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The Honey Creek Member: A New Holocene Alluvial Stratigraphic Unit in the Midwest

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This paper describes the type locality and type section for the Honey Creek Member, a stratigraphic unit first recognized in the Honey Creek drainage in southeastern Nebraska. The alluvial chronology for Honey Creek basin is similar to the regional chronology of streams in the Midwest, and all of the formal members of the DeForest Formation occur in the basin. However, the lithology of one unit, the Honey Creek Member, does not correlate with any of the formally recognized members of the DeForest Formation. The Honey Creek Member is composed of grayish brown silt loam overbank facies coarsening downward to a gravelly loam channel facies with prominent, large-scale cross-bedding. At its type locality, aggradation of the Honey Creek Member occurred from ca. 3700 ^{14}C yrs. B.P. to ca. 600 ^{14}C yrs. B.P. Paleochannels preserved within the unit suggest thar aggradation was interrupted by at least two episodes of channel entrenchment and filling. The Honey Creek Member is significant because it has been identified within many basins across the eastern Plains. Recognition and detailed mapping of this unit facilitates our understanding of fluvial behavior during the late Holocene.

INDEX DESCRIPTORS: Honey Creek Member, Holocene alluvium, DeForest Formation.

The purpose of this paper is to describe the type locality and type section of the newly established Honey Creek Member of the DeForest Formation. The DeForest Formation is a regional lithostratigraphic unit that includes Holocene-age alluvium in Iowa and adjacent areas (Daniels et al. 1963, Bettis and Littke 1987, Bettis 1990, Mandel and Bettis 2001). The Honey Creek Member was first recognized as an informal unit in Honey Creek drainage basin in southeastern Nebraska (Fig. 1), (Dillon 1991, 1992). Eleven radiocarbon ages obtained from various materials are combined with soil-stratigraphic relationships to establish a Holocene chronologic framework for the type locality. Although the Honey Creek Member aggraded during the late Holocene (ca. 3700–600 ^{14}C yrs. B.P.), the lithology of the unit does not correlate with any of the formally recognized members of the DeForest Formation, which also occur in the basin. Thus, the Honey Creek Member was initially referred to as the Honey Creek fill and discussed as a possible local response to various internal and external controls on the drainage basin (Dillon 1991, 1992). Subsequent investigations demonstrated that both the Honey Creek fill and the DeForest Formation are mappable alluvial units occurring in basins throughout the region (e.g., Mandel and Bettis 2001, Dillon, 2004a,b). Because of its distinctive lithology and widespread occurrence in the eastern Great Plains, the Honey Creek fill has been formally recognized as the Honey Creek Member of the DeForest Formation (Mandel and Bettis, 2001). However, a detailed description of the type locality and section for the Honey Creek Member has been absent in the literature. Our paper provides the first complete description of this new member of the DeForest Formation. We are currently preparing a manuscript to document the occurrence of the Honey Creek Member in basins across the Midwest, and address its regional implications regarding late Holocene fluvial behavior.

BACKGROUND

The DeForest Formation was introduced in 1963 as a stratigraphic framework for a repeating sequence of Holocene alluvial deposits in western Iowa (Daniels et al. 1963). As originally defined, the DeForest Formation included five members that could be recognized on the basis of lithic characteristics and bounding unconformities (Daniels et al. 1963, Bettis 1990). Seven radiocarbon ages provided a general temporal framework for the members. From oldest to youngest, members of the DeForest Formation were named Soetmelk, Watkins, Hatcher, Mullenix, and Turton (Table 1). A sixth unit, post-settlement alluvium, was recognized but not given formal status within the model (Bettis 1990). The original model was restricted to the Loess Hills region of western Iowa (Daniels at al 1963, Bettis 1990).

Bettis and Littke (1987) and Bettis (1990) refined the DeForest Formation with four significant modifications (Table 1). First, through investigations in various basins, including more than 130 radiocarbon dates, the DeForest Formation was extended to include Holocene alluvial deposits throughout Iowa. Second, the Soetmelk Member, as defined in 1963, was subsequently recognized as late Wisconsinan loess and related alluvium in large valleys (Bettis 1990), and thus it was excluded from the model. In some reports these late Wisconsinan sediments were informally named "pre-Gunder" deposits (e.g., Bettis et al. 1992). However, this nomenclature is no longer used (Bettis, 2005, personal communication). Third, the Watkins and Hatcher members were re-assigned as beds within the newly established Gunder Member, while the Mullenix and Turton members were re-assigned as beds within the new Roberts Creek Member (Bettis and Littke 1987, Bettis 1990). While the Gunder and Roberts Creek members are recognized throughout

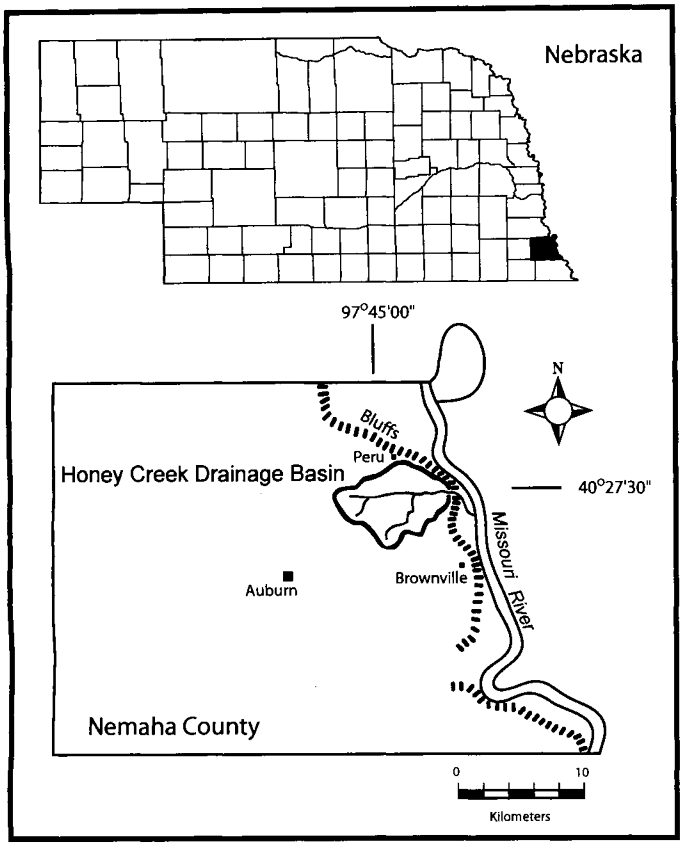

Fig. 1. Location of Honey Creek drainage basin in southeastern Nebraska.

the state of Iowa, they are only subdivided into beds in the area of thick loess in the western part of the state. This area, known as the Loess Hills region of Iowa, is a narrow band (4–16 km wide) along the margin of the Missouri River valley, and includes loess deposits up to 62 m thick (Bettis et. al. 1986, Prior 1991). In the Loess Hills region, streams tend to produce vertically stacked gulley fills that allow for detailed mapping of individual beds (Bettis 1990). Finally, two new members, the Corrington and Camp Creek members were defined. The Corrington Member was introduced to include Holocene alluvial fan deposits and colluvium along valley margins. The Camp Creek Member was introduced to include distinct deposits composed of Historic sediment (Bettis and Littke 1987, Bettis 1990). In addition, Bettis et al. (1996) modified the DeForest Formation to accommodate the landform-sediment assemblages associated with late Wisconsinan glacial tills of the Des Moines Lobe in central Iowa. In this paper, we focus on alluvium derived mostly from loess, and hence use the nomenclature of Bettis (1990).

