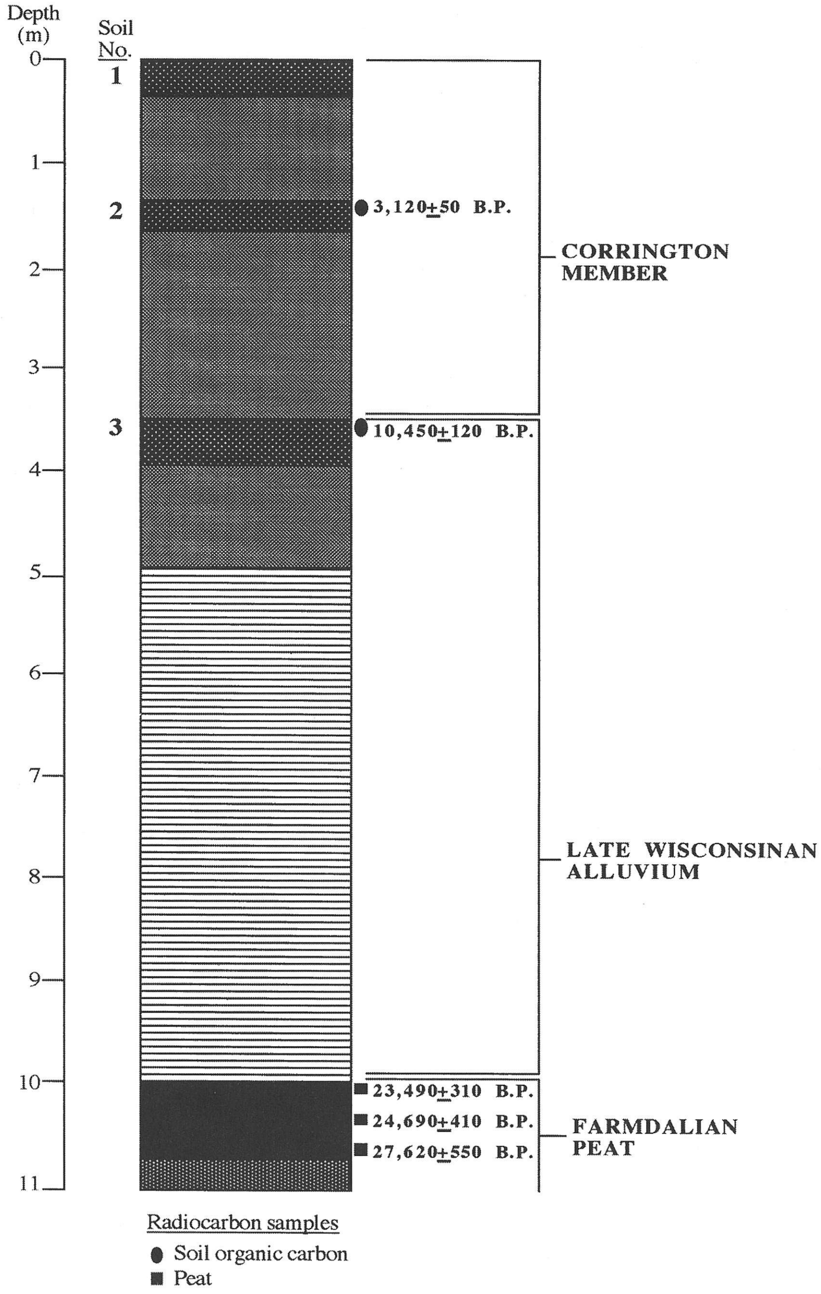


Fig. 23. Stratigraphic section for the Miles alluvial fan, stop 5.

The radiocarbon ages indicate that most of the fan aggraded between ca. 10,500 and 3,000 yr B.P. This is consistent with the chronology of Corrington fans elsewhere in the eastern Great Plains (see Hoyer, 1980; Bettis, 1990; Mandel, 1992b, 1995). Although the numerical ages of the floodplain deposits immediately beneath the fan are unknown, they rapidly aggraded sometime between ca. 23,500 and yr 10,500 yr B.P. The peat consists of plant material that slowly accumulated in a marsh between ca. 27,500 and 23,500 yr B.P. A summary of the plant-macrofossil and pollen records from the peat is presented below.

Paleobotanical Record

Richard Baker analyzed plant macrofossils in the upper and lower 50 cm of the peat at the Miles alluvial fan. Both levels are dominated by aquatic and wetland species. According to Baker, the aquatics include naiad *(Naias flexilis)*, crowfoot *(Ranunculus aquatilis, Ranunculus sceleratus)* and several pondweed *(Potamogeton spp.)* species, such as horned pondweed *(Zannichellia palustris)*. The wetland elements include sedges *(Carex spp.)*, spikerush *(Eleocheris palustris)*, bullrush *(Scirpus acutus type)*, and mint *(Mentha arvenis)*. Rare prairie taxa include sunflower *(Helianthus sp.)* and needle-and-thread grass *(Stipa spartea)*, and a few specimens of chenopods *(Chenopodium spp.)* represent the weedy

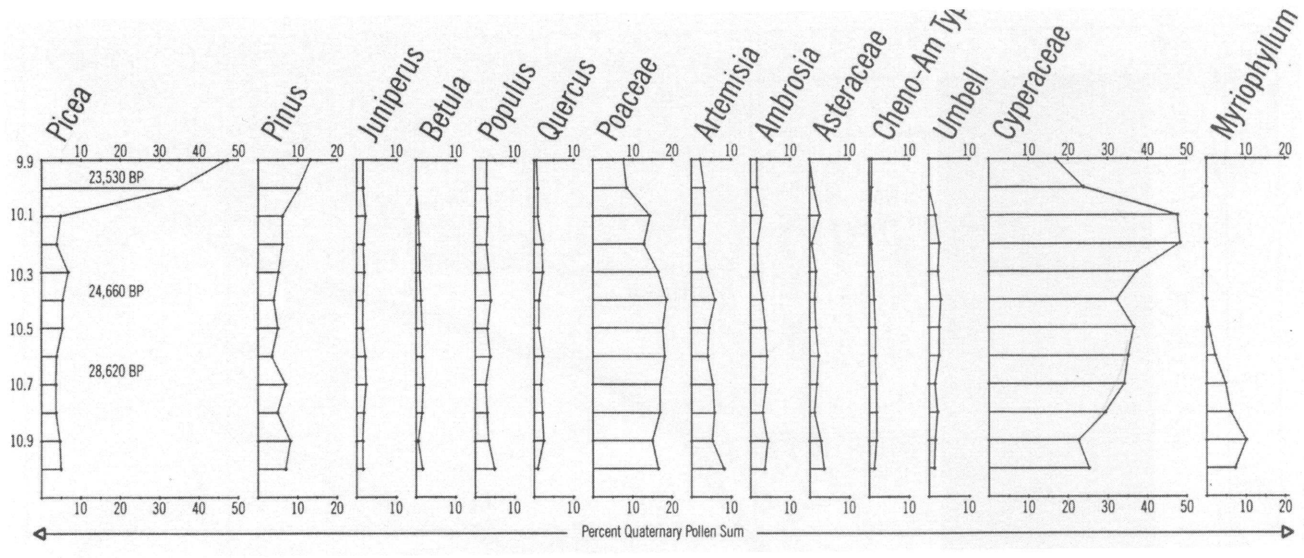


Fig. 24. Pollen-percentages for the Farmdalian peat at the Miles alluvial fan (stop 5).

element. The only tree identified is willow *(Salix)*. Baker concluded that at around 23,500 yr B.P., the site was a marsh. He stressed that marshes typically have poorer representation of plant macrofossils of upland elements than stream deposits exposed in cutbanks. Nevertheless, his analysis indicates that there was some prairie vegetation on the uplands.

Dr. Glen Fredlund's analysis of the pollen record at the Miles fan supports Baker's plant-macrofossil evidence for a marsh at this locality between ca. 28,600 and 23,500 yr B.P., but the regional vegetative signal gleaned from the pollen record is less clear. Well-preserved Pleistocene peat-pollen records are so scarce on the Great Plains that it is tempting to assume that any are regionally representative. However, because the pollen record at the Miles fan has relatively low taxonomic diversity, and because much of the profile is dominated by sedge pollen, Fredlund suggests that we are looking at a local signal. Accordingly, he kept all of the pollen taxa within the pollen sum used in tabulating percentages.

There are two obvious pollen zones within the peat bed: a zone 20-40 cm below the surface of the peat where sedge *(Cyperaceae)* pollen is very common, and a zone 0-20 cm below the surface of the peat where sedge pollen is less common and spruce (*Picea*) dominates the pollen spectra (fig. 24). *Populus* (aspen or cottonwood) is the other arboreal pollen taxa of significance throughout the profile. According to Fredlund, even the relatively modest percentages of *Populus* observed here likely represent a more significant part of the vegetation than the spruce. Yet if one were inclined to infer regional vegetation change from this pollen record, a hypothesized expansion of spruce woodlands going into the last glacial maximum is a reasonable interpretation.

Summary of Holocene Landscape Evolution in the South Fork of the Big Nemaha River Valley

Our visit to the Miles alluvial fan is the last stop that includes Holocene alluvial deposits. Hence, this is a good place to review the Holocene history of the South Fork of the Big Nemaha River. The record of alluvial stratigraphy and stream behavior of the study area is summarized in figures 25 and 26, and the reader is referred to these for the following discussion. Also, a complete listing of the radiocarbon ages used to determine the alluvial chronology of the Nemaha River is presented in table 8.

