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Palmer K. Bailey

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A PALEONTOLOGICAL STUDY OF PEDIMENT GRAVELS OF SOUTHWESTERN NORTH DAKOTA WHICH EXHIBIT EVIDENCE OF PERMAFROST ACTIVITY

A senior thesis prepared by Palmer K. Bailey for the Geology Department of the University of North Dakota in partial fulfillment of the requirements for the Degree of Bachelor of Science in Geology, Dr. Frank R. Karner, thesis advisor.

February, 1970
This Thesis submitted by Palmer K. Bailey in partial fulfillment of the requirements for the Degree of Bachelor of Science in Geology from the University of North Dakota is hereby approved by the Faculty Advisor under whom the work has been done.

[Signature]
(Advisor)
ABSTRACT

Large remnants of pediment surfaces in the unglaciated southwestern portion of North Dakota exhibit evidence of a former permafrost environment in the form of ice-wedge fillings and bedding contortions. Under proper moisture conditions the "fossil" polygonal pattern of the wedge fillings may be observed on air photos. The molluscan fauna collected from the fluvial deposits which cover the pediment surfaces indicates that there was a relatively warm, moist climate during the time of deposition. Because of paleontological, topographic, and geomorphic evidence, it is suggested that the two sites of Tuthill, Laird, and Frye (1964) are not correlative and that one of them, the Marple Ranch site, correlates with the two sites of this study. Although age determinations based upon Pleistocene mollusks are generally considered unreliable, the pediment deposits are tentatively designated as Sangamon in age and the permafrost features are considered to be early Wisconsin.
INTRODUCTION

The Pleistocene geology of western North Dakota has been almost ignored compared to the extensively studied Wisconsin glacial features in the eastern portion of the state. Stratigraphic age relationships have remained controversial because of lack of evidence and the complexity of the problems. Early workers studying western glacial drifts based age interpretations upon an assumed uniform rate of stream dissection (Leonard, 1916, p. 525). Because of complex disruption of normal drainage by the numerous glacial advances, such interpretations are now considered unreliable. More recently an attempt was made using paleontological evidence to establish the age of a river terrace in Grant County (Tuthill, Laird, and Frye, 1964).

Attention was called to the two sites of this study by Dr. Lee Clayton of the University of North Dakota who observed a polygonal pattern on air photos of certain areas of southwestern North Dakota; ground investigation revealed that these areas were pediment surfaces. The fluvial surface deposits were found to contain wedge-shaped fillings of eolian silt and to exhibit intense contortions of bedding features.

These features are evidence of the former presence of large-scale polygonal patterned ground found in a permafrost environment. During the colder intervals of the Pleistocene Epoch the regional extent of permafrost was much greater than at present. Evidence of former permafrost conditions are found in various parts of the United States (Black, 1957, p. 1888; Denny, 1956, p. 338; Hoberg, 1949, p. 132;
Martin, 1958, p. 470; Schafer, 1949, p. 154; Wilson, 1958, p. 4; Wolfe, 1953, p. 136) and in Europe (Dimbleby, 1952, p. 1; West, 1968, p. 195; Wright, 1962, p. 942). This study is an attempt to determine the age and environmental relationships of the pediments, the permafrost features, and the subsequent eolian deposits.

Acknowledgments

Appreciation is expressed to Dr. Lee Clayton for bringing the sites to the author's attention and for presenting many valuable suggestions and ideas. Dr. Alan M. Cvanvara assisted in the identification of the fossils. Mr. J. Mark Erickson provided valuable technical and bibliographic assistance. I also wish to thank him for his continuous personal encouragement throughout the project.
METHOD OF STUDY

Field work consisted of measuring the stratigraphic section at each site and collecting bulk sediment samples of approximately twelve pounds each from individual lithologic units. In the laboratory ten pounds of sediment from each of the fossiliferous sand beds was concentrated by dry sieving through a Tyler sieve with a 0.589 mm opening. Four pounds of the fossiliferous sandy, clayey silt from the Zacher site was soaked and wet sieved. The fossils were picked under a binocular microscope at a magnification of 10X. The faunules are listed in Table I.
DESCRIPTION OF SITES

The pediment remnants of this study are located in an unglaciated area of the state consisting of typical "Great Plains" topography with numerous buttes and groups of hills. These surfaces slope at an angle of less than 3° and are capped by a six- to ten-foot thickness of high-regime-flow fluvial gravels with interbedded lenses and local beds of low-regime-flow fluvial sand. The fluvial deposits are covered by a veneer of unstratified eolian silt averaging approximately two feet in thickness. In places the silt extends downward into the gravels and is associated with intense contortion of the fluvial bedding. Both sites studied are located on such pediment remnants. Sand and gravel have been mined from both sites for use as road surfacing material.

