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KANSAN PROGLACIAL ENVIRONMENT, EAST-CENTRAL NEBRASKA

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ABSTRACT. A stream bank along a tributary of Salt Creek in east-central Nebraska displays a sequence of sediments deposited along an eastward flowing stream during part of the approach and subsequent retreat of the last ice sheet to expand into this area during the Kansan glaciation. The section exposes a series of beds of calcareous silt which contain fossil-rich lenses. Sediment characteristics and the habitat requirements of 31 species of snails recovered suggest that the silts accumulated on an aggrading floodplain and probably were derived from erosion of unweathered calcareous till and calcareous wind-blown silts deposited during an earlier ice advance from outwash a short distance to the west. Aggradation of this stream is attributed to a rise of base level that accompanied deposition of outwash along the Missouri River from an advancing glacier.

A disconformity separated these fine-grained sediments from a fining upward sequence of outwash which probably was deposited along the ice margin during the retreatal phase. Glacial ice surely buried the area when its margin advanced to about 12 km west of the site, but erosion by meltwater currents removed any till that may have been left in this location. Non-glacial alluvium overlies the outwash. Post-glacial dissection created a valley a little less deep than that of the modern stream, which is partly filled with pre-Wisconsinan alluvial sediments and by Peoria (Wisconsinan) loess.

The molluscan assemblage from the floodplain silts contains a few species that indicate a Kansan age. The vegetation was dominantly grassland with patches of woodland and shrubby areas that included a few spruce trees. The environment indicated by the fossils suggests a climate a little cooler and more moist than the the present one, perhaps comparable to that in west-central Minnesota or eastern South Dakota today.

INTRODUCTION

Little is known about the environmental conditions that existed near the margins of the early Pleistocene ice sheets of North America, although glacier border conditions during the Wisconsinan glaciation have been studied extensively (Black, 1965; Denny, 1951; Frye and Willman, 1958; Grüger, 1972; Wayne, 1967). One of the reasons, undoubtedly, is the paucity of good exposures in appropriate places.

Few exposures are available in eastern Nebraska where early Pleistocene sediments that underlie the loess-covered uplands can be examined. Multiple cycles of cutting and filling of the alluviated valleys in the glaciated part of Nebraska have provided broad expanses of young (Holocene) alluvial sediments, and only rarely do meandering streams sweep against a nose of the upland where older materials are likely to exist. One exposure worthy of note has been swept clean by a meander of Middle Creek, one of the tributaries of Salt Creek (fig. 1).

Single exposures rarely provide enough data to be worth reporting; the sediment sequence in this one, however, seems to record the fluctuating advance of the last glacial ice that spread across the eastern part of Nebraska. It is my purpose to describe this exposure and to use the sedimentary sequence and snail faunules collected from the exposure to interpret environmental conditions during that last advance of glacial ice into the Salt Creek Basin.

Eastern Nebraska was covered by glacial ice repeatedly during Early Pleistocene time, and the present topography of the region is largely a result of stream dissection of the former till plain, moraine, glaciofluvial, and glaciolacustrine surfaces that came into existence when the last ice sheet to invade the area disappeared. At its maximum extent, the ice margin reached a position 120 to 140 km west of the present course of the Missouri River (Flint and others, 1959). The limit of this ice advance is known only from subsurface records in east-central Nebraska, because the till remaining from it is buried beneath about 75 m of younger gravel, sand, and loessal silt (Keech and Engberg, 1978). The most extensive ice advance clearly evident at the surface reached Blue River (fig. 1), the progenitor of which was an ice marginal river that must have carried Missouri and Platte Basin drainage around the ice margin as well as meltwater from the continental glacier. Classically, these outermost tills and the associated deposits have been regarded as Kansan in age and were called Early Kansan and Medial Kansan, respectively, by Reed and Dreeszen (1965). Tills of Nebraskan age were recognized in southeastern Nebraska and were considered to be less extensive than the younger deposits. Recent studies, however, have raised questions about the validity of some parts of this classification (Boellstorff, 1976, 1978), as well as the number of times major continental

Fig. 1. Map of southeastern Nebraska, showing major drainage lines and glacial boundaries. Arrow points to location of Middle Creek exposure. Base from U.S. Geol. Survey Map of Nebraska.

ice sheets have expanded into the upper Missouri Valley region. Because the youngest tills of east-central Nebraska have long been regarded as Kansan in age, since the glacial deposits treated in this report are the uppermost and youngest of the area, and because no other terminology has been introduced yet to replace the old, I continue to use the term Kansan stage in this report.