Although small alluvial fans and colluvial aprons (the Corrington Member) are present within Honey Creek basin, our investigation focuses on terrace and floodplain fills. Detailed descriptions of the lithic and soil characteristics of the DeForest Formation as defined in western Iowa are provided in Bettis (1990), in southeastern Nebraska by Mandel and Bettis (2001), in eastern Iowa by Bettis et al. (1992), and in southeastern Iowa by Bettis and Littke (1987:Table 1, p. 15).

ENVIRONMENTAL SETTING

Honey Creek drainage basin is located in southeastern Nebraska (Figs. 1,2), which is part of the Glaciated Central Lowlands of North America (Madole et al. 1991). In this region, upland surfaces are underlain by late Quaternary loess and alluvium and Pre-Illinoian tills and alluvium resting on Paleozoic bedrock (Reed and Dreeszen 1965, Bettis et al. 1986). Streams occupy deep valleys that are cut into bedrock and partially filled with Pleistocene and Holocene alluvium.

Table 1. The DeForest Formation as defined by Daniels et al. (1963), and re-defined by Bettis and Littke (1987) and Bettis (1990).

			Approximate Age[2,3]	
Daniels et al. (1963)	Approximate Age[1]	Bettis (1990)	Small Valleys[4] (<4th order)	Large Valleys[4] (>3rd order)
Postsettlement Alluvium	Historic	Camp Creek Member	<150	<500
		Roberts Creek Member		
Turton Member	250–76	Turton bed	800–150	1,300–500
Mullenix Member	1,000 - >250	Mullenix bed	1,800–1,000	3,800–1400
		Corrington Member[4]		8,700–3,000
		Gunder Member		
Hatcher Member	2,020–1,800	Hatcher bed	3,500–2,000	10,000–4,000
Watkins Member	11,000–2,020	Watkins bed	10,500–8,000	11,500–7,000
Soetmelk Member	14,300–11,000	late-Wisconsinan loess and alluvium	>11,500	>11,500

[1]Radiocarbon years before present, based upon 7 radiocarbon ages reported in Daniels et al. (1963)
[2]Radiocarbon years before present, from Bettis (1990)
[3]Note time-transgressive nature of fills
[4]Stream orders defined after Strahler (1952)
[5]Alluvial fan deposits where small valleys merge with large valleys

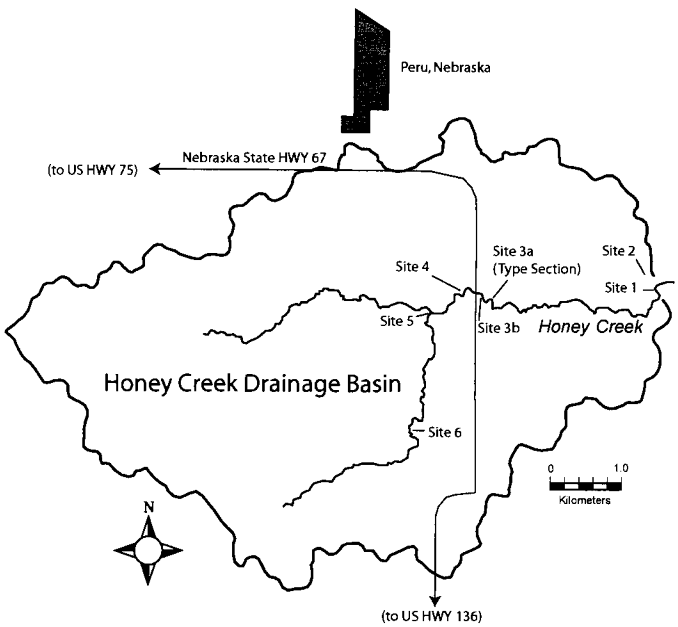

Fig. 2. **Honey Creek basin with locations of detailed study sites.**

Honey Creek is a 4th-order perennial stream draining approximately 37.6 km^2 and emptying into the Missouri River. In the middle and lower portions of the basin, the valley bottom is dominated by a single, broad, relatively flat surface approximately 200–300 m wide (Figure 3a). The modern Honey Creek channel and lower portions of tributary channels have entrenched 4 to 7 m below this surface; thus it is informally labeled the T-1 terrace (Figure 3b). Within the narrow, entrenched channel belt are active point bar and channel bar deposits along with numerous small, unpaired, discontinuous surfaces that are vegetated but frequently inundated. This assemblage of bar deposits and relatively stable surfaces is referred to as the T-0 complex (Figure 3b). Along many reaches of the entrenched channel margin, a low natural levee is present on the T-1 surface. Colluvial aprons and small alluvial fans are present along the valley margins where the T-1 surface merges with the uplands. Along the west to east-flowing trunk stream the valley is asymmetric, with gentle south-facing slopes and steep, forested north-facing slopes. The modern channel flows along the southern margin of the valley bottom through most if its course. South-facing slopes are mostly in crops or pasture, with dense riparian vegetation and forest along small tributary streams. Paleozoic bedrock and overlying Quaternary deposits are exposed along north-facing escarpments where meander bends have cut into the uplands. Loess thickness in Honey Creek basin and the region ranges from less than 1 m to about 9 m in places (Burchett and Smith, 1989, Dillon, 1992). Relief in the lower portion of the basin ranges from 30 to 55 m.

The basin is located within a moist, sub-humid, continental climate (Thornthwaite 1948) characterized by cold winters and hot summers. Average monthly temperatures range from -4.9°C in January to 25.3°C in July (Kerl, 1985). The mean annual precipitation at the nearby Auburn, Nebraska weather station is 86.6 cm for the period 1951-80 (Kerl 1985). The pre-settlement vegetation in the region is mapped as a mosaic of oak-hickory forest and tall-grass prairie (Kuchler 1964, Kaul and Rolfsmeier 1993, Baker et al. 2000). The oak-hickory forest is located on steep slopes, in ravines, and along stream channels. The tall grass prairie occurs on uplands and gentle slopes with silty and clay-rich soils (Kerl 1985, Kaul and Rolfsmeier 1993).