Duck Creek Site

Location of site: The Duck Creek site is located on a large pediment remnant approximately eight miles north-northeast of Hettinger, North Dakota, in Adams County (SW₁⁄₄ SE₁⁄₄ sec. 31, T. 131 W., R. 95 N.).

Lithology at Duck Creek site: The site is a large gravel pit approximately 200 feet long, 180 feet wide, and varying from six to twelve feet deep. It is located adjacent to a shallower pit of similar areal dimensions. The bedrock is the Tongue River Formation of the Fort Union Group which is here composed of medium-grained, yellow, cross-bedded sands with extensive limonite coloration. The overlying
Five to seven feet of strata are composed of poorly-sorted, flat-bedded, fluvial sandy gravel with lenses of small-scale cross-bedded sand. Above the fluvial sediments is a one- to three-foot layer of unstratified eolian silt which contains small pebbles and has a thin soil developed upon it. At nine places within the site wedge-shaped bodies of silt extend one to four feet downward into the underlying sediments. In parts of the pit there is a one- to three-inch thick layer of caliche along the contact of the loess and the fluvial deposits. There is extensive and complex contorting of the bedding planes in the fluvial deposits, particularly adjacent to and directly below the silt wedges. (See figs. 1 and 2)

Molluscan fauna of the Duck Creek site: In the list below, the first numeral following the name of the species is the number of specimens collected; the second is the percent frequency of occurrence in the site. All specimens were collected from a sixteen-inch thick sand bed at the base of the fluvial deposits on the west side of the site.

**Gastropods:**
- *Vallonia gracilicosta* Reinhardt 17 12.0%
- *Vallonia* sp. (fragments) 8 5.7
- *Catinella* cf. *C. avara* (Say) 99 70.2
- *Discus cronkhitei* (Newcomb) 9 6.4
- *Fossaria obrussa* (Say) 5 3.5
- *Pupilla* sp. (fragments) 2 1.4

**Bivalve:**
- *Pisidium* sp. (Pfeiffer) 1 0.7

Total specimens collected: 141

Seventeen fragments of mammal bones and teeth were collected from the same samples. The fragments of *Vallonia* are immature specimens probably referable to *V. gracilicosta*.
Figure 1. -- Generalized sketch of ice-wedge fillings.
Figure 2. -- Generalized geologic section at the Duck Creek site.
Zacher Site

Location of site: The Zacher site is located ten miles south-southeast of Elgin, North Dakota, in Grant County (NE\textdegree sec. 12, T. 132 N., R. 89 W.).

Lithology at Zacher site: The site is located on a small hilltop which has been mined for road surfacing material. The areal extent of the deposits before mining was an irregular shape, measuring approximately 250 feet by 100 feet. The total height of the section now exposed is 16.5 feet.

The bedrock at the site is the uppermost unit of the Cannonball Formation which consists of thinly bedded claystone, siltstone, and fine sandstone. The lowermost Pleistocene unit A, is a 2.5 foot thick bed of finely cross-bedded medium-grained sand which is dark-gray in color. (See fig. 3) Unit B is a dark-brownish-gray layer of fossiliferous sandy clayey silt which is 14 inches thick and apparently unstratified. Unit C is composed of yellowish-brown, coarse-grained, fossiliferous sand, is 12 inches thick, and exhibits small scale cross-bedding. The five-foot thick unit D consists of flat-bedded, pale yellowish-brown, sandy gravel. Unit E is a light-gray bed of fine sand 1.5 feet in thickness which shows no evidence of cross-bedding. Unit F is composed of dark-yellowish-brown, poorly sorted gravel with interbedded thin, sandy layers. The contained cobbles are angular and the bedding is poor. A one-foot layer of loess with a thin soil developed upon it constitutes the uppermost unit G.
Figure 3. -- Geologic section at the Zacher site
Molluscan fauna of the Zacher site: In the list below, the first number following the name of the species is the number of specimens in the faunule and the second is the percent frequency of occurrence in the site. Specimens were collected from beds B and C.

