Geomorphology, Quaternary Stratigraphy, and Geoarcheology of Fox Creek Valley, Tallgrass Prairie National Preserve, Northeast Kansas

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Kansas Geological Survey
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ABSTRACT

A geomorphological investigation was conducted in Fox Creek valley within the Tallgrass Prairie National Preserve, Chase County, Kansas. During the first stage of the study, Quaternary landforms were defined and mapped in the valley. This was followed by inspection of cutbank exposures along the creek and deep coring across the valley floor. Subsurface information gleaned from the exposures and cores was used to determine the lithostratigraphy and soil-stratigraphy of the landform sediment assemblages. The numerical ages of alluvial deposits and associated buried soils were determined by radiocarbon dating charcoal, plant macrofossils, and soil carbon. The radiocarbon chronology, combined with soil-stratigraphic data, was used to define temporal and spatial patterns of landscape evolution (erosion, deposition, and landscape stability), and to assess the geologic potential for buried prehistoric cultural resources in Fox Creek valley. Also, late-Quaternary vegetative change was inferred from $\delta^{13}C$ analysis of soil and sediment organic carbon.

The valley floor of Fox Creek consists of four Quaternary landforms: a low floodplain (T-0b), a slightly higher floodplain (T-0a), an alluvial terrace (T-1), and alluvial/colluvial fans. Members of the DeForest Formation, a lithostratigraphic unit that occurs throughout the eastern Plains, compose all of the Holocene landform sediment assemblages (T-0a, T-0b, and T-1) in the valley. Specifically, the T-0b surface is underlain by stratified, silty and loamy alluvium typical of the Camp Creek Member of the DeForest Formation. Although the numerical age of the T-0b fill is unknown, it probably is less than 400 years old and may be less than 200 years old in most of the valley. Two units of the DeForest Formation were identified beneath the T-0a surface: the Honey Creek Member and the Roberts Creek Member. The Honey Creek Member consists of brown (10YR 5/3-4/3, dry), silty alluvium with a moderately expressed surface soil (A-Bw-Bk horizonation). The numerical age of the Honey Creek Member in Fox Creek valley is unknown, but it aggraded sometime after ca. 2000 ^{14}C yr B.P. Aggradation of the Honey Creek Member was interrupted by at least one episode of landscape stability, indicated by a weakly developed soil about 1.5 m below the T-0a surface. The Roberts Creek Member consists of fine-grained, organic-rich alluvium that fills paleochannels cut into the Honey Creek Member.

A subtle 1 m-high scarp separates the T-0a and T-1 surfaces in Fox Creek valley. The T-1 terrace dominates the valley floor and gently rises towards the valley wall where it either merges with alluvial/colluvial fans, or is bounded by a steep bedrock wall. The Gunder Member of the DeForest Formation forms most of the valley fill beneath the T-1 surface. It consists of moderately oxidized, brown (10YR 5/3, dry) to yellowish brown (10YR 5/4, dry) silty clay loam that has been strongly modified by surface-soil development (A-Bt-Btk horizonation). Aggradation of the T-1 fill was underway at ca. 11,200 ^{14}C yr B.P. and may have continued into the early Holocene. However, there is a gap in the alluvial record between ca. 11,200 and 4500 ^{14}C yr B.P. The early-through-middle Holocene appears to have been a period of net sediment removal on the valley floor of Fox Creek. Sediment storage resumed during the late Holocene and was characterized by rapid floodplain sedimentation from ca. 4500 ^{14}C yr B.P. until sometime between ca. 3500 and 2100 ^{14}C yr B.P. By ca. 2100 ^{14}C yr B.P., sedimentation slowed, and soil development was underway on the late Holocene floodplain soon after 2100 ^{14}C yr B.P. There was another episode of floodplain sedimentation sometime after 2100 ^{14}C yr B.P., resulting in burial of the soil only on the lowest portion of the T-1 terrace near the stream channel.

Large, low-angle alluvial/colluvial fans on the margins of the valley floor are composed of fine- and coarse-grained sediment that accumulated during the late Pleistocene. The top of a strongly expressed, brown (7.5YR 4/3, dry) to reddish brown (5YR 4/3, dry) buried soil (paleosol) with At-Bt horizonation is about 1.25-1.50 m below the surface of the fans. Decalcified organic carbon from the upper 10 cm of this paleosol yielded radiocarbon ages of 24,560$\pm$350 and 22,620$\pm$340 yr B.P. Based on the lithology of the alluvial/colluvial deposits, the fans are composed of the Severance formation, an informal lithostratigraphic unit recognized in eastern Kansas and Nebraska.

The $\delta^{13}C$ values determined on organic carbon in soil and sediment samples from Core 3 (T-1 fill) suggest that between ca. 4500 and 2100 ^{14}C yr B.P., the valley floor of Fox Creek was characterized by a mixed C_3/C_4 plant community. However, there is a distinct shift to less negative $\delta^{13}C$ values after ca. 2100 ^{14}C yr B.P., suggesting that C_4 vegetation (i.e., warm-season grasses) increased in abundance

at the expense of C_3 plants (i.e., trees). The increase in C_4 vegetation may represent warmer (and possibly drier) conditions and/or increased fire frequency, which would have reduced woody plant cover in the valley.

Results of the geomorphological investigation indicate there is high potential for buried Late Archaic and Early Ceramic cultural deposits in Fox Creek valley. These deposits will be associated with the T-1 fill (Gunder Member), as was observed at site 14SC1304. In addition, the T-1 fill may harbor Early Paleoindian cultural deposits, although this potential is only moderate because no buried soils were observed in late-Wisconsinan alluvium beneath the Gunder Member. Also, there is high to moderate potential for buried Early through Late Ceramic cultural deposits in the T-0a fill, and Historic cultural deposits may be buried in the T-0b fill.

INTRODUCTION

The Nature Conservancy and the National Park Service have plans to restore vegetation and natural surface runoff along Fox Creek, the primary drainage in the Tallgrass Prairie National Preserve. Specifically, the lower reach of Fox Creek at the southern edge of the Preserve will see the reestablishment of plants that reflect the natural pre-Euro-American contact tallgrass prairie ecosystem. A short distance upstream along Fox Creek, row crops will be planted that reflect the cultural landscape at ca. 1880 when rancher Stephen Jones owned and operated the Spring Hill Ranch. The commitment of these two locales to long-term use for either tallgrass prairie or row crops will make subsequent identification, dating, and interpretation of landforms and late Quaternary deposits along Fox Creek more difficult. Also, future projects that involve land modification, including the removal of agricultural terraces to restore natural drainage, may affect buried cultural resources. Hence, this investigation was conducted to provide baseline geomorphological and geoarcheolgical data for the area of Fox Creek valley within the Preserve.

The primary objectives of this investigation were to (1) define and map Quaternary landforms and lithostratigraphic units in Fox Creek valley, (2) determine the soil-stratigraphy of the landform sediment assemblages, (3) determine the radiocarbon ages of alluvial deposits and associated buried soils in order to define temporal and spatial patterns of landscape evolution (erosion, deposition, and landscape stability) in the valley, (4) reconstruct late-Quaternary vegetative change in the study area based on $\delta^{13}C$ analysis of soil and sediment organic carbon, and (5) assess the geologic potential for buried prehistoric cultural resources in Fox Creek valley.

ENVIRONMENTAL SETTING

Physiography and Bedrock Geology

The Tallgrass Priarie National Preserve is in the Flint Hills region of Fenneman's (1931) Central Lowlands physiographic province. The Flint Hills trend north-south along the western edge of the Osage Cuestas and Glaciated Region of eastern Kansas. The Flint Hills region derives it name from the abundance of chert, or flint, scattered across its surface. Like the Osage Cuestas to the east, the Flint Hills were formed by erosion of westward-dipping strata. The rock units are Permian in age, and limestone members in the region contain many bands of chert. Because chert is much less soluble than the limestone that encloses it, weathering of the softer rock forms a clay-rich soil that contains a large volume of chert fragments (Wilson, 1984:19). This gravel-rich soil armors the rocky uplands and causes slower erosion than in adjacent areas where the limestone does not contain chert.

Surface features and the geologic structure of the Flint Hills region are similar to those in the adjacent Osage Cuestas, but a prominent rocky escarpment nearly 100 m high separates the regions. This escarpment, which forms the eastern border of the Flint Hills region, is the most rugged surface feature in Kansas (Self, 1978:44). The east-facing slope of the escarpment is composed of resistant cherty limestones interbedded with softer shale layers. Weathering of the shales has created a landscape that resembles step-like benches. The highest of these benches form the uplands of the Flint Hills. The uplands are gently rolling, especially towards the western boundary of the Flint Hills. Major rivers and streams have dissected portions of the uplands, forming prominent strath terraces. These terraces are erosional surfaces cut across bedrock as stream channels laterally migrated and downcut, leaving little to no alluvium on the rock-cut straths (Mandel, 2006a). Many of the small, first- and second-order streams in the region have steep gradients and deeply entrenched channels bordered by rocky ledges.

From an archeological perspective, the abundance of chert bands in the limestones is perhaps the most important characteristic of the Flint Hills environment (Mandel, 2006a). Because of its superior flaking qualities, Flint Hills chert provided excellent raw material for chipped stone tools and was heavily exploited by prehistoric inhabitants of the region.

Quaternary Geology

Pleistocene Stratigraphy

The Pleistocene stratigraphy of the unglaciated portion of the Flint Hills region is based on a framework of late-Quaternary loesses, alluvium, and colluvium. Although loess has not been documented in the Tallgrass Prairie National Preserve, these deposits are regional in extent and thus provide references to which more localized fluvial and colluvial units can be stratigraphically related. Therefore, recognition of the loess stratigraphy of northeastern Kansas is relevant to this study.

At least four stratigraphically superposed loesses occur in northeastern Kansas: the Loveland, Gilman Canyon, Peoria, and Bignell (Mandel and Bettis, 2003a). 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 northeastern Kansas is Illinoian in age (Marine Isotope Stage 6), and that the Sangamon Soil developed in the upper part of the unit is buried by Wisconsinan deposits (Follmer, 1978). Luminescence dating (TL and IRSL) at the Loveland paratype section in western Iowa and the Eustis section in south-central Nebraska indicates that the Loveland loess was deposited between about 160,000 and 130,000 yr B.P. (Forman et al., 1992; Maat and Johnson, 1996; Forman and Pierson, 2002)

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 125,000 to 55,000 yr B.P. (isotope stages 5d to 3). At some localities, the Sangamon Soil represents several soils welded together to form a "pedocomplex" that may represent formation over a longer time span (Schultz and Tanner, 1957; Fredlund et al., 1985; Morrison, 1987).

The Gilman Canyon Formation is the earliest Wisconsinan loess in northeastern Kansas and was first described in south-central Nebraska (Reed and Dreeszen, 1965). The Gilman Canyon Formation is a dark, noncalcareous silt loam that has been modified by pedogenesis. In northeastern Kansas, the Gilman Canyon Formation is usually thin (<2 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 24,000-23,000 yr B.P. at the top (Johnson et al., 1990; Johnson and Zhaodong, 1993; Mandel and Bettis, 1995; Pye et al., 1995; Matt and Johnson, 1996; Muhs et al., 1999).

Peoria Loess, the dominant surficial deposit on uplands and Pleistocene terraces in northeastern Kansas, overlies the Gilman Canyon and Severance formations, and is typically a calcareous, massive, light yellowish tan to buff colored silt loam. The thickness of the Peoria Loess is extremely variable, but it tends to be thickest near major river valleys. Radiocarbon ages from the Peoria Loess in the Eastern Plains range from about 24,000-23,000 yr B.P. at its base to 12,000 yr B.P. near the top (Martin, 1993; Johnson et al., 1993; May and Holen, 1993; Mandel and Bettis, 1995, 2001a).

In some areas of northeastern Kansas, primarily along the bluffs of the Kansas and Missouri rivers, Bignell Loess mantles the soil at the top of the Peoria Loess. Where this occurs, the buried soil developed in Peoria Loess is referred to as the Brady Soil (Feng et al., 1994; Schultz and Stout, 1945). Johnson and Willey (2000) noted that the widespread development of the Brady Soil between ca. 10,500 and 9,000 yr B.P. implies that the loess-mantled uplands were stable during much of the Pleistocene-Holocene transition. Where it is not buried by Bignell Loess, the soil at the top of the Peoria Loess has either been overprinted by modern pedogenesis (Dreeszen, 1970; Thorp et al., 1951) or been removed by erosion, along with the overlying Bignell Loess (Johnson and Willey, 2000). Radiocarbon and luminescence ages within the Bignell Loess indicate that sediment composing the unit accumulated episodically throughout the Holocene (Mason et al., 2006).

Recent investigations in northeastern Kansas and southeastern Nebraska identified colluvial and alluvial facies of the Gilman Canyon Formation beneath slopes and Pleistocene terraces, respectively (Mandel and Bettis, 2001a, 2003a). This interpretation was based on (1) the stratigraphic relationship of the colluvium and alluvium to the Peoria Loess, (2) the morphology and of the paleosol(s) developed in the colluvium and alluvium, and (3) the numerical age of the colluvium and alluvium. Subsequently, Mandel and Bettis (2001a) established the Severance formation, an informal lithostratigraphic unit consisting of colluvium and alluvium underlying *in situ* or reworked Peoria Loess on slopes and alluvial terraces in the Central Lowlands. 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 (Mandel and Bettis, 2003b). The upper 3-4 m of the Severance formation are oxidized and often have two or more paleosols forming a pedocomplex developed in them. Radiocarbon ages determined on organic carbon from the paleosols range from ca. 25,000 to 15,000 yr B.P., with most clustering between ca. 24,000 to 18,000 yr B.P. (Mandel and Bettis, 2003b). The paleosols have thick, well-expressed Bt horizons with brown, strong brown, yellowish brown, and/or reddish brown matrix colors; prismatic to subangular-blocky structure; iron and manganese oxide stains and concretions; discontinuous clay films and silt patches; and common macropores. With few exceptions, the radiocarbon ages and soil properties are typical of paleosols composing the pedocomplex of the Gilman Canyon Formation on the adjacent uplands.

Holocene Stratigraphy

Deposits of fine-grained Holocene alluvium in Fox Creek valley, and elsewhere in the Flint Hills region, strongly resemble those of the DeForest Formation. This formation is a formal lithostratigraphic unit originally defined by Daniels et al. (1963) in western Iowa and subsequently refined by Bettis and Littke (1987), Bettis (1990, 1995), Bettis et al. (1996), Mandel and Bettis (2001a), and Dillon and Mandel (in press). The DeForest Formation has been traced into southeastern Nebraska (Dillon, 1992; Mandel, 1994a, 1999; Mandel and Bettis, 1995, 2001a), northwestern Missouri (Fosha and Mandel, 1991), and northeastern Kansas (Mandel et al., 1991; Mandel, 1994b, Mandel and Bettis, 2001a, 2003a; Mandel et al., 2006).

The DeForest Formation consists of eight formal members, one of which, the Honey Creek Member, is new (Dillon and Mandel, in press). Only four members of the formation, the Camp Creek, Roberts Creek, Honey Creek, and Gunder, have been identified in Fox Creek valley.

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, Honey Creek, and Roberts Creek members, depending on the geomorphic setting and history of land use (Mandel and Bettis, 2003a). The thickness of the Camp Creek Member is extremely variable in Fox Creek valley basin, ranging from a few centimeters to over 4 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 400 ^{14}C yr B.P. (Mandel and Bettis, 2003a).

The Roberts Creek Member consists of dark-colored, clayey, silty, and loamy alluvium. This member usually occurs only as channel fills in small (< fourth-order) valleys, but it forms channel fills and thick flood drapes in larger valleys. In the unglaciated area of northeastern Kansas, the Roberts Creek Member can overlie a wide variety of deposits including the Gunder and Corrington members, coarse-grained older alluvium, and loess (Mandel and Bettis, 2003a). Roberts Creek Member deposits usually occur beneath floodplains and low terraces, and it is separated from the younger Camp Creek Member of the formation 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 northeastern Kansas, surface soils developed into the Roberts Creek Member are thick, black (10YR 2/1, dry) to dark grayish brown (10YR 4/2, dry) Mollisols. These soils are morphologically less developed and have darker colored B and C horizons than soils developed in the older Gunder and Corrington members. The Roberts Creek Member ranges in age from ca. 3,000 to 500 ^{14}C yr. B.P. (Mandel and Bettis, 2003a).

The Gunder Member consists of strongly to moderately oxidized, dominantly silty and loamy alluvium lacking a loess cover. Lower parts of this member may be reduced and/or coarse grained. In the unglaciated area of northeastern Kansas, Gunder Member deposits occur in valleys of all sizes and unconformably overlie coarse-grained and often organic-rich older alluvium, loess, or bedrock (Mandel and Bettis, 2003a). Younger members of the formation are separated from the Gunder Member by a fluvial erosion surface or a hiatus marked by a buried soil. Surface soils developed in the Gunder Member are thick Mollisols with brown (10YR 5/3, dry) to yellowish brown (10YR 5/4-5/6, dry) Bw, Bt, Bk, and/or Btk horizons. Buried soils occur 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 ^{14}C yr. B.P. at its base to about 2,000 ^{14}C yr B.P. at its surface (Bettis, 1990, 1995; Mandel and Bettis, 1992).

The Honey Creek Member is a grayish brown (10YR 5/2, dry) to brown (10YR 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 typically forms a channel fill inset into 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/or A-Bw profiles are common in this unit. The Honey Creek Member aggraded between ca. 3,700 and 500 ^{14}C yr B.P. (Dillon, 1992; Dillon and Mandel, in press).

Vegetation

The vegetative cover on the valley floor of Fox Creek is a product of recent human intervention. In 1995, most of the valley floor was seeded with brome grass (*Bromus* sp.), and the fields are periodically cut for hay. Although the tallgrass prairie on the adjacent uplands has been affected by decades of cattle grazing, the natural vegetative community is fairly intact.

The tallgrass prairie of the Flint Hills is dominated by warm season C^4 grasses, especially big bluestem (*Andropogon gerardi*) and little bluestem (*Andropogon scoparius*). Other common species include switchgrass (*Panicum virgatum*), Indian grass (*Sorghastrum scoprius*), sideoats grama (*Bouteloua curtipendula*), panic grass (*Panicum scribnerianum*), and June grass (*Koeleria pyramidata*) (Küchler, 1974). Numerous species of annual and perennial forbs occur in the tallgrass prairie, but they account for less than five percent of the prairie community (Küchler, 1974).

There is a narrow riparian forest adjacent to the channel of Fox Creek. This forest is dominated by cottonwood (*Populus deltoides*), hackberry (*Celtis occidentalis*), willow (*Salix* sp.), elm (*Ulmus* sp.), oak (*Quercus* sp.), and black walnut (*Juglans nigra*). This ribbon of trees allows woodland fauna, such as whitetail deer, to penetrate into the adjacent prairie. Hence, in addition to providing botanical food resources, such as hackberry seeds, the riparian forest played a role in providing game for prehistoric people who occupied the grasslands of the Flint Hills.

Climate

The modern climate of northeastern Kansas is continental; summers are very hot, and winters are very cold. There also are extremes in precipitation, with years of drought sometimes followed by periods of excessive annual rainfall. The Flint Hills region is within Thornthwaite's (1948) moist subhumid (C_2) climatic zone, where annual precipitation exceeds evapo-transpiration. The C_2 climate is characterized by hot, humid summers and cold, dry winters.

The mean annual precipitation at Cottonwood Falls, Kansas, for the period August 1, 1948, to December 31, 2005, is 34.86 inches (High Plains Regional Climate Center, 2006). The average maximum and minimum temperature in January is 41.1º F and 18.6º F, respectively. The average maximum and minimum temperature in July is 91.4º F and 67.9º F, respectively (High Plains Regional Climate Center, 2006).

June and January are normally the wettest and driest months, respectively, for the study area. Approximately 75 percent of the precipitation falls during the six months of the growing season, 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 northeastern Kansas during spring and early summer usually converge with warm, moist, maritime tropical (mT) air that is flowing north from the Gulf of Mexico. The overrunning of mP and cP air by warmer mT air often produces intensive rainfall of short duration along the zone of convergence. During late summer, convectional thunderstorms also can produce heavy rainfalls.

Eastern Kansas is subject to severe drought when the strong westerlies of winter persist into spring and summer. Intensification of westerly (zonal) airflow in the upper atmosphere has the effect of blocking the northward penetration of moist Gulf air into the mid-continent (Bryson and Hare, 1974:4), thus promoting drought (Mandel, 2006a). Prolonged severe drought can have significant effects on ecosystems of the grasslands. For example, shortgrass prairie in western Kansas may respond to drought by expanding eastward into the area of mixed and tallgrass prairie. Also, increased aridity tends to increase fire frequency in the prairies. The dynamics of drought-related vegetational perturbations and their implications for late Quaternary landscape evolution and prehistoric human adaptations are discussed elsewhere (see Mandel, 2006a).

METHODS

Field Methods

The field investigation initially involved reconnaissance of Fox Creek valley. At this early stage of the study, landforms identified on the 7.5-minute U.S.G.S. topographic map (Strong City, Kansas, Quadrangle; Figure 1) and 1:5,000-scale black-and-white aerial photographs were field checked, and stream cutbanks exposing thick sections of valley fill were recorded and photographed. Following the reconnaissance, cutbanks deemed accessible were revisited and described. However, most of the cutbanks were very steep and dangerously high and could not be cleaned with a hand shovel. Hence, nearly all of the soil-stratigraphic data were gleaned from 6.5-cm-diameter cores collected with a trailer-mounted Giddings hyrdaulic soil probe (Figure 2). Coring was concentrated at the northern end of the project area in order to sample all valley-floor landform sediment assemblages along a single transect (Figure 3). This sampling strategy yielded data needed for preparing a cross-sectional diagram of late-Quaternary deposits stored in Fox Creek valley (Figure 4).

