9-1947

The Post-Kansan Geologic History of the Lower Platte Valley Area

Gilbert Carl Lueninghoener
University of Nebraska

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GILBERT CARL LUENINGHOENER

UNIVERSITY OF NEBRASKA STUDIES

September 1947

NEW SERIES NO. 2

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University of Nebraska Studies
September 1947

THE POST-KANSAN GEOLOGIC HISTORY OF THE LOWER PLATTE VALLEY AREA

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GILBERT CARL LUENINGHOENER

NEW SERIES NO. 2

PUBLISHED BY THE UNIVERSITY AT LINCOLN, NEBRASKA

THE UNIVERSITY OF NEBRASKA

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ACKNOWLEDGMENTS

It will be impossible to give recognition to everyone who has helped in this research problem. There are, however, a number of individuals who deserve special acknowledgment. Sincere thanks are due Dr. C. Bertrand Schultz, who sponsored and directed this work and who gave freely of his time and effort. The writer is deeply indebted to Dr. A. L. Lugn, whose work on the Pleistocene geology of Nebraska is, in substance, the foundation on which this research is based. Credit is due to Prof. E. F. Schramm, Chairman of the Department of Geology, University of Nebraska, for help and timely advice. Recognition is due Prof. T. M. Stout for his personal interest and valuable suggestions.

Dr. G. E. Condra, State Geologist, and Mr. Eugene C. Reed, Assistant State Geologist, have given valuable direction and advice. Acknowledgments are due to Doctors N. A. Bengtson and E. E. Lackey of the Department of Geography, University of Nebraska. Messrs. H. W. Whitelock and D. J. Crooks of the U. S. Soil Conservation Service have given aid in the photogrammetric phase of this research. Dr. Richard Flint of the Department of Geology, Yale University, and Mr. Walter Hansen of the United States Geological Survey spent two days in field work in the area with the author. Messrs. W. D. Frankforter and Jerome Wright have given help in field work.

Grateful acknowledgment and thanks are due to the administration of Midland College, where the writer is employed, for an adjustment of schedule which has made it possible to carry this research program.

Thanks are due to Mr. Lon Wright, Superintendent of the Department of Utilities of Fremont, Nebraska, and his staff. At the time the water survey for the city of Fremont was made, the writer had the opportunity to do work related to this research problem.

The Department of Geology, University of Nebraska, purchased a complete stereoscopic set of Agricultural Adjustment Administration aerial photographs of Saunders and Cass counties. With these photographs, and photographs purchased by the writer, complete stereoscopic aerial photographic coverage of the area was available for study.

THE POST-KANSAN GEOLOGIC HISTORY OF THE LOWER PLATTE VALLEY AREA

INTRODUCTION

This investigation is essentially a geomorphological study of the lower Platte River Valley area in eastern Nebraska. The area comprises Saunders, Dodge, Washington, Douglas, Sarpy, and Cass counties.[1]

The area defined above is one of the most critically located of any for the study of the post-Kansan history of the lower Platte River Valley. It lies between the older till (Nebraskan and Kansan) borders to the west and the younger till (Illinoian, Iowan, and Wisconsin) borders to the east.[2] Physiographic changes have therefore transpired in a strictly post-Kansan periglacial region. The Kansan till is the youngest in the area. The area includes Todd Valley, which is an old abandoned Platte River Valley[3] of great significance in interpreting the post-Kansan history.

The purpose of this research is to establish the chronological order of events in terms of erosions and depositions that have transpired since the melting and disappearance of the ice of the Kansan age of glaciation.

[1] Field study in Cass County was limited to the area including the Platte River Valley and tributaries and to the west banks of the Missouri River between Plattsmouth and Rock Bluffs, Nebraska. Photogrammetric studies, however, were made of the whole area.

[2] William C. Alden, 1932, "Glacial Geology of the Central States," XVI International Geological Congress session, 1933. *Guidebook 26, Excursion C-3,* p. 3 (map by Frank Leverett).

[3] G. E. Condra, 1903, "An Old Platte Channel," *American Geologist,* XXXI (June 1903), pp. 361–369.

PROCEDURE

A detailed photogrammetric study of the area was made. Agricultural Adjustment Administration aerial photographs covering the entire area were stereoscopically studied. Terrace and valley fills were mapped by this method and then transferred to a map grid, which was traced from the county soil maps of the respective counties in the area. The scale of the aerial contact photographs used is approximately three inches per mile. The soil map grid scale is one inch per mile. After completion of the map on this scale, it was photographically reduced to a scale of one-half inch per mile.

This map contains the drainage pattern of the Platte and tributaries and four different terrace-fill levels. The stereoscopic aerial photographic study not only revealed the terrace distribution but also the locations of exposures suitable for field study. This proved to be a most effective and time-saving method for guiding field observation as much sterile area could be eliminated in the field work.

Nearly all mapped terrace surface areas were visited in the field. Those that were not examined showed so obviously their characteristics in the aerial photographs that study in the field was considered unnecessary. The method of aerial photographic study has the advantage of transcending limitations of time, distance, and weather conditions. It should be clearly understood, however, that it was not used as a substitute for field work or to the exclusion of field work. This method was used in combination with field work to make it strategically effective.

Profile sections were studied in strategically located places. This was done to give control points in as nearly equally spaced distances as possible. Stratigraphic information derived from well logs was studied wherever such information was available.

The stratigraphic information is presented to the reader in block diagram form. It is believed by the writer that block diagrams are well adapted to convey information of this kind. It should be mentioned that by the very nature of block diagrams all vertical and some horizontal scales are greatly exaggerated. Exact horizontal scales therefore cannot generally be included in a block diagram

and, if used, may not be expected to apply in all parts of it. However, the total area of any of these block diagrams can be compared and checked with the feature represented in the plate accompanying this report where the horizontal scale is uniform throughout.

In the study of the stratigraphy of marine formations the uniform thickness of a bed in a large area is an important factor, but in the study of Pleistocene continental deposits the thickness of a formation may range greatly, even within a few feet or yards horizontally. In most cases, the thickness of a Pleistocene bed is of little significance. The fact that a certain deposit or formation is present and that its stratigraphic relation to other beds is shown is most important. Where vertical or horizontal distances were thought to have significance, the writer has included them in the block diagrams. In the study of the continental Pleistocene, structure and stratigraphic relationships can best be visualized in three dimensions. The use of block diagrams seems, therefore, not only justifiable but essential.

Each of the profile sections has been designated by a number and a name. The number is also the order of presentation in this dissertation, and the name is usually a name of a nearby town, city, stream, or owner on whose land the profile section is located. Locations of profile sections are given in a four-fold system, namely: (1) by graphic indication on the plate accompanying this dissertation; (2) by the conventional descriptive method of section number, township, and range; (3) by approximate distance in miles from a certain town; (4) by aerial photographic locational description.

The aerial photograph is identified by code letters and numbers. The exact position of the location is then defined by a grid system of x and y axes. These axes intersect in the southwest corner of the photograph. Conventionally, the east-west distance is represented by the x axis and the north-south distance by the y axis. Coordinate distances are measured on the contact print in inches and decimal parts of an inch.

PHYSIOGRAPHIC DESCRIPTION

The total area of Saunders, Dodge, Washington, Douglas, Sarpy, and Cass counties is 2,798 square miles. It is located in the east central part of Nebraska. The area is irregular in shape and has northwest-to-southeast and northeast-to-southwest diagonal dimensions of 85 miles and 60 miles respectively. The area is bounded on the east by the Missouri River which also forms the state boundary line. Washington, Douglas, Sarpy, and Cass counties form the first most eastern row of counties and Saunders and Dodge the second row. The Platte River extends from the west side diagonally across to the southeast in the shape of an open letter z. Figure 1 is a block diagram index map of the area.[4]

The western part of Washington County drains southward into the Elkhorn Valley by way of the Bell Creek drainage system. The central part of the county's drainage constitutes the headwaters of the Papillion Creek system. Short streams with high gradients drain the eastern upland area into the Missouri. The Missouri River flood plain constitutes approximately the eastern fourth of the county. In Washington County, along the west bluffs, is an intermediate "Bench" or "Second Bottom." This bench or terrace is approximately one mile wide and stands approximately 80 feet above the river flood plain. The terrace in this county is nearly continuous. The western one-fourth of Douglas County constitutes part of the flood plain of the Platte. The central area of the county is drained by the approximately parallel branches of the Papillion Creeks system. Big Papillion and Little Papillion creeks join in the southeastern part of the county. In the extreme eastern part, Douglas County has similar drainage to Washington County, i.e., short, high-gradient streams with deep valleys joining the Missouri.

The Platte River forms the boundary line between Sarpy and Cass counties. In the eastern part of Sarpy County, the two branches of the Papillion Creek system converge. The streams in the northern part of Sarpy County are nearly all parts of the Papillion Creek

[4] Technically, the index map represents an area larger than the six named counties. The diagram has been extended to include and show relationships to contiguous features such as the Shell Creek terrace.

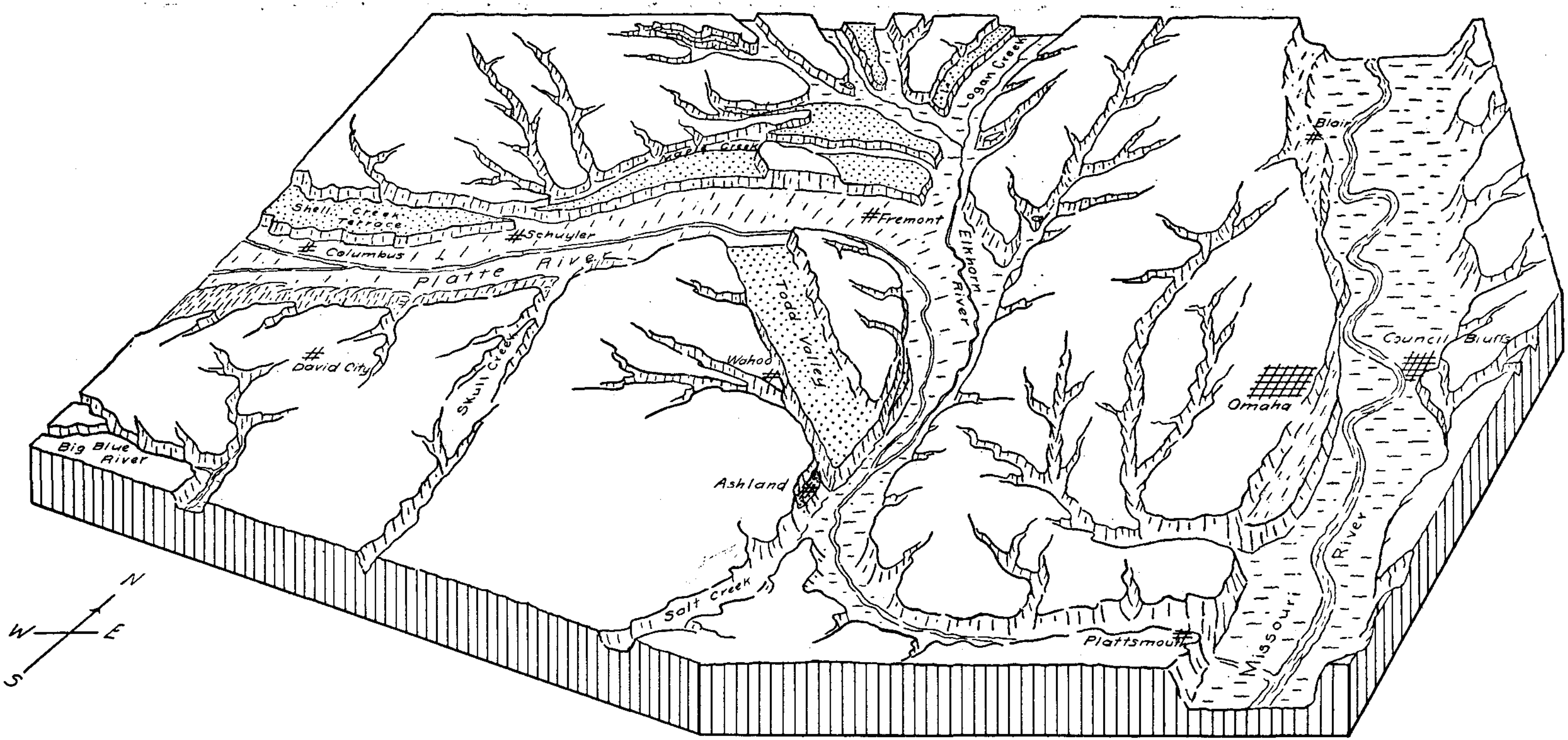

FIG. 1. Index map of the lower Platte River Valley area. Approximate dimensions of block 50 x 80 miles.

system while the southern part of the county drains into the Platte River.