Vallonia gracilicosta Reinhardt 28 6.3%
Vallonia sp. (fragments) 25 5.6
Catinella cf. C. avara (Say) 216 48.7
Discus cronkhitei (Newcomb) 12 2.7
Fossaria obrussa (Say) 57 21.8
Pupilla muscorum (Linnaeus) 10 2.2
Pupilla hebes (Ancey) 20 4.5
Pupilla sp. (fragments) 44 9.9
Vertigo tridentata Wolf 18 4.1
Vertigo sp. (fragments) 10 2.2
Deroceras laeve (Muller) 4 0.9

Total specimens collected: 444

The fragments of Vallonia, Pupilla, and Vertigo are broken and immature pieces probably referable to the listed species of their respective genera.

Three calcareous spheres 1 to 2 mm in diameter were found in the samples and are tentatively identified as gastropod eggs. Also present were 20 fragments of bones and teeth and 162 fragments of reworked fossil shells.
INTERPRETATION

Permafrost Features

Using the previously described permafrost evidence, a few interpretations of some past geologic events can be made. The pediments of southwestern North Dakota were once covered by polygonal patterned ground where the surface was divided into large rough polygons by ice-wedges which extended downward into the frozen substrate. As the wedges grew by addition of surface or interstitial water (Leffingwell, 1919, p. 179-243; Pewe and others, 1969, p. 51; Schenk, 1963, p. 84), stress was applied to the sediments between the wedges, causing a disturbance of the sedimentary bedding structures. As the climate warmed and caused the wedges to melt, some of the adjacent materials slumped into the vacant space, adding to the complexity of the bedding contortions. The resulting shallow wedge-shaped trenches were filled by eolian silt. As water now percolates down through the sediments, the difference in permability of the gravel and sand is expressed as a slight color difference in the overlying vegetation. Under proper moisture conditions the polygonal pattern of the silt fillings can be observed on air photos. (See fig. 1)

There has been question if the fillings are actually the result of ice-wedges or simply "sand wedges" which are reported to also occur in areas of permafrost (Pewe and others, 1969, p. 54). Because of the complexity of the contortions and their extent below the level of the silt, the apparent slumping of sediments into vacant wedges, and the regular, rounded, trough shape of the silt fillings, it is concluded that these features are the result of true ice-wedges.
The Duck Creek site contained nine of these fillings; the Zacher site contained no wedge fillings but displayed extensive bedding contortions. The small remnant of sediments which now composes the Zacher site could easily be contained between a set of wedges. The author visited the Marple Rance site of Tuthill, Laird, and Frye (1964), and found two fillings. There has been considerable erosion of the bluff since their work; therefore these fillings were probably not exposed at that time. Where it is stated that "at one place the gravel appears to have been forced upward into the overlying unit (p. 145)", they may have described permafrost disturbance near a "fossil" wedge.

Reworked Fossils

The large thick shell fragments from the Zacher site are considered to be reworked fossil material. They are buff to light-brown in color, measure 2 to 7 mm in length, and often display ornamentation of a scale typical of large gastropods and bivalves. However, no complete specimens of these larger shells are present in the faunule. The arc-shaped, parallel ridges on some fragments resemble growth lines of bivalves which were an estimated 5 to 30 mm in length. Some doubly curved pieces display a flange-like structure along one edge similar to that on a fragment of a gastropod which has been broken along the suture line. Estimating from the curvature of the fragments, the original gastropod was at least 10 mm in diameter. A few fragments resemble complete valves of small bivalves, one of which can be identified as Bicorbula sp., a typical
bivalve from the Paleocene of North Dakota. All of the fragments are darker in color and much more weathered in appearance than the other molluscan specimens; they closely resemble in these characteristics fossils from the Cannonball Formation which underlies the site. Further support of the conclusion that they are reworked fossils is their almost total absence from the fine-grained unit B. The lithology is evidence of a low energy environment in which fragments of such size could not be transported. The overlying unit C, in which 161 of these fragments were found, is composed of coarse sand—evidence of a higher energy depositional environment. The fossiliferous bed at the Duck Creek site consists of sediments intermediate in size to those in the two beds at the Zacher site, but contain no similar fragments probably because of a difference in source material. The Zacher site is composed of material principally from the Tongue River and Cannonball Formations, while the Duck Creek site consists of sediments from the Tongue River Formation and younger units only. It is concluded that the fragments at the Zacher site are reworked fossils from the Cannonball Formation and have no direct association with the fauna living at the time of deposition of the sediments.