Detailed descriptions of soil profiles were made in the field using standard procedures and terminology outlined by Soil Survey Division Staff (1993) and Birkeland (1999). Stages of carbonate morphology were defined according to the classification scheme of Birkeland (1999:TA1-5), and sedimentary features preserved in C horizons of some soils were described to help reconstruct depositional environments.

Soils were included in the stratigraphic framework of every section and core that was described. Soils are important to the subdivision of Quaternary sediments, whether the soils are at the present land surface or buried (Birkeland,1999). After soils were identified and described, they were numbered consecutively, beginning with 1, the modern surface soil, at the top of the section or core.

Laboratory Methods

Physical and chemical analyses were performed to characterize and confirm field descriptions of stratigraphic units and soils, assist in interpretation of depositional processes and post-depositional weathering, and reconstruct paleoenvironments. A column of samples from Core 3 was analyzed for particle-size distribution, organic carbon content, and $\delta^{13}C$ values of organic carbon. Also, a column of samples from Core 11 was analyzed for organic carbon content and $\delta^{13}C$ values of organic carbon.

Grain-Size Analysis

Soil and sediment samples were air dried and sent to the University of Iowa's Quaternary Materials Laboratory, located within the Geoscience Department, to determine particle-size distribution and organic carbon content. A slightly modified version of the pipette method, using a known loess standard (Soil Survey Staff, 1996) was used to determine particle-size distribution of the samples. Hydrogen peroxide was used to oxidize organic matter in organic-rich samples, and acetic acid digested carbonate from 10 g samples of the <2 mm sample fraction. The samples were then dispersed in a sodium metaphosphate solution and shaken on a reciprocal shaker overnight. Silt and clay aliquots were drawn from the appropriate pipette depth based on particle-size settling velocity, oven dried, and weighed to the nearest milligram. Wet sieving recovered the sand fraction. The results, presented as weight percentages, total to 100% of the <2 mm fraction.

Stable Carbon Isotope ($\delta^{13}C$) Analysis and Determination of Organic Carbon Content

Samples were collected for stable carbon isotope ($\delta^{13}C$) analysis of organic carbon from two cores: Core 3 taken on the T-1 terrace, and Core 11 taken on the T-0a floodplain (Figure 3). Some of the samples from Core 3 were split and sent to the Paul H. Nelson Stable Isotope Laboratory at the University of Iowa and the Stable-Isotope Biogeochemistry Laboratory at McMaster University. This comparative analysis provided quality control. Samples from Core 11 also were sent to both laboratories, but the Paul H. Nelson Stable Isotope Laboratory closed before that facility analyzed the samples. Hence, the Stable-Isotope Biogeochemistry Laboratory at McMaster University was the sole source of the $\delta^{13}C$ data for Core 11.

Samples sent to the University of Iowa were received at the Quaternary Materials Laboratory, where they were ground to ensure homogeneity, then decalcified with 1 N HCl, centrifuged, rinsed three times with ultra pure water to remove excess HCl, and dried. The samples were then transferred to the Paul H. Nelson Stable Isotope Laboratory where they were weighed, wrapped in tin cylinders, and combusted in a Costech CHNS ECS-4010 element analyzer. Sample weights varied according to depth and organic matter content, as determined by soil color using a Munsell® Color Chart. The organic carbon (O.C.) content of the decalcified samples was determined by the element analyzer and EAS 3.1 Software. A CONFLO interface carried the combusted samples from the elemental analyzer to a Finnigan MAT 252 isotope ratio mass spectrometer, which measured $\delta^{13}C$ values for each sample. Various National Institute for Standards and Technology (NIST) standards (Acetanilide, Sulfanimide, LSVEC-Lithium Carbonate, LIPS, and ANU-Sucrose) were analyzed with the samples to evaluate accuracy. A linear regression analysis correlated the known and experimental standard values; the regression equation then normalized sample

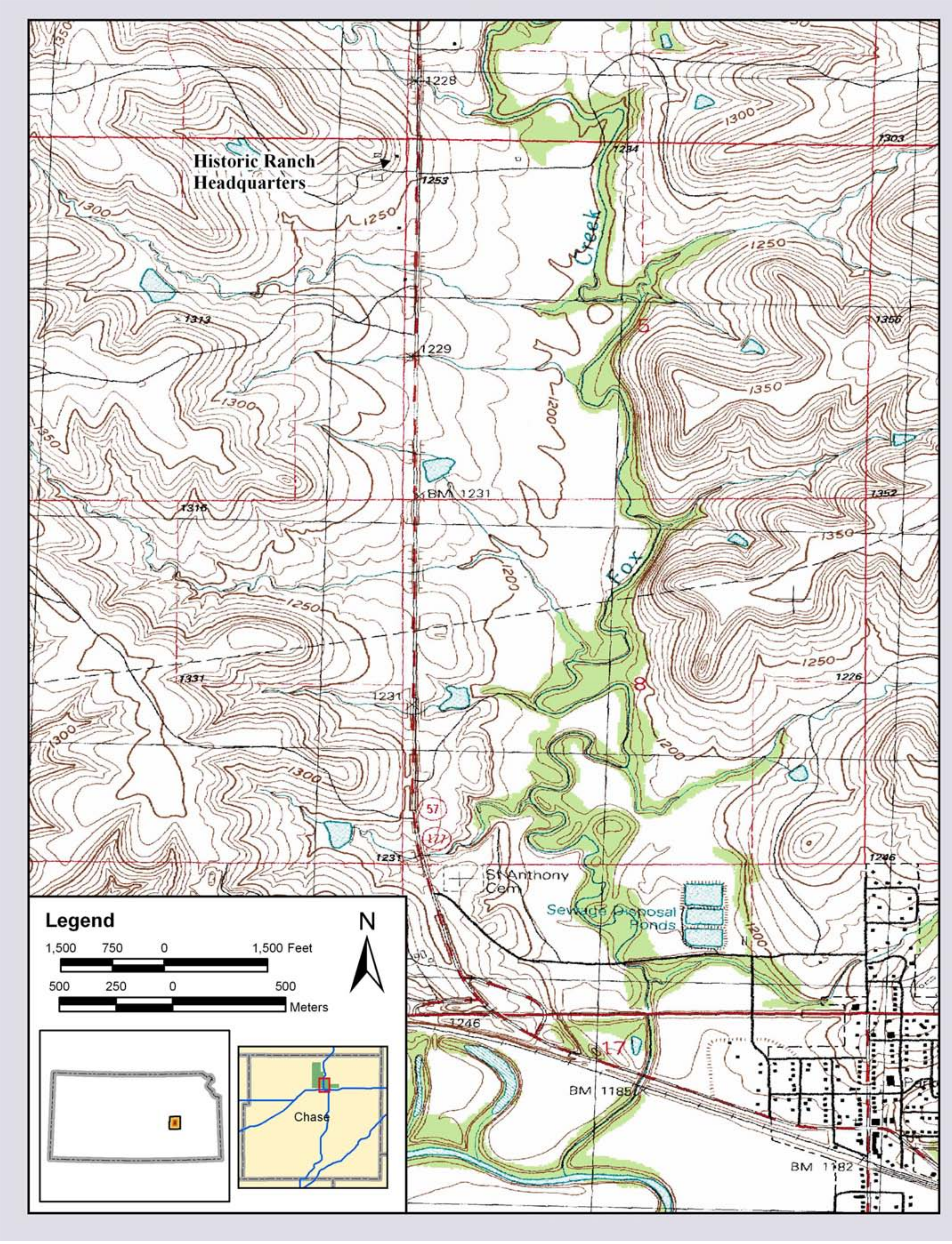

Figure 1. Topographic map of Fox Creek valley (from U.S.G.S. 7.5 minute Strong City Quadrangle).

Figure 2. The trailer-mounted Giddings hydraulic soil probe used to collect cores in Fox Creek valley.

values. Randomly selected replicates taken throughout the soil profile show precision better than 0.2‰. Stable carbon isotope values are reported relative to the Vienna PeeDee Belemnite (VPDB) scale.

Samples sent to the Stable-Isotope Biogeochemistry Laboratory at McMaster University were ground to a fine powder and treated with 3M HCl for 12 hours in 50 ml polypropylene centrifuge tubes. The reacted sediment was then centrifuge and rinsed with 18.2Ω de-ionized water until neutrality was obtained. The samples were then given a final centrifuge rinse with acetone, decanted, and left to dry in an oven set at 60°C for 24 hours. After the samples were dried they were once again ground to a fine powder for isotopic analysis. The samples were run on a continuous flow isotope ratio mass spectrometer (CF-IRMS). Samples were combusted in a Costech Elemental Combustion System (Costech ECS 4010). The O.C. content of the decalcified samples was determined by the Costech element analyzer. Separation of CO_2 from N_2 was done in a GC column. The separated CO_2 was then carried in a helium stream to the mass spectrometer via a Conflo III. The mass spectrometer used was the Finnegan Delta Plus XP, where the CO_2 was measured and the results are reported in standard delta (δ) notation in permil (‰) with respect to VPDB for carbon. Sample reproducibility for these bulk sediment samples is <0.3 ‰.

Radiocarbon (^{14}C) Dating

Nine specimens, including four charcoal, two wood, one peat, and two soil samples, were collected for radiocarbon dating and submitted to the Illinois Geological Survey's Isotope Geochemistry Section. The samples were decalcified and all but two were assayed using atomic mass spectrometry (AMS). Two of the charcoal samples were large enough for conventional dating methods. The ^{14}C ages were $\delta^{13}C$ corrected and are reported in radiocarbon years before present (^{14}C yr B.P.) (Table 1).

The two bulk soil samples collected for radiocarbon dating came from a buried paleosol. The radiocarbon ages determined on soil carbon extracted from these samples are mean residence times for all organic carbon in the samples (see Campbell et al., 1967). Although mean residence time does not provide the absolute age of a buried soil, it does give a minimum age for the period of soil development, and it provides a limiting age on the overlying material (Birkeland, 1999:137; Haas et al., 1986; Geyh et al., 1975; Scharpenseel, 1975).

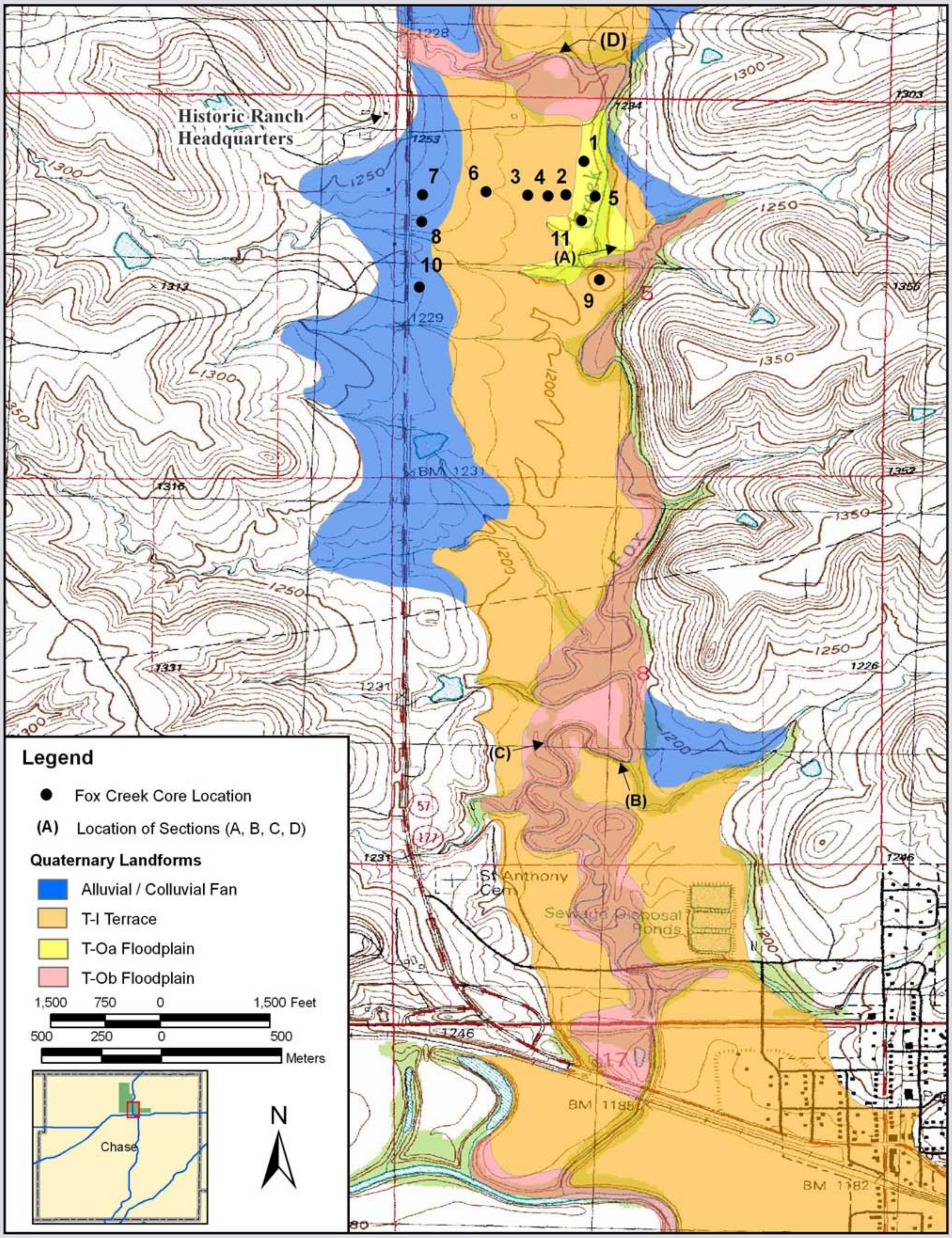

Figure 3. Map showing the distribution of cores, sections, and Quaternary landforms in Fox Creek valley.

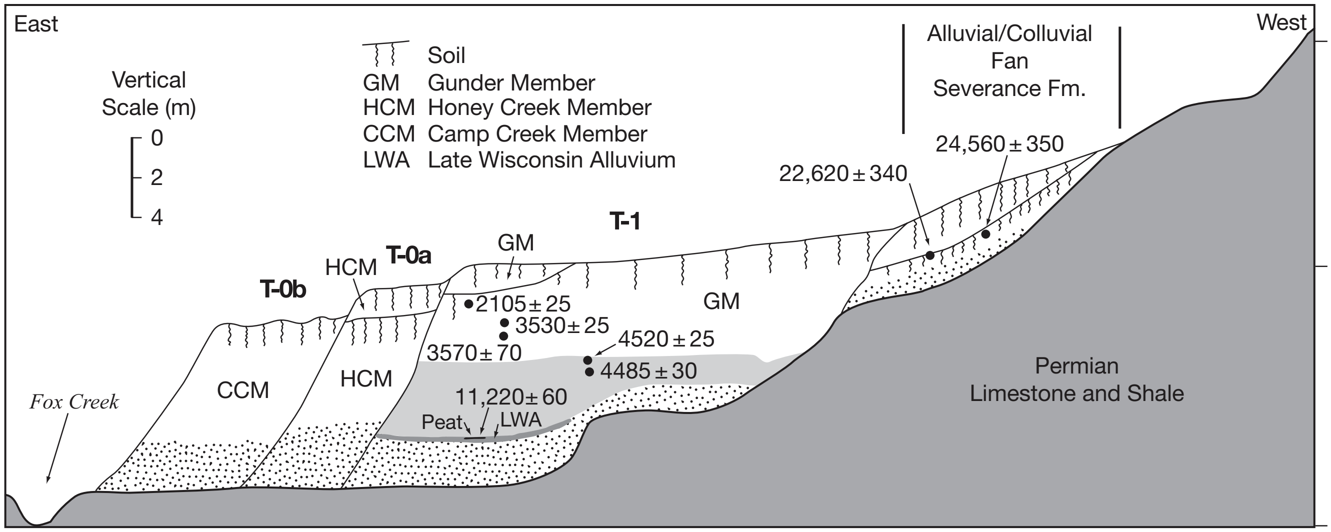

Figure 4. Generalized cross-section of Fox Creek valley showing landforms, soil stratigraphy, lithostratigraphic units, and radiocarbon ages.

GEOMORPHOLOGY OF FOX CREEK VALLEY

Fox Creek flows south into the Cottonwood River and is a third-order tributary according to Strahler's stream classification system (see Strahler, 1964). In much of the area where Fox Creek flows through the preserve, its channel is against or near the eastern valley wall (Figure 1). Consequently, Fox Creek valley is asymmetrical within most of the preserve; the surface of the valley floor gently dips eastward towards the stream channel and is bounded by a steep valley wall on the eastern side of the channel. A small segment of the channel crosses to the western side of the valley floor northeast of the Historic Ranch Headquarters, and the channel shifts to the middle of the valley floor about 625 m northwest of Strong City's sewage disposal ponds (Figure 1).

The valley floor of Fox Creek is about 1,000 m wide and consists of four Quaternary landforms: a low floodplain (T-0b), a slightly higher floodplain (T-0a), an alluvial terrace (T-1), and alluvial/colluvial fans (Figure 3). T-0b is the lowest geomorphic surface in the valley landscape (Figure 4) and is frequently flooded. Its surface is characterized by prominent ridge and swale topography (Figure 5). The ridges are natural levees and the tops of former point bars, and the swales mark the positions of flood chutes and paleo-channels.

The T-0a surface is 1-2 m higher than T-0b and is separated from T-1 by a gently sloping 1 m-high scarp (Figure 4). There are only small remnants of T-0a within the preserve, all within the northern segment of the valley (Figure 3). Although it is a component of the floodplain complex and prone to flooding, T-0a does not flood as frequently as T-0b. Also, unlike T-0b, T-0a is relatively flat and featureless.

The T-1 terrace dominates the valley floor of Fox Creek (Figure 3). This broad geomorphic surface has a 1-2 % slope and gently rises towards the valley wall where it either merges with alluvial/colluvial fans (Figures 4 and 6), or is bounded by a steep bedrock wall. With the exception of a few subtle swales marking the positions of paleo-channels, the T-1surface is featureless.

Large, low-angle alluvial/colluvial fans have formed where some of the first and second-order drainage elements enter Fox Creek valley (Figures 3 and 4). Three of these fans have merged to form a bajada that parallels the valley wall from the Historic Ranch Headquarters southward for about 2 km. As will be discussed later, the alluvial/colluvial fans contain fine and coarse-grained alluvium and colluvium derived from the uplands.

Figure 5. Photograph of the T-0b surface. Note the ridge and swale topography.

Figure 6. View of the valley floor of Fox Creek looking west towards the Historic Ranch Headquarters. The Giddings soil probe is collecting Core 3 from the T-1 fill.

STRATIGRAPHY AND ALLUVIAL CHRONOLOGY

The stratigraphy of Quaternary landform-sediment assemblages in Fox Creek valley was determined from 11 cores and four cutbank exposures (Figure 3). Most of the effort was directed towards the T-1 terrace because this landform composes more than 75% of the valley floor.

T-1 Terrace

Five cores (2, 3, 4, 6, and 9) were taken on the T-1 terrace in the NW 1/4 of Section 5, T.19 S., R.8 E., with four of these cores collected along an east-west transect (Figure 3). In addition, the T-1 fill was inspected at three cutbank localities (Sections A, B, and D). In cores 2, 3, 4, and 6, and at section D (Figure 3), the upper 4-6+ m of the T-1 fill consists of moderately oxidized, fine-grained overbank (flood) deposits typical of the Gunder Member of the DeForest Formation (Figures 7 and 8). The matrix color of soil and sediment below A or AB horizons and above Cg horizons is brown (10YR 5/3-4/3, dry) and yellowish brown (10YR 5/4, dry) (Figure 9 and Tables 2-7). However, reduced fine-grained alluvium (Cg horizons) characterized by gray matrix colors is common near the bottom of the Gunder Member (Figure 9). An abundance of organic matter, including plant macrofossils, is indicated by unusually high organic carbon contents in Cg horizons (Table 8). The reduced, organic-rich alluvium that often comprises the lower 1-2 m of the Gunder Member overlies gravelly lateral-accretion (channel) deposits mantling bedrock.

The upper 2-3 m of the Gunder Member has been strongly modified by pedogenesis. Surface soils developed on T-1 are Mollisols with well-expressed A-Bt or A-Bt-Btk horizonation (Tables 2-7). Core 3 contains a 45 cm-thick mollic epipedon (Ap + A horizon) with organic carbon contents ranging from 2.00 to 1.57% (Table 8). Organic carbon contents remain high (1.50-0.86%) in the AB and upper Bt1 horizons, then steadily decrease with depth.

The grain-size data for Core 3 indicate only a slight increase in clay content across the boundary separating the A and Bt1 horizon (Table 8). In fact, the grain-size distribution is fairly uniform from the lower 10 cm of the plow zone (Ap horizon) to a depth of 575 cm below the T-1 terrace. The highest proportions of clay are in the Bt2 horizon, with values ranging between 32.59 and 34.78 %. However, there is good evidence for clay illuviation in the form of argillans (clay films) in the Bt horizons of the surface soils developed in the T-1 fill.