METHODS

Alluvial landforms were mapped using aerial photographs and USGS 7.5 minute topographic maps. Extensive streambank exposures were examined in the field. Six sections were selected for detailed description and sampling (Fig. 2). A Giddings hydraulic soil probe was used to collect 14 continuous, 5 cm-diameter cores along four transects. Lithologic descriptions of selected exposures and cores follow standard methods and terminology outlined by Allen (1970) and Birkeland (1984, 1999), and descriptions of surface and buried soils follow standard soil terminology (Soil Survey Staff 1993). Samples from selected alluvial deposits and soil horizons were submitted to the Kansas State University Soil Characterization Laboratory for particle-size analysis and determination of total carbon content. Particle-Size analyses were conducted using the modified pipette method of Kilmer and Alexander (1949) and Soil Survey Staff (1982). Total carbon was determined by combustion using procedures described in Tabatabai and Bremner (1970). Wood, charcoal, and bulk sediment samples were submitted to the University of Texas Radiocarbon Laboratory (Table 2). The samples were pretreated with 2% HCl and 2% NaOH prior to radiocarbon analyses. At the time these samples were analyzed (1991), $\delta^{13}C$ correction was not standard practice unless specifically requested. However, with the exception of two dates, all radiocarbon ages are $\delta^{13}C$ corrected.

RESULTS

Four lithologically distinct Holocene stratigraphic units are recognized in the upper portions of the Honey Creek valley fill. The units are identified on the basis of color, primary sedimentary structures, pedogenic development, and stratigraphic position. Three of the units are correlated with the Gunder, Roberts Creek and Camp Creek members of the DeForest Formation. The fourth unit consistently includes colors, primary sedimentary and pedogenic structures that, in combination, are not described in other members of the DeForest Formation. This unit is the newly established Honey Creek Member. Physical and pedogenic properties of the DeForest Formation, along with their temporal relationships as they occur in Honey Creek basin, are summarized in Table 3.

Although the Honey Creek and Roberts Creek members both occur as fills inset into the Gunder Member, the stratigraphic relationship between them is not clearly revealed in Honey Creek basin. However, the Honey Creek Member comprises most of the late Holocene fill in the lower and middle portions of the basin, while the Roberts Creek Member is only identified in the upper reaches of the drainage, and as discrete gully fills which extend from small, upland tributaries across the T-1 surface. In addition, radiocarbon ages from the basin suggest that the Honey Creek Member is older than the Roberts Creek Member.

Lithology and Bedding Features

At its type section (Figs. 3b, 4, and Table 4) the Honey Creek Member is composed of brown (10YR 5/3-4/3) to dark grayish brown (10YR 4/2) and dark gray (10YR 4/1) silt loam and gravelly loam. Two alluvial facies are consistently present in exposures of the Honey Creek Member. The lower facies includes bedded silt loam, sandy loam, and poorly sorted gravelly loam with lenticular, loamy gravel beds up to 1 m thick. The bedding