Approximately the northern half of Cass County, with the exception of a small area in the northwest, drains northward into the Platte River. The small area in the northwest part drains into Salt Creek, and this in turn, into the Platte. The southern half of the county essentially constitutes the Weeping Water Creek drainage system which has a general southeast trend and joins the Missouri River in the extreme southeast corner of the county. In the eastern part of the county a few short tributaries drain into the Missouri.

Saunders County is bounded on the north and on the east by the Platte River. An old abandoned river valley called Todd Valley [5] extends from northwest to southeast across Saunders County.

An oval-shaped upland area east of Todd Valley is drained in part by short streams flowing southwestwardly. These streams either deploy onto Todd Valley or form the headwaters of several entrenched valleys in Todd Valley. By far the greater part of this oval-shaped area is drained by such eastward-flowing streams as Elm Creek, Otoe Creek, Clear Creek, and an unnamed creek at Yutan. The pattern of these creeks and their high terrace remnants clearly indicate that these separate streams at one time formed a single integrated stream system. The main trunk of this ancient stream has been partly engulfed by the lateral erosion of the Platte River. Figure 2 graphically indicates the relations existing at the time when Todd Valley functioned as a valley for the Platte River. The ancient integrated Clear Creek system joined the ancient Platte at a location four miles south of Yutan. Figure 3 depicts the conditions of the present day and shows the dismembered branches of ancient Clear Creek.

Dr. A. L. Lugn [6] has demonstrated that the abandonment of Todd Valley by the Platte River was due to a tributary of the ancient Elkhorn River working headward and diverting the waters from Todd Valley. Entrenchment was easier in the position of the newly-formed course than in the Todd Valley fill. This deeper entrenchment in the new course resulted in a permanent diversion.

[5] Condra, loc. cit.

[6] A. L. Lugn, 1935, "The Pleistocene Geology of Nebraska," *Nebraska Geological Survey*, Bul. 10, pp. 156–158.

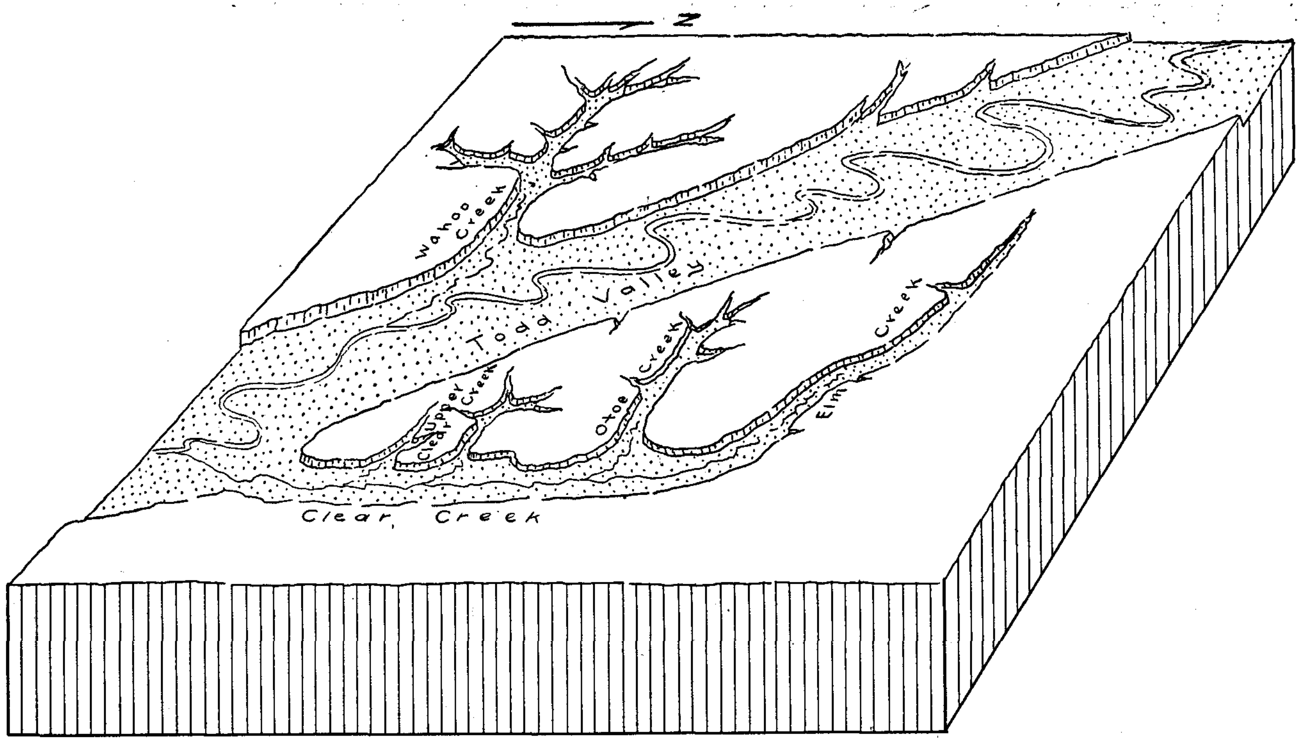

FIG. 2. Todd Valley and tributary systems before the diversion of the Platte River. Approximate dimensions of block 20 x 22 miles.

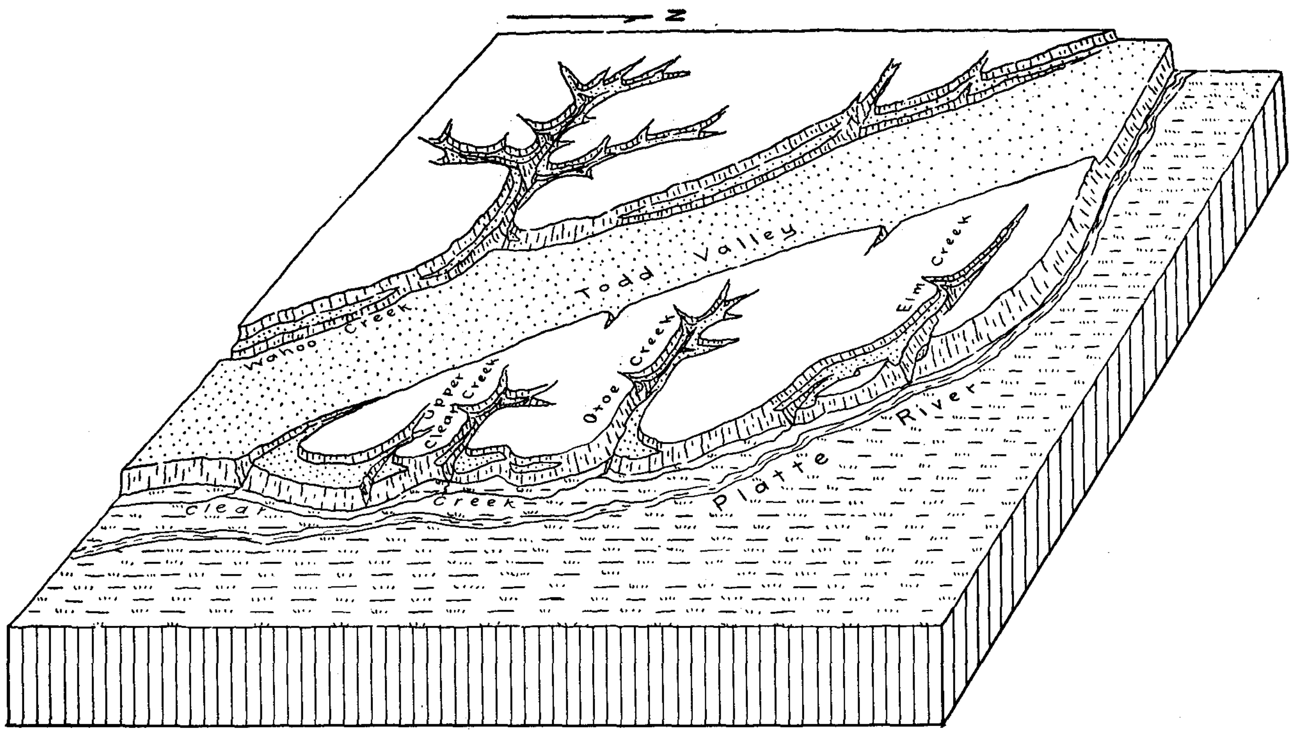

FIG. 3. Todd Valley and tributary systems after the diversion of the Platte River. Approximate dimensions of block 20 x 22 miles.

Most of the drainage of the western part of Saunders County either joins Sand Creek or Wahoo Creek. Sand Creek has integrated a number of streams flowing from the upland, and it, in turn, flows to join Wahoo Creek two miles southeast of Wahoo. These two streams then constitute the lower part of Wahoo Creek. Both Sand Creek and lower Wahoo Creek closely follow at the base of the west wall of Todd Valley, where they have entrenched themselves. The southwestern and south central parts of the county are drained by tributaries of Salt Creek.

The Platte River forms the south boundary of Dodge County. The southern one-third of the county constitutes a part of the flood plain of the Platte River. The remaining two-thirds of the county is drained by the Elkhorn River and its tributaries. The Elkhorn River Valley joins the Platte River Valley a short distance south of the extreme east central part of the county. The Elkhorn River system is an entrenched system. Alluviation and subsequent entrenchment have produced large terrace areas in the central part of the county which are equivalent to Todd Valley. The Elkhorn River has five large to medium-sized tributaries joining it in this county. The tributaries are: (1) Maple Creek, (2) Pebble Creek, (3) Cuming Creek, (4) Logan Creek, (5) Clark Creek. The direction of flow of these streams in the order named is east, southeast, southeast, south and south.