Most of the larger streams of eastern Nebraska flow southeastward, and many of them probably came into existence along the margin of the glacier as it melted. Maps of the buried bedrock topography of southeastern Nebraska (Burchett and Dreeszen, 1964; Burchett and others, 1972; Keech and Engberg, 1978) show a stream-cut topography that correlates only slightly with modern surface drainage. Salt Creek, which flows northeastward, unlike other major streams of the region, follows the trend of a bedrock lowland. Well records (Smith, 1961) show that the buried lowland is filled with 120 to 140 m of fine grained sediments, and many records in that area show only a single body of till — the one that caps the surface beneath a veneer of loess. Many of the sediments exposed in road cuts, stream banks, and quarry bluffs are glaciolacustrine (Stanley, 1974) or, less commonly, glaciofluvial deposits overlain by till. It is evident, therefore, that many of the valleys draining toward the east were blocked and filled with fine grained waterlaid sediments.

THE MIDDLE CREEK CUT

Middle Creek is an eastward-flowing tributary of Salt Creek and, like many of the southeastward-flowing rivers of eastern Nebraska, follows the position and orientation of an ice-marginal drainage line. Topographic and soils maps and aerial photographs indicate the existence of loess-covered terraces along Middle Creek that stand 10 to 12 m above the modern floodplain surface, some of which probably are remnants of its glacial sluiceway ancestor. The exposure that is the subject of this study is at the south end of one of those terraces.

The cut consists of two distinct parts (fig. 2). The main part contains calcareous, fossiliferous silts and clayey silts that are overlain disconformably by gravels and sands. The east end of the stream embankment and the road cut about 50 m west of it display noncalcareous sands and silts that filled a valley cut into the older sediments.

The "Valley Fill" sediments.—A massive, noncalcareous silt makes up the upper half of the alluvial fill at the east end of the embankment (fig. 2 and app., unit 23), and similar material is exposed along the road cut to the west of the main stream exposure. The soil profile on it has been mapped as Sharpsburg silty clay loam (Quandt, 1974), and the material is undoubtedly Peoria loess of Wisconsinan age. The loess rests on a buried weathered zone developed on a sandy and clayey silt that contains lenses of loose sand and gravelly sand at its base (fig. 2 and app., units 19, 20, 21, 22). This lower half of the alluvial fill rests on the sediments of the main part of the exposure along a sloping contact. The nature of the buried soil profile on it and its position beneath the

Fig. 2. Diagram of Middle Creek exposure. Numbers are units described in appendix. Lines at left of diagram are 5 m increments; vertical and horizontal scales are the same.

Peoria loess indicate that it is pre-Wisconsinan, probably Sangamonian, in age.

"Main Cut" sediments.—Two erosional unconformities separate the main part of the exposure into three sequences of sediments. The basal half of the exposure is fine grained — dominantly silts. All the invertebrate fossils and plant remains collected have come from this part of the section. It is overlain by cross-bedded gravelly sand (fig. 2). The sedimentary sequence becomes finer grained upward and culminates in a thick bed of silt and fine sand, which is overlain by sandy and clayey silt.

The lowest beds in the exposure (fig. 2 and app., beds 1, 2, 4, 5) are calcareous fine sand and silt that contain scattered snail shells, but in a few places richly fossiliferous lenses of silt and streaks of organic matter are present, along with scattered small lenses of pebbly sand (3). Fossil snails are also present in the beds near the top of the silt sequence (8, 9). Beds 6 and 7 are massive calcareous very fine sand and silt that display micro-ripple-drift cross lamination.