The most striking aspect of the grain-size data for Core 3 is the paucity of sand (Table 8). Sand content is less than 3% to a depth of 205 cm, then fluctuates between about 7 and 12% from 210 to 320 cm below surface. Even at depths between 320 and 580 cm, the sand content remains low, with most values ranging between about 4 and 15%. The greatest sand content (34.67%) is at a depth of 600-605 cm in the 2C horizon. Even the gravel below the thick package of vertical accretion deposits appears to have a relatively small sand component.

The low sand content of the T-1 fill is attributed to the primary source of the alluvium: shale and chert-rich limestone forming the Flint Hills. The shale and limestone are fine grained (mostly clay and silt) and generate few sand-size particles as they weather. Also, late-Pleistocene loess that probably mantled the Flint Hills, but was stripped away by erosion during the Holocene (see Mandel et al., 2006), would have contributed a large quantity of silt but little sand to the Holocene alluvium in Fox Creek valley.

At Section A (Figure 3) and adjacent Core 9, a buried soil (Soil 2) with Ak-Bk-BCk-CBk horizonation is 139 cm below the T-1 surface (Table 6 and 7 and Figure 10). Soil 2 is developed in the Gunder Member, but like most buried soils associated with this unit of the DeForest Formation (see Bettis, 1995; Mandel and Bettis, 2001a), it is not laterally traceable across the valley.

The top stratum above Soil 2 consists of fine-grained overbank deposits and also has characteristics typical of the Gunder Member. This stratum is moderately oxidized and has been strongly modified by pedogenesis. The surface soil has well expressed A-Bt-Btk horizonation (Tables 6 and 7). The Bt horizon is 23 cm thick and is brown (10YR 4/3, dry) silty clay loam. Films and threads of $CaCO_3$ (stage I morphology) appear at a depth of 61 cm and continue down through the Btk horizons. The Btk1 and Btk2 horizons have a combined thickness of 78 cm and consist of brown (10YR 5/3, dry) and yellowish brown (10YR 5/4, dry) silty clay loam, respectively.

The Btk2 horizon of Soil 1 is welded to Soil 2. Soil welding, or "overprinting," accounts for the films and threads of calcium carbonate in the Akb horizon. The Bk1b and Bk2b horizons are 76 cm thick and consist of brown (10YR 4/3-5/3, dry) silty clay loam with stage I carbonate morphology. In Section A and Core 9, small fragments of charcoal and clumps of burned earth, probably representing a natural fire, were recorded at a depth of 225-230 cm, well within the Btkb horizon. Charcoal from this burn zone yielded an AMS radiocarbon age of 2105±25 yr B.P. (Figure 10). Based on this radiocarbon age, the rate of sedimentation had decreased by ca. 2100 ^{14}C yr B.P., allowing Soil 2 to form soon after that time.

The bottom of Section A is at a depth of 250 cm below the T-1 surface. Alluvial deposits below 250 cm were examined and described in Core 9 (Table 6 and Figure 10). In Core 9, the Btk2b horizon of Soil 2 is underlain by oxidized, yellowish brown (10YR 5/4, dry) silty clay loam that has been slightly modified by soil development (BCkb horizon) (Table 7). There is even less evidence of soil development in the CBkb horizon at a depth 390 to 610 cm. An abrupt change in soil color occurs at a depth of 610 cm, with oxidized, yellowish brown (10YR 5/4, dry) silty clay loam giving way to reduced, gray (5Y 5/1, dry) silty clay loam composing the lower 1.9 m of the Gunder Member. Also, an abrupt boundary separates the reduced portion of the Gunder Member from dark gray (10YR 4/1, dry), peat-rich alluvium at a depth 800 cm. A peat sample collected at a depth of 800 to 810 cm in Core 9 yielded an AMS radiocarbon age of 11,220±60 yr B.P. This radiocarbon age, combined with the stratigraphic record, indicates an unconformity at a depth of 8 m, with late Holocene alluvium overlying late Wisconsinan alluvium; the early and middle Holocene alluvium was stripped out by stream erosion.

Figure 7. Section D. Oxidized fine-grained alluvium composing the Gunder Member is exposed beneath the T-1 terrace.

Figure 8. Close-up of the Gunder Member exposed in Section D.

Based on the soil-stratigraphy observed in Section A and Core 9, sediments composing the top stratum probably were deposited on the scarp and near-scarp area of the T-1 terrace during floods that submerged only the low, proximal portions of this geomorphic surface. The high, distal portions of the T-1 terrace are isolated from low-magnitude floods and, therefore, did not receive the top-stratum sediments.

A thick package of T-1 fill also is exposed in Section B, nearly 2 km south of Section A (Figures 3 and 11). A buried soil about 1 m below the T-1 surface probably is the same buried soil (Soil 2) recorded in Section A and Core 9. The upper 4.5 m of the T-1 fill consists of oxidized, fine-grained deposits typical of the Gunder Member (Figures 11 and 12). The fine-grained alluvium is interbedded with gravel below a depth of 4.5 m.

A bed of charcoal-rich alluvium was recorded at a depth of 360-363 cm along the entire length of Section B. Wood charcoal recovered from this bed yielded a conventional radiocarbon age of 3570±70 yr B.P. The abundance of wood charcoal in the sediment suggests that a fire swept through the riparian forest

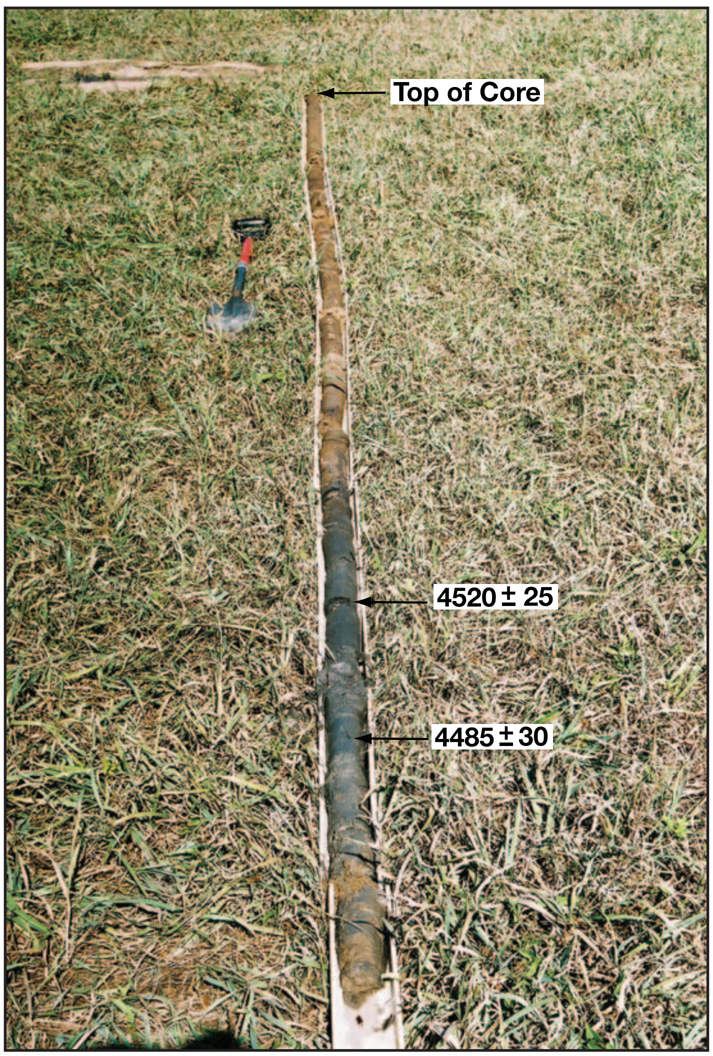

Figure 9. Core 3 taken on the T-1 terrace. Oxidized yellowish-brown Gunder Member alluvium overlies reduced dark-gray Gunder Member alluvium. Gravel is at the bottom of the core. The radiocarbon ages were determined on plant macro-fossils.

around 3500 ^{14}C years ago. At that time, rapid sedimentation was occurring on the late Holocene floodplain, as indicated by the unweathered, stratified alluvium in the lower 2 m of the Gunder Member. This interpretation is strongly supported by temporal information gleaned from prehistoric cultural deposits (site 14SC1340) 65 cm above the bed of charcoal-rich alluvium.

A portion of a bison vertebral column surrounded by charcoal and burned earth (Feature 1) was recorded at a depth of 294-300 cm (Figures 12, 13, and 14). In addition, a large concentration of burned earth and charcoal (Feature 2) is 7.1 m east of Feature 1 (Figures 15, 16, and 17). The top of Feature 2 is 290 cm below the T-1 surface.

Charcoal in direct contact with a vertebra (Figure 14) in Feature 1 was collected and submitted for AMS dating. This sample yielded a radiocarbon age of 3530±25 yr B.P., which is statistically the same as the ^{14}C age of 3570±70 yr B.P. determined on charcoal 65 cm below Feature 1. Together, these ages indicate that rapid floodplain sedimentation was occurring around 3500 ^{14}C years ago. Also, the ^{14}C age of the charcoal from Feature 1 indicates that at ca. 3500 yr B.P. Late Archaic people occupied the former floodplain (now the T-1 terrace) of Fox Creek.

Feature 2 is 60 cm long, 25 cm thick, and mostly composed of burned earth (Figure 17). Based on its stratigraphic position, this hearth-like feature is the same age as Feature 1. Many fine flecks of charcoal are scattered through the silty matrix of Feature 2, and a bulk sediment sample collected from the lower 10 cm of the feature yielded a small chert flake. Feature 2 dips to the east (Figure 16), conforming to the geometry of the underlying stratified floodplain deposits. These deposits are characterized by parallel, graded bedding (see the deposits below Feature 2 in Figure 16). The graded beds are sedimentation units characterized by a gradation in grain size, from coarser to finer sediment, upward from the base to the top of each unit. The graded beds are draped over a gravelly point bar; hence Feature 2 was close to the active channel of Fox Creek at ca. 3500 ^{14}C yr B.P. The charcoal and burned earth appear to have been splayed out by floodwaters that overtopped the point bar and deposited fine-grained alluvium above Feature 2.

The chronology of the T-1 fill in Fox Creek valley is inferred from radiocarbon ages determined on wood and peat collected from reduced sediments near the bottom of cores, and from charcoal recovered from natural burn zones and an archeological feature in the upper 4 m of the T-1 fill. Aggradation of the T-1 fill was underway at ca. 11,200 ^{14}C yr B.P. and may have continued into the early Holocene. However, there is a gap in the alluvial record between ca. 11,200 and 4500 ^{14}C yr B.P. The early-through-middle Holocene appears to have been a period of net sediment removal on the valley floor of Fox Creek, a pattern detected among third-order and smaller streams throughout the Central Plains and Midwest (see Mandel, 1994c, 1995, 2006b; Bettis and Mandel, 2002). Sediment storage resumed during the late Holocene and was characterized by rapid floodplain sedimentation from ca. 4500 ^{14}C yr B.P. until sometime between ca. 3500 and 2100 ^{14}C yr B.P. By ca. 2100 ^{14}C yr B.P., sedimentation slowed, and soil development was underway on the late Holocene floodplain soon after 2100 ^{14}C yr B.P. There was another episode of floodplain sedimentation sometime after 2100 ^{14}C yr B.P., resulting in burial of the soil only on the lowest portion of the T-1

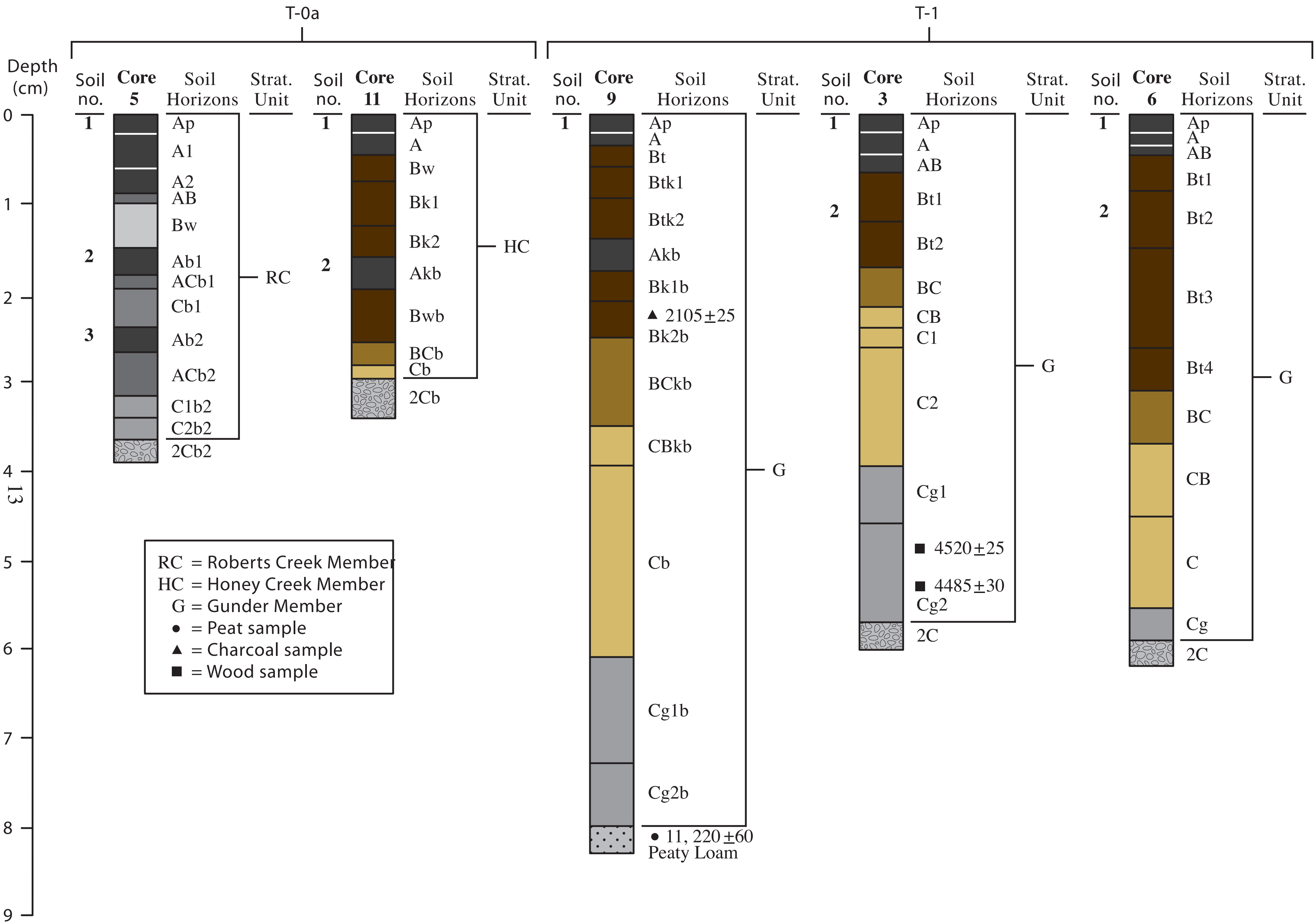

Figure 10. Stratigraphic columns for cores 3, 5, 6, 9, and 11.

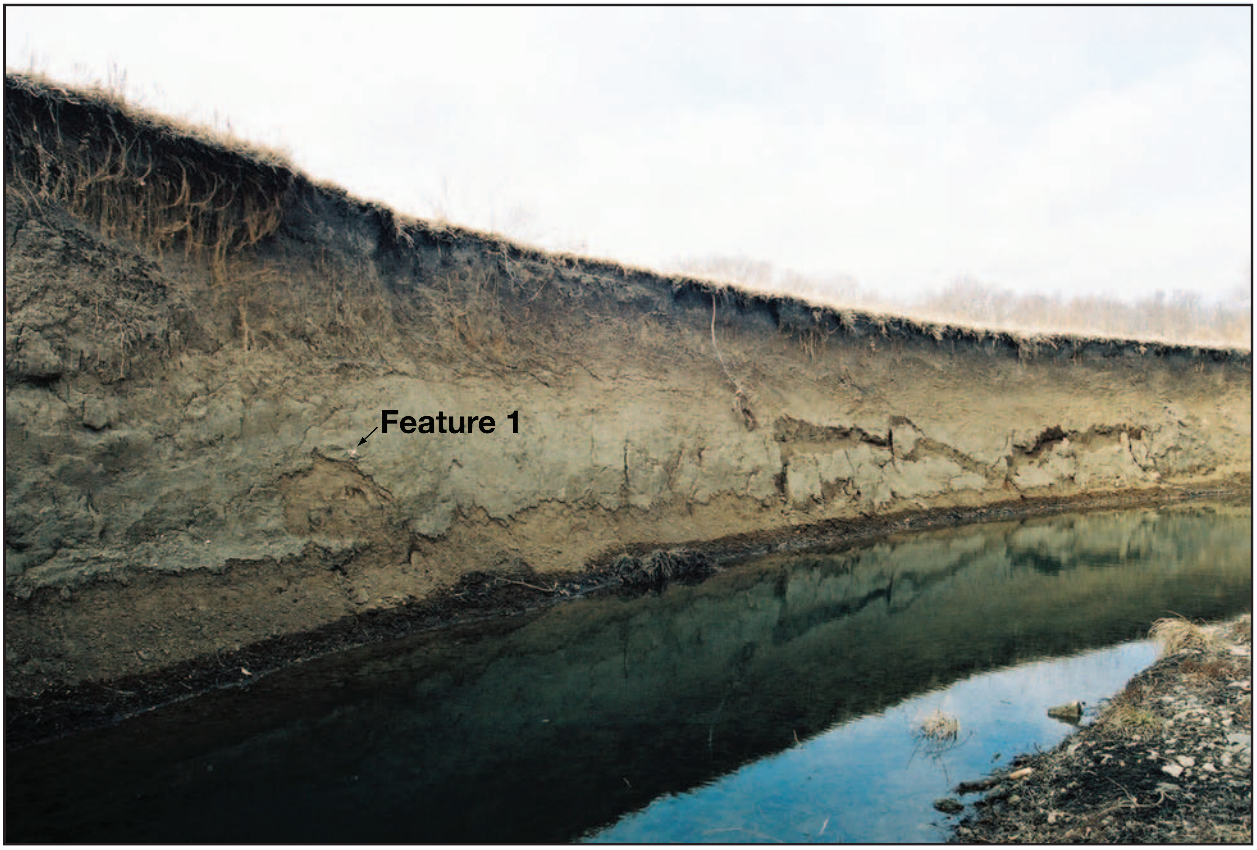

Figure 11. Section B. Archeological Feature 1 associated with site 14SC1340 is 294 cm below the T-1 surface.

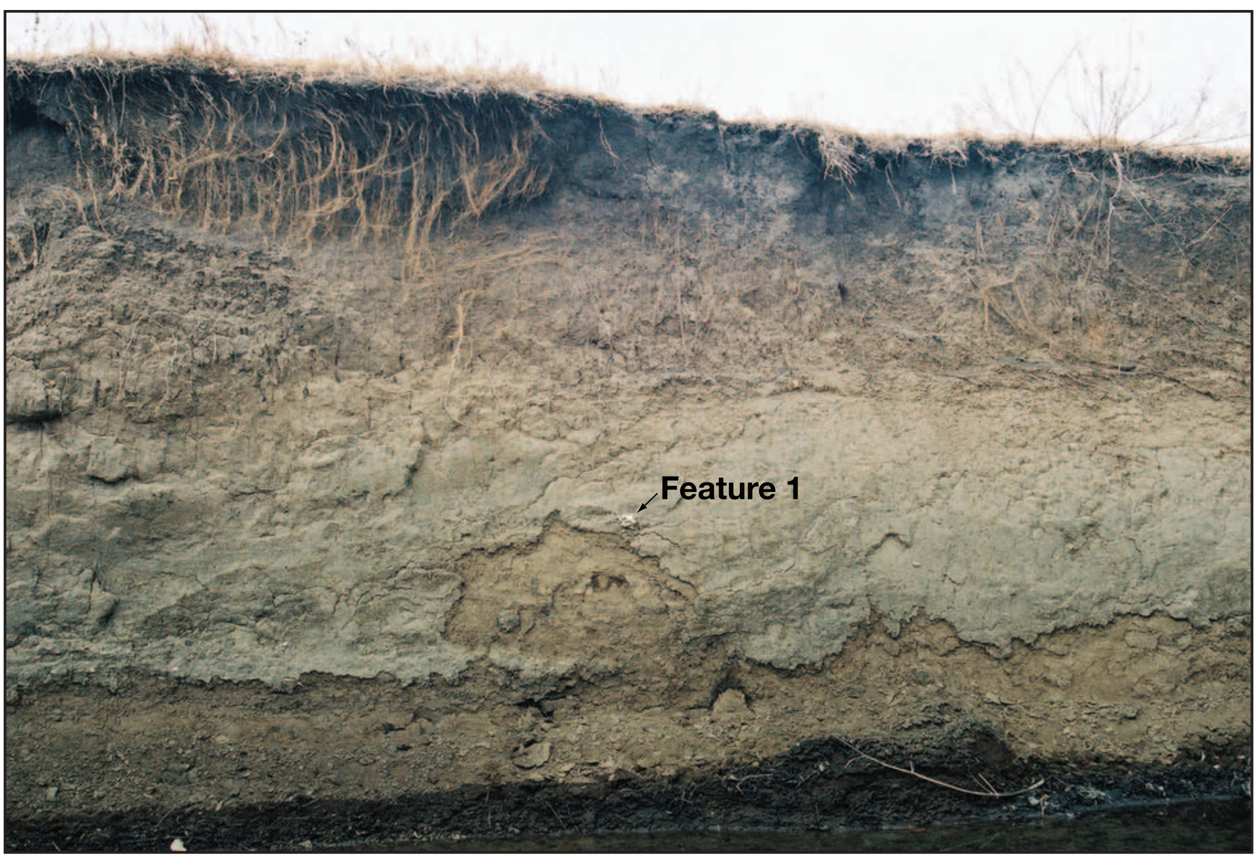

Figure 12. Close-up of Section B (site 14SC1340). The upper 4 m of the T-1 fill consist of oxidized, fine-grained alluvium (Gunder Member). Stratified gravel is at the bottom of the section.

terrace near the stream channel. However, the timing of this event is unknown.