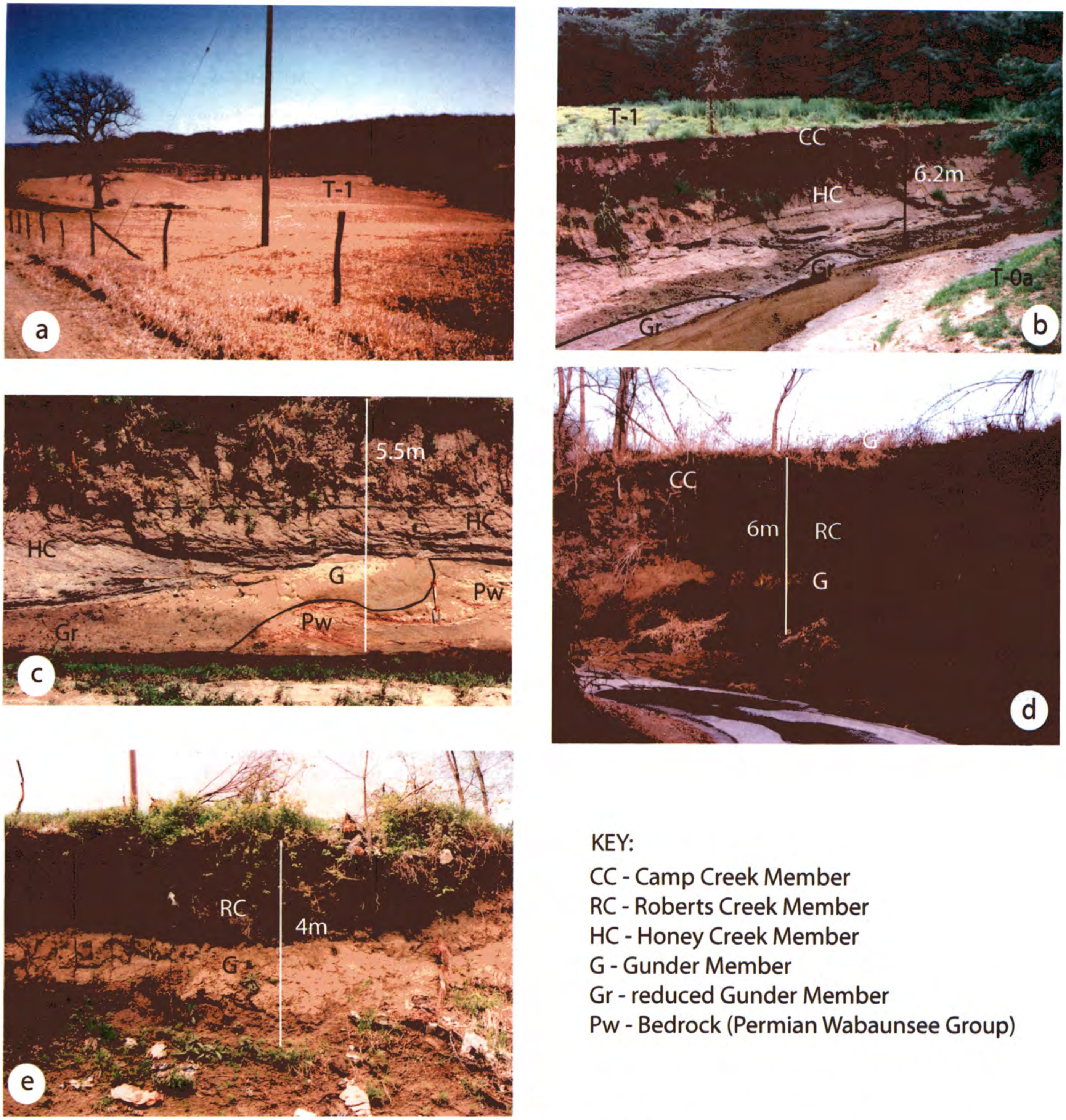

Fig. 3. (a) Honey Creek basin with steep north-facing bluffs. View is to the SE. (b) Type section of the Honey Creek Member at Site 3a. Note the grayish brown colors and prominent, large-scale cross bedding. (c) Honey Creek Member, oxidized and reduced Gunder Member, and bedrock at Site 3b. Note the clear, erosional contact betwee the Honey Creek and Gunder members. (d) Camp Creek, Roberts Creek and Gunder members at Site 6. Note the massive, very dark gray alluvium of the Roberts Creek Member. (e) Roberts Creek gully fill inset into Gunder Member at Site 4. Again, note the dark color and lack of cross bedding in the Roberts Creek Member.

Table 2. Radiocarbon ages determined on materials from Honey Creek Basin.

Stratigraphic Unit[1]	Location	Depth Below T-1 Surface (m)	Material Dated	Radiocarbon Age (RCYBP)[2]	Laboratory Number
CC	Site 4	3.96	Wood	Modern	TX-7346
CC	Site 4	3.65	Wood	630 ± 70	TX-7345
RC	Site 6	2.58	Charcoal	1150 ± 200	TX-7315
HC	Site 3a	1.01–1.14	Upper portion of buried soil	720 ± 70	TX-7143
HC	Site 3a	1.77–1.90	Lower portion of buried soil	1860 ± 70	TX-7142
HC	Site 5	4.50–4.55	Charcoal	1690 ± 90	TX-7343
HC	Site 3b	4.40–4.45	Wood	1870 ± 60	TX-7344
HC	Site 3a	4.25–4.30	Charcoal	2900 ± 60[3]	TX-6849
HC	Site 3a	7.00–7.20	Wood	3690 ± 70[3]	TX-6848
G	Site 6	4.25–4.35	Sediment	5240 ± 110	TX-7372
G	Site 4	4.60–4.65	Charcoal	8560 ± 110	TX-7373

1. Members of the DeForest Formation: CC = Camp Creek; HC = Honey Creek; RC = Roberts Creek, G = Gunder
2. All ages in uncalibrated radiocarbon years before present
3. Not C-13 corrected

typically includes large-scale trough cross-stratification and some epsilon cross-stratification (Figs. 3b and 3c). Climbing ripple lamination is also common in the bedded facies. Fine-grained beds in the lower facies are typically calcareous with reduced colors, including pale olive (5Y6/3), olive (5Y4/3) and very dark gray (5Y3/2). Faint, light olive-brown (2.5Y5/4) and dark yellowish brown (10YR4/4) mottles occur in the fine-grained beds in the lower portions of the member. Coarser beds are frequently poorly-sorted, with a pale olive (5Y6/3) calcareous matrix and common, distinct dark reddish brown (5YR3/3) and black (7.5YR2/0) stains. Gastropods (*Physa, Helisoma, Fossaria, Stenotrama,* and *Anguispira*) and pelycypods (*Sphaerium*) are common (genera identifications by Richard E. Oches, 1991, personal communication). Organic debris including wood, leaf mats and charcoal are common, with wood often occurring as logs greater than 5 cm in diameter.

The bedded lower facies of the Honey Creek Member grades upward to massive and finely laminated silt loam with few gastropods and charcoal fragments. The upper facies include lighter, oxidized colors (10YR5/3, 5/2, 4/2) and evidence of bioturbation in the form of krotovina, common earthworm chambers with casts, and disrupted laminae. A prominent, cumulic soil with A-Bw horizonation is formed in the upper portions of the fill (Figs. 3b, 4). Total thickness of the A horizons typically exceeds 70 cm, with very dark gray to black (10YR 3/1-2/1) matrix colors. The Bw horizon exhibits weak, subangular blocky structure with patchy light gray (10YR 7/2-6/2) silt coatings on ped faces. Multiple entrenched channel fills with abrupt, concave lower boundaries often occur within the Honey Creek Member. However, these channel fills exhibit the same sequence of facies and colors as the unit as a whole. At most exposures, the Honey Creek fill is at least 3 to 5 m thick.

Particle size analyses on the < 2 mm fraction yielded silt loam for all samples run. This is consistent with the poor degree of soil development in the Honey Creek Member. The total sand fraction at the type section does indicate a fining-upward sequence within the Honey Creek member (Fig. 4). However, it is important to note that the lower portion of the Honey Creek Member often includes beds of poorly-sorted sand and gravel with silt loam matrix.

The lithology and bedding features of the Honey Creek Member distinguish it from the other members of the DeForest Formation. Most significant to the comparison is the poorly sorted, large scale cross-stratification in the lower portion of the Honey Creek Member (Figs. 3b,3c). This facies is identified at exposures *throughout* Honey Creek basin and in basins across the region (e.g., Dillon 2004b, Mandel and Bettis 2003), yet other members of the DeForest Formation do not include such bedding styles. Channel facies and lower portions of the Roberts Creek and Gunder members mostly include horizontally bedded sand and silt, or thin sand and gravel lenses (Bettis 1990, Bettis et al. 1992, Mandel and Bettis 2001). Sections that exhibit trough cross-bedding typically include thin beds of clean, well-sorted sands and gravels that grade upward into the fine-grained facies with the characteristic dark gray or yellowish brown matrix colors (Bettis, 1990, Bettis et al. 1992). observations also apply to the Mullenix bed of the Roberts Creek Member, which is only mapped in vertically-stacked gully fills in the thick loess region of western Iowa (Bettis 1990). Along with its lithologic differences, the Honey Creek Member occurs over a much broader area.

Gunder Member alluvium includes more strongly oxidized matrix colors compared to the Honey Creek Member (Table 3; Figs. 3c,3d,3e). The Roberts Creek Member, on the other hand, consists of massive silt loam with much lower chroma and value (i.e., it is darker because of a higher organic matter content) compared to the Honey Creek Member (Table 3; Figs. 3d, 3e). Thus, the typical grayish brown color of the Honey Creek Member is intermediate between the yellowish brown of the Gunder Member and the dark gray of the Roberts Creek Member.