The base of the gravel bed (10) shows nearly a meter of relief, as if currents scoured the underlying silts and clays before and during gravel deposition. The basal part of this coarse-grained unit is cross-bedded sand with entrained pebbles and small cobbles. The cross beds are trough-shaped and indicate an eastward flow of water. The pebbles are dominantly rock types common to the northeast (table 1), although a few small armored mud balls composed of clayey till were found among the cobbles in the bed. Grain size analysis shows the sediment to be poorly sorted. Pebbles disappear above the basal 1 to 2 m, and the bedding becomes planar. The tendency to become finer grained upward continues, and the unit grades upward through interbedded silt and sand to silt (12), at the top of which concretions of chalky calcium carbonate have accumulated.

The top of the outwash silt bed is scoured; thus, its upper surface is a disconformity, and the overlying sediments are primarily a bed of clayey and sandy silt that is obscurely stratified (14). The base of the unit includes a lens of cobbly gravel (13) that has yielded a few bones and teeth of large vertebrates. The gravel lens is better sorted than is

TABLE 1
Lithologic distribution of pebbles in outwash gravel (bed 10)*

Lithology	Percent
Granites	6.5
Hornblende-quartz schist	0.6
Pink quartzite	3.2
Light gray quartzite	31.2
Graywacke (dark gray, fine-grained, quartzitic)	27.9
Chert	6.5
Limestone	1.3
Chalk	14.9
Shale, limonite, concretions, and other soft rock types	7.8

* Based on one sample of 154 pebbles, -3ϕ and larger.

the outwash lower in the exposures; it contains almost no silt or clay, and cobbles in it are larger than any in the outwash. Had this small area of alluvial sediment been large enough to have been delineated on the soil map, its soil profile probably would have been mapped in the Morrill series.

PALEONTOLOGY

Invertebrates: mollusks.—The silt beds in the lower half of the Middle Creek cut have yielded 31 taxa of land and fresh-water gastropods (table 2). Most of the sediment in the exposure is relatively barren of

TABLE 2
Middle Creek faunule; abundance, ecological niches,
climatic requirements, and geological range*

	No. of samples	No. of individuals	Percent	Ecological niche	Climatic group	Reported geologic range**
Order Basommatophora						
<i>Carychium exiguum</i> (Say)	2	51	2.2	C	ET	L. Pleist.-Hol.
<i>Fossaria</i> cf. <i>F. dalli</i> (Baker)	1	1	0.04	B	GSA	E. Plio.-Hol.
<i>Gyraulus circumstriatus</i> (Tryon)	1	1	0.04	A	GSA	M. Pleist.-Hol.
Order Stylomatophora						
<i>Stenotrema leaii</i> (Binney)	4	13	0.6	D	ET	M. Pleist.-Hol.
<i>Euconulus fulvus</i> (Müller)	1	10	0.4	D	GT	M. Pleist.-Hol.
<i>Nesovitreia electrina</i> (Gould)	2	33	1.4	D	NT	L. Plio.-Hol.
<i>N. binneyana</i> (Morse)	1	5	0.2	D	NT	?-Hol.
<i>Hawaiiia minuscula</i> (Binney)	7	158	6.7	E	GT	L. Mio.-Hol.
<i>Zonitoides arboreus</i> (Say)	1	1	0.04	D	GT	E. Plio.-Hol.
<i>Striatura milium</i> (Morse)	1	1	0.04	D	NT	L. Pleist.-Hol.
<i>Deroceras laeve</i> (Müller)	3	8	0.3	C	GT	M. Pleist.-Hol.
<i>Helicodiscus parallelus</i> (Say)	3	51	2.2	D	ET	E. Pleist.-Hol.
<i>H. singleyanus</i> (Pilsbry)	3	7	0.3	E	ST	L. Plio.-Hol.
<i>Punctum minutissimum</i> (Lea)	3	27	1.1	D	NT	L. Pleist.-Hol.
<i>Succinea</i> sp.	4	8	0.3	—	—	—
<i>Strobilops labyrinthica</i> (Say)	2	73	3.1	D	NT	L. Plio.-Hol.
<i>Gastrocopta contracta</i> (Say)	5	322	13.6	E	ET	E. Plio.-Hol.
<i>G. holzingeri</i> (Sterki)	6	271	11.4	E	NT	E. Pleist.-Hol.
<i>G. pentodon</i> (Say)	2	24	1.0	E	GT	M. Pleist.-Hol.
<i>G. proarmifera</i> Leonard	7	850	35.9	†(E)	GT	M. Pleistocene
<i>G. procera</i> (Gould)	6	117	4.9	E	ST	E. Pleist.-Hol.
<i>G. tappaniana</i> (C. B. Adams)	4	79	3.3	C	ET	L. Plio.-Hol.
<i>Pupoides albilabris</i> (C. B. Adams)	5	137	5.8	E	GT	E. Plio.-Hol.
<i>Vertigo milium</i> (Gould)	1	1	0.04	C	GT	L. Plio.-Hol.
<i>V. gouldi hubrichti</i> Pilsbry	1	1	0.04	†(C)	GT	M.-U. Pleist.
<i>V. ovata</i> Say	1	1	0.04	C	GT	E. Plio.-Hol.
<i>V. tridentata</i> Wolf	2	3	0.1	C	ET	M. Pleist.-Hol.
<i>Vallonia parvula</i> Sterki	1	7	0.3	E	ET	L. Plio.-Hol.
<i>V. perspectiva</i> Sterki	3	70	3.0	E	ST	Plio.-Hol.
<i>V. pulchella</i> (Müller)	3	29	1.2	E	NT	E. Pleist.-Hol.
<i>Cionella lubrica</i> (Müller)	2	6	0.3	D	NT	E. Pleist.-Hol.
calcareous eggs	1	3	0.1	—	—	—
	7	2369	99.98			