Sometime after ca. 2100 ^{14}C yr B.P. but before ca. 400 ^{14}C yr B.P., Fox Creek went through an episode of entrenchment, leaving its late Holocene floodplain as a terrace (T-1). This was followed by floodplain sedimentation forming the T-0a fill.

The alluvial record preserved beneath the T-1 terrace of Fox Creek resembles the fluvial sequence at the Eureka site (14GR371) on the eastern edge of the Flint Hills in Greenwood County, Kansas (see Mandel, 2006b; Wambsgans, 2006). It also is remarkably similar to alluvial records in southern Kansas (see Mandel, 1995, 2006b) and the southern Great Plains (see Hall, 1990). At Eureka, three major episodes of fluvial activity were recorded (Mandel, 2006b). First, between ca. 4000 and 3000 ^{14}C yr B.P., approximately 6 m of alluvium accumulated on the late Holocene floodplain (now the T-1 terrace) of the upper Fall River. At localities throughout the southern Great Plains, rapid sedimentation occurred on floodplains between ca. 5000 and 2000 yr B.P. Next, there was a ca. 1000 year period of decreased sedimentation rates, continuing to a period of landscape stability, soil development, and channel entrenchment. At the Eureka site, a buried soil near the top of the T-1 fill resembles the buried soil at Section A in Fox Creek valley and the Copan paleosol dated ca. 2000 to 1000 ^{14}C yr B.P. in southeastern Kansas and the Southern Plains (see Mandel, 1995, 2006b; Hall, 1990). These soils formed during slow alluviation, allowing for soil development. Finally, a period of resumed aggradation after ca. 1000 ^{14}C yr B.P. emplaced sediment on top of these soils.

Floodplain Complex (T-0a and T-0b)

Three cores – 1, 5, and 11 – were taken on the T-0a floodplain (Figure 3). In Core 1, a silty, 115 cm-thick top stratum that has been altered by pedogenesis (Soil 1) overlies a soil (Soil 2) developed in silty alluvium. Soil 1 has a moderately expressed A-Bw-Bk profile (Table 9). The mollic epipedon (Ap + A horizon) is 30 cm thick and consists of dark grayish brown (10YR 4/2, dry) silt loam. There is a brown (10YR 4/3, dry), silt-loam cambic (Bw) horizon above a Bk1 horizon with weak stage I carbonate morphology. The Bk1 and Bk2 horizons have a combined thickness of 66 cm and consist of brown (10YR 4/3 and 5/3, dry) silt loam. The Bk2 horizon is welded to Soil 2, as indicated by the threads of calcium carbonate and the prismatic structure in the Akb horizon.

Soil 2 is 185 cm thick and has Ak-Bw-BC horizonation (Table 9). The color and texture of Soil 2 is remarkably uniform through most of the profile. The Akb and Bwb horizons consist of dark grayish brown (10YR 4/2, dry) silt loam and brown (10YR 4/3, dry) silt loam, respectively. Brown (10YR 4/3, dry) silt loam composes the BCb and Cb horizons, though a few thin beds of very dark gray (10YR 3/1, dry) silty clay loam occur in the Cb horizon. The fine-grained alluvium below a depth of 330 is dark gray (5Y 4/1, dry) clay loam with distinct yellowish red (5YR 4/6, dry) mottles (Cgb horizon). The gray (reduced) matrix color and reddish (oxidized) mottles are products of high and low ground-water levels, respectively. Stratified gravel was penetrated at a depth of 387 cm, and the core was terminated at a depth of 450 cm.

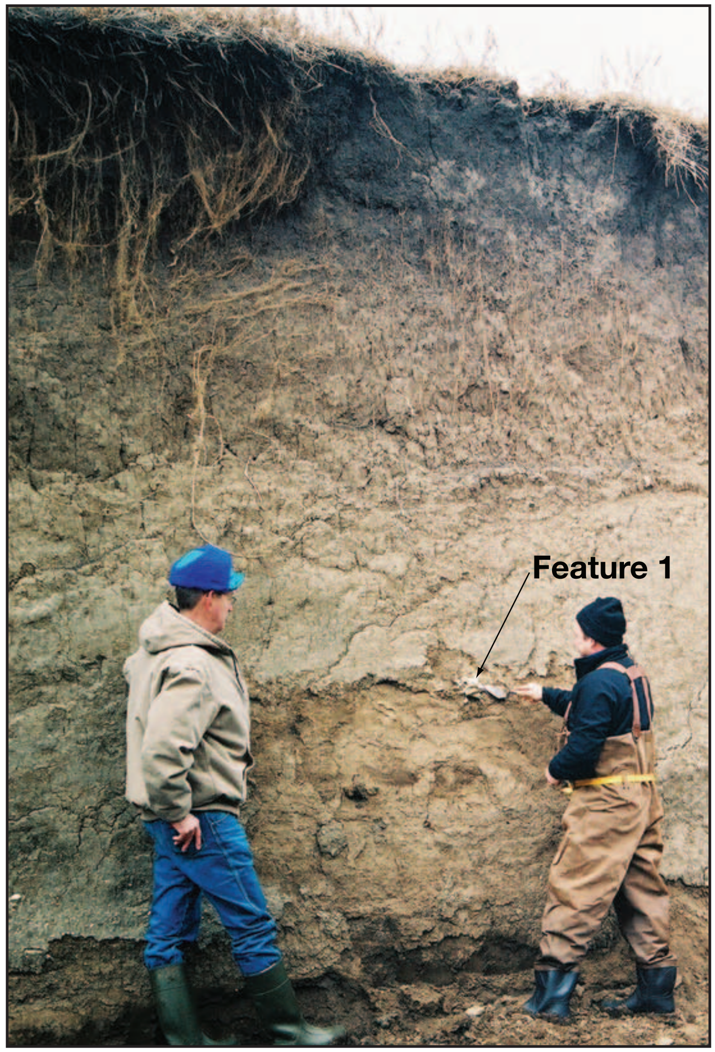

Figure 13. Bison vertebra being removed from the archeological Feature 1 in Section B (site 14SC1340).

Core 11, which was taken on the T-0a surface about 200 m south of Core 1 (Figure 3), exposed a soil-stratigraphic sequence identical to the one observed in Core 1 (Table 10). Yet there are some differences between these cores. Specifically, the top stratum is thicker (160 cm) and the depth to gravel is less (285 cm) in Core 11. Also, the gray (reduced), strongly mottled alluvium observed in the lower part of Core 1 does not occur in the lower part of Core 11. Overall, the lithology and soil-stratigraphy of the alluvium in cores 1 and 11 indicate that most of the T-0a fill is composed of the Honey Creek Member of the DeForest Formation (Figure 4). However, Core 5, taken closer to the channel compared to cores 1 and 11, revealed that the Honey Creek Member does not form all of the T-0a fill.

The upper 360 cm of Core 5 mostly consists of dark gray (10YR 4/1, dry) to dark grayish brown (10YR 4/2, dry) silty alluvium enriched with organic carbon. The surface soil has an overthickened, cumulic A horizon and a brown (10YR 4/3, dry) cambic (Bw) horizon (Table 11 and Figure 10). Two buried soils with weakly expressed A-AC profiles, are developed in the upper 360 cm of the core: Soil 2 at a depth of 150-195 cm, and Soil 3 at a depth of 237-310 cm (Table 11 and Figure 10). Gravel

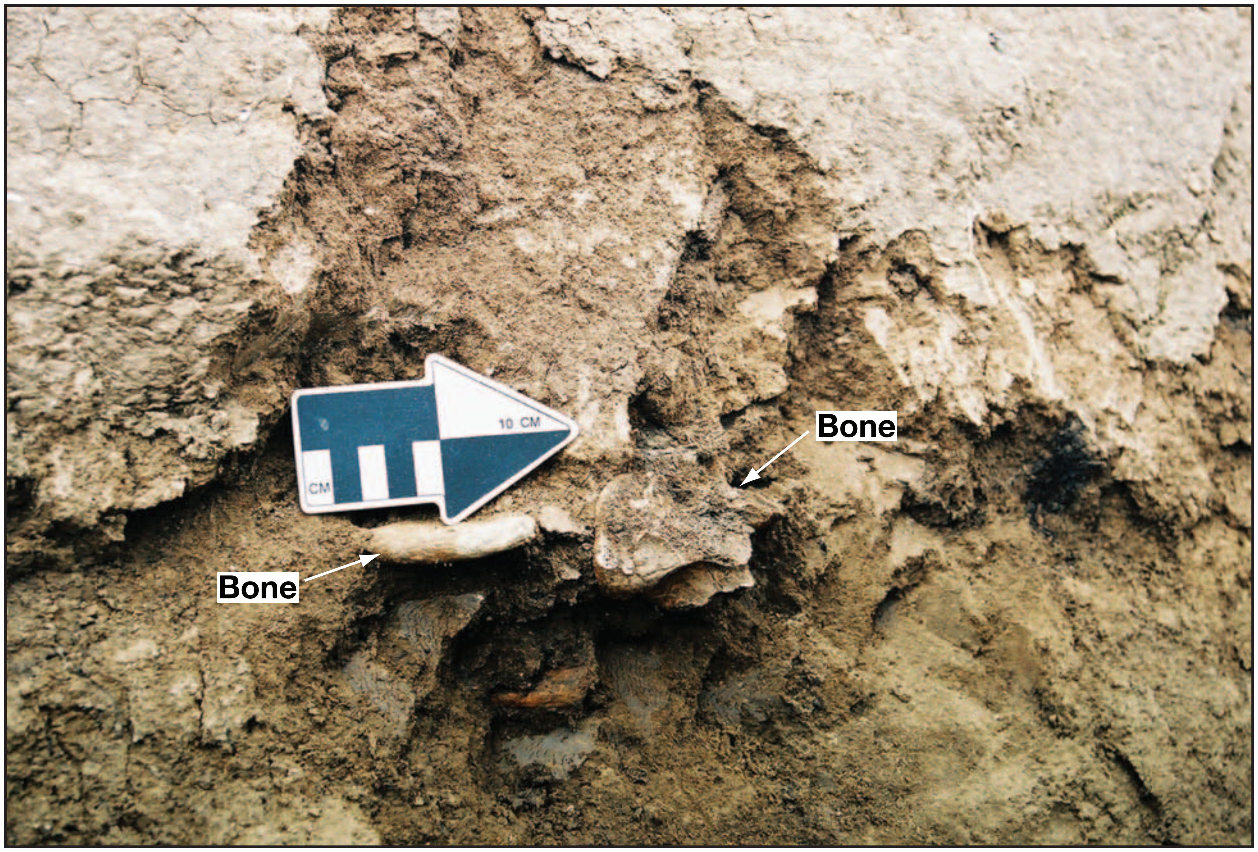

Figure 14. Close-up of archeological Feature 1 in Section B (site 14SC1340). Note the burned earth and charcoal beneath the bison bones.

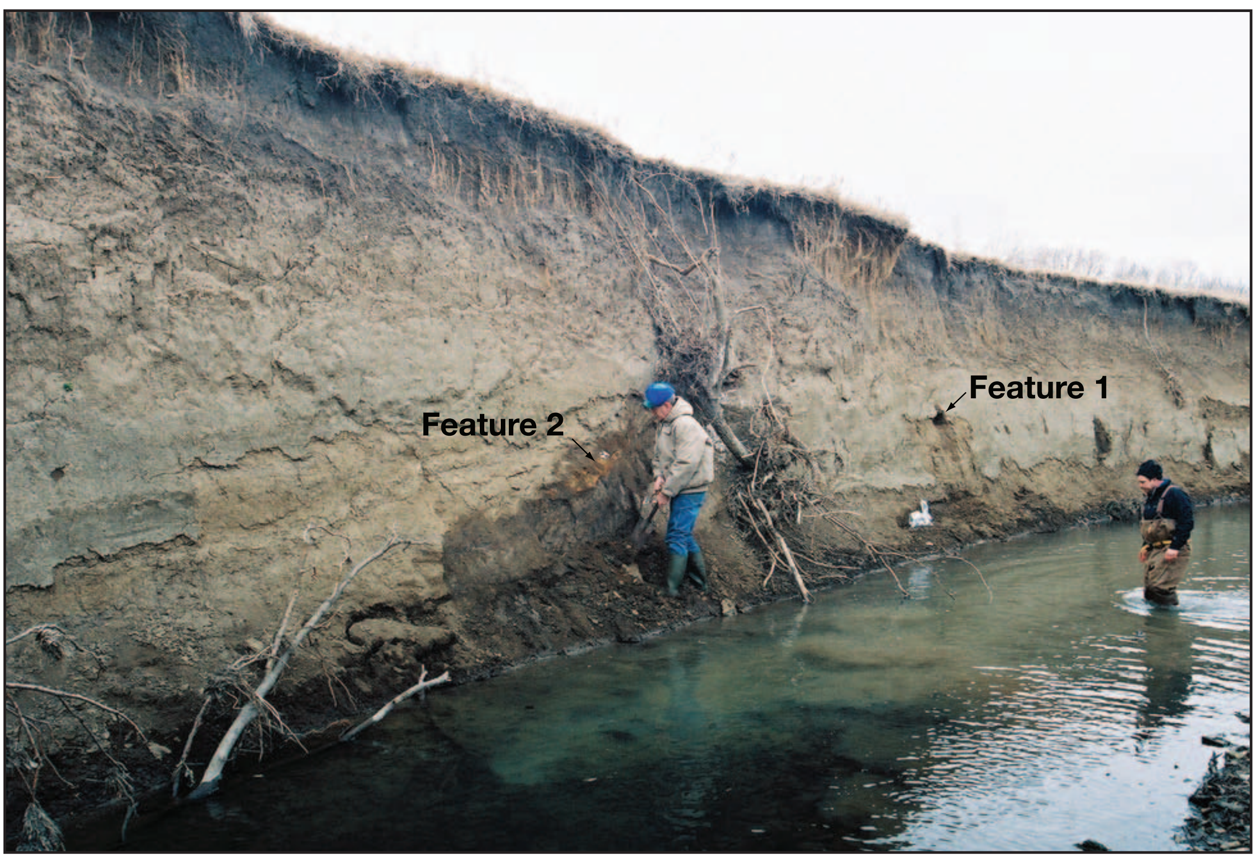

Figure 15. Section B showing archeological features 1 and 2 at site 14SC1340.

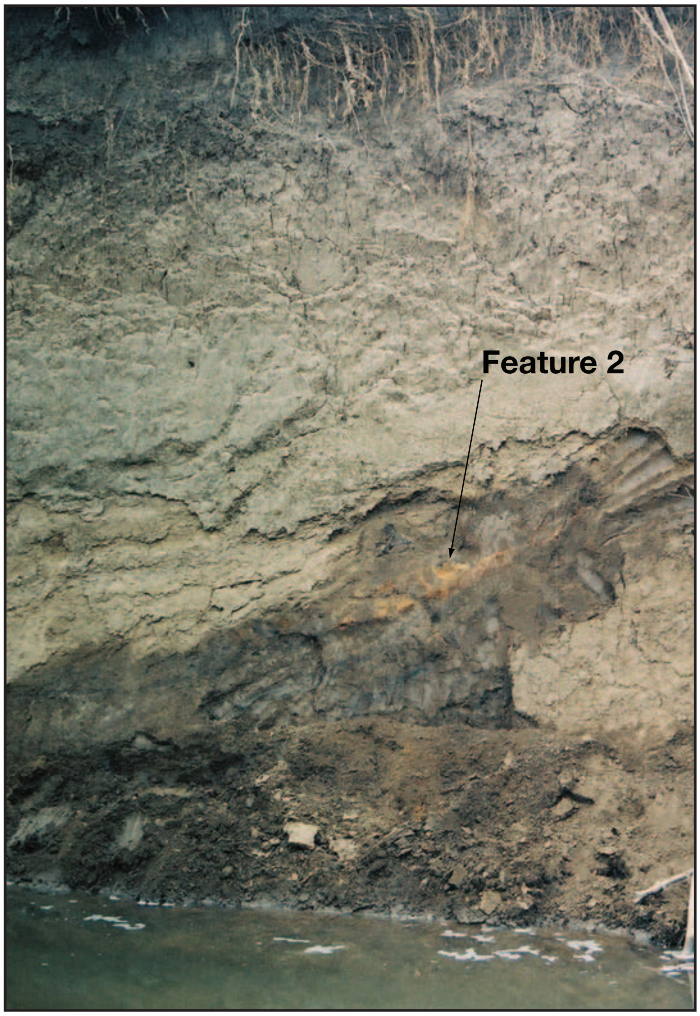

Figure 16. Archeological Feature 2 in Section B (site 14SC1340). The feature is 290-354 cm below the T-1 surface.

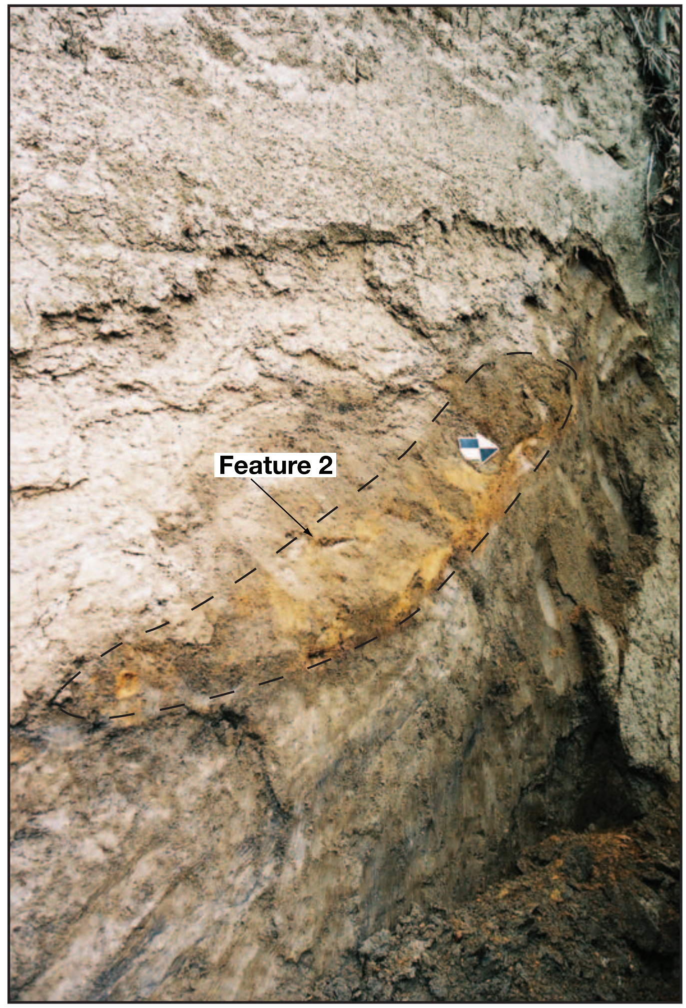

Figure 17. Archeological Feature 2 in Section B (site 14SC1340). Note the abundance of red and yellowish-red burned earth. The photo scale is 20 cm long.

was penetrated at a depth 360 cm. The fine-grained alluvium in Core 5 resembles the Roberts Creek Member of the DeForest Formation. In Fox Creek valley, this unit probably fills a late Holocene channel cut into the Honey Creek Member. However, additional coring is needed to clearly determine the stratigraphic relationship of the Roberts Creek Member relative to the Honey Creek Member.

The lowest geomorphic surface in Fox Creek valley, T-0b, was not cored because dense tree cover prohibited vehicle access (Figure 5). However, stream banks, including Section C (Figures 3 and 18), provided opportunities to examine the T-0b fill. At the southern end of Section C, a veneer of stratified, fine-grained alluvium typical of the Camp Creek Member of the DeForest Formation mantles a thick unit of stratified gravel representing a former point bar (Figure 19). The surface soil developed in the Camp Creek Member is an Entisol with a thin A horizon above a C horizon.

In most of Section C, a 3-5 m-thick unit of stratified, fine-grained alluvium (Camp Creek Member) overlies stratified gravel (Figure 20). The fine-grained alluvium is mostly dark grayish brown (10YR 4/2, dry) and brown (10YR 4/3, dry) silt loam with little evidence of soil development. The presence of an A-C soil profile at the top of the section is a good indicator of the youthfulness of the alluvium. The silty portion of the section is interbedded with very dark grayish brown (10YR 3/2, dry) silty clay loam and brown (10YR 5/3, dry) loam and very fine sandy loam. Lenses of fine gravel are common in the lower 1 m of the fine-grained alluvium.

A bed of charcoal-rich silt loam was recorded at a depth of 450-453 cm near the north end of Section C. Wood charcoal recovered from this bed yielded a conventional radiocarbon age of 2100±70 yr B.P. This is too old for the Camp Creek Member, which typically is less than 400 years old (see Mandel and Bettis, 2001a). Therefore, the charcoal either originated from older alluvium and was redeposited with the Camp Creek Member alluvium, or it is in Honey Creek or Gunder Member alluvium truncated by the Camp Creek Member. Additional radiocarbon dating is needed to resolve this problem.