The soils developed in the Honey Creek and Roberts Creek members are morphologically similar. However, like their respective alluvial parent materials, the soil formed in the Roberts Creek Member is darker and typically not as thick as the soil formed in the Honey Creek Member. Both soils show a lesser degree of development (A-Bw profiles) than soils formed in the Gunder Member, which typically has an argillic (Bt) horizon (Table 3).

The overbank facies of the Camp Creek Member is readily distinguished from the Honey Creek Member by its typically higher chroma, thin, horizontal bedding, and minimal degree of soil development (Table 3). Soils in the Camp Creek Member are Entisols with weak A-C horizonation. In addition, there is usually a notable difference in field consistence between the soft, friable Camp Creek Member and the hard, friable older members

Table 3. Physical, pedological, and chronological properties of the DeForest Formation in Honey Creek Basin, southeastern Nebraska.

	Gunder Member	Honey Creek Member	Roberts Creek Member	Camp Creek Member
Thickness	unknown but > 6 m	typically 3 to >6 m	1–2 m	typically < 1 m
Dry, Non-Reduced Matrix Color	yellowish brown (10YR5/6) to brown (10YR5/3)	brown (10YR5/3-4/3) to dark grayish brown (10YR4/2) and dark gray (10YR4/1)	very dark gray (10YR3/1) to grayish brown (10YR5/2)	brown to dark brown (10YR5/3-3/3) and dark grayish brown (10YR4/2)
Texture	silt loam and sandy loam, few sand lenses	silt loam, sand loam and gravelly loam; few lenticular gravel lenses	silt loam	silt loam, sand and gravel
Bedding Styles	mostly massive with some thin, discontinuous horizontal bedding and small-scale cross-bedded sand and gravel lenses	large-scale trough cross-stratification and epsilon cross-stratification grading upward to massive. Climbing-ripple lamination common	mostly massive with some thin horizontal bedding and laminated silt; common rip-up clasts from underlying Gunder alluvium	thin, horizontal bedding with cross bedding in bar deposits
Horizonation	A-Bt-BC-C	A-Bw-BC-C	A-Bw-BC-C	A-C
Thickness of A Horizon(s)[1]	>31 cm to >90 cm	>27 cm to >56 cm	>20 cm->58 cm	5–25 cm
B Horizon Structure	moderate fine prismatic parting to fine angular blocky, and moderate fine subangular blocky. Also coarse prisms and slabs similar to loess	weak, fine and medium subangular blocky	weak, fine prismatic parting to fine subangular blocky	no B horizon - weak, coarse platy structure common in A and C horizons
Mottling (oxidized portions)	brown (10YR5/3), yellowish brown (10YR5/4-5/6), grayish brown (10YR5/2)	brown (10YR5/3-5/4), dark yellowish brown (10YR4/6), dark brown (10YR3/4)	dark gray (10YR3/1-3/2) and brown to yellowish brown (10YR5/3-5/4)	none
Mottling (reduced protions)	dark brown (10YR3/3), dark gray (5Y4/1), olive yellow (2.5Y6/6), light olive gray to pale olive (5Y6/2-6/3)	light olive brown (2.5Y5/4-6/4), dark reddish brown (5YR3/3-3/4),	not observed	none
Age[2]	ca. 8,560 to 5,240 yr B.P.	ca. 3,700 to ca. 600 yr B.P.	ca. 1,200 to 500 yr B.P.	less than ca. 600 through Historic

[1]A horizon thickness does not include transitional, AB horizons, and hence represent minimum ranges
[2]All ages are in uncalibrated radiocarbon years before present. Ages of members based upon data collected in Honey Creek Basin

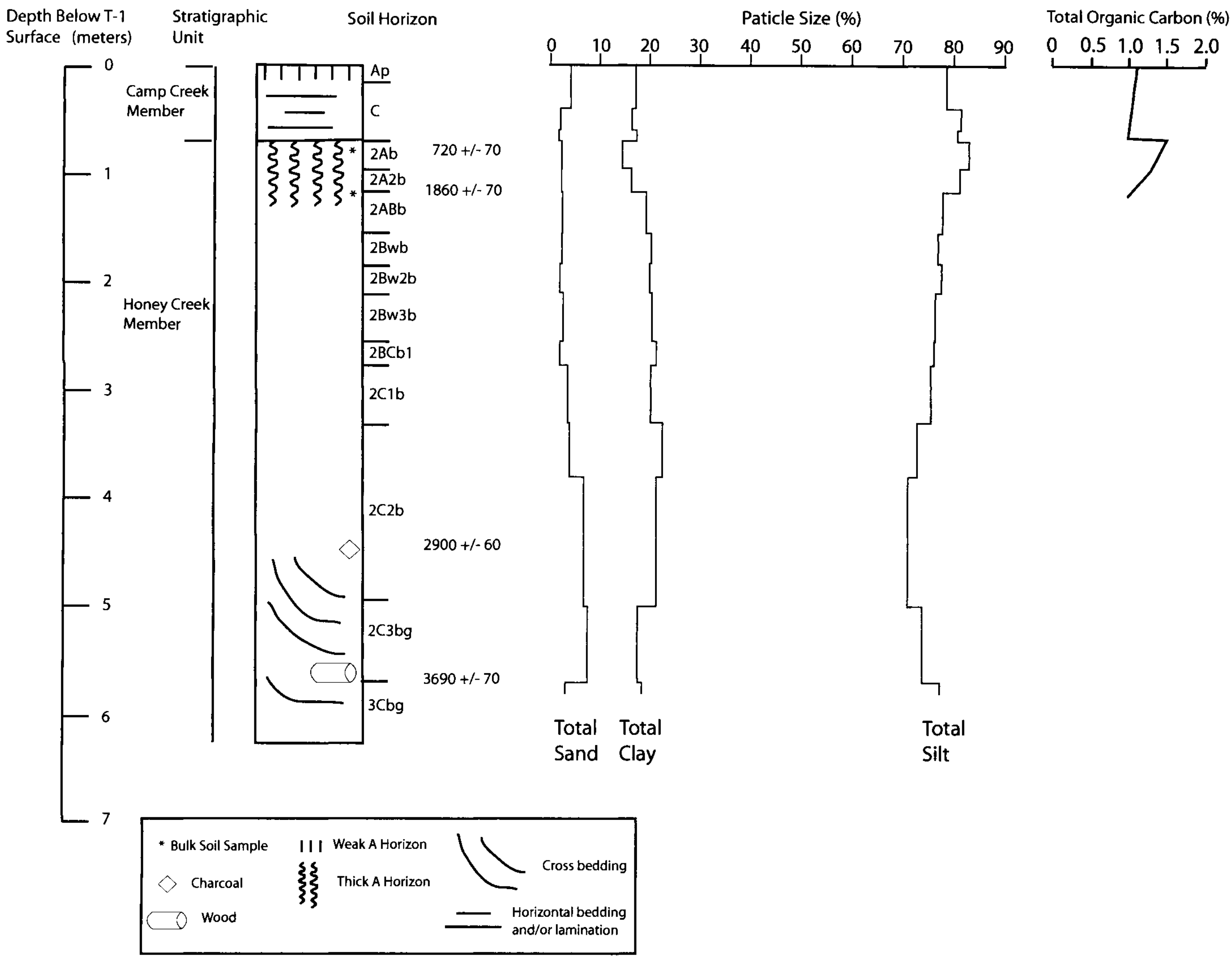

Fig. 4. Soil-stratigraphic relationships and laboratory data from the type section of the Honey Creek Member.