* See table 3 for ecological niche codes and table 4 for climatic group designations.

† Extinct forms.

** Abbreviations used: L = Lower, M = Middle, U = Upper; Mio = Miocene, Plio = Pliocene, Pleist = Pleistocene, Hol = Holocene.

shells, but in a few places small lenses of fossiliferous silt yielded large numbers of individuals. In all, I collected 7 samples of fossiliferous sediment over a period of 4 yrs. The most richly fossiliferous part collected, a lens about 5 cm thick and 1 m across in the basal part of this exposure (bed 2), yielded 1606 identifiable specimens from a bulk sample of about 3000 cc. A similar sample of a fossiliferous lens at the top of bed 7 contained 358 specimens. The total number of identifiable specimens recovered from the entire section is 2369. Six species, making up 78.3 percent of the total sample, are present in 5 or more of the 7 sampled lenses. Eleven species, constituting only 1.4 percent of the total individuals, were recovered from only one sample. Bands of carbonaceous matter were associated with most of the snail-bearing zones. A few leaves of *Picea* and *Salix* (?) along with a charophyte, some unidentified seeds, and small mammal bones and teeth, were recovered from the 3 samples that came from the lower part of the cut.

With two exceptions, a single specimen each of *Fossaria dalli* and *Gyraulus circumstriatus*, all taxa present are land snails. Two of the 31 species are extinct; the remainder have a wide distribution both geographically and geologically. Ecological, distributional, and stratigraphic data used in their evaluation are based on reports by Franzen and Leonard (1947), Leonard (1959), LaRocque (1966, 1970), Miller (1966, 1976), Hibbard and Taylor (1960), Taylor (1960), and Pilsbry (1946, 1948). Taylor (1960, 1965) has pointed out some of the important limitations in the use of Pleistocene fossil land and freshwater mollusks to make stratigraphic and paleoecologic interpretations.

The bulk of this faunule, 84.1 percent, representing 11 taxa, live on slopes or other surfaces that are sheltered but need not be wooded (tables 2, 3); the remainder require greater moisture and shade. Eight taxa, making up only 6.4 percent of the total sample, normally inhabit wet areas such as floodplains, and only two taxa, less than 0.1 percent of the total sample, are aquatic or semiaquatic forms.