Our findings suggest that the valley floor of the Nemaha River was entrenched to the bedrock surface and pre-Holocene loess-mantled terraces stood 15 or more meters above the valley floor at the beginning of the Holocene (ca. 10,000 yr B.P.). Only one of our localities, the Miles alluvial fan, dates to this poorly known period, but other early Holocene localities in this region also suggest that an entrenched channel and moist floodplain conditions were present at that time (Bettis, 1990; Mandel, in press). Floodplain stability was interrupted as rapid aggradation of fine-grained alluvium occurred from about 10,200 to 7,000 yr B.P. However, aggradation slowed between ca. 7,000 and 4,800 yr B.P., allowing development of a thick, cumulic soil on the middle Holocene floodplain. Early to middle Holocene aggradation formed the early part of the Gunder Member. Aggradation of the Gunder Member was temporarily halted by channel incision (to the bedrock surface in some places) and widening around 4,800 yr B.P., which isolated the top of the early Gunder deposits as a terrace. Aggradation in the incised channel ensued about 4,700 yr B.P., and development of the late Gunder Member began. Aggradation continued until 3,600 yr B.P., and flood drapes that were laid down when large floods spilled out of

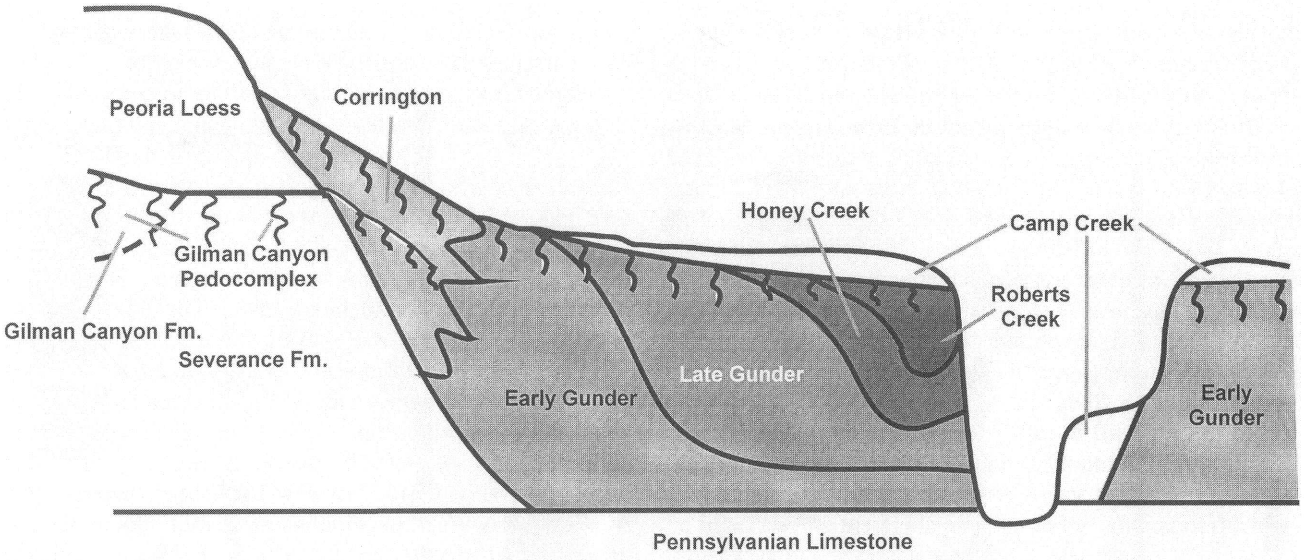


Fig. 25. Stratigraphic and temporal relationships of Wisconsinan formations and units of the Holocene DeForest Formation along the South Fork Big Nemaha River.

the incised channel onto the low terrace buried soils developed in the upper part of the late Gunder Member.

Alluvial fans began to develop where small valleys entered the main valley, and continued to prograde the floodplain and interfinger with Gunder Member deposits from about 10,000 to soon after 3,100 yr B.P. Deposits comprising the fans are the Corrington Member of the DeForest Formation.

Moderate incision of the Nemaha's channel, not as deep as had occurred earlier, took place about 3,200 yr B.P. Roberts Creek Member alluvium, more organic rich than all other DeForest Formation units, accumulated in the newly formed incised channel.

Soon before 1,800 yr. B.P., the channel incised again and the surface of older DeForest Formation fills were once again isolated as a low terrace (T-1). Aggradation ensued and continued until ca. 1,000-800 yr B.P., eventually filling the incised channel. This late Holocene aggradation episode formed the Honey Creek Member of the DeForest Formation. Aggradation of the Honey Creek Member was characterized by rapid alluviation punctuated with short episodes of floodplain stability and soil formation. The Honey Creek Member aggraded almost to the same level as the surface of the late Gunder Member.

Relative floodplain stability and soil formation occurred on the floodplain between about 1,000 and 800 yr B.P., then was interrupted by minor incision and the beginning of accumulation of the Camp Creek Member. Between 800 and about 100 yr B.P., the stream flowed in a moderately incised meandering channel much shallower than but about as wide as the modern incised channel. Soon after straightening of the stream downvalley from the study area, a knickpoint moved through this section of the valley, and the channel deepened to the bedrock surface and isolated the early Camp Creek Member and older alluvial fills as a terrace.

It is important to note that aggradation of the T-1 fill spanned all but the last 1,000 years of the Holocene. However, alluviation was not a simple process that created vertically stacked deposits. Instead, it was contemporaneous with incision of the valley. Brakenridge (1984) referred to this form of valley alluviation as an "ingrown" meandering river process. With an ingrown meander, alluvium is laterally inset, or "shingled," against older fill, resulting in a sloping terrace surface. Also, progressively younger deposits occur below a progressively younger and lower geomorphic surface.

Geologic Potential for Buried Cultural Deposits

Given that the first detailed study of late Quaternary landscape evolution in the South Fork of the Big Nemaha River valley was conducted in support of an archaeological survey (Mandel, 1996), we should say something about the geologic potential for buried cultural resources. As noted in the preceding discussion, alluvial deposits dating to different periods of the late Quaternary are preserved beneath various geomorphic surfaces in the study area. This information, combined with soil-stratigraphic data, may be used to direct future archaeological research. Specifically, the results of this study allow us to predict where buried archaeological materials for each cultural period are likely to occur in the valley landscape.

The determination of geologic potentials for buried cultural deposits is largely based on the soil record. Buried soils represent previous land surfaces that were stable long enough to develop recognizable soil-profile characteristics. As Hoyer (1980) pointed out, if one assumes that the probability of human use of a particular landscape position was equal for each year, it follows that the surfaces which remained exposed for the longest time would represent those with the highest probability for containing cultural materials.

The Sangamon Geosol is a regional late Quaternary stratigraphic marker. It is formed in a wide range of deposit types and in a variety of paleolandscape positions. Morphological characteristics of this geosol vary with paleolandscape position. Thick, well-horizonated examples with brown or reddish brown B horizon colors are associated with relatively stable, well drained positions of paleolandscapes, while poorly horizonated profiles with gley colors (gray, greenish gray, bluish gray) are associated with poorly drained paleolandscape positions. Thin and/or truncated profiles are typically associated with sloping parts of paleolandscapes.

In sum, the Sangamon Geosol is an important stratigraphic marker in the region. Deposits and soils above the Sangamon Geosol are Wisconsinan or younger while underlying deposits are pre-Wisconsin. In its type in Illinois, the Sangamon Geosol developed during the last interglacial and during part of the Wisconsin Episode (Marine Isotope Stages 5 and 4). Beyond the margin of Illinoian glaciation and the area of accumulation of Illinoian loess, the Sangamon Geosol is developed in pre-Illinoian deposits and may have formed over a much longer period of time than in the type area.

Stop 7. Martin Marietta Quarry near Dubois

The Martin Marietta quarry near DuBois (stop 7) is located about 2 km southeast of the community of DuBois (figs. 2 and 8). At this stop, we will examine the best-displayed sequence of colluvial and alluvial facies of the Severance Formation in the Nemaha River valley. Excavations at the quarry have cut across the boundary between the valley floor and uplands, exposing thick sections of the Severance Formation above Pennsylvanian limestone. Colluvial facies of the Severance Formation are mantled by 2 to 3 m of Peoria Loess. The most striking feature in the walls of the quarry is a 2- to 3-m thick zone of black, organic-rich alluvium near the base of the Severance Formation. Our discussion will focus on 1) the stratigraphy and lithology of the Severance Formation; 2) the paleobotanic information gleaned from the organic-rich alluvium; and 3) the age and geomorphic relationships of Severance Formation deposits.

Stratigraphy and Lithology

The following description of the stratigraphy exposed in the DuBois quarry is for a section that no longer exists. Recent expansion of the quarry removed this section, but new exposures have been created. The stratigraphy in these new exposures is similar to the stratigraphy that was described in our original section (fig. 30).

Two stratigraphic units are above bedrock at this locality: the Peoria Loess and the Severance Formation (fig. 30). The Peoria Loess is about 2.4 m thick and is the surficial deposit. The underlying Severance Formation is about 7.5 m thick and is the focus of our discussion.

The upper 4 m of the Severance Formation consist of poorly sorted loam and clay loam with few rounded to slightly angular pebbles. We suggest that this diamicton is a colluvial facies of the Severance Formation. As noted earlier, the quarry spans the boundary between the valley floor and uplands. Hence, given the landscape position, a colluvial origin seems reasonable for these deposits. A strongly expressed paleosol with a thick BA-Bt-BC profile is developed in the colluvial facies of the Severance Formation (fig. 30 and table 9). Pedological features of this paleosol include discontinuous clay films (argillans) and silt coatings (silans) on ped faces and in macropores; prismatic structure parting to subangular blocky structure; iron and manganese oxide concretions; common macropores; and a brown (10YR 5/3 to 7.5YR 4/3) matrix color. Interestingly, these features are typical for soils developed in loess facies of the Gilman Canyon Formation in south-central Nebraska and Kansas (Reed and Dreezen, 1965; Feng and others, 1994; Mandel and Bettis, 1995).

Sand content increases downward through the colluvial facies and into the alluvial facies of the Severance Formation. The colluvial facies grade into a 5-m thick package of trough-crossbedded, sandy alluvium resembling the coarse-grained alluvial facies of the Severance Formation at stop 4. The oxidized sandy alluvium overlies a 2.6-m thick bed of black, organic-rich silt loam. This organic-rich zone contains seeds and many small plant fragments. A radiocarbon age of 33,257 ±1,096 yr B.P. (A-0020) was determined on a twig recovered at a depth of 436-456 cm below the land surface or 200-220 cm below the top of the organic-rich zone. The sand content increases downward through the organic-rich zone, and a 50-cm thick zone of cobbly gravel separates it from the underling Pennsylvanian limestone. A summary of the paleobotanical information gleaned from the organic-rich alluvium is presented below.