The region can be divided into the following morphological units:

A. Dissected uplands.

B. Terrace lands or terrace-fill surfaces. These terrace lands can be divided into several levels. The writer wishes to propose the following names and numerical designations for these terrace levels:

1. Todd Surface. The name is taken from Todd Valley where this surface is well developed. It has extensive development elsewhere, particularly in central Dodge County. The level stands at an average height of 70 feet above the flood plain of the Platte River Valley and is the highest clearly recognizable terrace surface in the area. Upstream along the tributaries its height above the floodplains is less and finally at the heads of valleys it appears to grade into the upland surface. This terrace

is designated as LPT-4 (Lower Platte Terrace—Number Four). The order of numbering terraces here used is the same as that employed by Schultz and Stout.[7] The order of numbering is from the lowest terrace to the highest. Inasmuch as these terraces have not been correlated with the terraces farther westward, the writer wishes to modify the system by using prefix abbreviation letters (LPT-). Numerical equivalence therefore is not necessarily implied for terraces in the two areas. A very desirable amplification of this research obviously will be the extension of detailed study westward.

2. Fort Calhoun Surface. Intermittent areas of this terrace are well developed along the west wall of the Missouri River Valley from Blair to Fort Crook. This terrace stands about 80 feet above the flood plain along the Missouri River Valley. Along the Platte River, three miles southwest of Gretna, small well-developed surfaces also occur, where this surface is 65 feet above the Platte River flood plain. This terrace is also represented by several small, well developed, isolated surfaces one-half mile northwest of Fontanelle. The height at this place is 60 feet above the Elkhorn River flood plain. This surface is designated as LPT-3 (Lower Platte Terrace—Number Three.)
3. Linwood Surface. This surface is well developed along the south banks of the Platte River east of Linwood. It is represented in other areas along Salt Creek between Greenwood and Ashland. Many scattered remnants also occur throughout the lower Platte River Valley area. The surface at Linwood stands from 35 to 40 feet above the flood plain of the Platte River. (This is LPT-2.)

C. Flood Plains. Technically these also are terraces and are complex in detail. They appear to consist of at least two low-lying surfaces. The highest surface, LPT-1 (Lower Platte Ter-

[7] C. Bertrand Schultz and Thompson M. Stout, 1945, "Pleistocene Loess Deposits of Nebraska," *American Journal of Science*, (May 1945), pp. 231–244. The Lower Platte Terraces LPT-0, LPT-1, LPT-2, and LPT-3 appear to correspond to the T^0, T^1, T^2, and T^3 of Schultz and Stout. However, the LPT-4 or Todd Terrace is not the same as their T^4, but instead may equal their $T^{3'}$. The term "Peorian" as used in the present report appears to refer principally to the Tazewell-Cary portion of the "Peorian."

race—Number One), stands from 5 to 15 feet above the water level of the streams. The lower level, LPT-0 (Lower Platte Terrace—Number Zero), stands 0 to 10 feet above the water level. In mapping, these two levels have not been differentiated. These surfaces, no doubt, could be separated with much detailed work and study. With the large area covered in this report, it was found to be impractical to attempt to do this.

The relationship, distribution, and extent of these various physiographic units are graphically shown on the accompanying plate.

STRATIGRAPHIC UNITS

The following Pleistocene stratigraphic units are recognized in this paper:

1. LPT-0 Fill (Lower Platte Terrace—Number Zero). This is a black to dark gray carbonaceous valley fill, ranging in thickness from 0 to 15 feet. At several places, this has yielded fragments of Indian pottery which would indicate a recent age of only a few hundred to a thousand years at most.
2. LPT-1 Fill (Lower Platte Terrace—Number One). This is a dark buff, clayey silt, ranging from 0 to 20 feet in thickness.
3. LPT-2 Fill (Lower Platte Terrace—Number Two). This fill, where recognized, consists of alternate one to three-foot horizontal layers of humic silt and gray sand. The total thickness ranges from 0 to 15 feet.
4. "Peorian" [8] Formation. This formation is conventionally considered to be a loess. It ranges in texture from a silty clay to a clayey silt. The color is buff yellow, and it has a massive appearance. The fracture tends to be columnar. Evidence will be presented that this formation can be divided in this area into an "upland" and a "valley" phase. The valley phase is mainly a water-deposited material. It is similar in color to the upland phase, but it differs in that it is horizontally bedded

[8] The name Peorian was first used by Leverett (The Peorian Soil and Weathered Zone, Journal of Geology, Vol. 6, pp. 244–49, 1898) who applied it to a weathered zone. The term was later used by others as a formational and a time term. By long usage it has become established as a formational name and as such is used in the stratigraphic section of Nebraska (Condra and Reed, 1943, The Geological Section of Nebraska, Nebraska Geological Survey, Bul. No. 14, p. 6). It is not to be implied in this paper that the deposition of this formation necessarily took place in the Peorian interglacial age. (*See* also footnote 7.)

[9] Lugn, loc. cit.

and stratified. The average texture is slightly coarser than the upland phase, and in many places it contains sandy lenses.

5. Todd Valley formation. This formation, as originally defined by Lugn,[9] included all the fluviatile sands and gravels in Todd Valley. The writer (with the approval of Dr. Lugn) wishes to redefine this formation. The term "Todd Valley formation" is to apply only to the uppermost part of the fill, consisting of gray-white, fine sands in Todd Valley and to their equivalents in other valleys. The thickness of the redefined Todd Valley formation ranges from 0 to 50 or more feet.
6. *Citellus* zone soil.[10] This is a mature buried soil developed on the Loveland loess.
7. Loveland formation. This formation was first defined by Shimek.[11] Lugn [12] recognized in Nebraska both an "upland" and a "valley" phase of the Loveland formation. The upland phase in this area has a red color and is a loess. In describing the valley phase (Bul. 10, p. 130) Dr. Lugn states:

> ". . . . the valley phase represents an interval of greater erosive action and sedimentation than the immediately preceding Upland (Yarmouth) age, but not nearly as vigorous as the still earlier Grand Island (Kansan) age. When all of the more or less circumstantial evidence is considered, it is suggested that the formation of this phase of the Loveland formation, including the pre-Loveland erosion, may have been contemporaneous with the Illinoian glaciation.
>
> The valley phase of the Loveland seems everywhere to grade imperceptibly upward into the loess or tableland phase of the formation. The material grows less and less sandy until it is quite typical loess clay and silt in mechanical composition. . . ."

It is apparent that the valley phase, as defined above, was not contemporaneous with the upland phase of the Loveland. Condra and Reed [13] have proposed the term "Crete formation" for Lugn's "valley phase" of the Loveland formation. They

[10] C. Bertrand Schultz, 1934, The Pleistocene Mammals of Nebraska, *Bul. University of Nebraska,* State Museum, I, No. 41, Part 2, 359–360. Lugn, 1935, op. cit., pp. 141–142.

[11] B. Shimek, 1919, Geology of Harrison and Monona Counties, *Iowa Geological Survey,* XX, pp. 371–375.

[12] Lugn, op. cit., pp. 128–131.

[13] Condra and Reed, (In manuscript) Correlation of the Pleistocene Deposits of Nebraska. To be published by the Nebraska Geological Survey.

have also redefined the "valley phase" to apply only to the fluviatile deposits which were contemporaneous with the upland phase of the Loveland formation. The term "valley phase of the Loveland" will therefore be used here in its redefined meaning.

8. Crete formation.[14] This is the old "valley phase" of the Loveland of Lugn, as noted above.
9. Upland formation.[15] These sediments consist of greenish-gray silts and fine sands. The texture is somewhat coarser than reported by Lugn for the typical Upland formation. The stratigraphic sequence and lithologic characteristics, however, leave little doubt that these deposits are the Upland formation.
10. Kansan[16] Till. This material is typical glacial boulder clay, more or less oxidized and in part leached.
11. Nebraskan[17] Gumbotil. This is the leached and weathered upper part of the Nebraskan till. Similarly, a Kansan gumbotil was developed in the Kansan till. The writer, however, was unable to find outcrops of it in the area studied. Presumably, the Kansan gumbotil was mostly removed by erosion in this area.
12. Nebraskan[18] Till. This material typical glacial boulder clay, which ranges from unoxidized and unleached to oxidized and leached till.
13. David City[19] formation. This formation consists of sand and gravel.

[14] *Ibid.*
[15] Lugn, op. cit. p. 26.
[16] Condra and Reed, "The Geological Section of Nebraska," *Nebraska Geological Survey,* Bul. No. 14, p. 6.
[17] Lugn, op. cit., p. 25.
[18] Condra and Reed, op. cit., p. 6.
[19] Lugn, 1935, op. cit., pp. 38–40.

PROFILE SECTIONS

SECTION NO. 1 (GAS PIPELINE BRIDGE SECTION)

Location

About two miles southwest of Fremont, SW corner of SW¼ sec. 28, T. 17 N., R. 8 E. Aerial photograph description of location: 9–5–41, UQ–4B–4, x=1.6, y=4.7.[20] The beds are exposed along the precipitous south bluff of the Platte River Valley. The exposure is located at a point where the Platte River has by erosion engulfed the head of an alluviated tributary of Elm Creek. This section is midway and about one-fourth mile from both of Lugn's [21] Graham's Garden and Monnich's Camp sections.[22]

Discussion

The relationships are graphically indicated in Figure 4. The rectangle ABCD in the block diagram is enlarged to the border rectangle A′B′C′D′. A generalized profile is shown in the right side of the rectangle and a secondary rectangle EFGH, which shows a critical part of the section, has been enlarged and is represented by the rectangle E′F′G′H′.

Section

	Feet
1. "Peorian" formation. Yellow, clayey silt	50
2. Citellus zone (?) soil	1
3. Loveland formation (valley phase). Red-brown stratified silt and sand	0–3
4. Soil zone on the Upland (?) formation, very dark in color	1
5. Upland (?) formation. Reddish-gray, stratified silt	0–6

[20] Interpretation of the aerial photograph descriptive location: 9–5–41: picture exposed Sept. 5, 1941. UQ–4B–4: Saunders County, Nebraska, flight number 4 and picture number 4. x=1.6, y=4.7; grid system established by the writer. The zero point of the intersection of the coordinates is the southwest corner of the A.A.A. contact print. The numbers indicate the distances on the picture in inches and decimals thereof along the x and y axes respectively.

[21] Lugn, 1935, op. cit., pp. 41–42.

[22] The critical parts of the Graham's Garden section at the time of this study were heavily covered by an earth slide which took place about two years ago. This exposure is no longer available for field study.