TABLE 3
Ecological niche: local habitats represented by mollusks in the
Middle Creek cut

Habitat	No. of species	No. of individuals	% of the sample
A. Seasonal ponds	1	1	0.1
B. Pond or stream margins, on wet mud, in shallow pools	1	1	
C. Hygrophilic: moist plant debris, under sticks and debris; shaded areas not far from water	8	152	6.4
D. Woodland: moist areas under leaf litter, under fallen logs, in tall marsh grass	10	220	9.3
E. Sheltered areas: wooded and open slopes, shrubs, grass, rocks; not restricted to wooded areas and can tolerate less shade	11	1992	84.1

The lenticular nature of the fossiliferous parts in this exposure, coupled with the presence of species from situations that range from ponds, mud flats, and wet shaded areas to drier open slopes and uplands, suggest that most of the mollusks in this assemblage came from stream drift accumulations.

Two river drift samples collected from lenses of twigs and leaf litter on floodplains of small permanent streams in Parke and Johnson Counties, Ind., contained 5.8 and 5.7 percent aquatic species, respectively. Floodplain-inhabiting species make up 28.4 and 9.2 percent, woodland species 36.9 and 7.3 percent, and species of open sheltered areas 27.1 and 75.6 percent of each of the samples. These percentages probably reflect reasonably well the relative areas of each environment from which wash was received on the two floodplains, for the Parke County area is more heavily wooded and the Johnson County stream drains more farmland and pasture with less wooded terrain. If a similar relationship existed in the drainage area from which this Middle Creek faunule was derived, the relative number of individuals from aquatic, floodplain, woodland, and sheltered open areas suggests that most of the terrain was not forested but was prairie, much as it is today.

Eleven of the taxa and more than half the individuals in the faunule are either extinct or have such wide tolerances that they are of little value in climatic interpretation (tables 2, 4). The remainder are almost equally divided among eastern and northern assemblages. The smallest number are in the southern assemblage.

TABLE 4
Climatic group (after Miller, 1976)

Habitat	No. of species	No. of individuals	Percentage of sample
Group 1. Northern terrestrial (NT): northern species, distributed in an east-west direction; southern limits in Great Plains controlled by high summer temperatures	9	455	19.2
Group 2. Southern terrestrial (ST): limited in their northward distribution in the Great Plains by length and severity of winters	3	194	8.2
Group 3. Eastern terrestrial (ET): eastern United States; range into Great Plains seems related to available moisture	8	520	22.0
Group 4. General terrestrial (GT): wide tolerances, extinct, or data inadequate; of little value for climatic interpretation	11	1191	50.3
Group 5. General semi-aquatic (GSA): wide tolerances; distribution across Great Plains depends on existence of seasonal ponds	2	2	.1

All the non-extinct taxa in these faunules could be expected as part of the present eastern Nebraska fauna. None of the species is restricted to cooler regions nor is any limited to warmer environments. One species in it, however, *Gastrocopta procera*, present in all samples except one but rare in the two larger samples, probably could not have survived ice-marginal conditions. Only the presence of *Picea* needles in one of the samples and the absence of warmth-loving deciduous woodland species found now on the wooded slopes and floodplains in eastern Nebraska suggest a change from present climatic and vegetational patterns. The faunal assemblages recovered from the two samples that were large enough to be compared contained 15 species in common, including all the abundant ones, in approximately the same proportions. Climatic conditions, thus, must have remained unchanged during the time these sediments were deposited.

Most of the taxa in the Middle Creek faunule are geologically long ranging; they have been reported from early Pleistocene or older sediments, and they are living today. A few, however, do not, and they help place this faunule stratigraphically. *Gastrocopta proarmifera*, the most abundant taxon in this faunule, has been reported only from middle Pleistocene sediments (Leonard, 1950). Brice (1966) collected it from silts in southwestern Nebraska beneath a Yarmouth paleosol, and Wayne (1958) reported it from the pro-Kansan Cagle Silt in Indiana. Nine taxa in the faunule have been recovered only from beds of middle Pleistocene (Kansan-Yarmouth) age and younger (table 2). For 3 of these, the oldest reported occurrence is the pro-Kansan Cagle Silt of Indiana. Based on the presence of these few species of restricted age, the fossiliferous sediments in the Middle Creek cut are mid-Pleistocene, probably Kansan, in age.