of the DeForest Formation. Finally, channel facies, and occasionally the overbank facies of the Camp Creek Member include re-deposited Historic artifacts such as brick fragments and colored glass, which are absent in older members.

Stratigraphic Position

The Honey Creek Member is typically identified in the lower and middle reaches of trunk streams. At the type locality, it occupies a broad paleovalley (approximately 100 m wide and 4 to 7 m deep) with multiple channel fills cut into the Gunder Member (Figure 5). The bedding style, facies relationships and geometry of the Honey Creek Member indicate an actively migrating stream, consistent with its broad, shallow valley cut into older sediments (e.g., Brakenridge 1984).

Lower boundary

At the type locality, and in basins throughout the region, the lower boundary of the Honey Creek Member is an erosional, disconformable contact with the underlying Gunder Member (Figs. 3c,5). The erosional nature of the contact is verified through radiocarbon age determinations and the common presence of krotovina and pedogenic features in the underlying Gunder Member, indicating that a former soil has been stripped (e.g., Bettis 1990, Dillon 1992, Mandel and Bettis 2001). Although it is often inset into the Gunder Member, the Honey Creek Member has also been observed in contact with older deposits such as late Wisconsinan loess and alluvium, and bedrock (Fig. 3c). It has not been seen in contact with the Roberts Creek Member. Instead, both deposits occur as separate channel fills cut into the Gunder Member (e.g., Mandel and Bettis 2001, 2003, Dillon 2004b).

Upper boundary

The upper boundary of the Honey Creek Member is typically marked by a prominent soil with a cumulic A horizon and a Bw (cambic) horizon. A similar soil occurs in the upper portions of the Roberts Creek Member, and can be traced throughout Honey Creek basin. Many earlier reports informally refer to this soil as the "pre-settlement soil" (e.g., Bettis 1990).

Table 4. Detailed description of the type section for the Honey Creek Member of the DeForest Formation.

Location: se, nw, nw, ne, Section 34, T. 6N, R. 15E, Nemaha County, Nebraska
Landscape Position: T-1 terrace exposure along south-facing cutbank
Estimated Slope: <1%
Vegetation: Formerly plowed field now in pasture
Described by: Jeremy S. Dillon
Date Described: 10/15/91
Comments: This profile is shown in Figure 3b. The contact between the Honey Creek Member and the underlying reduced, Gunder Member is erosional and irregular across the section. The thickness of the Honey Creek Formation at this locality ranges from approximately 5 to 8 meters.

Depth (cm)	Soil Horizon	Description
		DEFOREST FORMATION - CAMP CREEK MEMBER
0–15	Ap	Brown to dark brown (10YR5/3-3/3) silt loam; very dark grayish brown (10YR3/2) moist; weak, coarse platy structure parting to fine and medium granular; soft, friable, abundant fine roots; few fine pores; few casts; non effervescent; clear, smooth boundary.
15–70	C	Brown to dark brown (10YR5/3-3/3) horizontally stratified silt loam; very dark grayish brown to very dark gray (10YR3/2-3/1) moist; few yellowish brown (10YR5/6) stains and fine faint mottles; massive parting to weak coarse platy structure; soft, friable; common fine and medium roots; abundant casts; abundant fine and medium pores; thin bedded and laminated; laminae pale brown (10YR6/3) and disrupted by bioturbation features; stratification becomes more prominent in lower 20cm; non effervescent; abrupt, smooth boundary.
		DEFOREST FORMATION - HONEY CREEK MEMBER
70–95	2Ab	Very dark gray (10YR3/1) silt loam; black (10YR2/1) moist; fine to medium granular structure; soft, friable; few fine roots; abundant fine and common medium pores; abundant casts; non effervescent; clear, smooth boundary.
95–117	2Ab2	Very dark gray to very dark grayish brown (10YR3/2-3/3) silt loam; very dark gray (10YR3/1) moist; fine to medium granular structure; soft, friable; few fine roots; common fine and few medium pores; abundant casts; non effervescent; gradual, smooth boundary.
117–155	2ABb	Dark grayish brown to dark brown (10YR4/2-3/3) silt loam; very dark grayish brown (10YR3/2) moist; weak medium subangular blocky structure parting to fine granular; slightly hard, friable; few fine and medium roots; few fine and medium pores; abundant casts; non effervescent; gradual, smooth boundary.
155–183	2Bwb	Brown to dark grayish brown (10YR4/3-4/2) silt loam; dark brown (10YR3/3-4/3) moist; weak fine to medium subangular blocky structure; hard, friable; few fine pores; few casts; discontinuous, few light brownish gray (10YR6/2) patchy silt coatings on ped faces; few 3 cm–8 cm diameter burrows filled with grayish brown to dark brown (10YR5/2-3/3) granular silt loam; non effervescent; clear, smooth boundary.
183–210	2Bw2b	Dark grayish brown to brown (10YR4/2-4/3) silt loam; dark grayish brown to dark brown (10YR4/2-3/2) moist; weak fine to medium subangular blocky structure; hard, friable; few fine pores; rare casts in 1 cm–2 cm diameter chambers; few light brownish gray (10YR6/2) patchy silt coatings on ped faces; few burrows 5 cm–10 cm diameter filled with grayish brown to dark brown (10YR5/2-3/3) granular silt loam; non effervescent; gradual, smooth boundary.
210–255	2Bw3b	Brown to grayish brown (10YR4/3-5/2) silt loam; dark brown (10YR3/3) moist; weak fine subangular blocky structure; hard, friable; few fine pores; few fine casts; very few light brownish (10YR6/2) gray patchy silt coatings ; few faint, discontinuous dark grayish brown (10YR4/2) silt coatings; non effervescent; gradual, smooth boundary.
255–277	2BCb	Brown (10YR 5/3-4/3) to dark grayish brown (10YR4/2) silt loam; dark grayish brown to dark gray (10YR4/2-4/1) moist; massive; few charcoal flecks; non effervescent; clear, smooth boundary.
277–330	2Cb	Dark brown to very dark gray (10YR3/3-3/1) stratified silt loam; very dark gray (10YR3/1) and dark gray (10YR4/1) moist; dark yellowish brown (10YR4/4) and black (10YR3/1) mottles; dark reddish brown (5YR3/4) and black (10YR3/1) FeO and MnO stains; laminated and thin bedded; laminae pale brown to light yellowish brown (10YR6/3-6/2); massive; soft, friable; few fine roots; few fine to medium pores, some filled with casts; non effervescent; gradual, curved boundary.