Figure 18. Section C. The Camp Creek Member of the DeForest Formation is exposed beneath the T-0b surface (modern floodplain).

Figure 19. A portion of Section C. Stratified gravel composes a former point bar beneath the T-0b surface.

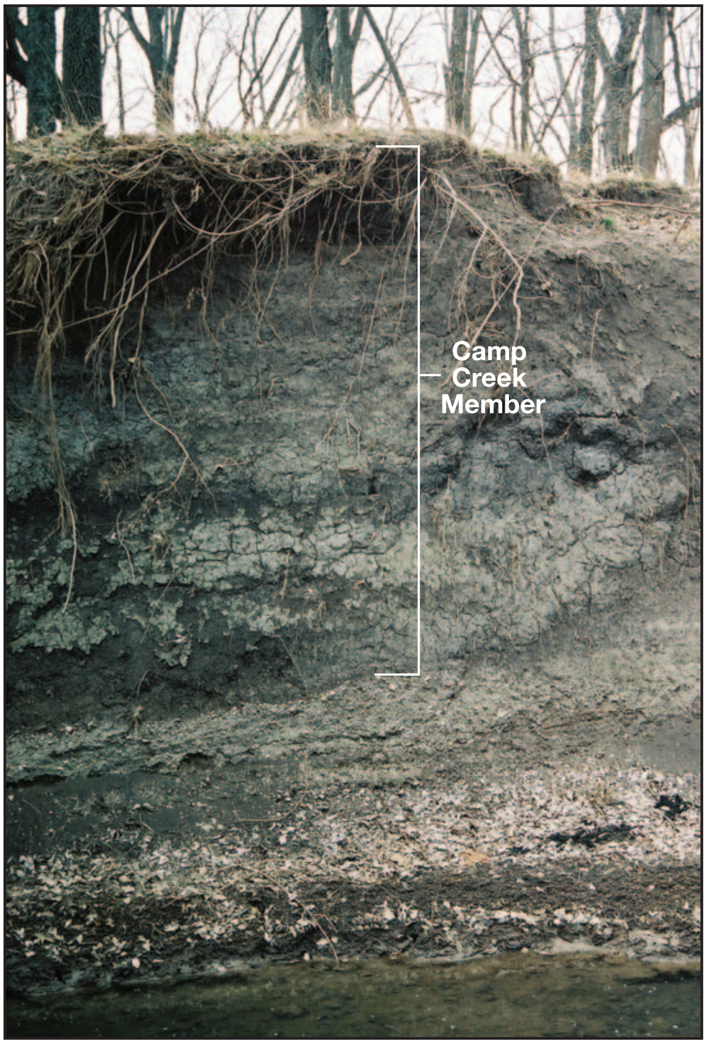

Figure 20. Section C. Note the stratified fine-grained alluvium composing the Camp Creek Member beneath the T-0b flood plain.

Alluvial/Colluvial Fans

Although the valley floor of Fox Creek is dominated by the T-1 terrace and floodplain complex (T-0a and T-0b), large, low-angle alluvial/colluvial fans are common on the western side of the valley floor, and fan remnants occur on the eastern side (Figure 3). Three cores – 7, 8, and 10 – were collected on a fan immediately southeast of the Historic Ranch Headquarters (Figures 3 and 21).

In Core 7, a 165 cm thick top stratum of fine-grained alluvium interbedded with angular limestone and chert pebbles (colluvium) overlies a distinct paleosol (Figure 22). The surface soil has strongly expressed A-BA-Bt horizonation (Table 12). The mollic epipedon (Ap + A) is 38 cm thick and consists of dark grayish brown (10YR 4/2, dry) silty clay loam. Dark grayish brown silty clay loam in the BA horizon grades downward into silty clay comprising the Bt1 horizon. The argillic (Bt1-Bt4) horizon is 95 cm thick and has common, distinct, clay films. The hue of the soil matrix becomes redder with depth, ranging from 10YR in the Bt1, Bt2, and Bt3 horizons to 7.5YR in the Bt4 horizon. The Bt4 horizon is welded to the top of Soil 2, accounting for clay films and angular blocky structure in the Atb horizon.

The buried paleosol (Soil 2) has well expressed At-Bt horizonation with strong morphological features, including prismatic structure and thick, continuous, dark brown (7.5YR 3/2, dry) clay films in the Btb horizon. The soil matrix of the Btb horizon is reddish brown (5YR 4/3, dry) (Figure 23) and there are few manganese oxide concretions. Angular pebbles representing colluvium are scattered through the paleosol. The frequency of these pebbles increases with depth, and gravelly silty clay (2Cb horizon) comprises the lower 10 cm of the core. The core was terminated in gravel at a depth of 200 cm.

The soil-stratigraphy in cores 8 and 10 is basically the same as the soil-stratigraphy observed in Core 7 (Tables 13 and 14 and Figure 24). However, the buried paleosol (Soil 2) in Core 8 is considerably thicker than the one in Core 7. Also, there are many manganese-oxide coatings in the Bt2b and BCtb horizons in Core 8.

Figure 21. Core 7 locality on the low-angle/colluvial fan. The Historic Ranch Headquarters is on the hill in the background. The view is to the northwest.

The upper 10 cm of the Atb in cores 7 and 8 were collected for radiocarbon dating. Decalcified organic carbon from these samples yielded radiocarbon ages of 24,560±350 and 22,620±340 yr B.P., respectively. These ages are consistent with radiocarbon ages determined on soil carbon from the Severance formation in northeastern Kansas and southeastern Nebraska (see Mandel and Bettis, 2003a, 2003b).

As noted earlier, soils developed in the Severance formation typically have thick, well-expressed Bt horizons with brown, strong brown, yellowish brown, and/or reddish brown matrix colors; prismatic structure; iron and manganese oxide stains and concretions; prominent clay films; and common macro-pores. The soils developed in the alluvial/colluvial fans in Fox Creek valley have all these characteristics. Based on the lithologic properties, radiocarbon data and soil characteristrics, the large, low-angle alluvial/colluvial fans in Fox Creek valley are composed of the Severance formation.

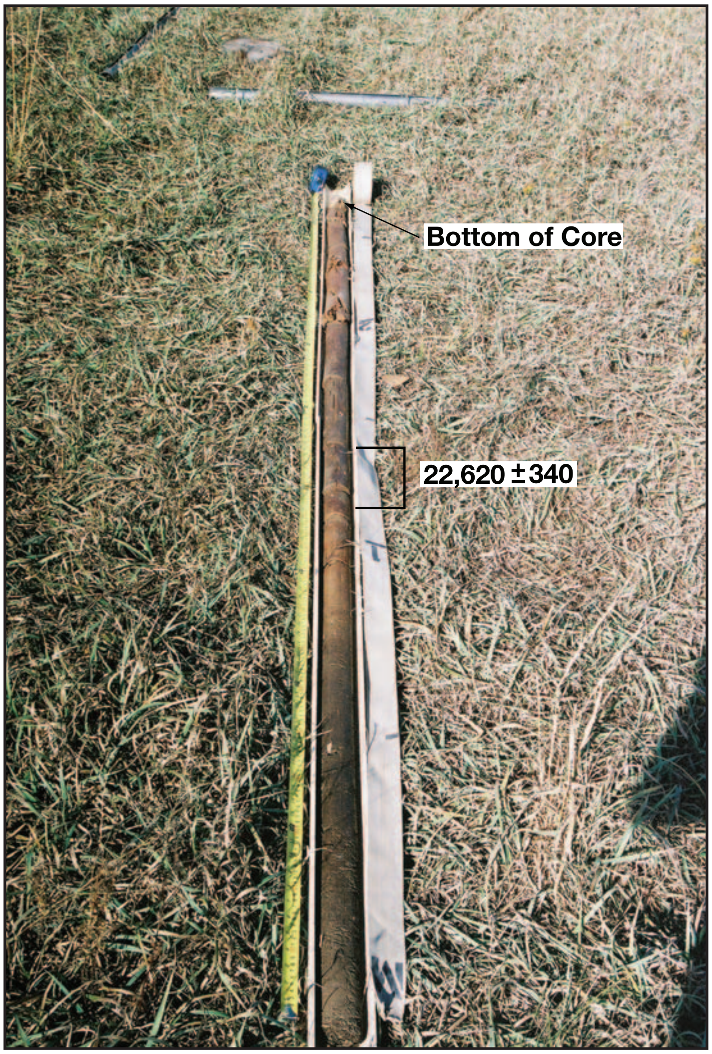

Figure 22. Core 8 taken on a low-angle alluvial/colluvial fan southeast of the Historic Ranch Headquarters. The radiocarbon age was determined on decalcified organic carbon from the upper 10 cm of a buried paleosol (Soil 2) developed in the Severance formation.

Figure 23. Core 8 after it was split open. Note the reddish-brown color of the Severance formation.

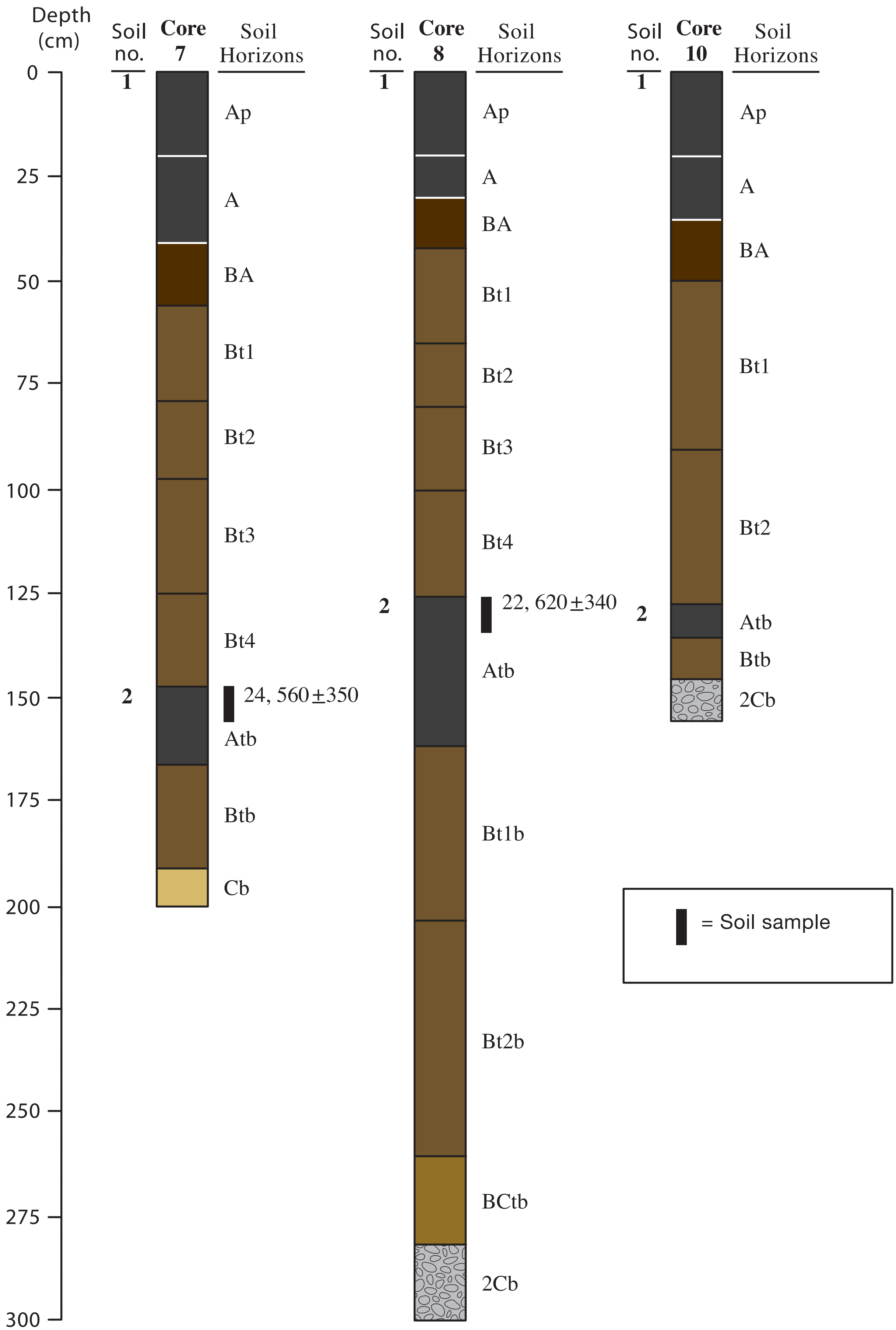

Figure 24. Stratigraphic columns for Cores 7, 8, and 10 taken on an alluvial/colluvial fan.

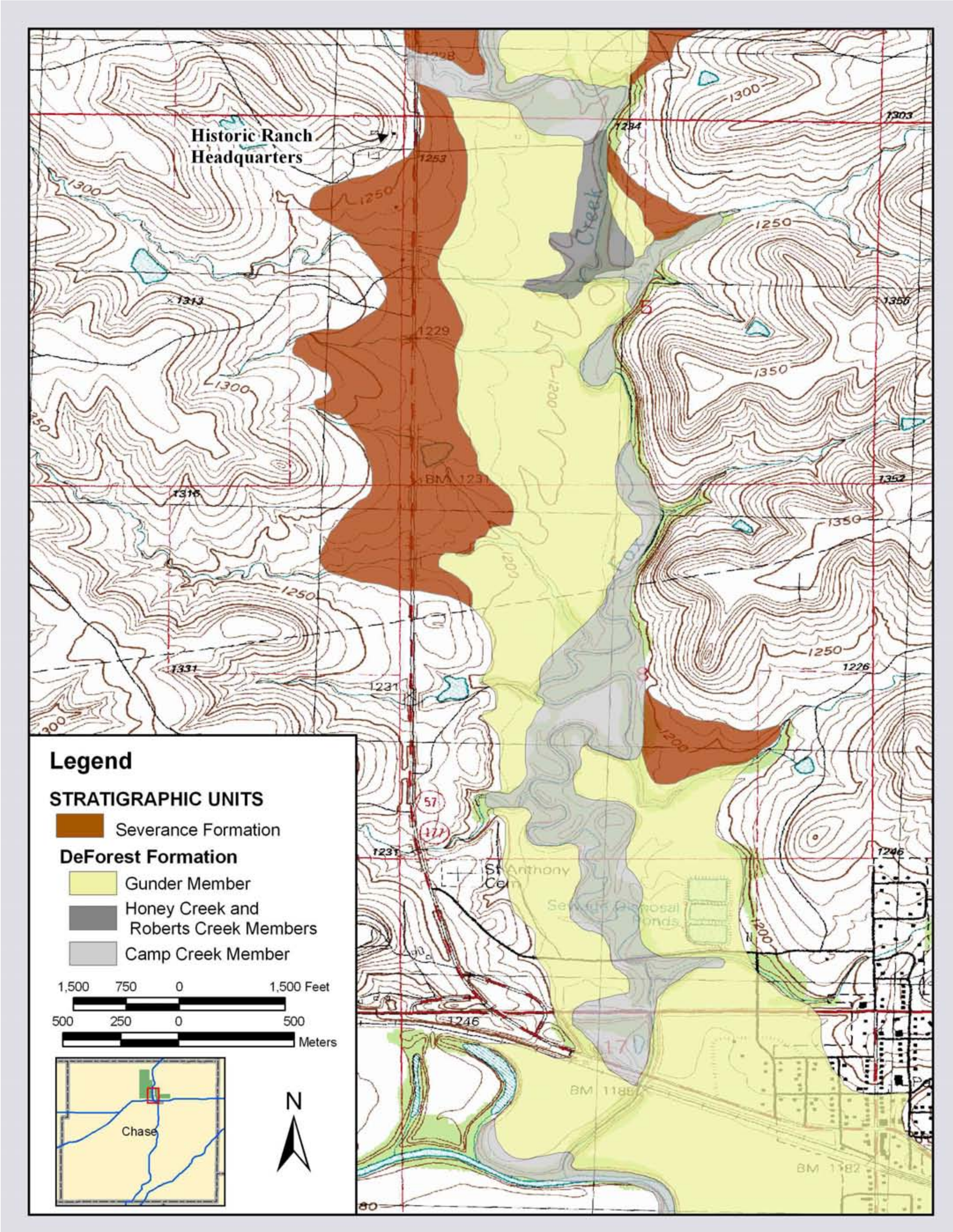

Figure 25. Map showing the Quaternary stratigraphic units in Fox Creek valley.

STABLE CARBON ISOTOPES

Stable carbon isotope analysis of organic carbon in soils has been successfully used in many paleoenvironmental studies (e.g., Ambrose and Sikes 1991; Fredlund and Tieszen 1997; Guillet et al., 1988; Kelly et al., 1991, 1993; Krishnamurthy et al., 1982; Nordt,1993, 2001; Nordt et al., 1994, 2001; Schwartz, 1988; Schwartz et al., 1986). To understand the theory behind this analytical technique, the ecology of C_3 and C_4 plants must be considered. During photosynthesis, C_4 plants discriminate less against $^{13}CO_2$ than C_3 plants (O'Leary 1981; Vogel 1980). This difference in carbon isotope fractionation results in a characteristic carbon isotope ratio in plant tissue that serves as an indicator for the occurrence of C_3 and C_4 photosynthesis (Nordt 1993:52). Boutton (1991a) demonstrated that the $\delta^{13}C$ value of C_3 plant species range from -32 to -20‰, with a mean of -27‰, whereas the $\delta^{13}C$ values of C_4 plant species range from -17 to -9‰, with a mean of -13‰. Thus, C_3 and C_4 plant species have distinct, non-overlapping $\delta^{13}C$ values and differ from each other by approximately 14‰ (Boutton, 1991b).

Nearly all trees, shrubs, forbs, and cool-season grasses are C_3 species. Hence forests and most other temperate plant communities are dominated by C_3 species. Plants with the C_4 photosynthetic pathway are common in warm, semiarid environments with high light intensity, such as grasslands, savannas, deserts, and salt marshes. Studies have shown that both the proportion of C_4 species and the proportion of C_4 biomass in a given plant community are strongly related to environmental temperature (Boutton et al., 1980; Terri and Stowe, 1976; Tieszen et al., 1979). These relationships are invaluable in paleoecological studies when the relative proportions of C_3 vs. C_4 species can be reconstructed (Nordt et al., 1994).

The carbon isotopic composition of plant litter changes only slightly as it decomposes and is incorporated into soil organic matter (Melillo et al., 1989; Nadelhoffer and Fry, 1988). Consequently, the isotopic composition of soil organic matter reflects the dominant species (C_3 vs. C_4) in the plant community that contributed the organic matter (Dzurec et al., 1985; Nadelhoffer and Fry 1988; Stout and Rafter 1978). The stable carbon isotopic composition of soil organic matter in surface and buried soils may, therefore, be used to infer vegetation change (Hendy et al., 1972; Krishnamurthy et al., 1982; Nordt et al., 1994). Going one step further, stable carbon isotopic values may be used to reconstruct climate.

Organic carbon in the late Quaternary alluvial deposits and soils in Fox Creek valley are derived primarily from two inherited sources and one pedogenic source. One inherited source is the erosion and redeposition of organic-rich material derived from the A horizons of upland soils. Because the Fox Creek basin encompasses an area that is bioclimatically and geologically uniform, organic carbon from upland soils reflects one set of paleoenvironmental conditions and not an average of several climatic or vegetational zones as is the case with larger drainage basins. This inherited organic source is, therefore, desirable for interpreting past vegetation and climatic shifts (Nordt, 2001).

A second inherited source of organic carbon is older alluvium that has been eroded and redeposited. This source is undesirable, but it should not significantly bias $\delta^{13}C$ interpretations because organic carbon contents of the older alluvium are low.

During periods of floodplain stability, organic carbon derived from pedogenic processes is superimposed on, and mixed with, the inherited organic carbon fraction (Nordt, 2001). With the establishment of vegetation on floodplains, decaying organic matter accumulates in the soil and yield $\delta^{13}C$ signatures that are in equilibrium with ambient vegetation conditions. This source of organic carbon is desirable for reconstructing late Quaternary vegetation and climate (Nordt, 2001).

The $\delta^{13}C$ values determined at the University of Iowa's Paul H. Nelson Isotope Laboratory for Core 3, which sampled the Gunder Member beneath the T-1 surface, illustrate the nature of vegetation change from ca. 4500 ^{14}C yr B.P. to sometime after ca. 2100 ^{14}C yr B.P. (Figure 26). The bounding ages are based on radiocarbon ages determined on plant macrofossils and charcoal from the bottom of Core 3 and the upper part of Section A, respectively. The grain-size distribution, organic carbon content, and radiocarbon ages suggest that sediment composing the lower 2 m of the profile accumulated rapidly (Figure 26). Therefore, variations in $\delta^{13}C$ values in this interval are probably influenced by shifts in detrital organic matter, rather than primarily reflecting changes in the contribution of standing vegetation to soil organic matter. The abundance of woody plant macrofossils in the reduced sediments below a depth of 4 m supports this interpretation.

Between about 400 and 150 cm below the T-1 surface, the $\delta^{13}C$ values remain fairly consistent, ranging between -19.5 and -18.2‰ (Table 8). These values indicate a mixed C_3/C_4 plant community, though C_4 plants composed 55-65% of the vegetative cover.

There is a distinct shift to less negative $\delta^{13}C$ values above 150 cm (Figure 26), which suggests that C_4 vegetation increased in abundance at the expense of C_3 plant cover. The timing of this shift is unknown, but it probably occurred after ca. 2100 ^{14}C yr B.P. This interpretation is based on a radiocarbon age of 2105$\pm$25 yr B.P. determined on charcoal 225 cm below the T-1 surface at Section A, not in Core 3. Regardless of the timing, the increase in C_4 vegetation may represent warmer (and possibly drier) conditions and/or increased fire frequency, which would have reduced woody plant cover in the valley.