Paleobotanical Record

Bulk sediment samples were collected at 20-cm intervals in the organic-rich zone near the base of the Severance Formation. Richard Baker has completed an analysis of plant macrofossils in samples from the uppermost level (0-20 cm) and five lowest levels (140-160, 160-180, 180-200, and 200-220 cm). According to Baker, the organic-rich zone contains rare but diverse aquatic elements in its lower levels and abundant and diverse aquatic elements in its upper 20 cm. Aquatic taxa include water milfoil (*Mynophyllum sibiricum*), naiad, crowfoot, and three to four species of pondweed. Wetland elements are also important and diverse; these gradually increase in abundance through the lower levels and are less diverse, but with a few abundant taxa, in the top level. There is an abundance of spikerush and bullrush in the upper 20 cm of the organic-rich zone, and those taxa, plus several mints, smartweed *(Polygonum lapathifolium)*, arrowhead *(Sagittaria latifolia)*, rice cutgrass *(Leersia oryzoides)*, are in the lower levels. Prairie species, including big bluestem, prairie clover *(Dalea candida)*, sunflower, and wild bergamot *(Monarda fistulosa)*, are sparse throughout the lower levels and are absent at the top of the organic-rich zone. Weedy taxa are sparse but diverse in the lower levels, but

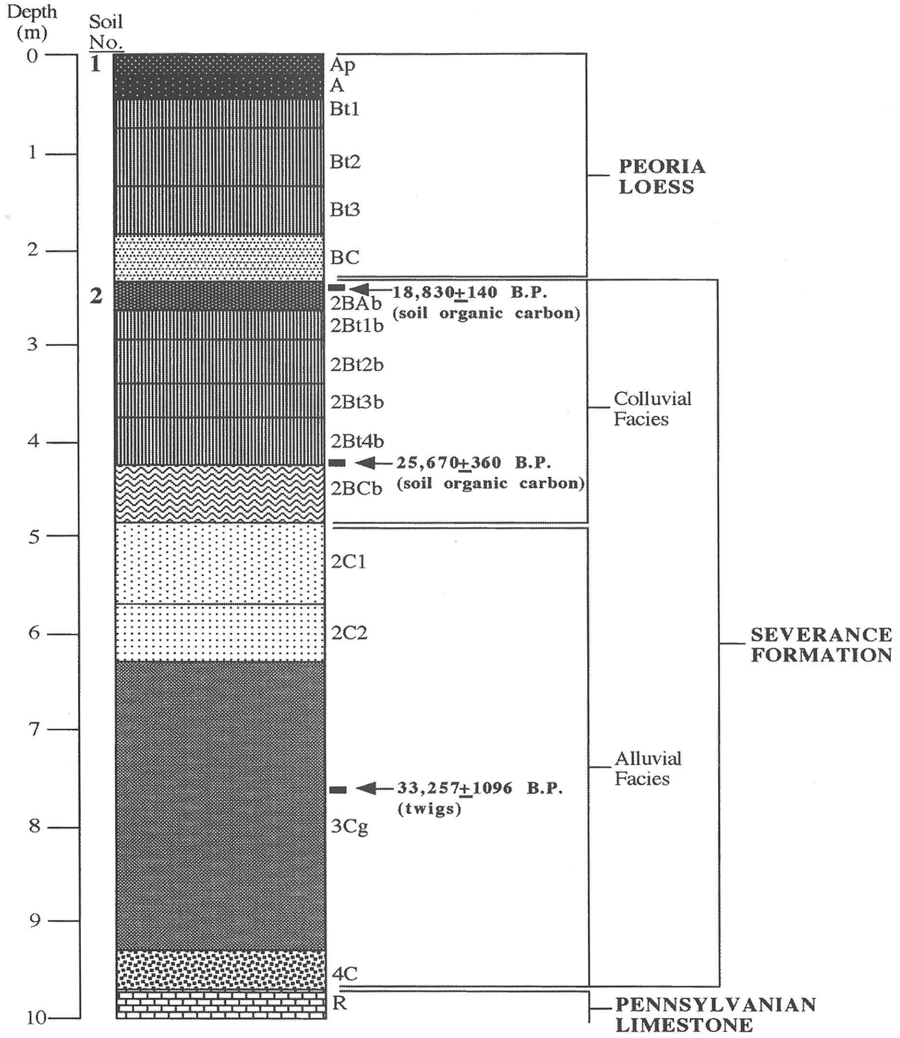


Fig. 30. Stratigraphic section for the Martin Marietta quarry near Dubois, stop 7.

only one abundant chenopod is found in the upper 20 cm. Willows and perhaps poplar are present in the lower levels, but they are absent at the top. Based on these findings, Baker suggests that there was a marsh at this locality about 33,000 yr B.P., with prairie on the uplands.

Age and Geomorphic Relationships of Severance Formation Deposits

We have seen Severance Formation deposits at three localities: stops 3, 4, and 7. These deposits are similar in stratigraphic position, but how are they temporally and geomorphically related? Radiocarbon ages from buried soils atop the Severance Formation, and ages determined on plant macrofossils near the base of the alluvial fill at stops 4 and 7, suggest that Severance Formation deposits at these two localities are roughly contemporaneous. As for landscape position, both localities occur between 1,010 and 1,020 ft in elevation, with the stop 7 section, situated near the valley margin, being slightly higher. At stop 3, alluvial facies compose most if not all of the Severance Formation. At stop 7, however, a wedge of loess-mantled colluvium overlies the alluvial facies of the formation. The loess-mantled Severance Formation alluvium at stop 3 occurs in a stratigraphic position similar to the Severance Formation colluvium at stop 7 (beneath Peoria Loess), but the alluvium at stop 3, in the center of the valley, is at least 10 ft higher in elevation than the Severance Formation alluvium at either stops 4 or 7 (fig. 8).

Two interpretations of the relationship of the Severance Formation alluvium at stop 3 with that at stops 4 and 7 are posed. The first interpretation is that the alluvium buried by loess beneath the terrace at stop 3 is Wisconsinan in age, but slightly older than the Severance Formation deposits at stops 4 and 7. Similar Wisconsin-episode alluvium has been described in south-central Iowa (Baker and others, 1991), and radiocarbon-dated sections with similar stratigraphy and ages are present along the Wolf River and its tributaries in northeastern Kansas (Mandel, in press). In the South Fork of the Big Nemaha River valley, the Severance Formation may represent a complex of alluvial fills (multiple terrace fills?) sharing similar stratigraphic position beneath Peoria Loess, with the Severance Formation pedocomplex developed into their surface (and buried in the subsurface?), but with ages potentially spanning the early through late Wisconsin (Marine Oxygen Isotope stages 4, 3 and early 2).

A second interpretation is that the loess-mantled alluvium at stop 3 is pre-Wisconsinan in age and should not be considered part of the Severance Formation. We suggest that this is not the case because the buried soil formed in the upper part of the alluvium lacks the reddish hues, thick clay films, and solum thickness typical of pre-Wisconsinan soils in the region (Mandel and Bettis, 1995). We admit, however, that correlation using soil properties is full of potential problems and should be avoided and viewed with skepticism. These loess-mantled terrace fills warrant intensive study since they may record landscape conditions and fluvial system behavior during a very poorly understood part of the late Pleistocene.

Stop 8. Vitt Borrow Pit, Seneca, Kansas

At this stop, we will examine Pre-Illinoian glacial till in the upper South Fork of the Big Nemaha River valley near Seneca, Kansas (figs. 2, 31 and 32). A small borrow pit dug into a re-entrant in the eastern valley wall exposes an approximately 7-m thick section of Independence Formation diamicton and a truncated weathering profile. Our discussion will focus on the stratigraphy of the diamicton, and the weathering profile.

Northeastern Kansas was glaciated during the Pre-Illinoian episode prior to 500 ka. Deposits emplaced during at least two and as many as five glacial episodes have been described from localities in Kansas (Frye and Leonard, 1952; Dort, 1966, 1985; Bayne and others, 1971; Aber, 1988, 1991). Two diamictons are commonly recognized in Kansas. The lower diamicton has been called the Nebraskan, Nickerson, Iowa Point, or lower Kansan till, while the upper diamicton has been called Kansan, Cedar Bluffs, or upper Kansan. Most recently, Aber (1991) proposed the Independence Formation to include all these glacial diamictons and stratified sediments associated with them. The presence of a weathering profile in the lower diamicton at some localities (Bayne, 1968; Bayne and others, 1971) indicates a minimum of two Pre-Illinois episode glaciations separated by nonglacial conditions during which the weathering profile developed.

The age of the Independence Formation is constrained by paleomagnetic, radiometric, and biostratigraphic studies. Studies of the remnant magnetism of glacial diamictons in Kansas have found that all exhibit normal polarity (Aber, 1991). This suggests that they accumulated during the Bruhns chron (after 0.72 Ma B.P.) or less likely the Jarmillo subchron (1.0-0.9 Ma B.P.). Lava Creek B volcanic ash (0.62 Ma B.P.) has been found in a terrace fill interpreted as post-dating glaciation along the north wall of the Kansas River valley near the community of De Soto in Leavenworth County, Kansas (Geil, 1987), thus providing a maximum limiting age. Martin and Schultz (1985) have assigned the Walthena Local Fauna, collected from beneath Independence Formation diamicton in Doniphan County, to the Sappan subprovince of the Irvingtonian Provincial Land Mammal Age. Sappan faunas in sections with radiometric control all predate 1.2 Ma B.P. The available evidence constrains Independence Formation diamictons and associated stratified sediments to the period between about 0.62 and 0.78 Ma B.P., during Marine Oxygen Isotope stages 16-18.

Vitt Section Stratigraphy and Weathering Profile

The Vitt section is located between 1,130 and 1,150 ft in elevation near the base of the valley wall, which rises to about 1,200 ft (fig. 31). Small exposures along a road leading to a radio tower near the top of the bluff indicate that the valley wall in this area is formed in diamicton. A buried bedrock valley, locally filled with more than 100 m of glacial deposits, crosses northeastern Kansas from Marshall County eastward to Atchison County (Denne and others, 1982). The buried valley usually contains both diamictons of the Independence Formation, often separated by lacustrine sands and silts (Aber, 1991). The Seneca section and nearby stream exposures of the Independence Formation are located within this buried valley.

The eastern part of the Vitt section was slumped when described in 1999, but the central and western parts provided reasonably good exposures. Exposures here consist of matrix-dominated loamy diamictons with inclusions of deformed sand and gravel (fig. 32). The deposits are heavily jointed and range from oxidized and unleached (OJU) in the upper part of the exposure downward to unoxidized and unleached (UJU). A few pieces of wood were observed in the UJU diamicton in the lower few meters of the section. Sand, pebbly sand, and silt bodies in the diamicton sequence disrupt the normal downward progression of oxidized to unoxidized weathering zones. Oxidation occurs where oxygenated water passes through the diamicton along subvertical fractures (joints) outward into the matrix and throughout the sand and silts.