Vertebrates.—A few vertebrate remains have been recovered from the gravel lens that lies beneath the soil profile at the top of the cut. In April, 1978, the calcaneum of a camel was dug from this gravel bed. Following a severe storm that caused a small mudslide in April, 1979, teeth of horse and bison were found in the slide debris on and at the base of the bluff. Additional scattered bones and teeth probably are present in the gravel, but systematic excavation probably would be needed to recover them. A few bones and teeth of small vertebrates have been recovered from some of the samples that yielded the snails. They have not yet been studied.

DEPOSITIONAL ENVIRONMENTS

The fine-grained sediments in the lower part of the exposure record a series of episodes of aggradation in the valley of a stream that probably flowed eastward, as Middle Creek now does. The sediments are obscurely stratified and calcareous, consist of silts, clays, and fine sands with a gravel lens, and contain land snails, some of which live in a marshy floodplain environment. These suggest the floodplain of a stream that is slowly aggrading to keep pace with a rising base level. The thin zones of clayey silt that contain organic matter probably mark brief

periods of stability. Bed 6 appears massive, but the lower part contains a series of micro-ripple-drift cross-laminae that resemble those described by Stanley (1974), which formed as a result of density currents in an ice marginal lake elsewhere in the Salt Creek basin.

Aggradation-dissection cycles have been common on Great Plains streams, but the sediments that have accumulated during Holocene cut-fill episodes differ from those in the Middle Creek cut. Modern valley fills rarely contain free calcite or snail remains, although carbonaceous zones are common. This difference indicates that the cause and rate of aggradation of the calcareous, snail-rich sediments of the Middle Creek cut may have differed from the modern processes that cause cutting and filling. As glacial ice expanded into the upper Missouri drainage basin 250 km or more to the north, outwash accumulation along the Missouri River would have blocked the mouths of all tributaries of the Missouri, including the Platte, to which Salt Creek is a tributary. The spasmodically rising base level would have been projected upstream along all tributaries and undoubtedly affected the stream that flowed through the present Middle Creek drainage basin. Sediments that aggraded the valley floor probably were derived from fresh, unweathered till left on the upland by glacial ice of a slightly earlier advance rather than from weathered till and loess, which is the source for noncalcareous modern valley fills. Some also may have been derived from loess blown from glacial outwash and the Platte-Missouri aggradational plain that existed along the route now followed by Blue River, a few kilometers to the west. A few of the sediments in the exposure suggest that the floodplain may have been ponded from time to time, but positive evidence of lacustrine conditions was not observed.

The top of the fine-grained sequence is uneven, as if it has been scoured by currents in the stream that deposited the gravelly sand that overlies it. The poorly sorted, cross-bedded sediment is that of a heavily loaded, rapidly flowing river. Pebble and cobble lithology in this gravel (table 1) indicate a northeast provenance (Stanley and Wayne, 1972), and the sediment pattern and structures (Saunderson, 1975) suggest deposition in a glacial meltwater channel. The sediment becomes finer grained upward, so the volume and velocity of water evidently decreased, as it would have when a glacier margin melted from the area. The horizontally stratified calcareous sands and silts record a later slower movement of glacial meltwater through this valley.

The valley of Blue River, 12 km to the west, marks the position reached by the margin of the last ice sheet to reach this part of Nebraska (fig. 1), and till deposited during this advance caps the upland adjacent to Middle Creek. This creek and most other northwest-southeast trending streams of eastern Nebraska (fig. 1) formed as drainage lines along the ice margin during brief pauses in the shrinkage of the Kansan glacier from its maximum extent. Absence of a till bed in the Middle Creek section can best be explained by erosion of the till by glacial meltwater currents that coursed through the valley before the outwash gravel was deposited.