Table 4. Continued

Depth (cm)	Soil Horizon	Description
330–490	2Cb2	Grayish brown (10YR5/2), dark gray (10YR4/1) and very dark gray (10YR3/1) stratified silt loam; very dark gray (10YR3/1) moist; common dark brown to reddish brown (7.5YR3/4 - 5YR3/4) stains; common light olive brown (2.5Y5/4) mottles; pale brown (10YR6/3) laminae throughout; many charcoal flecks; common gastropods and pelecypods; bedding thickens downward; lower 50 cm include poorly-sorted loamy gravel beds; at 410 cm to 490 cm poorly sorted, calcareous loamy gravel; clasts are mostly derived from local bedrock (calcareous siltstone, fine sandstone, limestone); loamy matrix pale olive (5Y6/3), dark reddish brown (5YR3/3), and dark gray (10YR4/1) with common dark reddish brown (5YR3/3) stains; strongly effervescent; abrupt, irregular lower boundary.
490–550	2C3bg	Bedded olive to very dark gray (5Y3/3-3/0) silt loam and gravelly loam; light brownish gray laminae in places; common dark yellowish brown (10YR4/4) to dark brown (7.5YR3/4) mottles; loamy gravel beds include common dark reddish brown (5YR3/3) and black (7.5YR2/0) FeO and MnO stains; common gastropods and pelecypods; olive silt slightly effervescent; dark gray silt non effervescent, gravel beds strongly effervescent; abrupt, irregular boundary.
		DEFOREST FORMATION - GUNDER MEMBER (reduced)
550–620	3Cbg	Yellow (2.5Y6/6) to brownish yellow (10YR6/6) silt loam; dark gray to olive gray (5Y4/1-5/2) moist; common olive (5Y6/5), black (2.5Y2/0), and few dark reddish brown (5YR3/3) mottles; massive; lower boundary below water level.

The Honey Creek Member is frequently mantled by overbank facies of the Camp Creek Member. The overbank facies of the Camp Creek Member may bury the soil formed in the upper portion of the Honey Creek Fill, or at some localities, the soil has been truncated and there is an erosional contact. Where the Camp Creek Member is absent, the soil in the upper portion of the Honey Creek Member is the surface soil on the modern landscape.

The stratigraphic relationship between the Roberts Creek and Honey Creek members is not clearly revealed in Honey Creek basin. However, at the type locality the Honey Creek Member occurs in the lower and middle portions of the basin, while the Roberts Creek Member is only identified in the upper reaches of the drainage, and as discrete gully fills which extend from small, upland tributaries across the T-1 surface. In addition, more recent studies indicate that both the Honey Creek and Roberts Creek members occur as discrete fills set into the Gunder Member (e.g., Dillon 2000b, Mandel and Bettis 2003). Finally, radiocarbon ages indicate that the Honey Creek Member is older than the Roberts Creek Member.

Chronology

Eleven radiocarbon ages were obtained on various materials from Honey Creek basin (Table 2). Six radiocarbon ages were determined on materials from the Honey Creek Member. At Site 3a, the type section yielded four superposed ages (Fig. 4). Wood recovered from poorly-sorted, cross-bedded sediments near the base of the section (about 7 m below the T-1 surface) yielded an age of 3,690 ± 70 yr B.P. Charcoal collected at the transition between the bedded lower facies and the overlying fine-grained, massive facies was dated at 2,900 ± 60 yr B.P. Also, two bulk samples were obtained from the buried soil in the upper portion of the deposit. Laboratory pretreated, decalcified organic carbon from the lower 12 cm of the buried A horizon yielded a radiocarbon age of 1,860 ± 60 yr B.P., while the upper 12 cm of the A horizon yielded an age of 720 ± 70 yr B.P. In addition, wood collected from the base of a concave channel fill located approximately 100 m upstream from the type section yielded a radiocarbon age of 1,870 ± 60 yr B.P. Finally, charcoal

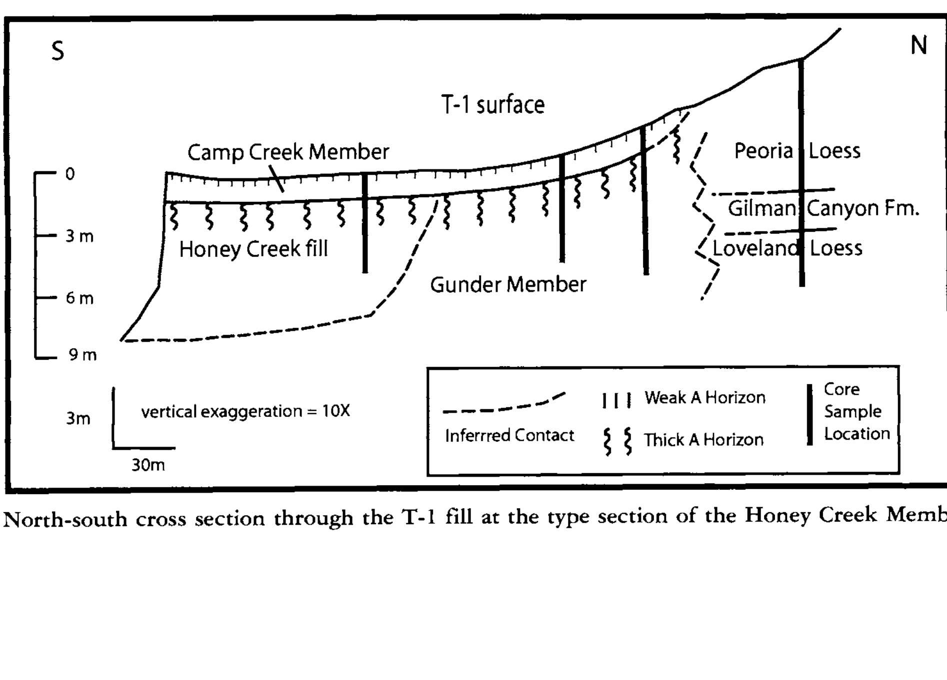

Fig. 5. North-south cross section through the T-1 fill at the type section of the Honey Creek Member (site 3).