In the central part of the exposure, a 0.5-0.25-m thick zone of very dense, sheared diamicton with fine sand/coarse silt lentils occurs about 3 m above the pit floor. Oxidized silt and pebbly sand bodies in this part of the section have their tops planed off. Stratified sand and pebbly sand bodies on the eastern end of the pit are deformed into a series of small folds trending roughly east-to-west. The underlying UJU diamicton is dislocated in a few small, wedge-shaped diapirs that intrude into the overlying sand. These trend northwesterly-southeasterly and appear to be pushed from the northeast. We have not made till fabric measurements, but push directions indicated by the folds and till diapirs in the stratified sediments are consistent with ice movement from the northeast for the upper diamicton.

We interpret stratigraphic relationships at the Vitt section to represent the two glacial diamictons of the Independence Formation. Other evidence supporting this conclusion is the presence of extensive buried sand deposits and springs in the eastern bluff line at elevations between 1,150 and 1,200 ft. These may be marking the outcrop pattern of stratified sediments separating the Independence Formation diamictons. Aber (1991) has described similar stratigraphic

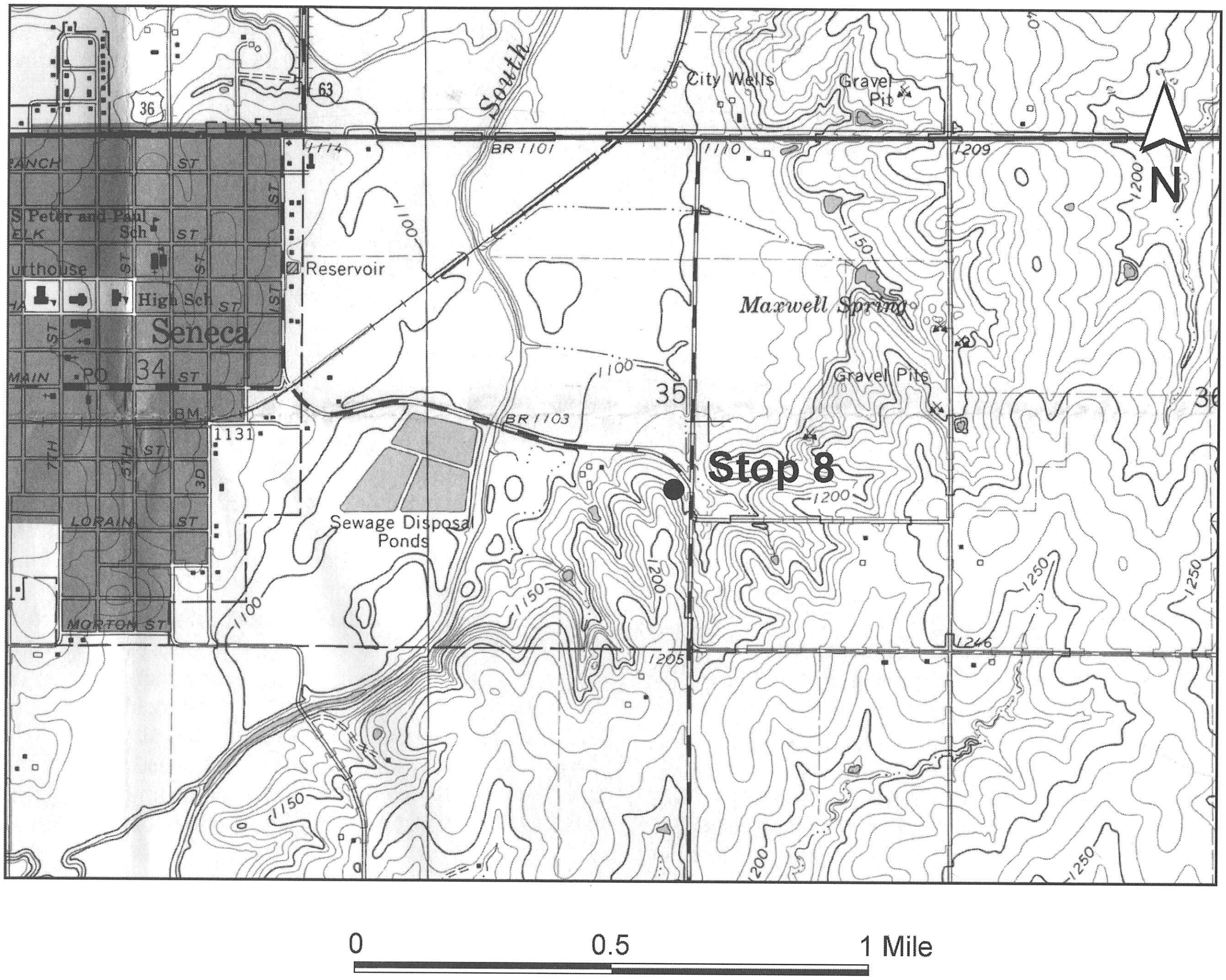


Fig. 31. Topographic map showing the location of stop 8.

relationships at the West Atchison section (type section for the Independence Formation) north of Kansas City.

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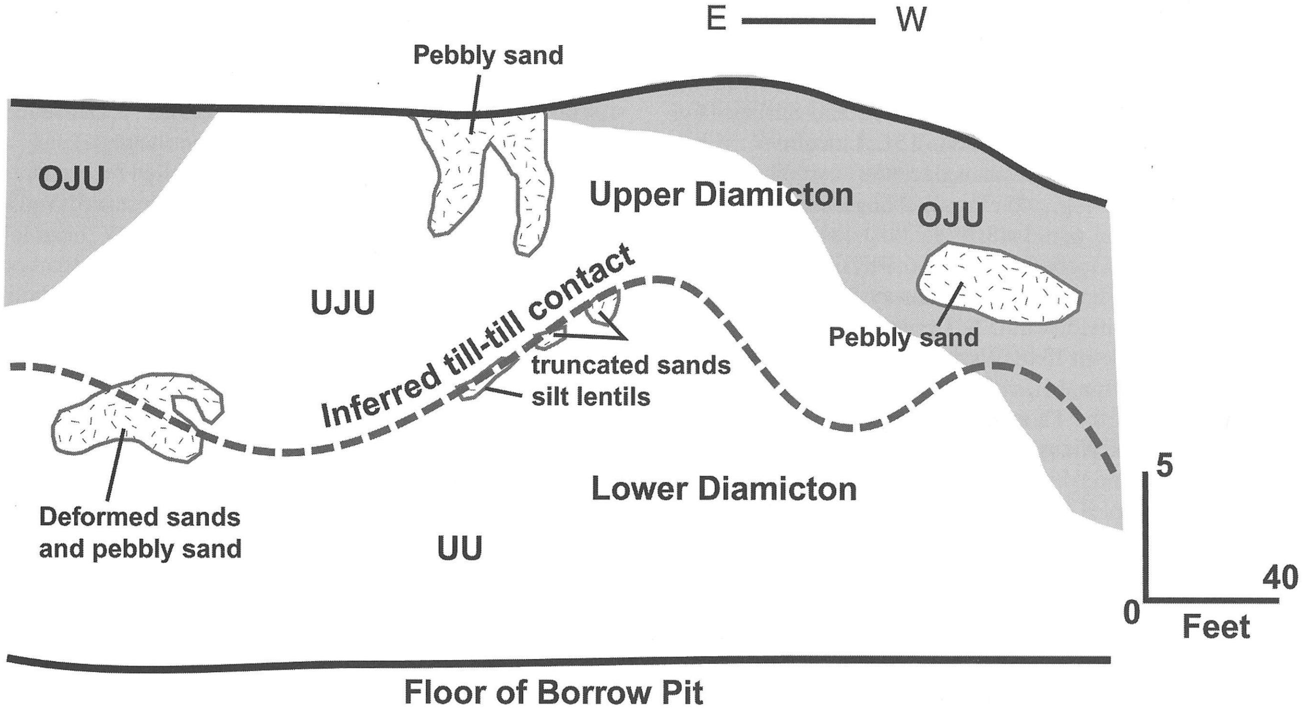

Fig. 32. The stratigraphy of the Vitt Section, stop 8.

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Table 1. Detailed description of the Peoria Loess and underlying Severance Formation at the Koester site (25PW58), stop 3. Description is from a core taken in 1996 (Mandel, 1996).

Landform: T-2 terrace
Parent material: Peoria Loess overlying alluvial facies of the Severance Formation.
Slope: 1 %
Drainage: Moderately well drained
Described by: Rolfe Mandel

Depth (cm)	Soil Horizon	Description
		PEORIA LOESS
0-19	Ap	Very dark grayish brown (10YR 3/2) silty clay loam, very dark brown (10YR 2/2) moist; moderate fine granular structure; hard, friable; noneffervescent; abrupt boundary.
19-72	Bt	Dark brown (10YR 4/3) silty clay, dark grayish brown (10YR 4/2) moist; common fine distinct yellowish red (5YR 4/6) and strong brown (7.5YR 4/6) and few fine faint gray (5Y 6/1) mottles; moderate medium and fine subangular blocky structure; very hard, very firm; common thin discontinuous dark brown (10YR 3/3) clay films on ped faces and in pores; many of the macropores are filled with very dark brown (10YR 2/2) silty clay loam; noneffervescent; gradual boundary.
72-96	BC	Yellowish brown (10YR 5/4) to brown (10YR 5/3) silty clay loam, dark brown (10YR 4/3) moist; common fine distinct gray (10YR 6/1), strong brown (10YR 4/6), and reddish yellow (7.5YR 6/6) mottles; weak medium prismatic structure parting to weak fine subangular blocky; very hard, very firm; many fine soft dark reddish brown (5YR 3/3 and 3/2) ferromanganese accumulations; noneffervescent; abrupt boundary.
		SEVERANCE FORMATION
96-226	2Bt1b	Dark brown (7.5YR 4/4) silty clay loam, dark brown (7.5YR 3/4) moist; moderate fine prismatic structure; very hard, very firm; common thin discontinuous dark brown (7.5YR 3/3) clay films on ped faces; few light brownish gray (10YR 6/2) depletion zones along pores and old root channels; common fine and very fine hard and soft ferromanganese concretions; noneffervescent; gradual boundary.
226-250	2Bt2b	Strong brown (7.5YR 4/6) silty clay loam, dark brown (7.5YR 4/4) moist; moderate fine prismatic structure; very hard, very firm; few thin discontinuous dark brown (7.5YR 3/3) clay films on ped faces; few fine patchy pale brown (10YR 6/3) silt coatings (silans); few light brownish gray (10YR 6/2) depletion zones along pores and old root channels; common fine and very fine hard and soft ferromanganese concretions; noneffervescent; gradual boundary.
250-275	2BCb	Yellowish brown (10YR 5/4) loam, dark yellowish brown (10YR 4/4) moist; common fine and medium faint strong brown (7.5YR 5/6) and few very fine faint light brownish gray (7.5YR 6/2) mottles; weak fine subangular blocky structure; hard, friable; few fine patchy pale brown (10YR 6/3) silt coatings (silans); common fine and very fine hard and soft ferromanganese concretions; noneffervescent; gradual boundary.