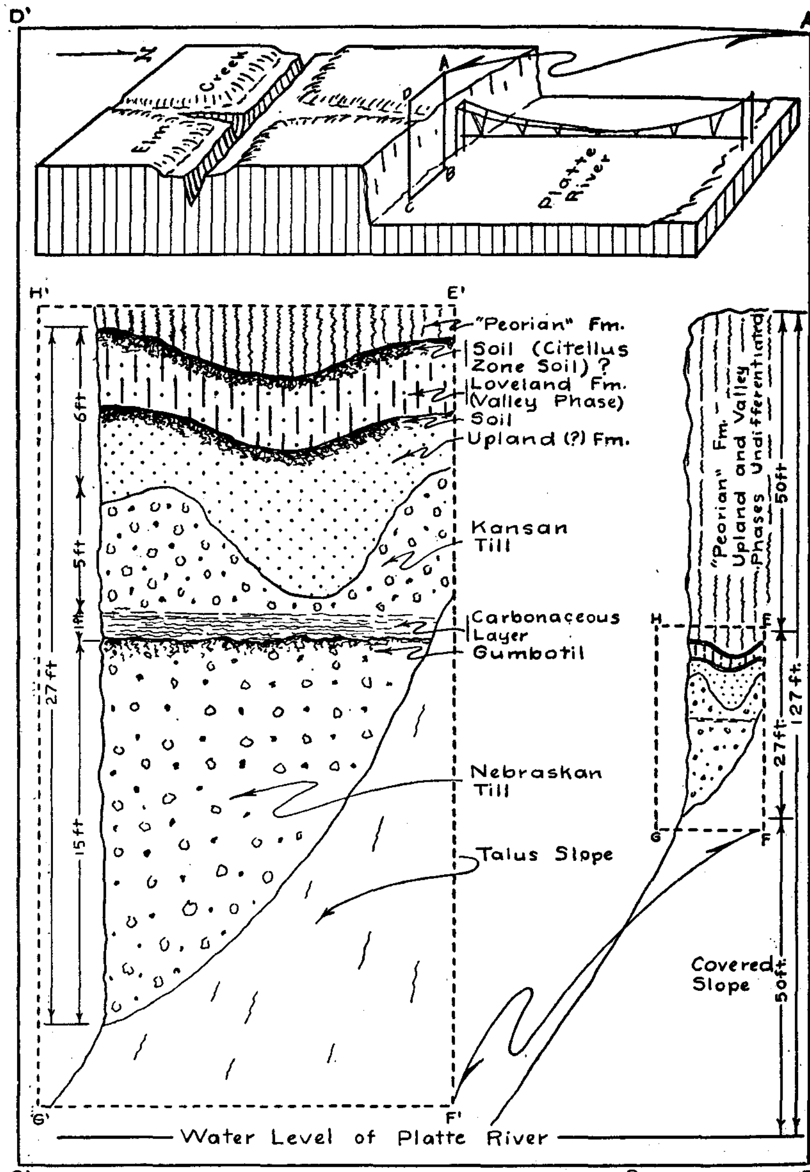

FIG. 4. Location of exposure described in Profile Section No. 1 (Gas Pipeline Section). The Platte River by erosion has engulfed the head of tributary of Elm Creek. Approximate size of block ¼ x 1½ miles.

6.	Kansan Till. The basal one foot consists of a carbonaceous layer and grades upward into the till	1–5
7.	Nebraskan Gumbotil	1
8.	Nebraskan Till	15
9.	Covered slope	50

CONCLUSIONS

This section is quite similar to the Graham's Garden section. Certain significant features, however, are shown which apparently are not in Lugn's Graham's Garden section. The valley phase of the Loveland and the Upland (?) formation by their stratification appear to be fluviatile in origin. They are obviously fills of a valley tributary to Elm Creek. This is evidence that the present-day drainage system at this place is pre-Upland (?) or at least pre-Loveland in age. The Loveland formation has unconformable contacts at both the top and bottom. This formation can be intermittently followed along the bluff for a distance of approximately one mile.

The unconformable relationship of the Loveland on the Upland (?) indicates two cycles of sedimentation separated by an erosional and a soil-forming interval.

The dark, very humic band at the base of the Kansan till, which grades upward into the till, is noteworthy because a peat or carbonaceous depositional condition appears to have given way to a glacial condition. It is probably a "forest" bed of late Aftonian or very early Kansan age.

SECTION NO. 2 (ELM CREEK SECTION)

LOCATION

About two miles south of Fremont, NW¼ of the SE¼, sec. 33, T. 17 N., R. 8 E. Aerial photograph description of location: 9–5–41, UQ–4B–3, $x = 6.2$, $y = 2.2$. The formations are exposed on the west side of a tributary to Elm Creek. See Figure 5.

DISCUSSION

Elm Creek is an alluviated tributary of ancient Clear Creek. The Platte River has dismembered this stream by intercision. See Figures 2 and 3. Due to this dismemberment, Elm Creek found a shorter course to its base level. Also, due to the Elkhorn-Platte entrenchment, Elm Creek acquired a lower base level, and it in turn entrenched itself in its own alluviated valley, leaving a well-developed terrace about 40 feet above the present stream level. Figures 5 and 6 graphically indicate this relationship.

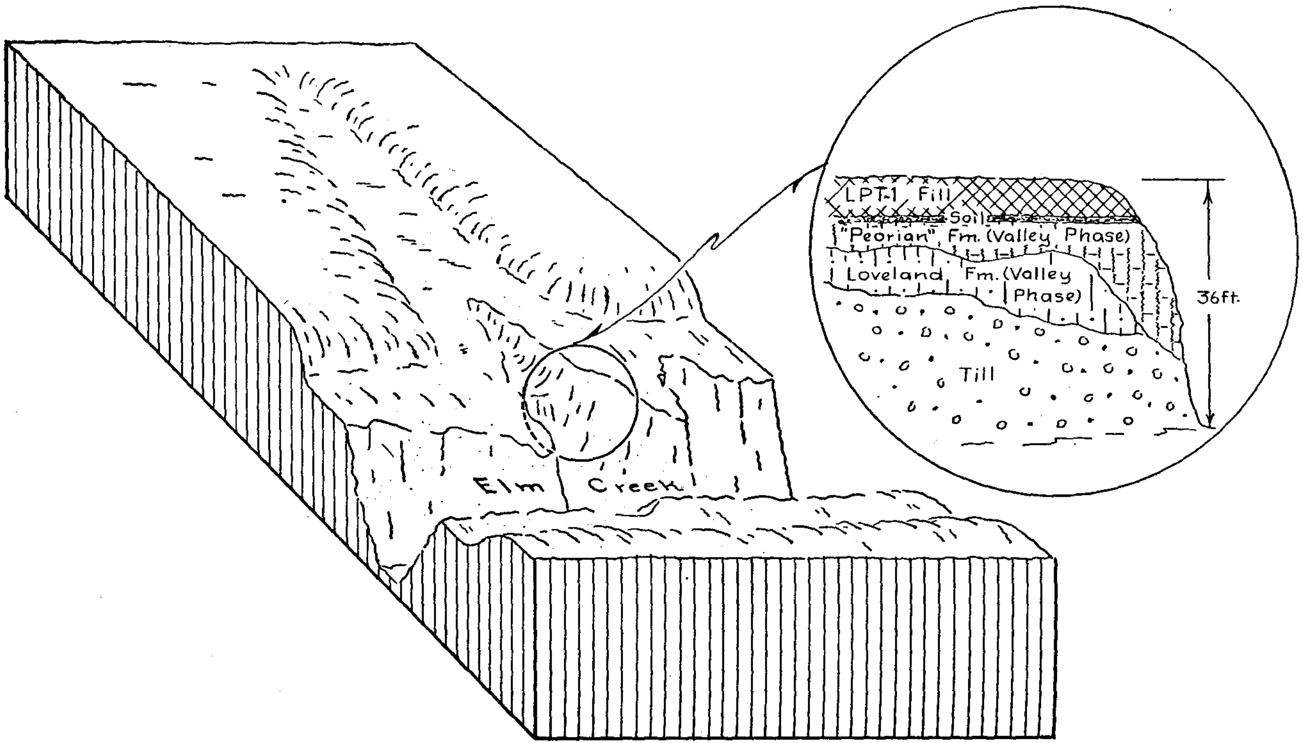

FIG. 5. Location of exposure described in Profile Section No. 2.
Approximate size of block 1/8 x 1/4 mile.

SECTION

		Feet
1.	LPT-1 Fill. Gray alluvium	0–15
2.	Soil. Black and very humic silt	1
3.	"Peorian" formation (valley phase). Yellow, stratified, clayey silt	15
4.	Loveland formation (valley phase). Stratified, red, clayey silt, contains gravel and cobble stones of reworked till	10
5.	Till	5

All thicknesses are only approximations inasmuch as the beds are channel fills and therefore range greatly in thickness.

CONCLUSIONS

The valley phase of the Loveland formation was deposited in a pre-Loveland valley. Post-Loveland erosion, in turn, eroded a valley which cut through the older valley phase of the Loveland and into the underlying till. This post-Loveland valley was then alluviated by the deposition of the valley phase of the "Peorian" loess, and an interval of soil-making followed. At some places, this soil was removed by erosion which took place after the deposition of the "Peorian" formation and before the deposition of the next fill, LPT-1. The deposition of LPT-1 fill followed an interval of erosion, and it (LPT-1 fill) in turn was eroded. This was followed by the filling in of LPT-0 fill. In Figure 5, the fill LPT-0 is not shown as part of the side wall of the entrenchment, but it is found at the head of the entrenched tributary gully in which these beds are exposed. Elm Creek entrenchment took place next. This has been a recent occurrence. At 9–5–41, UQ–4B–3, $x = 6.5$ $y = 2.5$, (aerial photograph descriptive location) on the east side of the gully, is located a "shelved" or "hanging, abandoned meander loop." This was made by Elm Creek at a time when it was flowing at a level approximately 25 feet higher than at present. A delicate erosional feature such as this one, which was developed in soft alluvium, could not maintain its form for any great length of time without noticeable deterioration.

The recency of the entrenchment is also demonstrated by the fact that it has cut through fill LPT-0 which is probably less than a few hundred years old. Additional evidence, however, is given by a dead tree which is located at 9–5–41, UQ–4B–3, $x = 6.2$, $y = 2.6$ (aerial photograph descriptive location). It stands on the

edge of the flood plain of Elm Creek. The tree shows 127 annual growth rings, and appears to have been cut several decades ago. It is therefore obvious that the entrenchment took place at least 150 years ago.

Elm Creek, with the exception of its "physiographic accident," the dismemberment and intercision by the Platte River appears to be a typical normal stream and this therefore provides evidence that the topography in the area is a pre-Loveland topography which has been repeatedly alluviated and eroded in a cyclic manner. For a composite graphic cross-section of this valley, see the enlarged circle in Figure 6.

Elm Creek, as stated previously, was formerly a tributary of ancient Clear Creek. This creek and its tributaries formerly drained into Todd Valley, which at that time was the valley of the Platte River. Normally, the tributaries of a main valley are younger than the main valley or trunk stream, and if the initial erosion of Elm Creek is pre-Loveland we should then suppose that the initial cutting or erosion of Todd Valley would be at least as old as the tributary. This reasoning would make the initial cutting of Todd Valley at least as old as pre-Loveland time. Based on the interpretation that the upland phase of the Loveland does not mantle Todd Valley, Lugn [23] concluded that the initial cutting of Todd Valley was post-Loveland in age but pre-"Peorian," because the upland phase of the "Peorian" mantles the surface of Todd Valley.

The Todd Valley sands (Todd Valley formation) in Todd Valley are, however, everywhere underlain, as far as is known, by a coarse sand or gravel.[24] This appears to be the Crete formation which is

[23] Lugn, 1935, op. cit., pp. 155–156.