Molluscan Fauna

The fossil fauna is similar to that which would be found living today near a stream on the Great Plains of the northern United States.

**Bivalve:** One valve of *Pisidium* was found in the sediment from the Duck Creek site. This genus can tolerate a wide variety of water conditions; some species can survive even in ephemeral streams.
<table>
<thead>
<tr>
<th>Species</th>
<th>Geologic Range</th>
<th>Duck Creek</th>
<th>Zacher Bed B</th>
<th>Zacher Bed C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GASTROPODS:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vallonia gracilicosta</td>
<td>Early Plio.-Rec. (3)</td>
<td>12.0%</td>
<td>7.5%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Vallonia sp. (fragments)</td>
<td></td>
<td>5.7</td>
<td>6.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Catinella cf. C. avara</td>
<td>Yarmouthian-Rec. (1)</td>
<td>70.2</td>
<td>39.2</td>
<td>89.2</td>
</tr>
<tr>
<td>Discus cronkritei</td>
<td>Mid. Plio.-Rec. (3)</td>
<td>6.4</td>
<td>2.8</td>
<td>2.4</td>
</tr>
<tr>
<td>Fossaria obrussa</td>
<td>Nebraskan-Rec. (3)</td>
<td>3.5</td>
<td>15.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Pupilla muscorum</td>
<td>Early Plio.-Rec. (3)</td>
<td></td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Pupilla hebes</td>
<td></td>
<td></td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>Pupilla sp. (fragments)</td>
<td></td>
<td>1.4</td>
<td>11.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Vertigo tridentata</td>
<td>Yarmouth-Rec. (2)</td>
<td></td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Vertigo sp. (fragments)</td>
<td></td>
<td></td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Deroceras laeve</td>
<td>Illinoan-Rec. (2) (3)</td>
<td></td>
<td>0.6</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>BIVALVES:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pisidium sp.</td>
<td></td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total specimens per faunule</strong></td>
<td></td>
<td>141</td>
<td>360</td>
<td>84</td>
</tr>
</tbody>
</table>

Aquatic Gastropods: Only one genus, the pulmonate Fossaria, occurred in the fauna. This hardy snail is often found living along the wet margins of streams and rivers. It can tolerate a wide range of turbidity and survive in marginal water conditions.

Terrestrial Gastropods: Four of the seven species found in the fauna occur primarily near streams. The other three, Vallonia gracilicosta, Pupilla muscorum, and Pupilla hebes typically are found in less moist habitats. It is not uncommon to find both types deposited together in fluvial sediments. The occurrence of Discus cronkhitei, Pupilla muscorum, Vertigo tridentata, and Deroceras laeve seems to indicate that part of the paleoenvironment was a wooded area. While most species of the assemblage can tolerate subarid to humid climate, Vallonia gracilicosta and Pupilla muscorum are found only in a subhumid to semiarid environment. According to Leonard (1952, p. 30,33) the present geographic range of Vallonia gracilicosta and Vertigo tridentata do not extend north of the 50th latitude. Thus, the mean annual temperature of the paleoenvironment was not significantly lower than that of the present environment. The size of the individuals in the faunules of the Duck Creek site and of unit C at the Zacher site are all somewhat smaller than what is considered "normal" for their respective species. It may be that this is the result of some environmental factor such as marginal moisture or temperature conditions. The specimens from unit B at the Zacher site, however, are significantly larger and indicate that the apparent dwarfism of the other faunules was caused, at least partially, by the
sorting effect of the higher energy streams which deposited the coarser units. This interpretation is supported by the higher percentage of aquatic snails in the unit B faunule and the small number of fragile, easily destroyed Pupilla and Vertigo shells in the other two faunules. The occurrence of relatively large calcareous gastropod eggs (?) in unit B suggests that there may have been larger snails than those preserved. Very little literature concerning these fossils is available and any conclusion drawn from such eggs (?) is little more than a speculation.