A dramatic excursion in $\delta^{13}C$ values occurs within the upper 20 cm of the profile, with a shift towards a strongly negative value (Table 8 and Figure 26). This shift is a product of the brome grass, a C_3 plant, recently introduced on the valley floor.

The $\delta^{13}C$ values for Core 3 and the core analyzed by Wambsgans (2006) at the Eureka site in Greenwood County are strikingly similar. At Eureka, carbon isotope values are increasingly heavy (less negative) between ca. 3000 and 1000 ^{14}C yr B.P., shifting from about -20‰ to 16‰. This shift reflects an increasing contribution of C_4 vegetation. Wambsgans (2006) suggests that by ca. 1000 ^{14}C yr B.P., organic carbon preserved in alluvium at Eureka had been contributed by 87% C_4 vegetation and 23% C_3 vegetation, the greatest C_4 input of the past 3,500 years.

The comparative analysis of $\delta^{13}C$ values for Core 3 samples assayed at the University of Iowa's Paul H. Nelson Isotope Laboratory and at McMaster University's Stable-Isotope Biogeochemistry Laboratory revealed remarkably similar curves (Figure 27). Hence, the general trends in vegetation change inferred from the $\delta^{13}C$ values are represented in both data sets. However, in comparing the data sets, there is a 1-2‰ offset in many of the $\delta^{13}C$ values. Given the consistency of the offset, this difference in values probably is a result of different sample pre-treatment methods used by the two laboratories. Nevertheless, the 1-2‰ offset is significant in estimating the difference in the ratio of vegetation type (C_3 vs. C_4) based on $\delta^{13}C$ values. Hence, the specific reason for the 1-2‰ offset must be determined before vegetation ratios can be estimated with a high level of confidence.

The $\delta^{13}C$ values determined at McMaster University's Stable-Isotope Biogeochemistry Laboratory for Core 11 (Honey Creek Member beneath the T-0a surface) are presented in Table 15 and illustrated in Figure 28. Unfortunately, the numerical age of the alluvium comprising Core 11 is unknown. However, as noted earlier, the T-0a fill probably aggraded after ca. 2100 ^{14}C yr B.P. but before 400 ^{14}C yr B.P. The greatest fluctuations in the $\delta^{13}C$ values occur in the lower 60 cm of the profile and probably reflect shifts in the input of detrital organic matter, similar to what occurs in the lower 2 m of Core 3. Within the Akb horizon of the buried soil, there is a distinct shift towards more negative $\delta^{13}C$ values, suggesting that increased floodplain stability allowed woody plants (C_3 vegetation) to expand on the valley floor and perhaps on the adjacent uplands. However, the episode of floodplain stability was followed by a period of instability and floodplain sedimentation that resulted in the burial of the Akb horizon. This period of floodplain sedimentation is accompanied by a distinct shift in $\delta^{13}C$ values suggestive of an increase in C_4 vegetation. Again, such an increase in C_4 vegetation may represent warmer (and possibly drier) conditions and/or increased fire frequency. The dramatic shift towards more negative $\delta^{13}C$ values in the upper 15 cm of the profile is a product of the brome grass that was recently planted on the T-0a surface.

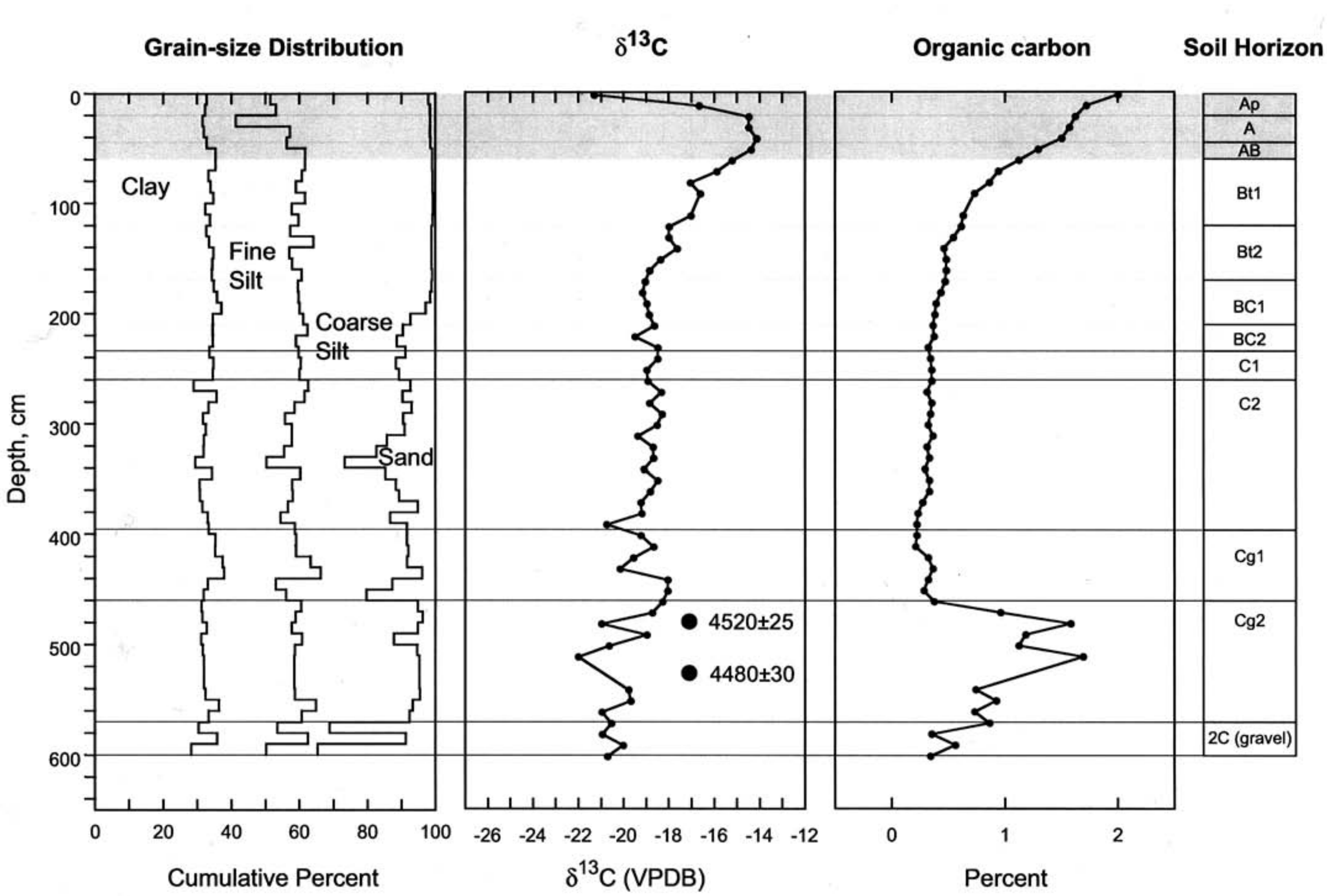

Figure 26. Diagram showing horiz onation, grain-size distribution, and depth function of $\delta^{13}C$ *and organic carbon for Core 3 (T-1 terrace.)*

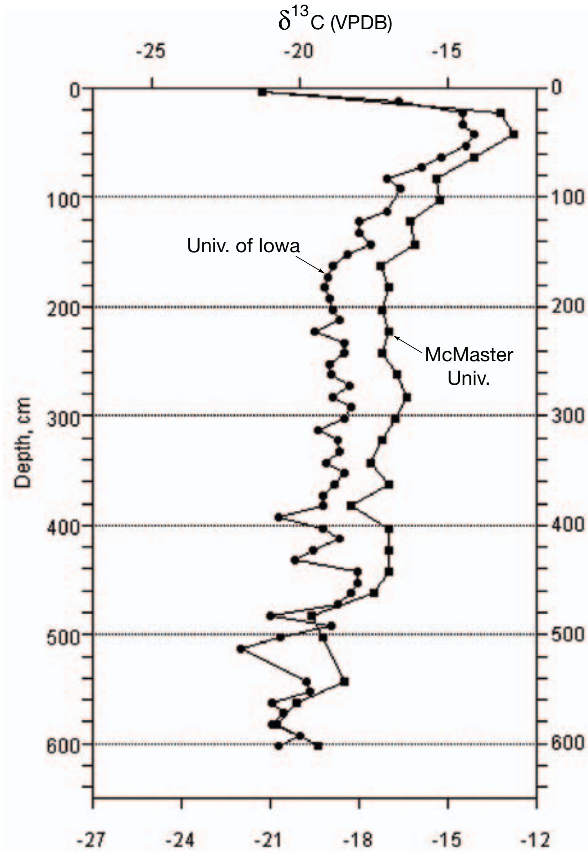

Figure 27. Diagram comparing δ^{13}C *values determined on organic carbon from Core 3. Samples were split and assayed at the University of Iowa's Paul H. Nelson Stable Isotope Laboratory and at McMaster University's Stable-Isotope Biogeochemistry Laboratory.*

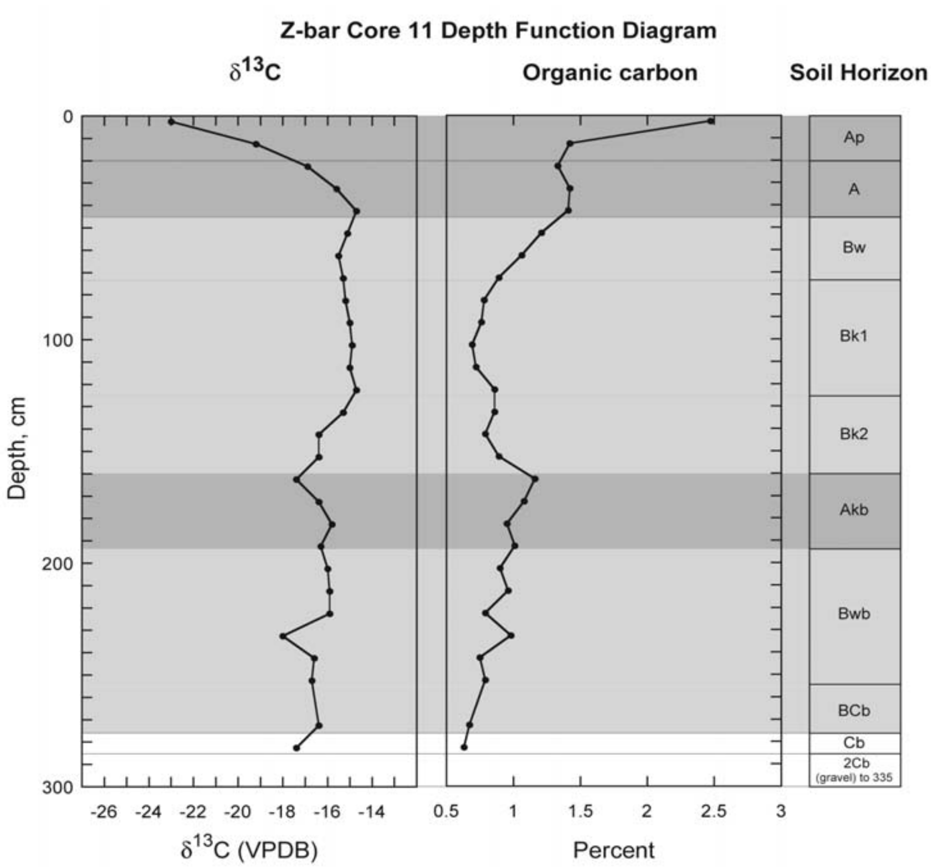

Figure 28. Diagram showing horizonation and depth function of δ^{13}C *and organic carbon for Core 11 (Honey Creek Member, T-Oa).*

GEOARCHEOLOGY OF FOX CREEK VALLEY

The record of human occupation in the Flint Hills region spans the past 11,500 years and may go further back in time. Yet few prehistoric sites have been recorded in the Tallgrass Prairie National Preserve, and only four had been recorded in Fox Creek valley prior to this investigation. The dense cover of brome grass on the valley floor may have hindered detection of surface sites. However, even though prehistoric cultural deposits probably occur at or near the land surface, it is likely that most of these deposits date to the Ceramic periods because nearly all of the geomorphic surfaces composing the valley floor post-date 2000 ^{14}C years B.P. The results of the geoarcheological investigation indicate that much of the archeological record, especially the Late Archaic, will occur in a buried context. Chronological information gleaned from cores and sections provides the basis for locating buried prehistoric cultural deposits in Fox Creek valley.

As previously noted, alluvial and colluvial deposits of certain ages are preserved in Fox Creek valley, and these deposits are associated with specific landforms. Recognizing the temporal and spatial pattern of Holocene and late-Pleistocene sedimentary deposits has important implications for predicting the locations of prehistoric cultural resources in the study area, and for explaining apparent gaps in the archeological record.

In this study, determining the geologic potential for buried cultural deposits in the valley landscape, as shown in Figure 29, considered the soil-stratigraphic record as well as the temporal and spatial pattern of sedimentary deposits. The presence/absence of Holocene-age buried soils, especially buried A horizons, is important in the evaluation of geologic site-preservation potential (Mandel, 1992). Buried soils represent previous land surfaces that were stable long enough to develop recognizable soil profile characteristics (Mandel and Bettis, 2001b). As Hoyer (1980) pointed out, if the probability of human use of a particular landscape position was equal for each year, it follows that the surfaces that remained exposed for the longest time would represent those with the highest probability for containing cultural materials. Holocene-age buried soils identified in the study area represent these surfaces, and evidence for human occupation would most likely be associated with them. However, prehistoric cultural deposits, even rich ones, also may be found in sediment that has not been modified by soil development (Hoyer, 1980; Mandel and Bettis, 2001b). The discovery of archeological features in stratified alluvium (non-soil) at site 14SC1340 (Section B) is a case in point. Hence the presence/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 potential for buried cultural materials.

Going one step further, geomorphic, chronostratigraphic, and soil-stratigraphic data were used to predict where buried archeological deposits dating to specific cultural periods are likely to occur in the Fox Creek valley (Table 16). For example, there is high geologic potential for buried Late Archaic and Early Ceramic cultural deposits associated with the T-1 fill (Gunder Member) (Table 16). Most of the alluvium beneath the T-1 terrace accumulated between ca. 4600 and 2000 ^{14}C yr B.P., and at section A, a soil that developed soon after ca. 2100 yr B.P. is buried beneath a 139 cm-thick top stratum of fine-grained alluvium. A similar soil-stratigraphic sequence was observed at Section B.

The high geologic potential for buried Late Archaic cultural deposits in the T-1 fill was realized at site 14SC1340, where two archeological features were recorded about 3 m below the T-1 surface. Charcoal associated with Feature 1 yielded a radiocarbon age of 3530$\pm$25 yr B.P., which places it in the Late Archaic period.

In addition to potential for buried Late Archaic and Early Ceramic cultural deposits, the T-1 fill may harbor Early Paleoindian cultural deposits, though this potential is ranked "moderate" because no terminal Pleistocene or early Holocene soils were recorded beneath the T-1 surface (Table 16). Core 9 revealed that organic-rich late Wisconsinan alluvium underlies late Holocene alluvium where Fox Creek cut deep into the bedrock floor of the valley (Figure 4). Peat at a depth of 8 m yielded a radiocarbon age of 11,200$\pm$60 yr B.P.; hence, the alluvium adjacent to and possibly below the peat has geologic potential for containing Clovis cultural deposits.

The numerical age of the T-0a fill is unknown. However, based on the alluvial chronology of the T-1 fill, the T-0a fill aggraded sometime after ca. 2000 ^{14}C yr B.P. Aggradation was interrupted by at least one episode of landscape stability, indicated by a weakly developed soil about 1.5 m below the T-0a surface. Taking the soil-stratigraphy and estimated chronology into account, the T-0a fill has high to moderate potential for buried Early through Late Ceramic cultural deposits (Table 16).

Valley fill beneath the T-0b surface appears to be too young to contain any *in situ* prehistoric cultural deposits (Table 16 and Figure 29). Although the numerical age of the T-0b fill has not been determined, it consists of stratified Camp Creek Member deposits that typically are less than 400 years old and often less than 200 years old in eastern Kansas.

The alluvial/colluvial fans examined on the margin of the valley floor have low geologic potential for containing buried cultural deposits (Table 16 and Figure 29). Organic carbon from buried soils developed in the Severance formation composing these fans yielded radiocarbon ages of ca. 24,600 and 22,500 yr B.P. The age of the top stratum mantling the buried soils is unknown, but the magnitude of surface-soil development suggests that the fans have been relatively stable for the past 12,000 years. Based on the available data, the large, low-angle

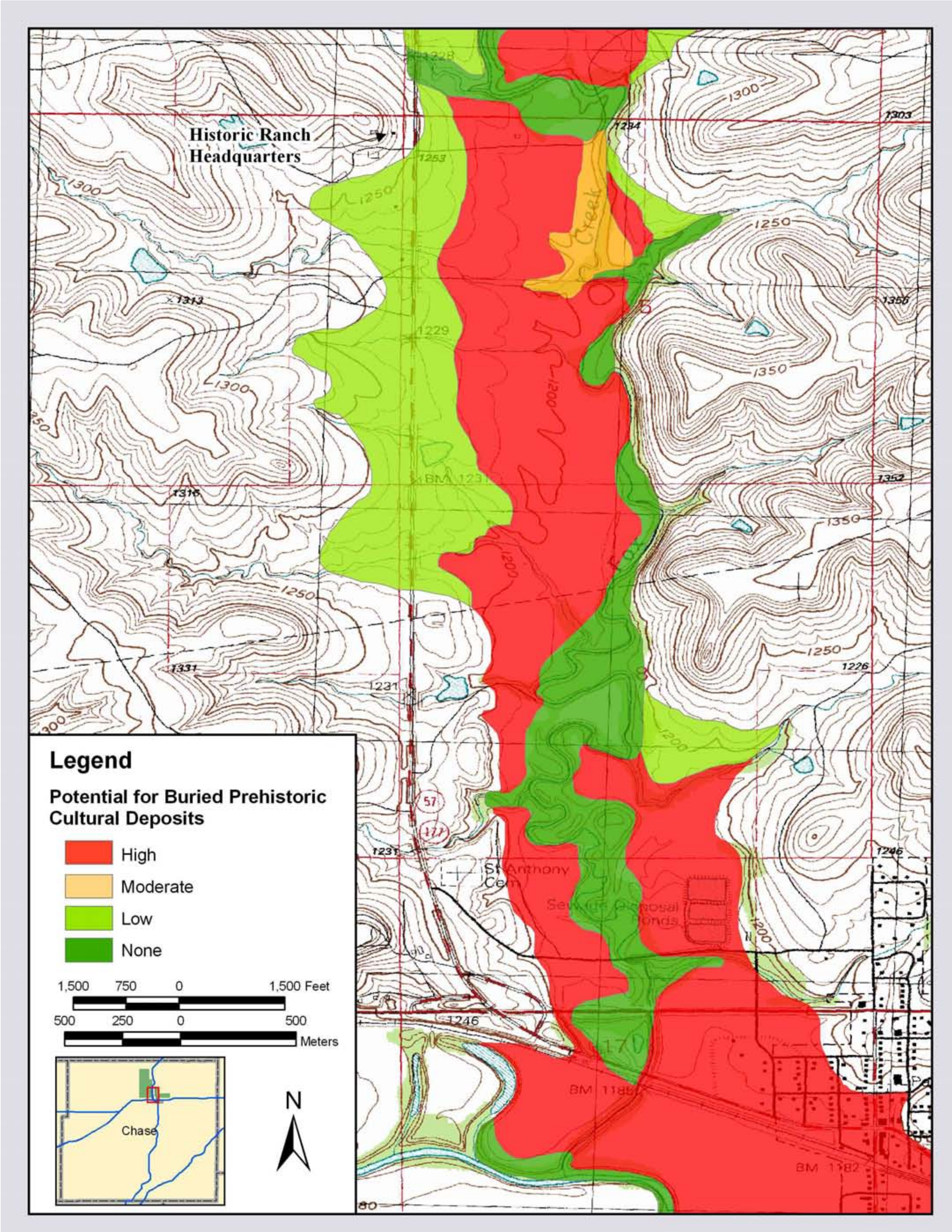

Figure 29. Map showing the geologic potential for buried prehistoric cultural deposits in Fox Creek valley.

alluvial/colluvial fans in Fox Creek valley can only contain buried Pre-Clovis cultural deposits, and that potential is ranked low because of the great antiquity of these landforms and the paucity of North American sites pre-dating the Clovis period.

This study has yielded new information that helps address the following archaeological questions. Why have no archeological sites dating to the warm, dry Altithermal (ca. 8000 - 5000 ^{14}C yr B.P.) been documented in Fox Creek valley? Were people living on the uplands or in other regions during this period? Also, why have few Late Archaic sites been recorded in the valley? This study indicates that geologic processes have affected the archeological record by removing portions of it and burying others. Specifically, during the early and middle Holocene, erosion and net transport of alluvium in Fox Creek valley removed most if not all Early and Middle Archaic cultural deposits that may have been associated with the alluvium. During the late Holocene, beginning around 4500 ^{14}C yr B.P., alluvium accumulated in Fox Creek valley and Late Archaic cultural deposits were deeply buried.