[24] Information by personal communication with two local welldrillers, Messrs. Joe Trutna, Wahoo, and Elmer Hansen, Ithaca. A total number of over one hundred wells have been drilled by these welldrillers in Todd Valley. Each of the two welldrillers, who work independently, gave information that agreed very closely. A composite log by Mr. Elmer Hansen is given verbatim. The words in parentheses are those of the writer.

"Soil	2′
Yellow clay (Upland phase of the "Peorian")	about 20′
Light gray, very fine sands, quick sands or dry sands; we never stop at this level for water. (Todd Valley formation)	less than 65′
Concrete gravel or road gravel, reddish brown in color (Crete formation). We get plenty of water at this level, we do not know the thickness of this gravel for it is not necessary to go through it to get plenty of water. We usually go into the gravel a distance of 5 to 15 feet. Average depths of Todd Valley wells are 90 feet."	

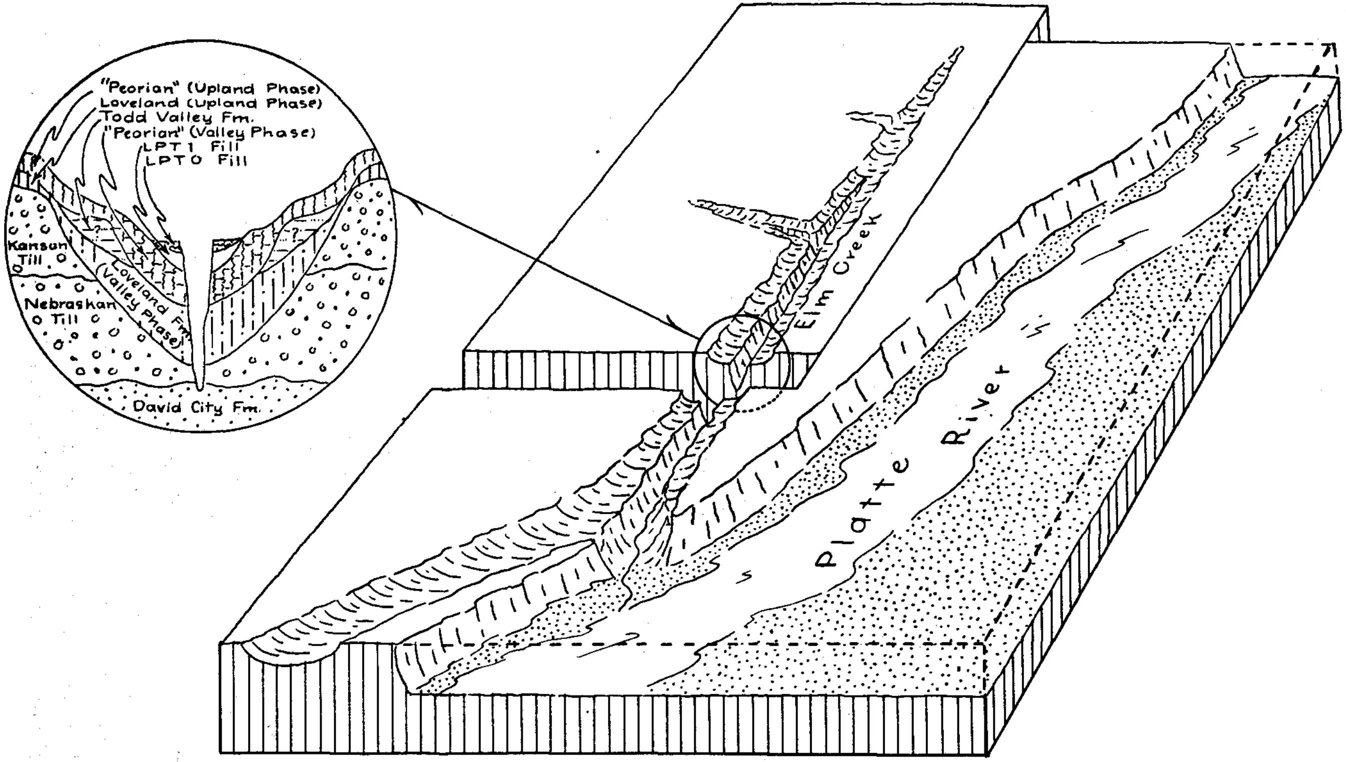

FIG. 6. Elm Creek and composite profile. Approximate dimensions of block 3 x 6 miles.

the basal phase of an alluviation which was concluded with the deposition of the valley and upland phases of the Loveland formation.

The valley phase of the Loveland formation in Todd Valley, however, seems to have been removed by erosion prior to the deposition of the Todd Valley formation. There is little doubt of its former presence in Todd Valley, because it is exposed in fills of other valleys in this area. The initial erosion of Todd Valley, therefore, took place prior to the deposition of the Crete formation, and Lugn's reasoning is correct only if applied to the age of the reopening and the subsequent Todd Valley formation alluviation. Todd Valley, with the exception of its Platte River diversion, seems not to have had any more of a special history than the other valleys with well-developed Todd surface equivalents.

SECTION NO. 3 (FONTANELLE SECTION)

LOCATION

One and one-half miles southwest of Fontanelle, E½, sec. 20, T. 18 N., R. 9 E. Aerial photograph description of location: 8–22–41, UP–2B–4, x = 4.2, y = 2.7.

DISCUSSION

The exposure is along the face of a terrace. It is graphically shown in the right enlarged circle of Figure 7. The terrace is one-fourth mile long and one-eighth mile wide, located along the east banks of the Elkhorn River Valley, and the surface stands approximately 30 feet above the water level of the Elkhorn River. The basal 15 feet consist of the valley phase of the "Peorian," which at this place is a stratified, buff, clayey silt. The top 15 feet consist of 2 to 3 foot alternating layers of gray-buff fine sand and gray humic silt.

CONCLUSIONS

This terrace is the same in elevation as the terrace on which the town of Nickerson stands. A terrace with the same height above the Elkhorn River flood plain is located one mile north of Nickerson, and another similar terrace is located two miles east of Winslow. No exposures occur at the Nickerson terrace. The terrace east of Winslow has an exposure in the SE¼, sec. 13, T. 19 N., R. 8 E. Aerial photograph descriptive location: 7–22–41, UQ–3B–16, x=6.9,

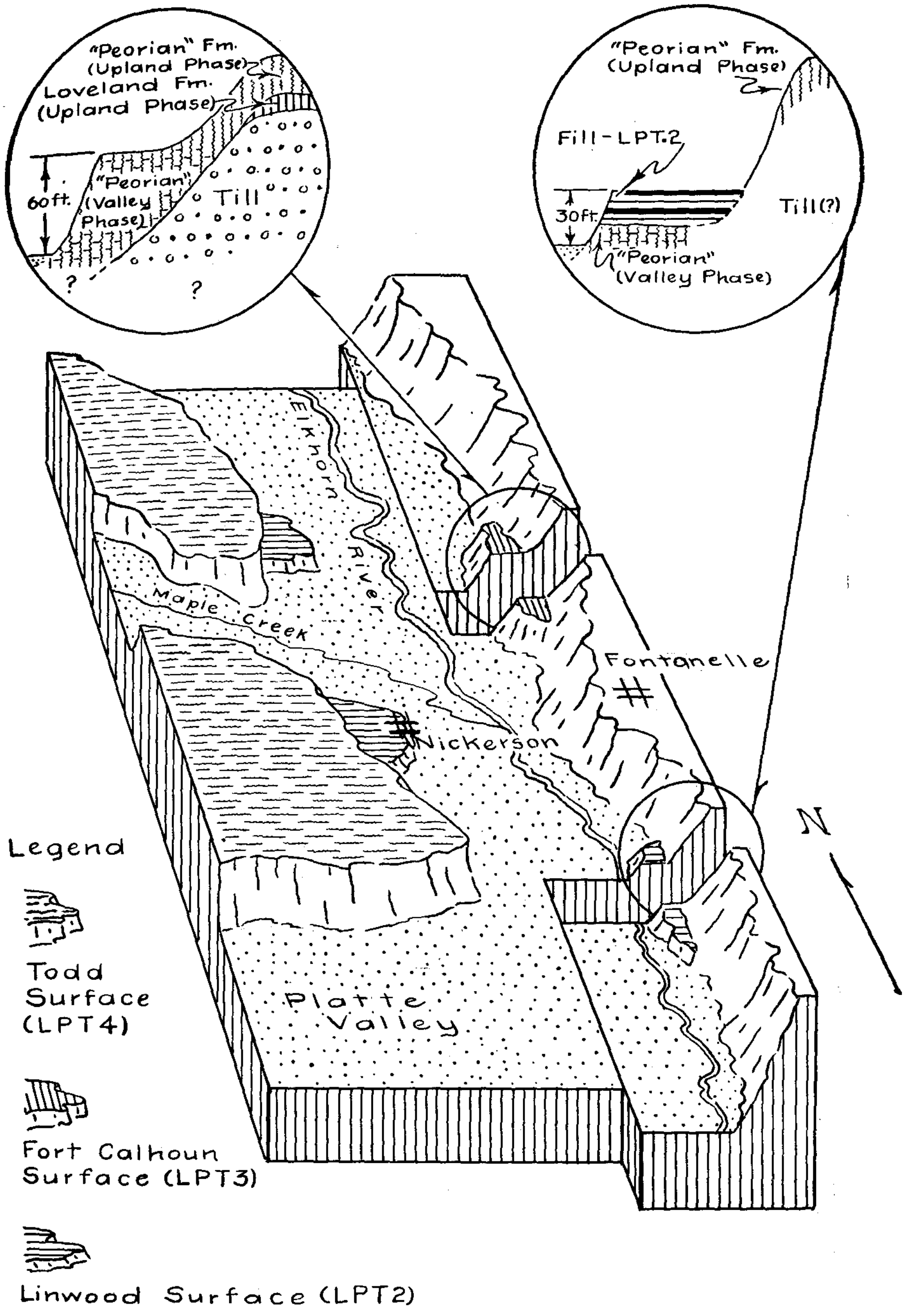

FIG. 7. Location of exposures described in Profile Sections Nos. 3 and 4. Approximate dimensions of block 3 x 6 miles.

$y = 4.8$. The sequence shown at this location is the same as in Profile Section No. 3. The evidence contained in this exposure proves that after the deposition of the valley phase of the "Peorian," erosion removed part of it and subsequent alluviation to the thickness of about 15 feet took place. Finally, erosion removed material to a depth of 30 feet. This terrace is the LPT-2 or the Linwood terrace in the writer's system of designation.

SECTION NO. 4 (FONTANELLE-NICKERSON SECTION)

LOCATION

Approximately one-half mile west of Fontanelle, SW¼, sec. 8, T. 18 N., R. 9 E. Aerial photograph description of location: 8–22–41, UP–2B–53, $x = 2.8$, $y = 2.0$

DISCUSSION

Outcrops occur along a new road which cuts across a narrow but well-developed terrace which is located on the east side of the Elkhorn River Valley near Fontanelle. The terrace is approximately one-half mile long and one-eighth mile wide. It stands 60 feet above the Elkhorn River flood plain. The upland phase of the "Peorian" caps the top of the bluff and extends downward into the valley into an exposure of the valley phase of the "Peorian" 60 feet in thickness. The characteristics of color and texture are very similar to those of the buff-colored upland phase but it is stratified. The upland phase of the "Peorian" appears to connect with the valley phase through an interfingering transitional colluvial phase. The upland phase of the "Peorian" overlies the upland phase of the Loveland formation and the till.