In summary, the environment in which the fossil fauna lived was similar to that existing in the same area today. Since evidence shows there was more widespread and intense fluvial activity and a greater extent of tree cover, it may be concluded that there was more precipitation at the time of deposition of the sediments than at the present. While it is difficult to determine the details of the paleoenvironment, it is apparent that the environment in which the fauna lived and the environment in which the permafrost features were developed were quite different.
Correlation with Marple Ranch site: The fauna of this study correlates quite well with that found in the Marple Ranch site of Tuthill, Laird, and Frye (1964). (See Table II.) All of the species present in the Duck Creek faunule and five of the eight species of the Zacher faunule are present at the Marple Ranch site. These five species comprise 88.3% of the specimens at the Zacher site. In comparison, only six of the fourteen species comprising only 64.0% of the specimens from the correlative Crull Ranch site of Tuthill, Laird, and Frye (1964) are present in the Marple Ranch faunule. The Marple Ranch site and the Zacher site are approximately three miles apart, at similar elevations, and appear to correlate topographically. The author has not visited the Crull Ranch site but it is suggested by Clayton (oral communication) that the two sites of Tuthill, Laird, and Frye (1964) do not correlate topographically. Clayton, who visited both sites with Tuthill, measured the height above river level of the two "terraces" on the same air photo pair using stereometric methods and found the Crull Ranch site to be 47±5 feet and the Marple Ranch site to be 110±5 feet above low water. No data is given in the original description of the Crull site concerning its elevation or topographic position.

The conclusions of Tuthill (1964) that the sediments of the sites were laid by a permanent stream depended upon two specimens which occurred in the Crull Ranch site only. This species, the branchiate *Valvata tricarinata*, is the only species of aquatic
<table>
<thead>
<tr>
<th>Species</th>
<th>Marple Ranch</th>
<th>Crull Ranch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyraulus parvus</td>
<td>3.5%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Lymnaea exigua</td>
<td>0.1</td>
<td>1.6</td>
</tr>
<tr>
<td>Lymnaea sp.</td>
<td>-</td>
<td>1.6</td>
</tr>
<tr>
<td>Vallonia gracilicosta</td>
<td>5.3</td>
<td>14.5</td>
</tr>
<tr>
<td>Vallonia sp. (fragments)</td>
<td>4.3</td>
<td>31.3</td>
</tr>
<tr>
<td>Cionella lubrica</td>
<td>2.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Catinella cf. C. avara</td>
<td>71.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Physa sp.</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Discus cronkhitei</td>
<td>3.2</td>
<td>-</td>
</tr>
<tr>
<td>Euconulus fulvus</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Nesovitrea binneyana</td>
<td>0.3</td>
<td>-</td>
</tr>
<tr>
<td>Fossaria obrussa</td>
<td>4.5</td>
<td>-</td>
</tr>
<tr>
<td>Fossaria dalli</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>Pupilla muscorum</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Pupilla sinistra</td>
<td>-</td>
<td>14.5</td>
</tr>
<tr>
<td>Vertigo modesta</td>
<td>2.8</td>
<td>-</td>
</tr>
<tr>
<td>Vertigo ovata</td>
<td>-</td>
<td>1.1</td>
</tr>
<tr>
<td>Valvata tricarinata</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Deroceras laeve</td>
<td>-</td>
<td>6.0</td>
</tr>
<tr>
<td>Zonitoides arbores</td>
<td>-</td>
<td>8.8</td>
</tr>
<tr>
<td>Gastrocopta holzingeri</td>
<td>-</td>
<td>1.1</td>
</tr>
<tr>
<td>Gastrocopta armifera</td>
<td>-</td>
<td>3.5</td>
</tr>
</tbody>
</table>

**BIVALVES:**

<table>
<thead>
<tr>
<th>Species</th>
<th>Marple Ranch</th>
<th>Crull Ranch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pisidium cf. P. nitidum</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Pisidium walkeri</td>
<td>0.1</td>
<td>-</td>
</tr>
</tbody>
</table>