In sum, the material remains of human occupation in Fox Creek valley have passed through a geologic filter to become the archeological record. Understanding the nature of the temporal and spatial patterns that this filter imposed on the archeological record is the first task in identifying archeological patterns that reflect human choices (Bettis and Mandel, 2002; Mandel, 2006b). The geoarchaeological investigation accomplished this task, but the predictive model presented here remains to be tested.

RECOMMENDATIONS FOR FUTURE RESEARCH

Additional investigations would further develop our understanding of late-Quaternary landscape evolution and environmental change in Fox Creek valley and the surrounding region. Specific research needs are presented below.

Future research should focus on gaining a better understanding of the alluvial chronology of the Holocene valley fills in Fox Creek valley. In addition to refining the temporal aspects of late Holocene landscape evolution, a well-defined chronology would provide a more precise record of vegetative change as recorded in the $\delta^{13}C$ values of organic carbon and in other bioclimatic indices.

Although radiocarbon ages have been determined on materials from the bottom and middle portions of the T-1 fill, and it is apparent that T-1 aggradation slowed around 2100 ^{14}C yr B.P., the time at which most of the T-1 surface stabilized is unknown. Also, the numerical age of the top stratum at sections A and B is unknown. Hence, there is uncertainty about when Soil 2 was buried at these localities on low portions of the T-1 terrace. Furthermore, the numerical ages of the T-0a and T-0b fills are unknown. Refinement of the late Holocene alluvial chronology will require additional coring and inspection of cutbank exposures so as to recover ^{14}C-dateable material.

The $\delta^{13}C$ values for cores 3 and 11 demonstrate the potential for stable carbon isotope analysis to provide information on the general characteristics of past vegetative cover (proportion of C_3 vs. C_4 cover) in Fox Creek valley and the drainage basin. Several issues important to interpretation of these data can be addressed with further $\delta^{13}C$ analyses. To accurately interpret the isotopic values in terms of standing vegetation, and thereby infer regional climatic change, it is important to understand the nature of local variability of isotopic composition of the soil organic carbon. Vegetation varies across the landscape, and we must therefore have a better understanding of how this variation translates into variations in buried organic carbon. This will require $\delta^{13}C$ analyses of soil and sediment samples from a larger suite of cores collected across the valley landscape. Once the bounding radiocarbon ages of the valley fills are firmly established, and the local variation of $\delta^{13}C$ values is better understood, stable carbon isotope profiles could be used as a correlation aid for linking localities together and for evaluating the time span represented by stratigraphic sections. Also, $\delta^{13}C$ analyses of soil and sediment samples from similar-age alluvial deposits in adjacent stream valleys, such as Palmer Creek, is needed to determine whether a regional bioclimatic signal is represented in the $\delta^{13}C$ record.

The available stable carbon isotope data suggest that after ca. 4500 ^{14}C yr B.P., prairie expanded and tree cover declined in Fox Creek valley. The composition of the prairie may have fluctuated during this period in response to climatic perturbations. Two lines of evidence preserved in the sedimetological record should be pursued to determine whether such compositional fluctuations occurred: plant macrofossils and phytoliths.

The deep cores on the T-1 terrace revealed that plant macrofossils are abundant in the reduced sediments composing the lower part of the Gunder Member. Baker et al. (2000) demonstrated that identification of the plant macrofossils, combined with radiocarbon dating of the plant remains, is a powerful tool for reconstructing vegetative change in a small drainage basin. This information can, in turn, be used to reconstruct regional climate, especially when it is combined with isotopic data.

Opal phytoliths preserved in the valley fills should be analyzed to determine whether there have been significant changes in the composition of the tallgrass prairie during the late Holocene. It is likely that phytoliths are well preserved in the T-1, T-0a, and T-0b fills, and cores taken for $\delta^{13}C$ analysis of organic carbon should be processed to recover these plant microfossils. Phytolith assemblages in soil and sediment samples can be analyzed to determine the proportion of chloridoid, panicoid, and festucoid types. The festucoid class of phytoliths is associated with the C_3 grasses, the chloridoid class is associated with the more arid, warm weather C_4 grasses, and the panicoid class is associated with the warm weather, more humid C_4

grasses, such as Paniceae and Andropogoneae (Twiss, 1983). Hence, an analysis of phytolith assemblages in radiocarbon-dated stratigraphic sequences can shed light on changes in prairie composition through time. Because these changes are often products of regional environmental changes, the phytolith record can be used to reconstruct late-Holocene bioclimates of the Flint Hills region.

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APPENDIX

Tables

Table 1. *Radiocarbon ages determined on samples from Fox Creek valley.*

Sample Locality	Material Assayed	Depth (cm)	Landform	Strat. Unit[1]	^{14}C Age (yr B.P.)	δ13C (°/oo)	Laboratory Number
Section C	Charcoal	450-455	T-0a	CC?	2100±25	-25.4	ISGS-5928
Section A	Charcoal	225-226	T-1	HC	2105±25	-26.0	ISGS-A0695
Section B	Charcoal[2]	294-295	T-1	GM	3530±25	-25.2	ISGS-A0696
Section B	Charcoal	360-361	T-1	GM	3570±70	-27.3	ISGS-5927
Core 3	Wood	480-485	T-1	GM	4520±25	-26.0	ISGS-A0701
Core 3	Wood	525-530	T-1	GM	4485±30	-25.2	ISGS-A0702
Core 9	Peat	800-810	T-1	LWA	11,220±60	-17.6	ISGS-A0712
Core 8	DSC[3]	124-134	A/CF[4]	SV	22,620±340	-15.5	ISGS-A0711
Core 7	DSC	147-157	A/CF	SV	24,560±350	-15.9	ISGS-A0713

[1]Stratigraphic Units: HC=Honey Creek Member; GM=Gunder Member; LWA=Late Wisconsin Alluvium; SV=Severance Formation
[2]The charcoal sample was collected from Feature 1 associated with site 14SC1340 at Section 2.
[3]DSC=Decalcified soil carbon
[4]A/CF=Alluvial/colluvial fan

Table 2. *Description of Core 2.*

Sediment: Alluvium
Slope: 1%
Drainage: Well drained

Depth (cm)	Soil Horizon	Description
		Gunder Member
0-20	Ap	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-30	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; very weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
30-45	AB	Brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure parting to moderate medium and coarse granular; friable; common fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
45-80	Bt1	Brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; moderate medium prismatic structure parting to weak fine subangular blocky; slightly hard; common thin distinct nearly continuous dark grayish brown (10YR 4/2) clay films on ped faces; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
80-146	Bt2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; moderate medium prismatic structure parting to moderate fine subangular blocky; slightly hard; common thin distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
146-180	Btk1	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; moderate medium prismatic structure parting to moderate fine subangular blocky; slightly hard; common thin distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine threads of calcium carbonate; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
180-305	Btk2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to weak fine subangular blocky; hard; few thin distinct patchy dark grayish brown (10YR 4/2) clay films on ped faces; few dark grayish brown (10YR 4/2) clay flows in macro-pores; few fine threads of calcium carbonate; few fine and very fine roots; few worm casts and open worm burrows;

Table 2 *continued*.

Sediment: Alluvium
Slope: 1%
Drainage: Well drained

Depth (cm)	Soil Horizon	Description
		Gunder Member few fine flecks of charcoal; common lenses of granules and fine pebbles; common fine and very fine pores; gradual boundary
305-360	BC	Yellowish brown (10YR 5/4) silty clay loam to clay loam, dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure; firm; many lenses of granules and fine pebbles; common fine and very fine pores; abrupt boundary.
360-378	C	Light olive brown (2.5Y 5/3) clay loam, olive brown (2.5Y 4/3) moist; massive; firm; many granules and pebbles scattered through the matrix; few fine and very fine pores; gradual boundary.
378-395	Cg1	Laminated gray (5Y 5/1) silty clay loam and clay loam, dark gray (5Y 4/1) moist; massive; firm; interbedded with fine gravel; few fine and very fine pores; abrupt boundary.
395-420	Cg2	Laminated greenish gray (10Y 5/1) silty clay loam, dark greenish gray (5Y 4/1) moist; massive; firm; interbedded with fine gravel; few shell fragments; few fine and very fine pores; abrupt boundary.
420-440	Cg3	Laminated gray (10YR 5/1) silty clay loam, dark gray (10YR 4/1) moist; common fine prominent strong brown (7.5YR 4/6), yellowish red (5YR 4/6), and red (2.5YR 4/6) mottles; massive; firm; interbedded with fine gravel; few shell fragments; few fine and very fine pores; gradual boundary.
440-512	Cg4	Laminated dark gray (10YR 4/1) silty clay loam, very dark gray (10YR 3/1) moist; massive; firm; common thin beds of plant macro-fossils; abrupt boundary.
512-520+	2C	Coarse gravel; refusal at 520 cm.

Table 3. *Description of Core 3*.

Landform: T-1
Sediment: Alluvium
Slope: 1%
Drainage: Well drained
Remarks: Plant macro-fossils collected at depths of 480-485 cm and 525-530 cm yielded AMS radiocarbon ages of 4520±25 yr B.P. and 4485±30 yr B.P., respectively.

Depth (cm)	Soil Horizon	Description
		Gunder Member
0-20	Ap	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-45	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; very weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
45-60	AB	Brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure parting to moderate medium and coarse granular; friable; common fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
60-120	Bt1	Brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; moderate medium prismatic structure parting to weak fine subangular blocky; slightly hard; common thin distinct continuous dark grayish brown (10YR 4/2) clay films on ped faces; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.

Table 3 *continued*.

Landform: T-1
Sediment: Alluvium
Slope: 1%
Drainage: Well drained
Remarks: Plant macro-fossils collected at depths of 480-485 cm and 525-530 cm yielded AMS radiocarbon ages of 4520±25 yr B.P. and 4485±30 yr B.P., respectively.

Depth (cm)	Soil Horizon	Description
		Gunder Member
120-170	Bt2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; moderate medium prismatic structure parting to moderate fine subangular blocky; slightly hard; common thin distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
170-210	BC	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure; slightly hard; few fine and very fine roots; common granules; few fine and very fine pores; gradual boundary.
210-235	CB	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure; slightly hard; few fine and very fine roots; common granules and pebbles; few fine and very fine pores; gradual boundary.
235-260	C1	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; massive; firm; many granules and pebbles; few fine and very fine pores; gradual boundary.
260-395	C2	Brown (10YR 5/3-4/3) silty clay loam, dark yellowish brown (10YR 4/4) moist; massive; firm; many granules and pebbles; few fine and very fine pores; gradual boundary.
395-460	Cg1	Laminated gray (10YR 5/1) silty clay loam interbedded with loam, dark gray (10YR 4/1) moist; common fine prominent strong brown (7.5YR 4/6) and yellowish red (5YR 4/6) mottles; massive; firm; interbedded with fine gravel; few fine and very fine pores; abrupt boundary.
460-570	Cg2	Laminated dark gray (10YR 4/1) silty clay loam, very dark gray (10YR 3/1) moist; massive; firm; common thin beds of plant macro-fossils; interbedded with granules and fine gravel; abrupt boundary.
570-600	2C	Gravel; refusal at 600 cm.
0-20	Ap	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-37	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; very weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
37-47	AB	Brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure parting to moderate medium and coarse granular; friable; common fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
47-76	Bt1	Brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; moderate medium prismatic structure parting to weak fine subangular blocky; slightly hard; common distinct continuous dark grayish brown (10YR 4/2) clay films on ped faces; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
76-130	Bt2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to weak fine subangular blocky; hard; few distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
130-248	Bt3	Yellowish brown (10YR 5/4) light silty clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to weak fine subangular blocky; hard; few distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine and very fine roots; common fine and very fine pores; gradual boundary.
248-289	BCk	Yellowish brown (10YR 5/4) silt loam, dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure; hard; few fine films and threads of calcium carbonate; many fine and very fine pores; abrupt boundary.
289-330	2C	Stratified chert-rich gravel; refusal at 330 cm.

Table 4. *Description of Core 4*.

Landform: T-1
Sediment: Alluvium
Slope: 1%
Drainage: Well drained

Depth (cm)	Soil Horizon	Description
		Gunder Member
0-20	Ap	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-37	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; very weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
37-47	AB	Brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure parting to moderate medium and coarse granular; friable; common fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
47-76	Bt1	Brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; moderate medium prismatic structure parting to weak fine subangular blocky; slightly hard; common distinct continuous dark grayish brown (10YR 4/2) clay films on ped faces; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
76-130	Bt2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to weak fine subangular blocky; hard; few distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
130-248	Bt3	Yellowish brown (10YR 5/4) light silty clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to weak fine subangular blocky; hard; few distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine and very fine roots; common fine and very fine pores; gradual boundary.
248-289	BCk	Yellowish brown (10YR 5/4) silt loam, dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure; hard; few fine films and threads of calcium carbonate; many fine and very fine pores; abrupt boundary.
289-330	2C	Stratified chert-rich gravel; refusal at 330 cm.

Table 5. *Description of Core 6.*

Landform: T-1
Sediment: Alluvium
Slope: 1%
Drainage: Well drained

Depth (cm)	Soil Horizon	Description
		Gunder Member
0-20	Ap	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-32	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; very weak fine subangular blocky structure parting to weak fine granular; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
32-42	AB	Brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure parting to moderate medium and coarse granular; friable; common fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
42-80	Bt1	Brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; moderate medium prismatic structure parting to weak fine subangular blocky; slightly hard; common thin distinct nearly continuous dark grayish brown (10YR 4/2) clay films on ped faces; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
80-150	Bt2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; moderate medium prismatic structure parting to moderate fine subangular blocky; slightly hard; common thin distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
150-260	Btk1	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; moderate medium prismatic structure parting to moderate fine subangular blocky; slightly hard; common thin distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine threads of calcium carbonate; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
260-310	Btk2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to weak fine subangular blocky; hard; few thin distinct patchy dark grayish brown (10YR 4/2) clay films on ped faces; few dark grayish brown (10YR 4/2) clay flows in macro-pores; few fine threads of calcium carbonate; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
310-370	BC	Yellowish brown (10YR 5/4) silty clay loam to clay loam, dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure; firm; common fine and very fine pores; abrupt boundary.
370-450	CB	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure; slightly hard; few fine and very fine pores; gradual boundary.
450-555	C	Light olive brown (2.5Y 5/3) clay loam, olive brown (2.5Y 4/3) moist; massive; firm; common granules and few lenses of pebbles; few fine and very fine pores; gradual boundary.
555-590	Cg	Laminated gray (5Y 5/1) silty clay loam and clay loam, dark gray (5Y 4/1) moist; massive; firm; interbedded with fine gravel; few fine and very fine pores; abrupt boundary.
590-620+	2C	Coarse gravel; refusal at 620 cm.

Table 6. *Description of Section A.*

Landform: T-1
Sediment: Alluvium
Slope: 1%
Drainage: Well drained
Remarks: Charcoal fragments collected at a depth of 225-230 cm yielded an AMS radiocarbon age of 2100±25 yr B.P.

Depth (cm)	Soil Horizon	Description
		Gunder Member
0-20	Ap	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak fine granular structure; friable; many fine and very fine roots; many worm casts and open worm burrows; clear smooth boundary.
20-38	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual smooth boundary.
38-61	Bt	Brown (10YR 4/3) light silty clay loam, dark brown (10YR 3/3) moist; weak fine prismatic structure parting to weak fine subangular blocky; firm; common thin discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; common fine and very fine roots; many worm casts and open worm burrows; common fine and very fine pores; gradual smooth boundary.
61-96	Btk1	Brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; weak medium prismatic structure parting to moderate fine subangular blocky; firm; common thin discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few films and threads of calcium carbonate; common fine and few medium roots; common worm casts and open worm burrows; common fine and very fine pores; gradual smooth boundary.
96-139	Btk2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to moderate fine subangular blocky; firm; few thin patchy dark grayish brown (10YR 4/2) clay films on ped faces; common films and threads of calcium carbonate; common fine and few medium roots; few worm casts and open worm burrows; many fine and very fine pores; clear smooth boundary.
139-174	Akb	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate fine and medium granular; friable; many films and threads of calcium carbonate; few fine and medium roots; many very fine and fine pores; gradual smooth boundary.
174-204	Bk1b	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak medium prismatic structure parting to weak fine subangular blocky; friable; many encrusted threads and few fine soft concretions of calcium carbonate; few fine and medium roots; many fine and very fine pores; gradual smooth boundary.
204-250	Bk2b	Brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; very weak fine subangular blocky structure parting to very weak very fine subangular blocky; friable; few fine threads of calcium carbonate; few small fragments of charcoal at a depth of 225 cm; few fine roots; common fine and very fine pores.

Table 7. *Description of Core 9.*

Landform: T-1
Sediment: Alluvium
Slope: 1%
Drainage: Well drained
Remarks: Peat collected at a depth of 800-810 cm yielded an AMS radiocarbon age of 11,220±60 yr B.P.

Depth (cm)	Soil Horizon	Description
		Gunder Member
0-20	Ap	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak fine granular structure; friable; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-38	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
38-61	Bt	Brown (10YR 4/3) light silty clay loam, dark brown (10YR 3/3) moist; weak fine prismatic structure parting to weak fine subangular blocky; firm; common thin discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; common fine and very fine roots; many worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
61-96	Btk1	Brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; weak medium prismatic structure parting to moderate fine subangular blocky; firm; common thin discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few films and threads of calcium carbonate; common fine and few medium roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
96-139	Btk2	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure parting to moderate fine subangular blocky; firm; few thin patchy dark grayish brown (10YR 4/2) clay films on ped faces; common films and threads of calcium carbonate; common fine and few medium roots; few worm casts and open worm burrows; many fine and very fine pores; clear boundary.
139-174	Akb	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate fine and medium granular; friable; many films and threads of calcium carbonate; few fine and medium roots; many very fine and fine pores; gradual boundary.
174-204	Bk1b	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak medium prismatic structure parting to weak fine subangular blocky; friable; many encrusted threads and few fine soft concretions of calcium carbonate; few fine and medium roots; many fine and very fine pores; gradual boundary.
204-250	Bk2b	Brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; very weak fine subangular blocky structure parting to very weak very fine subangular blocky; friable; few fine threads of calcium carbonate; few small fragments of charcoal at a depth of 225 cm; few fine roots; common fine and very fine pores; gradual boundary.
250-350	BCkb	Brown (10YR 5/3) to yellowish brown (10YR 5/4) silt loam, brown (10YR 4/3) to dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure parting to very weak very fine subangular blocky; friable; few fine threads of calcium carbonate; common fine and very fine pores; gradual boundary.
350-390	CBkb	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; very weak fine subangular blocky structure parting to very weak very fine subangular blocky; firm; few fine threads of calcium carbonate; common fine and very fine pores; gradual boundary.
390-610	Cb	Yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; common fine distinct yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) mottles; massive; firm; common fine and very fine pores; abrupt boundary.
610-730	Cg1b	Gray (5Y 5/1) silty clay loam, dark gray (5Y 4/1) moist; few fine faint light olive brown (2.5Y 5/4) mottles; massive; firm; common fine and very fine pores; gradual boundary.
730-800	Cg2b	Laminated gray (5Y 6/1) and dark gray (5Y 5/1) silty clay loam, dark gray (5Y 5/1) and very dark gray (5Y 3/1) moist; few fine faint light olive brown (2.5Y 5/4) mottles; massive; firm; common fine and very fine pores; abrupt boundary.
800-820	Cg3b	Dark gray (10YR 4/1) loam, very dark gray (10YR 3/1) moist; massive; firm; common lenses of peat.