CONCLUSIONS

The lithology of this terrace fill and the height of it above the flood plain identifies it as the "Peorian" [25] or Fort Calhoun terrace. The exposure affords evidence that the "Peorian" can be divided into an upland and a valley phase. It also proves that erosion prior to the "Peorian" deposition removed pre-"Peorian" material, at least to the depth of the present valley, and that the "Peorian" alluviation filled the valley to an elevation 60 feet above the present flood plain.

[25] It is not necessarily implied that this alluviation took place in the Peorian interglacial stage.

SECTION NO. 5 (HOOPER-WINSLOW BLUFFS SECTION)

LOCATION

Approximately one mile southwest of Winslow, SW¼, sec. 22, T. 19 N., R. 8 E. Aerial photograph description of location: 7-22-41, UQ-3B-15, x = 2.5, y = 2.9.

DISCUSSION

Figure 8 is a graphic representation of the outcrops of this section. Other exposures, than the one noted above, occur contiguously along the south bluffs of the Elkhorn River Valley. This section, however, was measured at the location indicated.

SECTION

	Feet
1. Soil	1
2. Loess. Very sandy silt mixed with clayey material. (Post-"Peorian")	30
3. "Peorian" formation. Massive, yellow, clayey silt	45
4. Todd Valley formation. Light gray, stratified, fine sand	37
5. Loveland formation (valley phase). Reddish-brown gravel and coarse sand	6

CONCLUSIONS

The post-"Peorian" loess has been carried by the wind from the Elkhorn River Valley and has formed a 30-foot lip on the north edge of the bluffs. These bluffs are in the leeward direction of the prevailing winds. It appears that deposition took place at a time when the Elkhorn River Valley was sparsely covered with vegetation, and this implies a depositional time when the climate was arid. The upland phase of the "Peorian" is a loess mantle that was deposited on the Todd Valley formation.

The Todd Valley sands are very typically exposed here.[26]

The reddish-brown gravels lie unconformably under the Todd Valley formation and differ lithologically from the gray-white Todd Valley sands. These reddish-brown gravels definitely represent a different and earlier cycle of sedimentation than the overlying Todd Valley formation. The characteristics of color, texture, and stratigraphic position identify these gravels as the Crete Formation. The occurrence of this formation proves that the initial erosion of the Elkhorn Valley, like the Todd Valley, dates back to pre-Crete time.

[26] Wherever identified, the Todd Valley formation consistently is made up of light gray, stratified, well-sorted, fine sand.

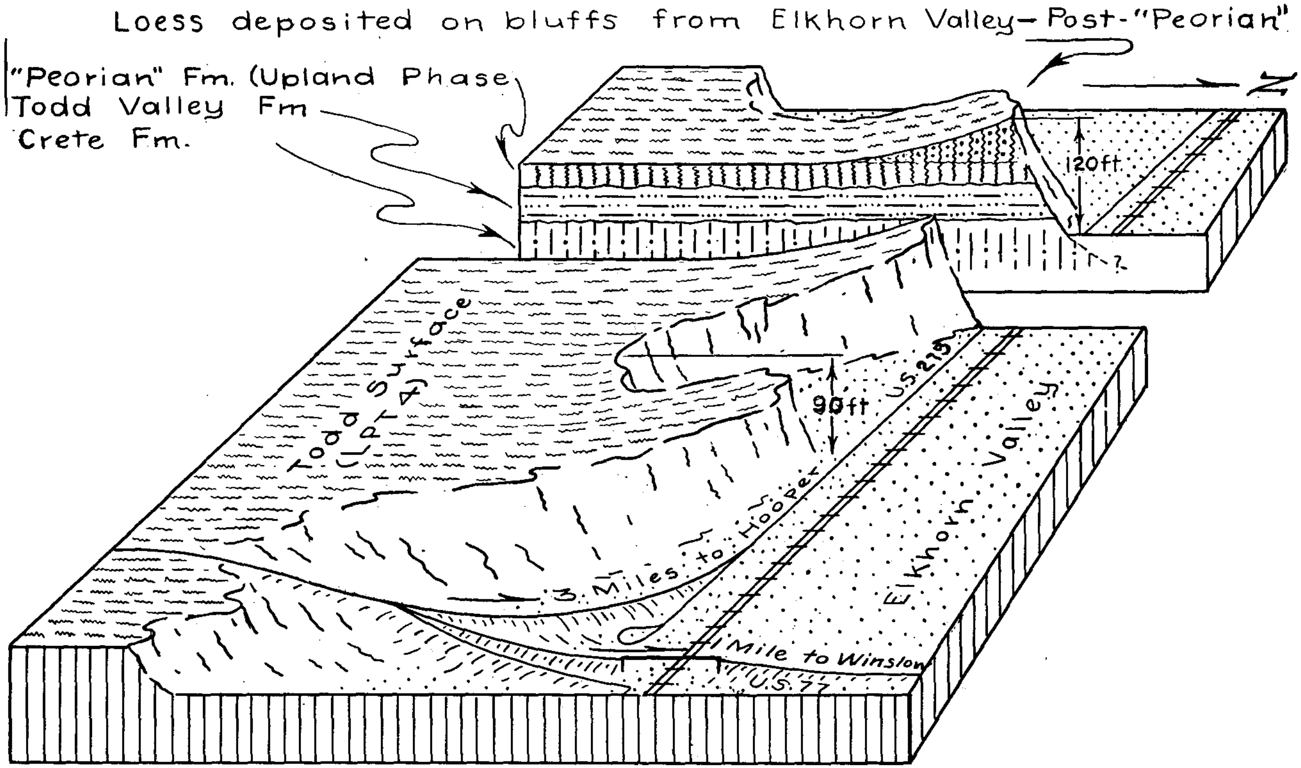

FIG. 8. Location of exposure described in Profile Section No. 5. Approximate size of block 1½ x 2 miles.

SECTION NO. 6 (LOGAN CREEK SECTION)

LOCATION

About one and one-half miles north of Winslow on U. S. Highway 77, east side of road, on the top of the bluff overlooking the Elkhorn-Logan Valley, center of west side of sec. 22, T. 19 N., R. 8 E. Aerial photograph description of location: 7–23–41, UQ–3B–25, x = 4.4, y = 3.4.

DISCUSSION

This is a typical hill-top, road-cut exposure. The top of the hill is 127 feet above the flood plain of the valley (Fig. 9). The exposed part of the profile section is located at the top of the hill.

SECTION

	Feet
1. "Peorian" formation. Gray-buff silt	11
2. *Citellus* zone soil. This is a maturely developed soil	4
3. Loveland formation (upland phase). Red, clayey, silt	3–12
4. Till	4
5. Covered slope to the flood plain	96

The surface slopes downward at right angles to the road-cut to a tributary of the main valley. This tributary valley is dissected through the "Peorian" into the till. The top of the "Peorian" at the edge of the terrace is 25 feet above the water level of the stream. A lower terrace (LPT-0), consisting of a gray-black fill, stands 10 feet above the water level of the tributary stream.

CONCLUSIONS

The soil zone at the top of the Loveland is typical of many upland exposures of the Loveland formation. The upland phase of the Loveland is finer textured than the valley phase. The exposures reveal a normal upland sequence.

SECTION NO. 7 (CROWELL-ELKHORN SECTION)

LOCATION

About one mile northwest of Crowell, NW¼ of sec. 3, T. 20 N., R. 6 E. Aerial photograph descriptive location: 9–5–41, UQ–4B–62, x = 2.4, y = 6.6.

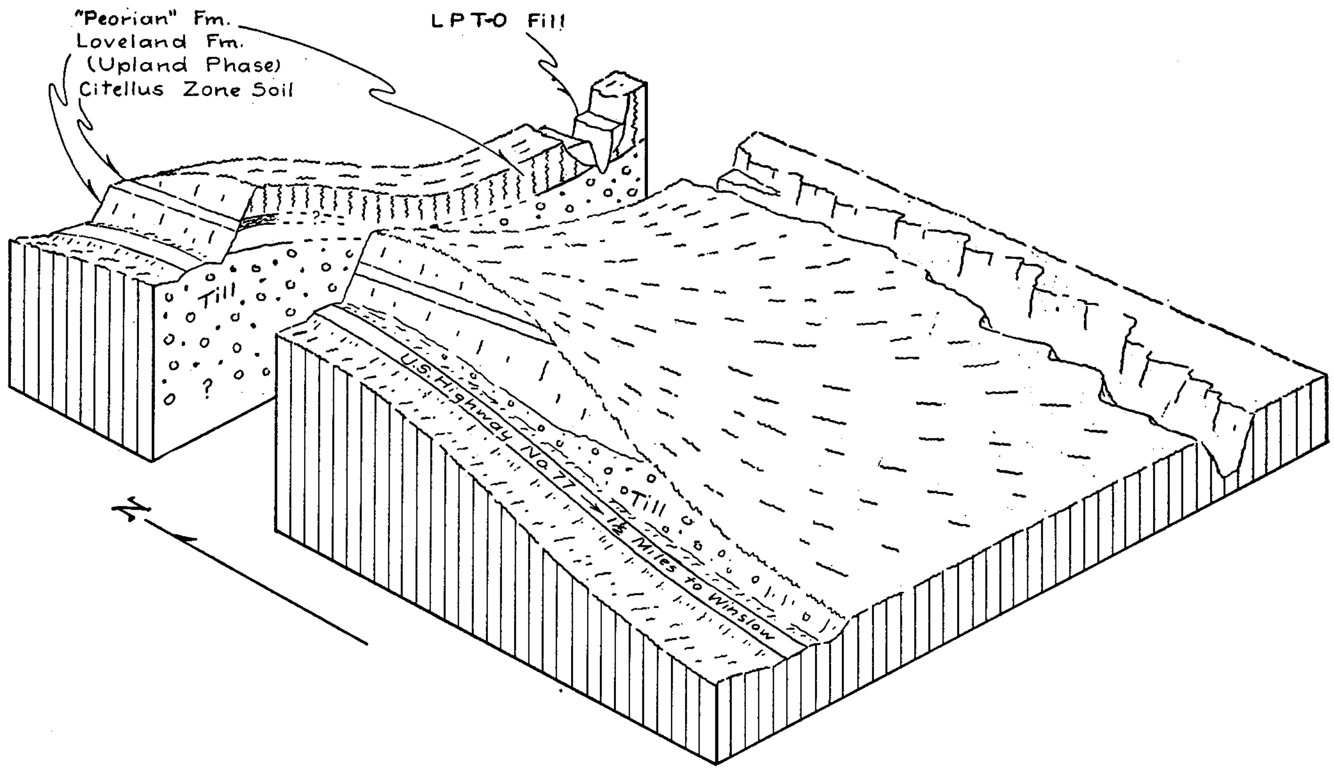

FIG. 9. Typical hill-top road-cut exposure described in Profile Section No. 6. Approximate dimensions of block ⅛ x ⅛ mile.