The beds at the top of the exposure have texture and bedding characteristics similar to those observed as channel, point bar, and over-bank sediments of modern streams in the area. The largest cobbles in the gravel probably were derived from till on slopes and upland. The color, texture, and structure of the soil profile developed on this old alluvial bed indicate that it developed under warm, moist, but well drained conditions, very likely after the stream that deposited the sediments had begun to incise its valley and left these sediments perched in a terrace. Ruhe, Daniels, and Cady (1967) described soil profiles morphologically similar to this one as products of "Late Sangamon" weathering.

The sediments exposed at the east end of the stream cut and along the county road bank to the west contain alluvium deposited on the floodplain of Middle Creek after it had trenched below the early post-glacial (post-Kansan) surface. The soil profile that caps this younger alluvial part of the exposure has, in its B-horizon, strong brown colors associated with the late Sangamon weathering (app., bed 22). Debris from the B-horizon of the Morrill soil at the top of the cut extends as colluvium down the paleoslope and merges into the buried paleosol on the post-dissection alluvium (fig. 2). The noncalcareous silt overlying this buried alluvium and colluvium is Peoria loess of Wisconsinan age.

The thickness of the Peoria loess is highly variable in southeast-central Nebraska. Most upland ridges are capped with loess that is from 1 to 6 m thick, but both it and the pre-Wisconsinan soil are missing from lower slopes, evidently as a result of late Wisconsinan erosion (Ruhe, Daniels, and Cady, 1967, p. 72-76). Some gently sloping upland surfaces are not overlain by a detectable veneer of loess, although they display a strongly developed soil profile (for example, Morrill, as here, and Pawnee, on till). Presumably, loess was washed from these sites as fast as it accumulated, to be redeposited along the floodplains of the streams.

DISCUSSION AND SUMMARY

The sequence, lithology, sedimentary structures, and fossil content of the Middle Creek cut indicate that rising base level, probably a result of outwash deposition along the Missouri Valley, caused aggradation to take place well upstream on tributaries during the advance of the Kansan glacier that terminated at Blue River in east central Nebraska. The glacier margin surely had reached the Missouri drainage basin but could have been as far as 250 km from the location studied or as near as a few tens of kilometers when mollusk assemblages were buried in the sediment of the aggrading progenitor of Middle Creek. As the ice advanced across this location, erosion, probably by the glacial meltwater stream that deposited the cross-bedded gravel, destroyed younger mollusk-rich sediments that may have accumulated in this valley, as well as the till that should have been deposited over them when the ice sheet margin reached Blue River. Therefore actual ice-marginal climatic conditions cannot be determined from these sediments as they have been in the Central Lowland for the Wisconsinan glaciation (Wayne, 1967).

The present ranges of all the mollusks in the faunule overlap from eastern Nebraska to eastern South Dakota and west-central Minnesota. Absence of other warmth-loving species now in the eastern Nebraska fauna suggests that climatic and vegetational conditions resembled those of west-central Minnesota, a region of prairie, in which patches of trees and shrubs are present.

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APPENDIX

“Main cut” part of section measured in bank of
Middle Creek, Seward County, Nebr.

NW ¼ SEC. 36, T 11 N, R 4 E

Soil Horizons	Unit	Description*	Thickness
A	18	Loam, brown (7.5YR4/2 dry), granular structure, pH 6.4 (BTB), base clear	0.20 m
B21t	17	Clay loam, brown (7.5YR4/4 dry), subangular blocky structure, clay skins 0.1 mm, pH 5.8 (CPR), base clear	0.25 m
B22t	16	Clay loam, sandy, a few pebbles, yellowish brown (10YR5/6 dry), subangular blocky structure	0.15 m
B3	15	Clay loam, brown (10YR4/3 sl. moist), subangular blocky structure, clay skins 0.1 mm, pH 6.0 (CPR), base clear	0.20 m
C	14	Silt, clayey, sandy, and pebbly, dark yellowish brown (10YR4/4 sl. moist), weak blocky structure, not calcareous, obscurely stratified, thickness varies	1.0 to 2.00 m
	13	Gravel and sand, dark brown (10YR3/3) stained with limonite; a lentil present only in part of exposure; has yielded a few vertebrate bones and teeth, base abrupt, undulating	0 to 1.0 m
	12	Silt, light gray (2.5Y7/2 moist), calcareous, horizontally stratified; upper 20 cm contains abundant chalky nodules, top of unit scoured, grades into unit below	0.6 m
	11	Sand, light gray (2.5Y7/2), calcareous, consists of medium to fine sands interbedded, but weathers as a single massive unit	1.3 m
	10	Sand, coarse, pebbly, grayish brown (10YR5/2) to light yellowish brown (10YR6/4), calcareous, horizontally bedded	0.8 m