275-400	2C	Yellowish brown (10YR 5/4) loam interbedded with brown (10YR 5/3) very fine sandy loam and strong brown (7.5YR 4/6) silty clay loam, massive; slightly hard, friable; common fine pale brown (10YR 6/3) and very pale brown (10YR 7/3) silt bodies; common fine and very fine hard and soft ferromanganese concretions; noneffervescent.

Table 2. Detailed description of of the late Gunder Member and underlying Severance Formation in profile SF-1 at site 25PW65, stop 4.

Landform: T-1 terrace
Parent material: Alluvium
Slope: < 1 %
Drainage: Moderately well drained
Described by: Rolfe Mandel
Comments: A burned-rock feature was recorded at a depth of 40-45 cm. Organic carbon from a bulk soil sample collected from the upper 10 cm of the 2Bt3b horizon (200-210 cm below surface) yielded a radiocarbon age of 15,110±110 yr B.P. (ISGS-4468).

Depth (cm)	Soil Horizon	Description
		LATE GUNDER MEMBER
0-20	Ap	Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) to black (10YR 2/1) moist; weak fine granular structure; friable; abrupt smooth boundary.
20-42	A	Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) to black (10YR 2/1) moist; moderate medium and coarse granular structure; friable; gradual smooth boundary.
42-90	Bw	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; common fine faint yellowish brown (10YR 5/4) and fine distinct (10YR 5/6) mottles; weak fine prismatic structure parting to moderate fine and very fine subangular blocky; friable; clear smooth boundary.
		SEVERANCE FORMATION
90-121	2Bt1b	Dark brown (10YR 3/3) heavy silty clay loam, very dark grayish brown (10YR 3/2) moist; common fine distinct dark yellowish brown (10YR 4/4) and few fine faint yellowish brown (10YR 5/4) mottles; strong medium and coarse prismatic structure parting to strong medium and fine angular blocky; hard, firm; many thick continuous very dark gray (10YR 3/1) to very dark grayish brown (10YR 3/2) clay films on ped faces; gradual smooth boundary.
121-200	2Bt2b	Dark brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; common fine distinct dark yellowish brown (10YR 4/4) and fine faint yellowish brown (10YR 5/4) mottles; moderate medium prismatic structure parting to moderate fine angular blocky; hard, firm; many thin continuous very dark grayish brown (10YR 4/2) clay films on ped faces; common very fine soft dark concretions (iron and manganese oxides); gradual smooth boundary.

200-249	2Bt3b	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; common fine and very fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) and few fine and very fine prominent yellowish red (5YR 4/6) mottles; moderate medium prismatic structure parting to moderate fine angular blocky; hard, firm; common thin continuous dark brown (10YR 4/3) clay films on ped faces; common fine and very fine soft and hard dark concretions (iron and manganese oxides); gradual smooth boundary.
249-280	2Bt4b	Yellowish brown (10YR 5/4) light silty clay loam, dark yellowish brown (10YR 4/4) moist; many fine and medium prominent yellowish brown (10YR 5/6 and 5/8), strong brown (7.5YR 5/8) and yellowish red (5YR 4/6) mottles; moderate medium prismatic structure parting to moderate fine angular blocky; hard, friable; common thin discontinuous dark brown (10YR 4/3) clay films on ped faces; common fine and very fine soft and hard dark concretions (iron and manganese oxides); common dark red (2.5YR 3/6) and yellowish red (5YR 5/8) iron segregations in macropores; few dark gray (10YR 4/1) and very dark grayish brown (10YR 3/2) reduction zones along root paths and pores; gradual smooth boundary.
280-340	2Bt5b	Brown (10YR 5/3) light silty clay loam, dark brown (10YR 4/3) moist; common fine and medium prominent yellowish brown (10YR 5/6 and 5/8), strong brown (7.5YR 5/8) and yellowish red (5YR 4/6) mottles; weak medium and fine prismatic structure parting to weak fine subangular blocky; hard, friable; common thin discontinuous dark brown (10YR 4/3) clay films on ped faces; few fine and very fine soft and hard dark concretions (iron and manganese oxides); few dark red (2.5YR 3/6) and yellowish red (5YR 5/8) iron segregations in macropores; few dark gray (10YR 4/1) and very dark grayish brown (10YR 3/2) reduction zones along root paths and pores; gradual smooth boundary.
340-400	2BCtb	Brown (7.5YR 5/3) sandy clay loam, dark brown (7.5YR 4/3) moist; many fine prominent strong brown (7.5YR 5/8) and yellowish red (5YR 4/6 and 5/8) mottles; weak coarse prismatic structure parting to weak fine subangular blocky; common thick dark brown (10YR 3/3) clay flows in pores and few thin patchy dark brown (10YR 4/3) clay films on ped faces; few fine and very fine soft and hard dark concretions (iron and manganese oxides).

Table 3. Detailed description of the Camp Creek Member and underlying Roberts Creek Member in profile RC-1 at site 25PW65, stop 4.

Landform: T-1 terrace
Parent material: Alluvium
Slope: < 1 %
Drainage: Poorly drained
Described by: Rolfe Mandel

Depth (cm)	Soil Horizon	Desription
		CAMP CREEK MEMBER
0-20	Ap	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; friable; abrupt smooth boundary.

20-33	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak medium and coarse platy structure parting to weak fine granular; friable; abrupt smooth boundary.
		ROBERTS CREEK MEMBER
33-91	2Ab	Very dark gray (10YR 3/1) heavy silty clay loam, black (10YR 2/1) moist; weak fine subangular blocky structure parting to weak medium and coarse granular; hard, friable; gradual smooth boundary.
91-124	2Bg1b	Dark gray (10YR 4/1) heavy silty clay loam to light silty clay, very dark gray (10YR 2/1) moist; moderate medium and fine prismatic structure parting to moderate fine angular blocky; very hard, very firm; gradual smooth boundary.
216-279	2Bg3b	Dark gray (10YR 4/1) heavy silty clay loam to light silty clay, very dark gray (10YR 2/1) moist; few very fine distinct yellowish brown (10YR 5/6) mottles; moderate coarse prismatic structure parting to moderate medium angular blocky; very hard, very firm; gradual smooth boundary.
279-332	2BCgb	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; common fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) and fine faint yellowish brown (10YR 5/4) mottles; weak coarse prismatic structure parting to weak fine prismatic; hard, firm; faint bedding; common black (10YR 2/1) clay flows in macropores; gradual smooth boundary.
332-500+	2Cg	Stratified grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; interbedded with very dark grayish brown (10YR 3/2) silty clay loam, very dark brown (10YR 2/2) moist; many fine and medium distinct yellowish brown (10YR 5/6 and 5/8) and few fine strong brown (7.5YR 4/6) mottles; massive.

Table 4. Detailed description of the late Gunder Member in profile LG-1 at site 25PW65, stop 4.

Landform: T-1 terrace
Slope: 1 percent
Parent material: Alluvium
Described by: Rolfe Mandel
Vegetation: Plowed field
Comments: Six cultural zones were identified in profile 1: zone 1 at 0-20 cm; zone 2 at 40-45 cm; zone 3 at 121-124 cm; zone 4 at 160-175 cm; zone 5 at 200-210 cm; zone 6 at 240-250 cm. Charcoal from zone 4 yielded a radiocarbon age (corrected) of 3,650±180 yr B.P. (Tx-9016). Wood from an organic-rich zone 8.14 to 8.30 m below the terrace surface yielded a radiocarbon age of 4,760±70 yr B.P. (ISGS-3414).

Depth (cm)	Soil Horizon	Description
		LATE GUNDER
0-28	Ap	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine and medium granular structure; friable; noneffervescent; abrupt wavy boundary.
28-45	A	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure parting to weak fine and medium granular structure; friable; noneffervescent; gradual smooth boundary.
45-55	BA	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; friable; noneffervescent; gradual smooth boundary.
55-75	Bw1	Dark brown (10YR 3/3) heavy silt loam, very dark grayish brown (10YR 3/2) moist; few fine faint dark yellowish brown (10YR 4/4) mottles; weak fine prismatic structure parting to weak fine subangular blocky; common 10YR 3/2) organic stains on ped faces; noneffervescent; gradual smooth boundary.
75-91	Bw2	Brown (10YR 5/3) heavy silt loam, dark brown (10YR 3/3) moist; common fine faint dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/4) mottles; weak medium prismatic structure parting to weak fine subangular blocky; friable; many very fine pores; noneffervescent; gradual smooth boundary.
91-121	Bw3	Brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; common fine faint dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/4) mottles; weak medium and coarse prismatic structure parting to weak fine and medium subangular blocky; friable; many very fine pores; few thin lenses of very fine sand; noneffervescent; abrupt smooth boundary.
121-160	2Bt1b	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; few fine distinct yellowish brown (10YR 5/6) mottles; moderate medium prismatic structure parting to moderate fine prismatic; hard, firm; common distinct discontinuous very dark gray (10YR 3/1) to dark gray (10YR 4/1) clay films on ped faces; common very fine pores; noneffervescent; clear smooth boundary.