Table 8. *Grain-size distribution, $\delta^{13}C$ values, and organic carbon content for Core 3.*

		Grain-Size Distribution							
Depth (cm)	Soil Horizon	Total Sand %	Coarse Silt %	Fine Silt %	Total Silt %	Total Clay %	Texture	$\delta^{13}C$ (‰)	Organic Carbon (%)
0- 5	Ap	2.63	49.98	20.13	70.11	27.26	SiCL	-23.3	2.00
10- 20	Ap	2.12	46.39	18.75	65.14	32.75	SiCL	-16.7	1.72
20- 25	A	1.58	45.28	20.87	66.15	32.28	SiCL	-14.5	1.62
30- 35	A	1.46	57.18	9.73	66.91	31.63	SiCL	-14.5	1.57
40- 45	AB	1.63	41.16	25.24	66.40	31.98	SiCL	-14.1	1.50
50- 55	AB	1.38	42.41	23.46	65.87	32.76	SiCL	-14.4	1.29
70- 75	Bt1	0.94	37.42	26.28	63.70	35.37	SiCL	-15.2	1.12
80- 85	Bt1	0.83	38.41	27.45	65.86	33.31	SiCL	-15.9	0.94
90- 95	Bt1	0.77	40.31	24.97	65.28	33.95	SiCL	-17.1	0.86
100-105	Bt1	0.65	37.62	27.04	64.66	34.69	SiCL	-16.6	0.73
110-115	Bt1	0.73	41.50	25.41	66.91	32.36	SiCL	-17.0	0.63
120-125	Bt2	0.80	39.43	25.92	65.35	33.85	SiCL	-18.0	0.61
130-135	Bt2	0.99	41.69	24.73	66.42	32.59	SiCL	-18.0	0.54
140-145	Bt2	1.06	34.78	30.70	65.48	33.45	SiCL	-17.6	0.46
150-155	Bt2	1.05	41.88	22.29	63.51	34.78	SiCL	-18.4	0.48
160-165	Bt2	0.99	41.17	23.52	64.69	34.32	SiCL	-18.9	0.48
170-175	BC	0.89	38.43	26.37	64.80	34.31	SiCL	-19.0	0.47
180-185	BC	1.05	39.31	24.82	64.13	34.83	SiCL	-19.2	0.43
190-195	BC	1.47	38.79	24.01	62.80	35.73	SiCL	-19.0	0.39
200-205	BC	2.85	37.10	23.02	60.12	37.02	SiCL	-18.9	0.38
210-215	CB	7.29	31.60	26.55	58.15	34.56	SiCL	-18.7	0.36
220-225	CB	9.64	27.96	27.91	55.87	34.49	SiCL	-19.5	0.37
230-235	CB	11.39	29.72	24.28	54.00	34.64	SiCL	-18.5	0.32
240-245	C1	8.79	31.44	26.20	57.64	33.57	SiCL	-18.5	0.34
250-255	C1	11.56	27.99	25.76	53.75	34.69	SiCL	-19.0	0.35
260-265	C2	10.80	29.12	25.52	54.64	34.57	SiCL	-18.9	0.35
270-275	C2	7.31	30.04	33.66	63.70	28.99	SiCL	-18.3	0.31
280-285	C2	9.70	28.81	25.80	54.61	36.69	SiCL	-18.9	0.35
290-295	C2	6.99	34.43	25.24	59.67	33.34	SiCL	-18.3	0.34
300-305	C2	9.52	34.69	24.09	58.78	31.70	SiCL	-18.5	0.32
310-315	C2	9.00	33.22	25.28	58.50	32.50	SiCL	-19.4	0.36
320-325	C2	14.22	28.00	25.88	53.88	31.90	SiCL	-18.7	0.31
330-335	C2	17.31	27.30	23.53	50.83	31.86	SiCL	-18.7	0.33
340-345	C2	26.79	22.90	20.89	43.79	29.42	SiCL	-19.1	0.29
350-355	C2	14.66	25.18	25.95	51.13	34.21	SiCL	-18.5	0.33
360-365	C2	11.58	30.49	27.21	57.70	30.72	SiCL	-18.8	0.33
370-375	C2	10.72	31.32	27.21	58.53	30.76	SiCL	-19.2	0.27
380-385	C2	5.24	38.20	25.05	63.25	31.51	SiCL	-19.2	0.23
390-395	C2	13.33	32.28	21.46	53.74	32.94	SiCL	-20.7	0.22
400-405	Cg1	8.47	32.79	25.40	58.19	33.34	SiCL	-19.2	0.22
410-415	Cg1	8.50	32.49	23.72	56.21	35.29	SiCL	-18.7	0.21
420-425	Cg1	8.03	33.05	23.78	56.83	35.15	SiCL	-19.6	0.32
430-435	Cg1	8.33	28.51	25.72	54.23	37.44	SiCL	-20.2	0.36
440-445	Cg1	3.94	29.88	28.36	58.24	37.82	SiCL	-18.1	0.32
450-455	Cg1	12.74	34.25	20.03	54.28	32.99	SiCL	-18.1	0.28
460-465	Cg2	20.38	23.60	24.20	47.80	31.82	CL	-18.3	0.37
470-475	Cg2	5.26	34.17	29.29	63.46	31.28	SiCL	-18.7	0.96
480-485	Cg2	3.69	37.54	27.23	64.77	31.54	SiCL	-21.0	1.58
490-495	Cg2	5.24	37.10	24.90	62.00	32.76	SiCL	-19.0	1.18
500-505	Cg2	12.25	26.99	29.68	56.67	31.08	SiCL	-20.6	1.12
510-515	Cg2	5.35	35.97	27.03	63.00	31.65	SiCL	-22.0	1.69
540-545	Cg2	4.77	36.76	26.48	63.24	31.98	SiCL	-19.8	0.74
550-555	Cg2	4.53	36.74	26.35	63.09	32.37	SiCL	-19.7	0.92
560-565	Cg2	6.66	28.55	28.47	57.02	36.32	SiCL	-20.9	0.73
570-575	2C	7.64	31.66	27.36	59.02	33.34	SiCL	-20.5	0.86
580-585	2C	31.18	15.35	23.13	38.48	30.35	CL	-20.9	0.35
590-595	2C	8.66	28.80	26.72	55.52	35.82	SiCL	-20.0	0.56
600-605	2C	34.67	15.10	22.05	37.15	28.19	CL	-20.7	0.34

Table 9. *Description of Core 1.*

Landform: T-0a
Sediment: Alluvium
Slope: 1%
Drainage: Well drained

Depth (cm)	Soil Horizon	Description
		Honey 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; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-30	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
30-49	Bw	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure; friable; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
49-70	Bk1	Brown (10YR 4/3) heavy silt loam, dark brown (10YR 3/3) moist; weak fine prismatic structure parting to weak fine subangular blocky; friable; common fine threads of calcium carbonate; common fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
70-115	Bk2	Brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; weak medium prismatic structure parting to weak fine prismatic; friable; common threads of calcium carbonate; common fine roots; few worm casts and open worm burrows; common fine and very fine pores; abrupt boundary.
115-150	Akb	Dark grayish brown (10YR 4/2) to brown (10YR 4/3) silt loam, very dark grayish brown (10YR 3/2) to dark brown (10YR 3/3) moist; weak fine prismatic structure parting to weak fine subangular blocky; friable; common threads of calcium carbonate; few fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
150-230	Bwb	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure; friable; few fine roots; few worm casts and open worm burrows; many very fine and common fine pores; gradual boundary.
230-300	BCb	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; very weak fine subangular blocky structure; friable; few fine roots; few worm casts and open worm burrows; many very fine and common fine pores; gradual boundary.
300-330	Cb	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; massive; friable; interbedded with very dark gray (10YR 3/1) silty clay loam, black (10YR 2/1) moist; few fine roots; many very fine and common fine pores; abrupt boundary.
330-387	Cgb	Dark gray (5Y 4/1) clay loam, very dark gray (5Y 3/1) moist; common fine distinct yellowish red (5YR 4/6) mottles; massive; firm; stratified; interbedded with fine gravel; common fine and medium and few coarse pores; abrupt boundary.
387-450	2Cb	Stratified chert-rich gravel.

Table 10. *Description of Core 11*.

Landform: T-0a
Sediment: Alluvium
Slope: 1%
Drainage: Well drained

Depth (cm)	Soil Horizon	Description
		Honey 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; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-45	A	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine granular structure; friable; many fine and very fine roots; many worm casts and open worm burrows; gradual boundary.
45-73	Bw	Dark grayish brown (10YR 4/2) to brown (10YR 4/3) silt loam, very dark grayish brown (10YR 3/2) to dark brown (10YR 3/3) moist; weak fine subangular blocky structure; friable; common fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
73-125	Bk1	Brown (10YR 4/3) heavy silt loam, dark brown (10YR 3/3) moist; weak fine prismatic structure parting to weak fine subangular blocky; friable; common fine threads of calcium carbonate; common fine roots; common worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
125-160	Bk2	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak medium prismatic structure parting to weak fine prismatic; friable; common threads of calcium carbonate; common fine roots; few worm casts and open worm burrows; common fine and very fine pores; abrupt boundary.
160-193	Akb	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine prismatic structure parting to weak fine subangular blocky; friable; many films and threads of calcium carbonate; common fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
193-255	Bwb	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure; friable; few fine roots; few worm casts and open worm burrows; many very fine and common fine pores; gradual boundary.
255-277	BCb	Brown (10YR 4/3) loam, dark brown (10YR 3/3) moist; very weak fine subangular blocky structure; friable; few fine roots; few worm casts and open worm burrows; many very fine and common fine pores; gradual boundary.
277-285	Cb	Olive brown (2.5Y 4/3) gravelly clay loam, dark olive brown (2.5Y 3/3) moist; massive; friable; many pebbles and granules; few fine roots; common fine and very fine pores; abrupt boundary.
285-335	2Cb	Stratified chert-rich gravel.

Table 11. *Description of Core 5.*

Landform: T-0a
Sediment: Alluvium
Slope: 1%
Drainage: Well drained

Depth (cm)	Soil Horizon	Description
		Roberts Creek Member
0-20	Ap	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine granular structure; friable; many fine and very fine roots; many worm casts and open worm burrows; clear boundary.
20-60	A1	Very dark gray (10YR 3/1) silt loam to light silty clay loam, black (10YR 2/1) moist; weak fine granular structure; friable; many fine and very fine roots; many worm casts and open worm burrows; common fine pores; gradual boundary.
60-90	A2	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine granular structure; friable; common fine and very fine roots; many worm casts and open worm burrows; common fine pores; gradual boundary.
90-100	AB	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 granular; friable; common fine and very fine roots; common worm casts and open worm burrows; common fine pores; gradual boundary.
100-150	Bw	Brown (10YR 4/3) silt loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure; friable; few fine and very fine roots; common worm casts and open worm burrows; common fine and very fine pores; clear boundary.
150-180	Ab1	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine granular structure; friable; few fine and very fine roots; common worm casts and open worm burrows; common fine pores; gradual boundary.
180-195	ACb1	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; few faint beds of very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; very weak fine granular structure; friable; few fine and very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
195-237	Cb1	Laminated very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist and very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; few fine faint brown (7.5YR 4/3) mottles; massive; soft, very friable; few very fine roots; common fine and very fine pores; abrupt boundary.
237-262	Ab2	Very dark gray (10YR 3/1) silt loam to light silty clay loam, black (10YR 2/1) moist; weak fine granular structure; friable; few very fine roots; few worm casts and open worm burrows; common fine and very fine pores; gradual boundary.
262-310	ACb2	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; very weak fine granular structure; friable; faint bedding; common fine and very fine pores; gradual boundary.
310-340	C1b2	Dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) moist; common fine and medium faint dark grayish brown (2.5Y 4/3) and few fine prominent strong brown (7.5YR 4/6) and yellowish red (5YR 4/6) mottles; massive; friable; few small bivalves; few granules and coarse sand grains; few fine pores; gradual boundary.
340-360	C2b2	Dark grayish brown (2.5Y 4/2) gritty clay loam, very dark grayish brown (2.5Y 3/2) moist; few fine prominent strong brown (7.5YR 4/6) and yellowish red (5YR 4/6) mottles; massive; firm; many small bivalves; many granules and coarse sand grains; few fine pores.

Table 12. *Description of Core 7.*

Landform: Alluvial/Colluvial Fan
Sediment: Alluvium and colluvium
Slope: 2-3%
Drainage: Well drained
Remarks: Decalcified soil carbon from the upper 10 cm of the Atb horizon yielded a radiocarbon age of 24,560±350 yr B.P.

Depth (cm)	Soil Horizon	Description
		Severance Formation
0-20	Ap	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; many fine and very fine roots; common worm casts and open worm burrows; clear boundary.
20-38	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; many fine and very fine roots; common worm casts and open worm burrows; gradual boundary.
38-52	BA	Dark grayish brown (10YR 4/2) heavy silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate fine subangular blocky structure; hard; few fine angular pebbles; common fine and very fine roots; common worm casts and open worm burrows; gradual boundary.
52-77	Bt1	Dark grayish brown (10YR 4/2) silty clay, very dark grayish brown (10YR 3/2) moist; moderate medium angular blocky structure; very hard; common distinct discontinuous clay films on ped faces; few fine angular pebbles; common fine and very fine roots; common worm casts and open worm burrows; few fine pores; gradual boundary.
77-105	Bt2	Brown (10YR 4/3) silty clay, dark brown (10YR 3/3) moist; moderate medium angular blocky structure; very hard; common distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine angular pebbles; few fine and very fine roots; few fine pores; gradual boundary.
105-124	Bt3	Dark yellowish brown (10YR 4/4) silty clay, dark yellowish brown (10YR 3/4) moist; moderate medium angular blocky structure; very hard; common distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine angular pebbles; few fine and very fine roots; common fine and medium pores; gradual boundary.
124-147	Bt4	Brown (7.5YR 5/4) silty clay, brown (7.5YR 4/4) moist; common fine distinct yellowish red (5YR 4/6) mottles; moderate medium angular blocky structure; very hard; common distinct discontinuous brown (7.5YR 5/3) clay films on ped faces; few fine angular pebbles; common fine and medium pores; clear boundary.
147-165	Atb	Brown (7.5YR 4/3) silty clay, dark brown (7.5YR 3/3) moist; few fine distinct yellowish red (5YR 4/6) mottles; moderate medium angular blocky structure; very hard; common prominent thick continuous dark brown (7.5YR 3/2) clay films on ped faces and clay flows in macro-pores; few fine angular pebbles; common fine and medium and few coarse pores; gradual boundary.
165-190	Btb	Reddish brown (5YR 4/3) silty clay, dark reddish brown (5YR 3/3) moist; common fine distinct yellowish red (5YR 4/6) mottles; moderate medium prismatic structure parting to moderate fine angular blocky; common prominent thick continuous dark brown (7.5YR 3/2) clay films on ped faces and clay flows in macro-pores; few fine hard and soft manganese oxide concretions; few fine angular pebbles; common fine and medium and few coarse pores; gradual boundary.
190-200+	2Cb	Gravelly brown (7.5YR 4/4) silty clay, dark brown (7.5YR 3/4) moist; massive; very hard; angular chert and limestone clasts compose 75% of material by volume.

Table 13. *Description of Core 8.*

Landform: Alluvial/Colluvial Fan
Sediment: Alluvium and colluvium
Slope: 2-3%
Drainage: Well drained
Remarks: Decalcified soil carbon from the upper 10 cm of the Atb horizon yielded a radiocarbon age of 22,620±340 yr B.P.

Depth (cm)	Soil Horizon	Description
		Severance Formation
0-20	Ap	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; many fine and very fine roots; common worm casts and open worm burrows; clear boundary.
20-30	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; many fine and very fine roots; common worm casts and open worm burrows; gradual boundary.
30-40	BA	Dark grayish brown (10YR 4/2) heavy silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate fine subangular blocky structure; hard; few fine angular pebbles; common fine and very fine roots; common worm casts and open worm burrows; gradual boundary.
40-65	Bt1	Dark grayish brown (10YR 4/2) silty clay, very dark grayish brown (10YR 3/2) moist; moderate medium angular blocky structure; very hard; common distinct discontinuous clay films on ped faces; few fine angular pebbles; common fine and very fine roots; common worm casts and open worm burrows; few fine pores; gradual boundary.
65-80	Bt2	Brown (10YR 4/3) silty clay, dark brown (10YR 3/3) moist; moderate medium angular blocky structure; very hard; common distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine angular pebbles; few fine and very fine roots; few fine pores; gradual boundary.
80-100	Bt3	Dark yellowish brown (10YR 4/4) silty clay, dark yellowish brown (10YR 3/4) moist; moderate medium angular blocky structure; very hard; common distinct discontinuous dark grayish brown (10YR 4/2) clay films on ped faces; few fine angular pebbles; few fine and very fine roots; common fine and medium pores; gradual boundary.
100-124	Bt4	Brown (7.5YR 5/4) silty clay, brown (7.5YR 4/4) moist; common fine distinct yellowish red (5YR 4/6) mottles; moderate medium angular blocky structure; very hard; common distinct discontinuous brown (7.5YR 5/3) clay films on ped faces; few fine angular pebbles; common fine and medium pores; clear boundary.
124-163	Atb	Brown (7.5YR 4/3) silty clay, dark brown (7.5YR 3/3) moist; few fine distinct yellowish red (5YR 4/6) mottles; moderate medium angular blocky structure; very hard; common prominent thick continuous dark brown (7.5YR 3/2) clay films on ped faces and clay flows in macro-pores; few fine angular pebbles; common fine and medium and few coarse pores; gradual boundary.
163-203	Bt1b	Reddish brown (5YR 4/3) silty clay, dark reddish brown (5YR 3/3) moist; common fine distinct yellowish red (5YR 4/6) mottles; moderate medium prismatic structure parting to moderate fine angular blocky; common prominent thick continuous dark brown (7.5YR 3/2) clay films on ped faces and clay flows in macro-pores; few fine hard and soft manganese oxide concretions; few fine angular pebbles; common fine and medium and few coarse pores; gradual boundary.
203-260	Bt2b	Reddish brown (5YR 4/4) heavy silty clay, dark reddish brown (5YR 3/4) moist; common fine distinct yellowish red (5YR 4/6) mottles; strong medium prismatic structure; common distinct discontinuous reddish brown (5YR 4/3) clay films on ped faces and clay flows in macro-pores; many fine manganese oxide coatings on ped faces and common fine hard manganese concretions; few fine angular pebbles; common fine and medium and few coarse pores; gradual boundary.
260-280	BCtb	Yellowish brown (10YR 5/8) and reddish yellow (7.5YR 6/8) silty clay, dark yellowish brown (10YR 4/6) and strong brown (7.5YR 5/8) moist; weak medium prismatic structure parting to very weak angular blocky; very hard; common thick distinct brown (7.5YR 4/3) clay flows of ped faces and in macro-pores; many fine manganese oxide coatings on ped faces and common fine hard manganese concretions; common angular pebbles; common fine and medium and few coarse pores; gradual boundary.
280-290+	2Cb	Gravelly brown (7.5YR 4/4) silty clay, dark brown (7.5YR 3/4) moist; massive; very hard; angular chert and limestone clasts compose 75% of material by volume.

Table 14. *Description of Core 10*.

Landform: Alluvial/Colluvial Fan
Sediment: Alluvium and colluvium
Slope: 2-3%
Drainage: Well drained

Depth (cm)	Soil Horizon	Description
		Severance Formation
0-20	Ap	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; many fine and very fine roots; common worm casts and open worm burrows; clear boundary.
20-35	A	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; many fine and very fine roots; common worm casts and open worm burrows; gradual boundary.
35-50	BA	Dark grayish brown (10YR 4/2) heavy silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate fine subangular blocky structure; hard; few fine angular pebbles; common fine and very fine roots; common worm casts and open worm burrows; gradual boundary.
50-90	Bt1	Brown (10YR 4/3) heavy silty clay loam, dark brown (10YR 3/3) moist; moderate medium angular blocky structure; very hard; common distinct discontinuous clay films on ped faces; few fine angular pebbles; common fine and very fine roots; common worm casts and open worm burrows; few fine pores; gradual boundary.
90-126	Bt2	Brown (7.5YR 5/4) silty clay, brown (7.5YR 4/4) moist; common fine distinct yellowish red (5YR 4/6) mottles; moderate medium angular blocky structure; very hard; common distinct discontinuous brown (7.5YR 5/3) clay films on ped faces; few fine angular pebbles; common fine and medium pores; clear boundary.
126-135	Atb	Brown (7.5YR 4/3) silty clay, dark brown (7.5YR 3/3) moist; few fine distinct yellowish red (5YR 4/6) mottles; moderate medium angular blocky structure; very hard; common prominent thick continuous dark brown (7.5YR 3/2) clay films on ped faces and clay flows in macro-pores; few fine angular pebbles; common fine and medium and few coarse pores; gradual boundary.
135-146	Btb	Reddish brown (5YR 4/3) silty clay, dark reddish brown (5YR 3/3) moist; common fine distinct yellowish red (5YR 4/6) mottles; moderate medium prismatic structure parting to moderate fine angular blocky; common prominent thick continuous dark brown (7.5YR 3/2) clay films on ped faces and clay flows in macro-pores; few fine hard and soft manganese oxide concretions; few fine angular pebbles; common fine and medium and few coarse pores; gradual boundary.
146-150	2Cb	Gravelly reddish brown (5YR 4/3) silty clay, dark reddish brown (5YR 3/3) moist; massive; very hard; angular chert and limestone clasts compose 80-85% of material by volume.

Table 15. *Organic carbon content and $\delta^{13}C$ values for Core 11.*

Depth (cm)	Soil Horizon	$\delta^{13}C$ (‰)	Organic Carbon (%)
0- 5	Ap	-23.0	2.47
10- 15	Ap	-19.2	1.42
20- 25	A	-16.9	1.33
30- 35	A	-15.6	1.42
40- 45	A	-14.7	1.41
50- 55	Bw	-15.1	1.21
60- 65	Bw	-15.5	1.06
70- 75	Bw	-15.3	0.89
80- 85	Bk1	-15.2	0.78
90- 95	Bk1	-15.0	0.76
100-105	Bk1	-14.9	0.69
110-115	Bk1	-15.0	0.72
120-125	Bk1	-14.7	0.86
130-135	Bk2	-15.3	0.86
140-145	Bk2	-16.4	0.79
150-155	Bk2	-16.4	0.89
160-165	Akb	-17.4	1.16
170-175	Akb	-16.4	1.08
180-185	Akb	-15.8	0.95
190-195	Akb	-16.3	1.01
200-205	Bwb	-16.0	0.90
210-215	Bwb	-15.9	0.96
220-225	Bwb	-15.9	0.79
230-235	Bwb	-18.0	0.98
240-245	Bwb	-16.6	0.75
250-255	Bwb	-16.7	0.79
270-275	Cb	-16.4	0.67
280-285	Cb	-17.4	0.63

Table 16. *Preservation potential for buried cultural deposits in Fox Creek valley.*

Cultural Periods	**Landform**			
	T-0a T-0b	**T-1**	**Alluvial/Colluvial Fans**	
Historic	-	+++	-	-
Late Ceramic	+++	-	-	-
Middle Ceramic	+++	-	+	-
Early Ceramic	+++	-	+++	-
Late Archaic	+	-	+++	-
Middle Archaic	-	-	+	-
Early Archaic	-	-	-	-
Paleoindian	-	-	++	?
Pre-Clovis	-	-	-	+

- No potential; + low potential, ++ moderate potential, +++ high potential