DISCUSSION

The Elkhorn River has meandered against a bluff at this place, and erosion has cut back into the uplands. By this erosion, it has partly engulfed a small tributary system. The erosional escarpment cuts diagonally across one of the branches of the tributary system and a diagonal, cross-section exposure of a small upland tributary is revealed (Fig. 10). The small rectangle ABCD has been enlarged to the rectangle A′B′C′D′. The enlarged rectangle illustrates the stratigraphic relationship of the following section:

SECTION

	Feet
1. Soil	1
2. "Peorian" formation (valley phase). This is a stratified, yellow, clayey silt	5–25
3. Todd Valley formation. Gray-white, well-sorted, stratified, fine sand	0–5
4. Loveland (valley phase). Reddish-brown sand, gravel and cobbles	0–10
5. Till. The top two to four feet is oxidized	0–35

A black silty fill (LPT-0), five feet in thickness, overlies a six foot bed of stratified gray sand in the lower part of the valley. The total thickness of the section is approximately 50 feet.

CONCLUSIONS

The sequence in the above section substantiates the stratigraphic relations found in other places. Of special significance, however, is the Todd Valley formation, for this indicates that the Todd Valley formation equivalent in short upland tributaries is also a fine-gray-white sand—the same as in the larger valley fills. The source of the material obviously was the till, and this material could not have been moved more than one-half mile because the heads of these tributaries are no farther away than this. The valley phase of the Loveland fill of this small tributary confirms the concept that the topography of today is an alluviated old surface, which is pre-Loveland in age. These valley heads of today are therefore the reopened equivalents of valleys which were first formed prior to the deposition of the valley phase of the Loveland formation, and reveals the extent of the physiographic heritage from pre-Loveland time.

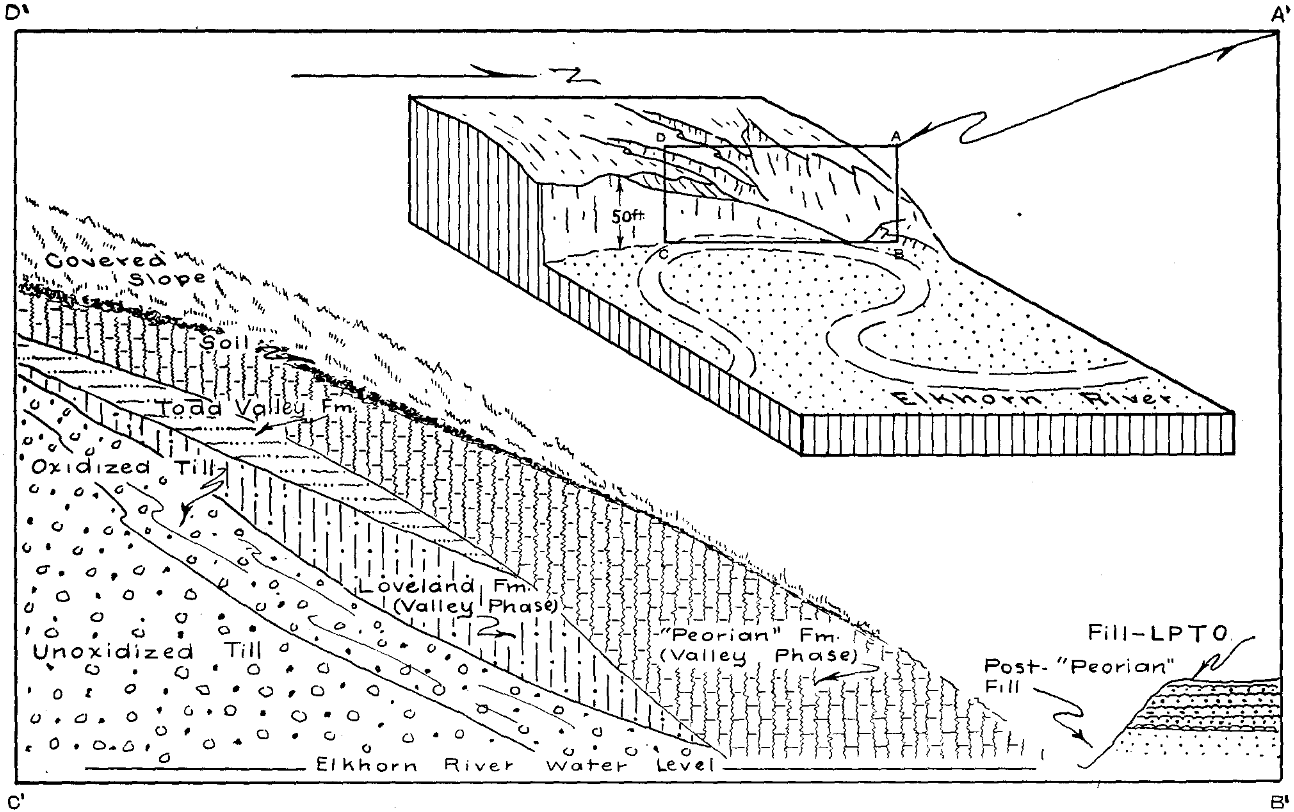

FIG. 10. Cross-section of a small upland tributary exposed by the erosion of the Elkhorn River described in Profile Section No. 7. Approximate dimensions of the block 1/8 x 1/2 mile.

SECTION NO. 8 (FORT CALHOUN TERRACE SECTION)

LOCATION

About three miles southeast of Fort Calhoun, center of west side of sec. 29, T. 17 N., R. 13 E. Aerial photograph description of location: 8–15–41, UP–1B–19, x = 4.3, y = 6.5.

DISCUSSION

This exposure is due to the entrenchment of an unnamed stream into a terrace the top of which stands approximately 80 feet above the flood plain of the Missouri River Valley. This terrace is sometimes referred to locally as the "Bench" (See Fig. 11, left enlarged circle). The main body of the terrace consists of the valley phase of the "Peorian" formation. It is a stratified, buff-colored, clayey silt. At some places, stratification is very faint, and the material has a massive appearance, but at other places stratification is very distinct. Sandy seams and lenses are common. Three different valley fill deposits are exposed in this terrace.

SECTION

	Feet
1. LPT-0 fill. Gray-black silt	0–5
2. LPT-1 fill. This is a dark buff, clayey silt	0–8
3. Soil	1
4. "Peorian" formation (valley phase)	40–70

The total thickness of the exposure is 70 feet.

The two fills, LPT-0 and LPT-1, failed to fill the old valley by approximately 15 feet. The aerial photographs of this area, when used stereoscopically, reveal a dendritic network of old alluviated valleys. Stream erosion is now in the process of headward cutting into these old valley fills, and many of these filled tributary valleys have not yet reached the reopening stage. A well-developed soil zone separates the LPT-1 fill from the "Peorian" fill.

Mr. Jens Jensen,[27] a welldriller at Blair, reported that the base of the "Peorian" is approximately at the base of the terrace, that is the height of the terrace (85 feet) and the thickness of the formation are about the same.

CONCLUSIONS

This section clearly indicates that the depth of the Missouri River Valley was as deep prior to the deposition of the valley phase

[27] Personal communication.

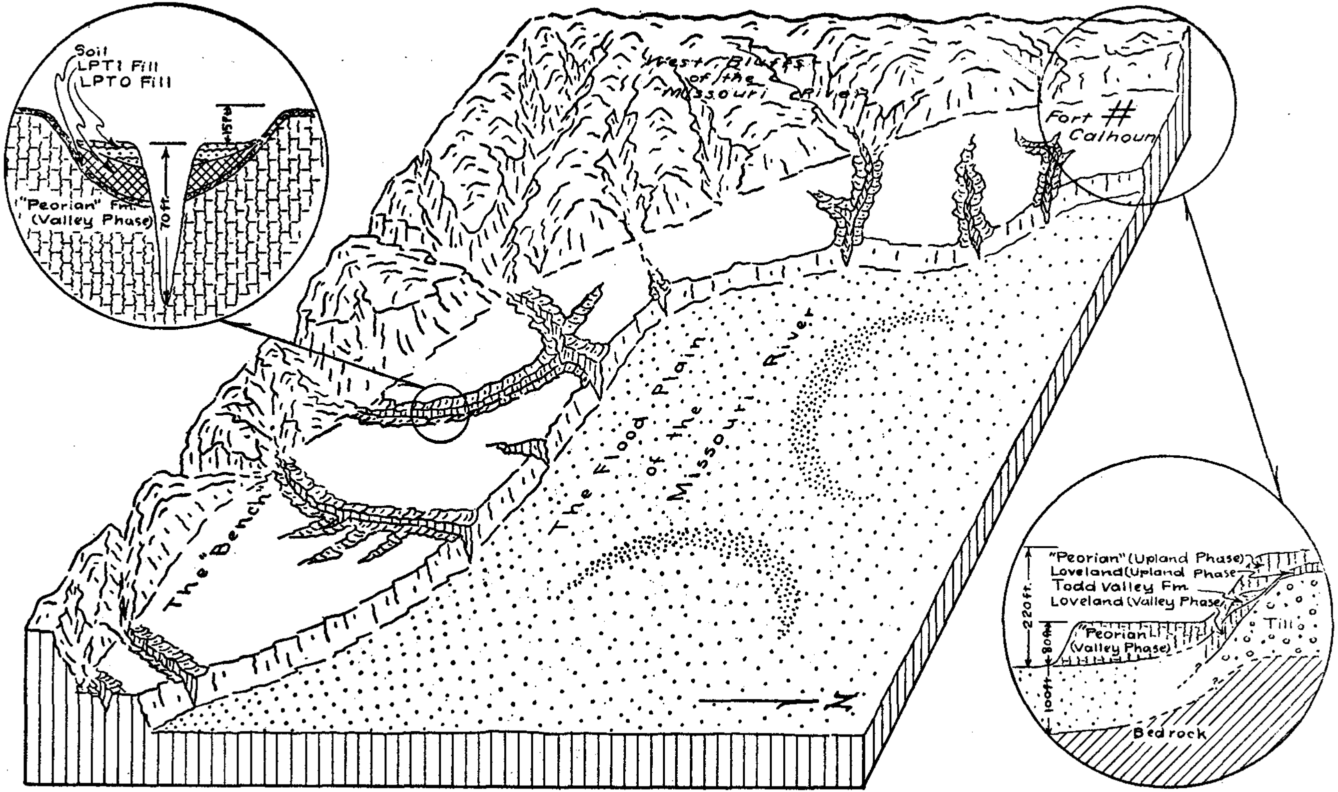

FIG. 11. Location of the exposures described in Profile Sections Nos. 8 and 9. LJT-2 is now known to be present in the upper left diagram. Also the "Peorian" in this area is capped by a soil and a younger loess. Approximate dimensions of block 3 x 4 miles.

of the "Peorian" as it is today and that the broad Missouri River Valley was subsequently filled to a depth of 80 feet. The volume of this alluviation truly was enormous. A well-developed, but not very deeply entrenched, dendritic drainage system was then developed in the "Peorian" fill. Following this entrenchment, a soil formed in these shallow valleys prior to the deposition of the LPT-1 fill.