**Total specimens per site**

<table>
<thead>
<tr>
<th>Site</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marple Ranch</td>
<td>729</td>
</tr>
<tr>
<td>Crull Ranch</td>
<td>174</td>
</tr>
</tbody>
</table>
snail in their fauna which cannot tolerate ephemeral water conditions; all of the gastropods at the Marple Ranch site can survive dry period. While most species of the bivalve *Pisidium* cannot live in truly ephemeral streams, its occurrence at the Duck Creek site shows that it can survive under the conditions which existed on a pediment surface with no associated large stream. Because of the above paleontological evidence, the irregular lateral extent of the lithologic units, the large areal extent and sloping character of the "terrace", its high topographic position, and the apparent geomorphic relationship with the adjacent highlands, it is suggested that the Marple Ranch site is not a terrace of the Cannonball River and does not correlate to the Crull Ranch site as reported by Tuthill, Laird, and Frye (1964), but is a pediment surface covered by fluvial and eolian sediment which correlates stratigraphically with the Duck Creek and Zacher sites of this study.

**Age determination:** The modern nature of Pleistocene molluscan faunas makes them difficult to use as stratigraphic time indicators. There are no diagnostic species in the fauna of either site which can be used to establish a minimum age of the assemblage. As shown on Table I, the apparent limiting species for establishing a maximum age of Illinoan is *Derceras laeve*. However, the reliability of the recorded geologic range of this species is at best very questionable. *Pisidium walkeri*, which was found in the Marple Ranch site by Tuthill (1964) is also considered by Hibbard and Taylor (1960) to have a range of Illinoan to Recent. (The assignment of Yarmouthian age to the Marple Ranch site by Tuthill (1964) was made on the basis of the species *Pupilla Sinistra* which was found only in the Crull
Ranch site. The acceptance of this species as an index to the Yarmouthian is by no means universal.) If an age is to be assigned to the fauna on the basis of present data it must be Illinoan or younger. The interpreted environment of deposition and the large areal extent of the pediments suggest a period of development during a relatively warm and stable interglacial time. Thus, the fauna must be considered Sangamon in age.
The modern character of most Pleistocene mollusks prevents accurate paleontological dating. Even if such a date could be established for these sites, the present state of the study of Pleistocene stratigraphy would probably prevent reliable correlation with any of the glacial features of North Dakota which are studied by physical geologists. So much controversy now exists that Taylor (1965, p. 601) suggests that only one species of mollusks actually evolved during the Pleistocene Epoch. Deevey (1965, p. 648) states that there is increasing evidence that the "Yarmouthian is a myth" and that no interglacial interval existed between Kansan and Illinoan glaciations. Such sweeping speculations challenge the very basis of Pleistocene stratigraphy and clearly demonstrate the unreliability of any age assignment based upon a molluscan fauna. Nevertheless, a few tentative conclusions can be drawn. If the pediments were developed during Sangamon time, they probably correspond to the widespread Sangamon erosion surface and paleosol. (Flint, 1957, p. 339; Frye and Leonard, 1965; Horberg, 1953, p. 36; Ruhe, 1956, p. 451 and 1969, p. 70; Simpson, 1960, p. 78). It is generally accepted that the climate during that time was comparable to that of present except for being somewhat less continental and more moist (Taylor, 1965, p. 603). The permafrost features must have developed during early Wisconsin time. Studies such as those by Wolf (1953, p. 139) and Martin (1958, p. 470) show that during the glacial maximum tundra conditions extended for into what is now temperate United
States. It is probable that the features of the present study correspond to the ice-wedges and "festoons" in central Montana which Schafer (1949, p. 154) considered to have formed during Middle Wisconsin time. By his calculations the mean annual temperature at that time was at least 8°C colder than at present. On the North Dakota pediments the wedge shape of the fillings is well preserved; therefore the loess must have been deposited either contemporaneously with or very shortly after the melting of the ice-wedges. The large blow-outs and northwesterly oriented ventifacts in the adjacent highlands were probably developed during this same period of eolian activity.

It is hoped that future studies, perhaps with the mammals or pollen, can more reliably date the events described in this study.
SELECTED REFERENCES


Wilson, L.R., Polygonal structures in the soil of central Iowa: Oklahoma Geol. Survey Notes, v. 18, no. 1, p. 4-6.