Soil horizon	Unit	Description*	Thickness
	9	Sand and gravel, grayish brown (10YR5/2) to light yellowish brown (10YR6/4), calcareous, crossbedded, graded within individual beds from gravel at base to sand at top; some beds near base contain secondary accumulations of limonite and MnO ₂ ; basal contact uneven, sharp	2.0 m
	8	Sand and silt, pale brown (10YR6/3), calcareous bedding inclined locally; contains thin lenses of silt with snail shells; entire unit locally missing through scour	1.0 m
	7	Clay, light olive brown (2.5Y5/4 to 2.5Y6/2, moist), blocky, calcareous; lenticular	1.0 m
	6	Silt, slightly clayey, brown (10YR5/3 moist), calcareous, massive, compact; upper 1.0 m contains scattered lenses of snail shells and organic matter; gradational into unit below	3.4 m
	5	Silt and very fine sand, pale brown (10YR6/3 moist), calcareous; bed looks massive, but contains ripple-drift cross laminae; base gradational	1.0 m
	4	Silt and fine sand, light gray (2.5Y7/2 moist), calcareous, massive, base sharp, undulating; contains sparse snail shells	0.2 to 0.5 m
	2/3	Silt, light brownish gray (2.5Y6/2), calcareous, laminated; small gravel lense at base in one part of exposure	1.0 m
	1	Silt, clayey, grayish brown (2.5Y5/2) in top 20 cm to light olive brown (2.5Y5/4) below top, calcareous, compact; contains sparse snail shells and iron-manganese concretions and locally, small pods of snail concentrations; lower part shows some minute cross laminations; base not exposed	2.3 m
	Total thickness of section		17.7 m

NW ¼ SEC. 36, T 11 N, R 4 E

“Valley fill” part of section measured at east end of bank of
Middle Creek, Seward County, Nebr.

Soil horizon	Unit	Description*	Thickness
A	25	Silt loam, clayey, dark grayish brown (10YR4/2)	0.2 m
B	24	Clay loam, yellowish brown (10YR5/4), sub-angular blocky structure, clear boundary	0.5 m
C	23	Silt, light yellowish brown (10YR6/4), non-calcareous, vaguely stratified to massive; unit thins abruptly toward southwest	4.5 m
Bb	22	Sand, silty, clayey, pebbly, brown (7.5YR5/4) lenticularly stratified, not calcareous, compact; grades laterally into a colluvially distorted loam that can be traced along paleoslope into B-horizon of main cut	2.0 m

Soil horizon	Unit	Description*	Thickness
C	21	Sand, silty, slightly pebbly, brown (7.5YR4/4), noncalcareous, fine and medium sand laminae about 1 cm thick	2.0 m
	20	Silt and fine sand, interbedded with lenses of med. sand, light yellowish brown (10YR6/3), laminated, noncalcareous; basal 0.5 m is silt, grayish brown (2.5YR5/2); limonitic zone at top and base of unit	2.0 m
	19	Sand, very fine, light yellowish brown (2.5YR 6/4) not calcareous	0.3 m

A similar section, differing only in minor details in the lower part, is exposed in the cut and ditch beside the road 100 m west of this exposure.

*All colors determined under field moisture conditions; pH was determined in the field by colorimetric methods, using bromthymol blue (BTB) and chlorphenol red (CPR).

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