160-175	2Bt2b	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; few fine distinct yellowish brown (10YR 5/6) mottles; moderate medium prismatic structure parting to moderate fine prismatic; hard, firm; common distinct discontinuous very dark gray (10YR 3/1) to dark gray (10YR 4/1) clay films on ped faces; common strong brown (7.5YR 5/8)burned earth; many small pieces of charcoal; few fire-cracked rocks; many common very fine pores; noneffervescent; abrupt smooth boundary.
175-200	2BCtb	Brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; common fine faint yellowish brown (10YR 5/4) mottles; weak medium subangular blocky structure parting to weak fine subangular blocky; friable; common fine pores; common distinct discontinuous very dark grayish brown (10YR 3/2) clay films and thick clay flows in pores; noneffervescent; abrupt smooth boundary.
200-250	3Ab	Dark grayish brown (10YR 4/1) silty clay loam, very dark grayish brown to very dark dark brown (10YR 3/2-2/2) moist; common fine distinct yellowish brown (10YR 5/4) mottles; weak fine subangular blocky structure parting to moderate medium and coarse granular; hard, firm; few fire-cracked rocks and flecks of charcoal in the upper and lower 10 cm of horizon; noneffervescent; gradual smooth boundary.
250-268	3Bt1b	Dark brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; common fine faint dark yellowish brown (10YR 4/4) and fine distinct yellowish brown (10YR 5/4) mottles; moderate medium and fine prismatic structure; hard, firm; common distinct nearly continuous very dark grayish brown (10YR 3/2) clay films on ped faces; noneffervescent; gradual smooth boundary.
268-295	3bt2b	Brown (10YR 5/3) heavy silt loam, brown (10YR 4/3) moist; few fine faint yellowish brown (10YR 5/4) mottles; weak fine and medium prismatic structure parting to weak fine subangular blocky; slightly hard, friable; common fine pores; few patchy dark brown (10YR 3/3) clay films on ped faces and few thick very dark grayish brown (10YR 3/2) clay flows in pores; noneffervescent; gradual smooth boundary.
295-352	3BCb	Brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; weak fine subangular blocky structure; soft, very friable; common fine pores; common dark brown (10YR 3/3) organic coatings on ped faces; common flecks of charcoal in lower 30 cm of horizon; noneffervescent; gradual smooth boundary.
352-465	3CBb	Brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; very weak very fine subangular blocky structure to massive; soft, very friable; common fine pores; common dark brown (10YR 3/3) organic coatings on ped faces; noneffervescent; gradual smooth boundary.
465-510	3C1	Brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; common fine faint yellowish brown (10YR 5/4) mottles; massive; soft, very friable; common fine pores; noneffervescent; gradual smooth boundary.
510-680	3C2	Horizontally laminated dark brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist, interbedded with brown (10YR 5/3) silt loam and fine sandy loam; most laminae are 2-5 mm thick; massive; soft, friable; few fine pores; noneffervescent; gradual smooth boundary.

680-814	3C3	Stratified light grayish brown (2.5Y 6/2) loamy fine sand, grayish brown (2.5Y 5/2) moist, interbedded with very dark grayish brown (10YR 3/2) silt loam, dark grayish brown (2.5Y 4/2) loam, and pale brown (10YR 6/3) fine sandy loam; common prominent coarse strong brown (7.5YR 5/6 and 4/6) and yellowish brown (10YR 5/8) mottles; massive; soft, friable; few lenses of fine gravel in lower 30 cm of horizon; few yellowish red (5YR 5/6) and strong brown (7.5YR 5/8) 1-3 cm thick lenses of iron-cemented coarse sand and fine gravel; most strata are horizontal but there is low-angle tabular cross-bedding in lower half of horizon; noneffervescent; abrupt wavy boundary.
814-842	4Cg	Dark gray (2.5Y 4/1) silty clay loam and clay loam, very dark gray (2.5Y 3/1); common dark fine and medium distinct dark gray (5Y 4/1) and dark greenish gray (5GY 4/1) mottles; massive; very hard, very firm; very sticky when moist; many large pieces of wood and other plant remains, including stems and leaves; noneffervescent; abrupt wavy boundary.
842-860+	5C	Stratified sand and gravel; single grain; loose.

Table 5. Detailed description of the Honey Creek Member in profile HC-1 at site 25PW65, stop 4.

Landform: T-1 terrace
Slope: 1 percent
Parent material: Alluvium
Described by: Rolfe Mandel
Vegetation: Plowed field
Comments: Three cultural zones were identified in profile 2: zone 1 at 0-20 cm, zone 2 at 275-279 cm, and zone 3 at 460-475 cm. Charcoal from an archaeological feature in zone 3 yielded a radiocarbon age (corrected) of 1,850±40 yr B.P. (Tx-9013). A piece of Nebraska Phase pottery (ca. 800-1,000 yr B.P.) was found in zone 1.

Depth (cm)	Soil Horizon	Description
0-21	Ap	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak fine and medium granular; slightly hard, friable; noneffervescent; abrupt wavy boundary.
21-33	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak medium and coarse granular; slightly hard, friable; noneffervescent; gradual smooth boundary.
33-46	Bw	Dark brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure; hard, friable; few discontinuous wavy 1-2 mm thick laminae of pale brown (10YR 6/3) silt loam in lower 5 cm of horizon; noneffervescent; abrupt smooth boundary.
46-81	2Ab	Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) moist; weak fine and medium subangular blocky structure parting to weak coarse granular; hard, friable; noneffervescent; gradual smooth boundary.

81-137	2Bwb	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; common fine faint dark brown (10YR 4/3) mottles; weak coarse prismatic structure parting to weak fine and medium subangular blocky; hard, friable; noneffervescent; abrupt smooth boundary.
137-150	3Ab	Very dark grayish brown (10YR 3/2) light silty clay loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure; hard, friable; noneffervescent; gradual smooth boundary.
150-220	3Bwb	Dark brown (10YR 3/3) silt loam, very dark grayish brown (10YR 3/2) moist; common fine faint dark brown (10YR 4/3) mottles; weak fine prismatic structure parting to weak fine subangular blocky; hard, friable; noneffervescent; abrupt smooth boundary.
220-242	4A1b	Dark gray (10YR 4/1) silty clay loam, very dark gray (10YR 3/1) moist; weak medium subangular blocky structure parting to weak fine subangular blocky; very hard, firm; noneffervescent; gradual smooth boundary.
242-270	4A2b	Dark grayish brown (10YR 4/2) light silty clay loam, very dark grayish (10YR 3/2) moist; weak medium subangular blocky structure parting to weak fine subangular blocky; very hard, firm; noneffervescent; gradual smooth boundary.
270-321	4Bwb	Brown (10YR 5/3) to dark brown (10YR 4/3) silt loam, dark brown (10YR 4/3) moist; few fine faint yellowish brown (10YR 5/4) and fine distinct yellowish brown (10YR 5/6) mottles; weak coarse prismatic structure parting to weak fine and medium subangular blocky; hard, friable; noneffervescent; abrupt smooth boundary.
321-345	5Ab	Dark gray (10YR 4/1) silty clay loam, very dark gray (10YR 3/1) moist; few fine faint dark brown (10YR 4/3) mottles; weak medium and coarse prismatic structure parting to weak fine subangular blocky; very hard, firm; noneffervescent; gradual smooth boundary.
345-357	5ABb	Dark brown (10YR 3/3) light silty clay loam, very dark grayish brown (10YR 3/2) moist; few fine faint dark brown (10YR 4/3) mottles; weak fine and medium prismatic structure parting to weak fine subangular blocky; hard, friable; noneffervescent; gradual smooth boundary.
357-380	5Bwb	Brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; few fine faint yellowish brown (10YR 5/4) and fine distinct yellowish brown (10YR 5/6) mottles; weak coarse prismatic structure parting to weak fine and medium subangular blocky; hard, friable; noneffervescent; clear smooth boundary.
380-419	5C	Stratified brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; common fine prominent yellowish brown (10YR 5/6 and 5/8) mottles; very weak coarse subangular blocky structure to massive; slightly hard, friable; interbedded with laminae of very dark grayish brown (10YR 3/2) and very dark gray (10YR 3/1) silty clay loam and pale brown (10YR 6/3) silt loam; noneffervescent; abrupt smooth boundary.

419-440	6Ab	Dark grayish brown (10YR 4/2) silty clay loam, very dark brown (10YR 2/2) moist; weak medium and coarse prismatic structure parting to weak fine subangular blocky; hard, firm; common brown (10YR 5/3) silt loam in pores and old root channels; noneffervescent; gradual smooth boundary.
440-460	6Bwb	Brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; common fine faint yellowish brown (10YR 5/4) and few fine distinct yellowish brown (10YR 5/6) mottles; weak medium subangular blocky structure parting to weak fine subangular blocky; hard, friable; common very dark gray (10YR 3/1) coatings on ped faces; noneffervescent; gradual smooth boundary.
460-475	6BCb	Brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; common fine distinct yellowish brown (10YR 5/6 and 5/8) and strong brown (7.5YR 4/6) mottles; weak coarse subangular blocky structure to massive; hard, friable; faint horizontal bedding; few very dark gray (10YR 3/1) coatings on ped faces; many fine and very fine pores; noneffervescent.

Table 6. Detailed description of the Camp Creek, Roberts Creek, and late Gunder members in the section at site 25PW63, Stop 4.

Landform: T-1 terrace
Slope: < 1 percent
Parent material: Alluvium
Described by: Rolfe Mandel
Vegetation: Plowed field
Comments: Two buried cultural zones were identified in profile 1: zone 1 at 248-260 cm, and zone 2 at 320-345 cm. Charcoal from feature 1 in zone 1 yielded a radiocarbon age (corrected) of 3,140±60 B.P. (Tx-9015). Wood collected at depths of 730-740 cm and 650-670 cm below the T-1 surface yielded radiocarbon ages (corrected) of 4,420±60 B.P (Tx-9017) and 4,060±70 yr B.P. (ISGS-3416), respectively.

Depth (cm)	Soil Horizon	Description
		CAMP CREEK MEMBER
0-20	Ap	Dark brown (10YR 3/3) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; very friable; noneffervescent; abrupt smooth boundary.
20-26	AC	Dark brown (10YR 3/3) silt loam, very dark grayish brown (10YR 3/2) moist; weak coarse platy structure parting to weak fine granular; friable; noneffervescent; abrupt smooth boundary.
		ROBERTS CREEK MEMBER
26-36	2Ab	Very dark grayish brown (10YR 3/2) silt loam, very dark gray (10YR 3/1) moist; weak coarse platy structure parting to weak fine granular; soft, very friable; few krotovina filled with dark brown (10YR 3/3) silt loam; noneffervescent; abrupt smooth boundary.