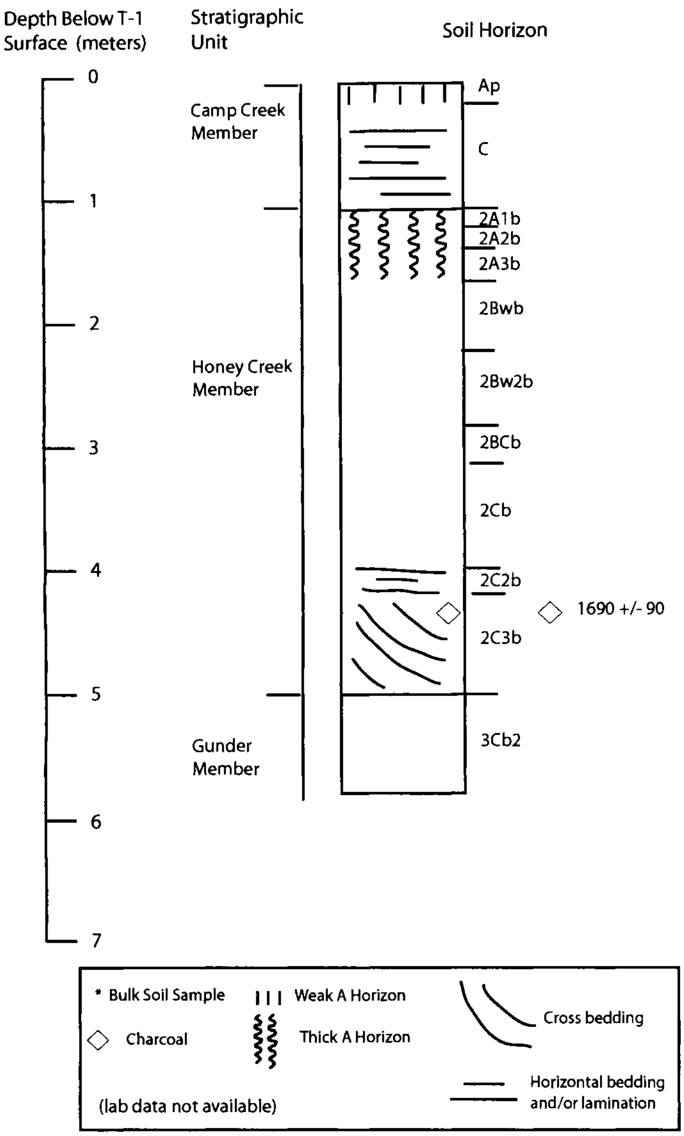

Fig. 6. Soil-stratigraphic relationships for a boundary-stratotype of the Honey Creek Member at site 5.

collected from the lower facies of the Honey Creek fill (Fig. 6) at Site 5 yielded a radiocarbon age of 1,690 ± 90 yr B.P. At this location, and at sections farther upstream, the erosional contact between the Honey Creek fill and the underlying, yellowish brown oxidized Gunder alluvium is clearly visible.

The Honey Creek Member consistently yields late Holocene (ca. 3700 to 600 ^{14}C yrs B.P.) ages within drainage basins across a wide area (Dillon and Mandel 1997, Mandel and Bettis 2003, Dillon 2004b). These ages are also supported by diagnostic archeological materials recovered from the unit (e.g., Mandel 1994, Mandel and Bettis 2001). These late Holocene ages are further supported by the degree of soil development in the upper portion of the deposit. In the Midwest, many studies have demonstrated that soils in alluvium with A-Bw profiles are typically less than about 2,000 years old, while soils with A-Bt horizonation are typically older (e.g., Bettis 1990, 1992, Mandel and Bettis 1995, 2001). The late Holocene age of the Honey Creek Member and the well-established Holocene chronology of the DeForest Formation are confirmed by numerous studies in basins across the eastern Great Plains region (e.g., Mandel and Bettis 1995, 2001, 2003, Dillon 2004b).

DISCUSSION

When the Honey Creek fill was initially described in southeastern Nebraska, the regional extent of the deposit was unknown; thus it was only recognized as an informal unit (Dillon 1991, 1992). Subsequent investigations in eastern Nebraska (e.g., Mandel 1996, 1999, Mandel and Bettis 2001, Dillon 2004a,b), the thick loess region of western Iowa (Bettis, personal communication), and eastern Kansas (Mandel and Bettis 2001, 2003) demonstrated its regional extent and consistent lithologic, stratigraphic, and chronologic relationships. Thus it is adopted as a Member of the DeForest Formation. Its recognition based upon objective lithologic characteristics is consistent with the definition of a lithostratigraphic unit (Dillon et al. 2001). The DeForest Formation was initially adopted for Holocene alluvial deposits in Iowa. However, the DeForest Formation (and the newly-defined Honey Creek Member) has been identified in drainage basins across a much broader region. As stratigraphic units do not end at state boundaries (Mandel and Bettis 1995) the DeForest Formation has been recognized in these states as well. Thus the Honey Creek fill was recognized as a formal, mappable member of the DeForest Formation.

As with the other members of the DeForest Formation, the consistent nature of the Honey Creek Member allows for its application to problems other than stratigraphy. For example, its distinctive lithic characteristics make it readily identifiable in the field; hence its recognition allows for rapid assessment of the likely age and potential significance of buried cultural materials (e.g., Mandel and Bettis 2001, 2003, Dillon 2004b). Plant macrofossils and other organic materials recovered from the Honey Creek Member have been used to reconstruct late Holocene paleoenvironments that concur with the stratigraphic relationships (e.g., Baker 2000, Baker et al. 2000).

In addition, the fact that the Honey Creek Member occurs over a wide area implies that regional-scale processes affected its distinctive lithology, rather than basin-specific variables. Hence, additional mapping of its distribution and relationship with other units (especially the Roberts Creek Member) may shed light upon fluvial processes and responses to various internal and external driving forces during the late Holocene.

CONCLUSIONS

The newly established Honey Creek Member is a lithologically distinct, objectively-mappable, late Holocene deposit, which consistently occurs in conjunction with, and within the framework of the DeForest Formation. The Honey Creek Member is significant because it occurs over a broad area of the Midwest, including eastern Nebraska and Kansas, northern Missouri, and in the thick loess area of western Iowa (e.g., Dillon 1992, Mandel and Bettis 2001, 2003). Hence, recognition and detailed mapping of this stratigraphic unit facilitates our understanding of fluvial behavior during the late Holocene.

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