36-83	3A1b	Very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; weak fine and medium subangular blocky structure parting to weak fine and medium granular; friable; common krotovina filled with dark brown (10YR 4/3) silt loam; noneffervescent; gradual smooth boundary.
83-104	3A2b	Very dark grayish brown (10YR 3/2) light silty clay loam, black to very dark gray (10YR 2/1 to 3/1) moist; weak fine and medium angular blocky and subangular blocky structure parting to weak coarse medium granular; friable; noneffervescent; gradual smooth boundary.
104-141	3ABtb	Very dark grayish brown (10YR 3/2) silty clay loam, very dark gray (10YR 3/1) moist; weak medium angular blocky and subangular blocky structure; hard, firm; common discontinuous clay films on ped faces; noneffervescent; gradual smooth boundary.
		LATE GUNDER MEMBER
141-176	4Btb	Dark brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; common fine faint yellowish brown (10YR 5/4) mottles; moderate medium and coarse angular blocky structure; hard, firm; common thick prominent very dark gray (10YR 3/1) clay films and clay flows on ped faces and in pores; clay films cover 80-90 percent of most ped faces; noneffervescent; gradual smooth boundary.
176-229	4CBtb	Dark brown (10YR 4/3) light silty clay loam, dark brown (10YR 3/3) moist; common fine distinct yellowish brown (10YR 5/6 and 5/8) and strong brown (7.5YR 4/6 and 5/8) mottles; weak coarse prismatic structure parting to weak coarse subangular blocky; slightly hard, friable; faint bedding; few wavy laminae of pale brown (10YR 6/3) and brown (10YR 5/3) silt loam; few thin horizontal beds of very dark gray (10YR 3/1) silty clay; common thin prominent discontinuous very dark gray (10YR 3/1) clay films on ped faces and common thick very dark gray (10YR 3/1) clay flows on ped faces and in pores; noneffervescent; gradual smooth boundary
229-248	4C	Stratified pale brown (10YR 6/3) and brown (10YR 5/3) silt loam and dark brown (10YR 4/3) silty clay loam; few fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; massive; friable; beds consist of wavy laminae 2-4 mm thick; noneffervescent; abrupt smooth boundary.
248-287	5Atb	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; common fine faint yellowish brown (10YR 5/4) and few very fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; weak medium and coarse prismatic structure parting to weak medium and fine subangular blocky; hard, firm; common distinct nearly continuous very dark gray (10YR 3/1) clay films on ped faces; few fire-cracked rocks and many large pieces of charcoal; noneffervescent; gradual smooth boundary.
287-305	5Btb	Dark brown (10YR 4/3) silty clay, dark brown (10YR 3/3) moist; common fine and medium distinct yellowish brown (10YR 5/4) mottles; moderate medium prismatic structure; hard, firm; distinct nearly continuous very dark gray (10YR 3/1) clay films on ped faces and in pores; clay films cover 80-90 percent of most ped faces; noneffervescent; abrupt smooth boundary

305-320	6Btgb	50 percent very dark grayish brown (10YR 3/2), 50 percent dark brown (10YR 3/3) silty clay; common fine and medium distinct yellowish brown (10YR 5/4) and few very fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; weak fine and medium prismatic structure parting to weak fine subangular blocky; hard, firm; distinct nearly continuous very dark gray (10YR 3/1) clay films on ped faces and in pores; clay films cover 50-60 percent of most ped faces; noneffervescent; abrupt wavy boundary.
320-360	7Atb	Very dark grayish brown (10YR 3/2) silty clay, very dark brown (10YR 2/2) moist; common fine faint and distinct yellowish brown (10YR 5/4) mottles; weak coarse prismatic structure parting to weak fine subangular blocky and weak coarse granular; hard, firm; common distinct discontinuous very dark gray (10YR 3/1) clay films on ped faces and in pores; one fire-cracked rock and common burned earth and flecks of charcoal; noneffervescent; abrupt wavy boundary.
360-410	7Btb	Brown (10YR 5/3) silty clay loam, dark brown (10YR 4/3) moist; common fine faint yellowish brown (10YR 5/4) and light olive brown (2.5Y 5/3) and few very fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; moderate fine and medium prismatic structure; hard, firm; common distinct nearly continuous very dark grayish brown (10YR 3/2) clay films on ped faces and thick clay flows in pores; common fine and medium pores; noneffervescent; gradual smooth boundary.
410-430	7BCb	Brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; common fine faint yellowish brown (10YR 5/4) and few fine and very fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; weak coarse prismatic structure parting to very weak fine subangular blocky; slightly hard, friable; very faint bedding; common fine and medium pores; noneffervescent; gradual smooth boundary.
430-680	7C1	Stratified brown (10YR 5/3) and dark brown (10YR 4/3) silt loam grading downward to loam and fine sandy loam, dark brown (10YR 4/3 and 3/3) moist; common fine, medium, and coarse prominent yellowish brown (10YR 5/4 and 5/6) and few fine distinct strong brown (7.5YR 4/6) mottles; massive; hard, friable; few thin beds of brown (10YR 5/3) and pale brown (10YR 6/3) fine sandy loam and loamy fine sand; most of the beds are horizontally laminated; few pieces of wood charcoal scattered through the lower half of horizon; common fine and very fine pores; noneffervescent; abrupt wavy boundary.
680-730	7C2	Stratified sand and gravel; single grain, loose; low angle tabular cross-bedding; dense organic mats at 650-670 cm and 710-720 cm; abrupt wavy boundary.
730-765	7Cg	gray (2.5Y 3/1) moist; many large pieces of wood and other plant remains, including stems, leaves and seeds; sediment is noneffervescent; abrupt wavy boundary.
4316	R	Limestone

Table 7. Detailed description of the early Gunder Member in the section at site 25PW64, stop 4.

Landform: T-1 terrace
Slope: < 1 percent
Parent material: Alluvium
Described by: Rolfe Mandel
Vegetation: Plowed field
Comments: Two cultural zones were identified in profile 1: zone 1 at 0-20 cm and zone 2 at 78-82 cm. Charcoal from feature 1 in zone 2 yielded radiocarbon ages (corrected) of 4,440±70 yr B.P. (Tx-8952) and 3,920±70 yr B.P (Beta-95298).

Depth (cm)	Soil Horizon	Description
		EARLY GUNDER
0-21	Ap	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine and medium granular structure; friable; noneffervescent; abrupt smooth boundary.
21-44	Bw	Brown (10YR 5/3) silt loam, dark brown (10YR 3/3-4/3) moist; few fine faint yellowish brown (10YR 5/4) mottles; weak fine subangular blocky structure; friable; common very dark grayish brown (10YR 3/2) coatings on ped faces; common very fine pores; noneffervescent; gradual smooth boundary.
44-78	Bt	Brown (10YR 5/3) silty clay loam, dark brown (10YR 3/3-4/3) moist; common fine distinct yellowish brown (10YR 5/4) and dark yellowish brown (10YR 4/4) mottles; moderate fine and medium prismatic structure parting to moderate fine subangular blocky; slightly hard, friable; common distinct nearly continuous very dark grayish brown (10YR 3/2) clay films on ped faces; common very fine pores; noneffervescent; abrupt smooth boundary.
78-109	2ABtb	Dark grayish brown (10YR 4/2) silty clay loam, very dark gray (10YR 3/1) moist; common fine faint yellowish brown (10YR 5/4) mottles; weak fine and medium prismatic structure parting to weak to moderate fine subangular blocky; slightly hard, friable; common distinct nearly continuous very dark grayish brown (10YR 3/2) clay films on ped faces; common very fine pores; noneffervescent; gradual smooth boundary.
109-132	2Btb	Dark brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; common fine faint yellowish brown (10YR 5/4) mottles; weak fine prismatic structure parting to weak fine subangular blocky; slightly hard, friable; common distinct nearly continuous very dark grayish brown (10YR 3/2) clay films on ped faces; noneffervescent; abrupt smooth boundary.
132-159	3ABtb	Grayish brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; common fine distinct yellowish brown (10YR 5/4 and 5/6) mottles; weak fine prismatic structure parting to weak fine subangular blocky; slightly hard, friable; common distinct discontinuous very dark grayish brown (10YR 3/2) clay films on ped faces; noneffervescent; gradual smooth boundary.

159-199	3Btb	Dark brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; common fine distinct yellowish brown (10YR 5/4 and 5/6) mottles; weak fine subangular blocky structure; slightly hard, friable; common distinct nearly continuous very dark grayish brown (10YR 3/2) clay films on ped faces; noneffervescent; gradual smooth boundary.
199-250	3BCb	Brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; common fine distinct yellowish brown (10YR 5/4 and 5/6) mottles; very weak fine subangular blocky structure; slightly hard, friable; noneffervescent.

Table 8. Radiocarbon ages for the study area.

Stop No. & Locality	Strat. Unit	Material Assayed (m)	Depth	Uncorrected Age (Y.B.P.)	Delta ^{13}C	Corrected Age (Y.B.P.)	Lab No.
STOP 2							
Old Bridge	Early Gunder Mbr.	Wood	12.11-12.31	NR*	-27.7	8,890±70	ISGS-3427
Old Bridge	Early Gunder Mbr.	Wood	12.11-12.25	NR	-26.7	8,890±70	ISGS-3426
Old Bridge	Early Gunder Mbr.	Wood	12.59-12.70	NR	-25.6	8,740±70	ISGS-3430
Old Bridge	Early Gunder Mbr.	Wood	12.05-12.27	NR	-26.9	8,630±70	ISGS-3436
Old Bridge	Early Gunder Mbr.	Wood	11.72-11.93	NR	-28.2	8,180±70	ISGS-3431
Old Bridge	Honey Creek Mbr.	Wood	9.22-9.33	NR	-28.0	3,870±70	ISGS-3429
Old Bridge	Honey Creek Mbr.	Wood	10.78-10.95	NR	-27.0	2,630±70	ISGS-3437
Old Bridge	Honey Creek Mbr.	Wood	8.55-8.66	NR	-26.6	1,910±70	ISGS-3424
STOP 4							
Farwell							
25PW63	Late Gunder Mbr.	Wood	6.50-6.70	NR	-28.0	4,060±70	ISGS-3416
25PW63	Late Gunder Mbr.	Wood	7.30-7.40	4,460±60	-27.5	4,420±60	Tx-9017
25PW63	Late Gunder Mbr.	Charcoal	3.23-3.28	3,150±60	-25.1	3,140±60	Tx-9015
25PW63	Severance Frm.	Plant frag.	8.72-8.73	NR	NR	37,100±520	CAMS-41681
25PW63	Severance Frm.	Charcoal	8.81-8.82	NR	NR	53,110±2870^	CAMS-33983
Floodplain~	Camp Creek Mbr.	Wood	3.75-3.90	NR	-28.6	Modern	ISGS-3415
25PW64	Early Gunder Mbr.	Charcoal	1.30-1.70	4,460±70	-26.0	4,440±70	Tx-8952
25PW64	Early Gunder Mbr.	Charcoal	1.30-1.70	3,920±70	-25.0	3,920±70	Beta-95298
25PW64	Late Gunder Mbr.	Wood	7.69-7.90	NR	-27.9	4,660±70	ISGS-3417
25PW64	Late Gunder Mbr.	Wood	7.75-7.98	NR	-27.6	4,530±70	ISGS-3418
25PW65	Late Gunder Mbr.	Wood	8.14-8.30	NR	-27.0	4,760±70	ISGS-3414
25PW65	Late Gunder Mbr.	Charcoal	1.60-1.75	3,670±180	-26.1	3,650±180	Tx-9016
25PW65	Honey Creek Mbr.	Charcoal	4.60-4.75	1,880±40	-26.8	1,850±40	Tx-9013
25PW65	Severance Frm.	Soil	2.00-2.10	NR	-23.0	15,110±110	ISGS-4468
STOP 5							
Miles Fan	Corrington Mbr.	Soil	1.30-1.40	2,920±60	-12.9	3,120±50	Tx-8945
Miles Fan	Corrington Mbr.	Soil	3.60-3.70	10,250±120	-12.9	10,450±120	Tx-8944
Miles Fan	----------	Peat	9.90-10.0	23,530±310	-27.0	23,490±310	Tx-8946
Miles Fan	----------	Peat	10.3-10.4	24,690±410	-27.3	24,640±410	Tx-8947
Miles Fan	----------	Peat	10.6-10.7	27,620±550	-27.4	27,580±550	Tx-8948
Miles Fan**	----------	Wood	ca. 10.0	NR	-25.1	19,920±240	ISGS-4681
Miles Fan**	----------	Wood	ca. 10.0	NR	-24.5	20,290±120	ISGS-4680
STOP 7							
DuBois Quarry	Severance Frm.	Soil	2.36-2.46	18,780±140	-22.4	18,830±140	Tx-9308
DuBois Quarry	Severance Frm.	Soil	4.16-4.26	25,730±360	-28.5	25,670±360	Tx-9309
DuBois Quarry	Severance Frm.	Wood	7.62-7.82	NR	NR	33,257±1096	ISGS A-0020
OTHER LOCALITIES							
Kinter's Ford	Early Gunder Mbr.	Soil	2.90-3.00	6,930±70	-16.5	7,070±70	Tx-8943
Kinter's Ford	Early Gunder Mbr.	Wood	7.05-7.20	NR	-28.6	6,120±70	ISGS-3405
Kinter's Ford	Early Gunder Mbr.	Wood	7.15-7.38	NR	-28.5	6,070±70	ISGS-3400
Kinter's Ford	Early Gunder Mbr.	Wood	6.70-6.90	NR	-28.3	5,640±70	ISGS-3401
Kinter's Ford	Early Gunder Mbr.	Wood	4.44-4.60	NR	-27.0	4,870±70	ISGS-3398
Kinter's Ford	Early Gunder Mbr.	Soil	1.80-1.90	4,630±110	-13.3	4,780±110	Tx-8942
Kinter's Ford	Honey Creek Mbr.	Wood	5.22-5.44	NR	-27.3	3,780±70	ISGS-3402
Kinter's Ford	Honey Creek Mbr.	Wood	6.48-6.80	NR	-26.4	3,300±70	ISGS-3446
Kinter's Ford	Roberts Creek Mbr.	Wood	3.49-3.70	NR	-27.5	3,270±70	ISGS-3399
Kinter's Ford	Honey Creek Mbr.	Wood	6.56-6.70	NR	-28.3	3,010±70	ISGS-3404
Kinter's Ford	Honey Creek Mbr.	Wood	6.53-6.64	NR	-25.9	2,800±70	ISGS-3403
Kinter's Ford	Honey Creek Mbr.	Wood	7.23-7.55	NR	-26.4	2,190±70	ISGS-3452
Kinter's Ford	Camp Creek Mbr.	Wood	6.56-6.79	NR	-27.5	370±70	ISGS-3453
25PW83	Late Gunder Mbr.	Wood	8.30-8.50	NR	-26.4	3,590±70	ISGS-3450
25PW83	Late Gunder Mbr.	Charcoal	200-205	2,290±70	-26.2	2,270±70	Tx-9014

*NR = Not Reported

^Age rejected

**Sample was collected ca. 100 m downstream from the Miles Fan.

~Sample was collected on the west side of the South Fork of the Big Nemaha River, immediately west of site 25PW63.

Table 9. Detailed description of the Peoria Loess and underlying Severance Formation in the section at the Martin Marietta DuBois Quarry, stop 7.

Landform: T-1 terrace
Parent material: Alluvium
Slope: 1-2 %
Drainage: Moderately well drained
Described by: Rolfe Mandel and Art Bettis
Remarks: Organic carbon from bulk soil samples collected from the upper 10 cm of the 2BAb horizon (236-246 cm below land surface) and the lower 10 cm of the 2Bt4b horizon (416-426 cm below surface) yielded radiocarbon ages of 18,830±140 yr B.P. (Tx-9308) and 25,670±360 yr B.P. (Tx-9309), respectively. Twigs collected 90-110 cm below the top of the organic-rich zone near the base of the section, or 762-782 cm below the land surface, yielded an AMS radiocarbon age of 33,257±1096 (ISGS A-0020).

Depth (cm)	Soil Horizon	Desription
		PEORIA LOESS
0-20	Ap	Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1), moist; weak fine granular structure; friable; abrupt smooth boundary.
20-42	A	Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1), moist; moderate fine granular structure; friable; abrupt smooth boundary.
42-73	Bt1	Dark grayish brown (10YR 4/2) heavy silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate fine subangular blocky structure; hard, firm; common thin, discontinuous dark gray (10YR 4/1) clay films on ped faces; gradual smooth boundary.
73-135	Bt2	Dark brown (10YR 4/3) heavy silty clay loam, dark brown (10YR 3/3) moist; common fine distinct yellowish brown (10YR 5/4 and 5/6) mottles; weak medium and fine prismatic structure parting to moderate medium and fine subangular blocky; hard, firm; common thin, continuous dark grayish brown (10YR 4/2) clay films on ped faces; gradual smooth boundary.
135-182	Bt3	Brown (10YR 5/3) silty clay loam, dark brown (10YR 4/3) moist; common fine prominent yellowish brown (10YR 5/4 and 5/6) and strong brown (7.5YR 4/6 and 5/6) mottles; moderate medium and fine prismatic structure parting to moderate fine subangular blocky; hard, firm; few thin, discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; gradual smooth boundary.
182-236	BC	Light olive brown (2.5Y 5/3) silty clay loam, olive brown (2.5Y 4/3) moist; common fine prominent yellowish brown (10YR 5/4 and 5/6) and strong brown (7.5YR 4/6 and 5/6) mottles; weak medium and coarse prismatic structure parting to very weak fine angular blocky; hard, firm; few very fine and fine ferro-manganese stains; abrupt smooth boundary.

		SEVERANCE FORMATION
236-264	2BAb	Dark brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; common fine and medium prominent yellowish red (5YR 4/6 and 5/8) and red (2.5YR 4/8) mottles on ped faces and along root channels; weak fine and medium angular blocky structure; friable; few well-rounded to slightly angular pebbles 0.5-4.5 cm in diameter; poorly sorted; few white (10YR 8/2) silt coatings on ped faces; gradual smooth boundary.
264-289	2Bt1b	Brown (7.5YR 4/3) clay loam, dark brown (7.5YR 3/3) moist; many fine and very fine prominent yellowish red (5YR 4/6 and 5/8) and red (2.5YR 4/8) mottles on ped faces and along root channels; moderate medium and coarse prismatic structure parting to moderate fine prismatic; friable; common thin discontinuous brown (7.5YR 4/2) clay films on ped faces and in macropores; common white (10YR 8/2) patchy silt coatings on ped faces; few well-rounded to slightly angular pebbles 0.5-5.0 cm in diameter; poorly sorted; common macropores; few very fine hard black concretions (iron and manganese oxides); gradual smooth boundary.
289-340	2Bt2b	Brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; few fine distinct yellowish brown (10YR 5/6) and yellowish red (5YR 4/6 and 5/8) mottles; moderate medium prismatic structure parting to moderate fine and medium subangular blocky; hard, firm; common thin discontinuous brown (7.5YR 4/2) clay films on ped faces and in macropores; common white (10YR 8/2) patchy silt coatings on ped faces; few well-rounded to slightly angular pebbles 0.5-5.0 cm in diameter; poorly sorted; common macropores; common fine and very fine hard black concretions (iron and manganese oxides); gradual smooth boundary.
340-376	2Bt3b	Brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; few very fine distinct strong brown (7.5YR 5/6) mottles; moderate medium prismatic structure parting to moderate fine and medium subangular blocky; hard, firm; common thin discontinuous brown (7.5YR 4/2) clay films on ped faces and in macropores; few white (10YR 8/2) patchy silt coatings on ped faces; few well-rounded to slightly angular pebbles 0.6-5.0 cm in diameter; poorly sorted; common macropores; common fine and very fine hard black concretions (iron and manganese oxides); few gray (10YR 5/1) reduction zones along macropores; gradual smooth boundary.
376-426	2Bt4b	Brown (7.5YR 4/3) loam, dark brown (7.5YR 3/3) moist; few very fine distinct strong brown (7.5YR 5/6) mottles; weak medium prismatic structure parting to weak fine prismatic; friable; few thin discontinuous brown (7.5YR 4/2) clay films on ped faces and in macropores; few white (10YR 8/2) patchy silt coatings on ped faces; few well-rounded to slightly angular pebbles 0.5-6.0 cm in diameter; poorly sorted; common macropores; few very fine hard black concretions (iron and manganese oxides); common gray (10YR 5/1) reduction zones along macropores; gradual smooth boundary.
426-483	2BCb	Yellowish brown (10YR 5/4) fine sandy loam, dark yellowish brown (10YR 4/4) moist; common fine faint yellowish brown (10YR 5/6) mottles; very weak fine subangular blocky structure; friable; few macropores; gradual smooth boundary.
483-572	2C1	Light yellowish brown (10YR 6/4) to brownish yellow (10YR 6/6) fine sandy loam grading downward to fine and medium sand; single grain; loose; shallow trough-crossbedding; few thin beds of fine gravel; gradual smooth boundary.

NOTES

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