The LPT-2 fill is also present in this exposure, but it appears to have been almost completely removed by the erosion which preceded the deposition of LPT-1. Another shallow entrenchment and a subsequent alluviation of LPT-0 fill then took place. These alluviations were climaxed by a period of great erosion which in terms of percentage of the whole removed nearly all of the three fills. This last erosion and entrenchment has been a recent action because fill LPT-0 has been eroded. It appears to be this most recent erosion which formed the broad alluvial flood plain of the Missouri River.

This erosion must have taken place after the deposition of LPT-0 fill because it seems improbable that LPT-0 alluviation could have taken place at this exposure with a deep and broad flood plain standing 80 feet lower than the elevation of this exposure and close east of this location. If the Missouri River flowed at the same elevation during the deposition of LPT-0 fill as it does at the present, it must have had a narrow entrenched valley farther east in the main valley. The extensive removal of these fills in post-LPT-0 filling time is therefore convincing evidence that we are now in a time when streams are very actively eroding.

SECTION NO. 9 (BLAIR-FORT CALHOUN SECTION)

LOCATION

This is a composite section of the west bluffs of the Missouri River Valley in Washington County.

DISCUSSION AND CONCLUSIONS

Inasmuch as this is a composite section no detailed measurements or verbal description will be given. The enlarged right side circle in Figure 11 graphically summarizes general information derived from field work and also information from well logs supplied by Mr. Jens Jensen of Blair, Nebraska.

The dissected upland topography in this area is heavily loess-mantled. The short valleys, which are tributary to the Missouri River, have high gradients, and erosion has consequently produced deep valleys which contain thick exposures of the valley phase "Peorian." The "Peorian" typically rests unconformably on eroded remnants of the valley phase of the Loveland and Crete formations, and these in turn rest unconformably on the till.

The Todd Valley formation could not be identified at any place along these bluffs. It is possible that here the Todd Valley formation may not be the typical, grayish-white, fine sand. Instead, it may be a loess-like material and consequently may not have been differentiated from the "Peorian." Another possibility, and the more probable one, is that the erosion following the deposition of the Todd Valley formation was so severe that the fine sands were eroded and cleaned out of the valleys. Mr. Jens Jensen, previously cited, reported that when drilling wells on the shoulders of valleys tributary to the Missouri River Valley he commonly encounters 3 to 4 feet of gray-white, fine, dry sand underlying the "yellow-clay," and that below this sand, he also encounters a "red-clay, with stones the size of walnuts." This welldriller's description conforms very closely with the lithological characteristics of Todd Valley formation and the valley phase of the Loveland respectively.

Figure 12 is a pen tracing of a Kodachrome projection. The direction of the view is southwest looking down a tributary of Mill Creek. The location of the camera was in the approximate center of sec. 24, T. 18 N., R. 11 E. (aerial photograph descriptive location: 8–22–41, UP–2B–20, x = 2.8, y = 2.8). This is a high terrace level (level not determined) which is prominently developed on the upland topography along the Missouri River Valley in Washington County. The level is probably the equivalent of the Fort Calhoun terrace which is well developed at lower elevations bordering the Missouri River flood plain.

SECTION NO. 10 (ASH GROVE LIME AND CEMENT COMPANY QUARRY SECTION)

LOCATION

About one mile northeast of Louisville, center of sec. 14, T. 12 N., R. 11 E. Aerial photograph description of location: 8–13–41, UL–2B–137, x = 3.7, y = 6.2.

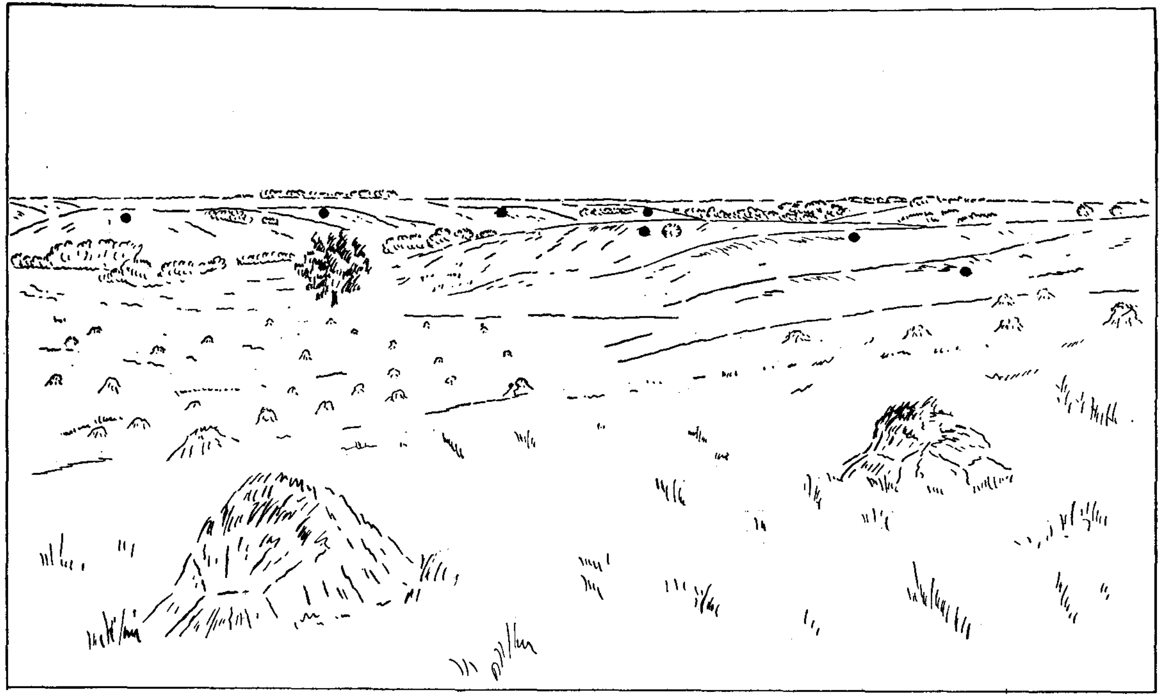

FIG. 12. View—location two miles south of Blair looking down a tributary of Mill Creek, showing a well-developed upland terrace level. Terrace spurs also extend into the valley.*

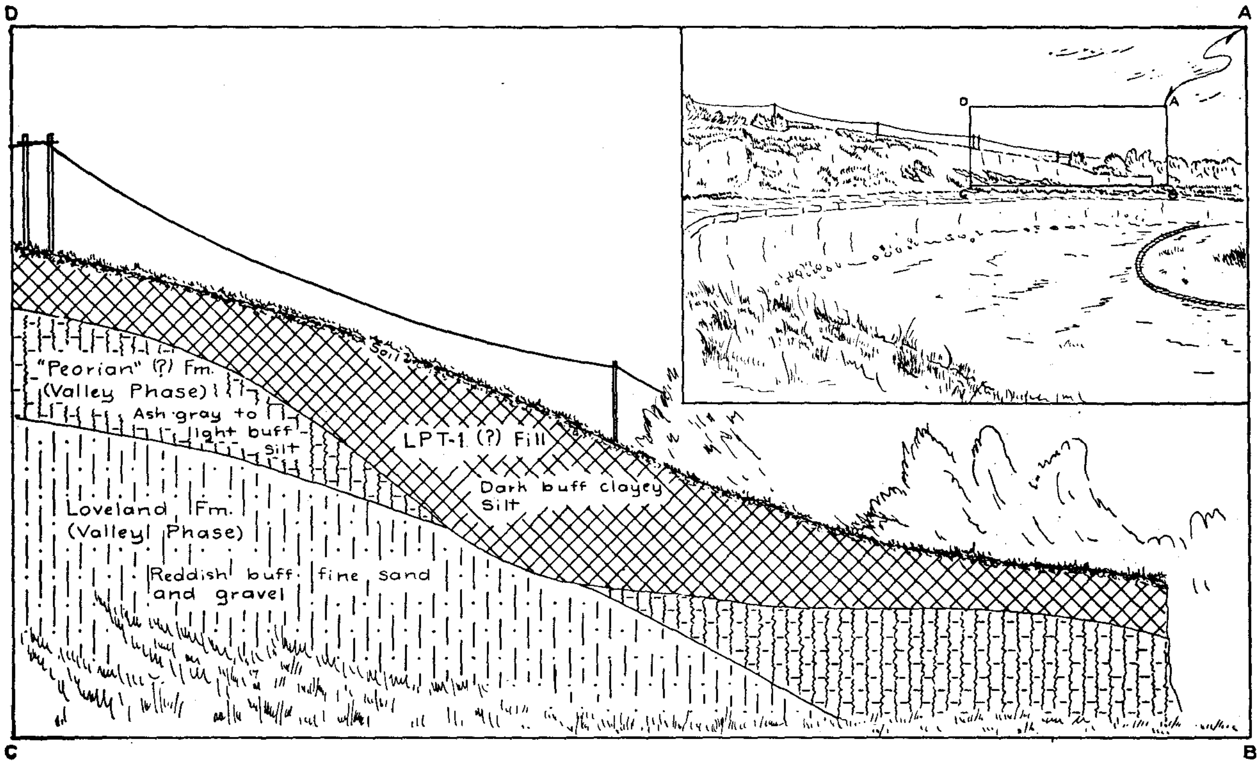

FIG. 13. Ash Grove Lime and Cement Quarry exposures described in Profile Section No. 10. Inset drawing shows the location of the exposure.

DISCUSSION

The inset view in Figure 13 is a pen tracing from the Kodachrome projection. The view is toward the south and reveals a portion of the Ash Grove Lime and Cement Quarry. The location is the one defined numerically above. The small rectangle ABCD is enlarged, and it graphically indicates the Pleistocene deposits at that location.

SECTION	Feet
1. Soil	1
2. LPT-1 (?) fill. Dark buff clayey silt	5–15
3. "Peorian" (?) formation. Ash gray to light buff silt	0–10
4. Loveland formation (valley phase). Reddish buff fine sand and gravel	0–15

Total thickness of the section is approximately 35 feet.

Figure 14 is a pen tracing of a projected Kodachrome. This point is one-fourth mile east of the location given above for Figure 13. Aerial photograph description of location: 8–13–41, UL–2B–137, x=3.9, y=6.9. Because of the proximity of the two exposures, this figure is not indicated as a separate profile section, but instead it is given as supplemental information to Profile Section No. 10. The stratigraphic relationships and the lithological characteristics are shown in the drawing.

These fills have been developed in valleys tributary to the Platte River. The Platte River Valley, from a position three miles east of Ashland to Plattsmouth, does not contain the older and higher (LPT-3 and LPT-4) terrace fill remnants of any recognizable size. This is due to the fact that the stream is entrenched in hard bedrock, and the valley is much narrower than it is farther upstream. The river, being confined to this narrow gorge, has eroded and removed all remnants of former older fills. The terraces in this part of the Platte River Valley are mainly LPT-1 and LPT-0. There are a few small remnants of LPT-2.

CONCLUSIONS

This section appears to show a normal stratigraphic sequence. The valley phase of the "Peorian" (?), however, is lighter in color than the typical "Peorian" of other localities. It has a yellowish ash-gray color. It seems possible that this may be the Todd Valley formation equivalent. If this is the Todd Valley formation equivalent, then the fill designated as LPT-1 fill is likely the valley phase

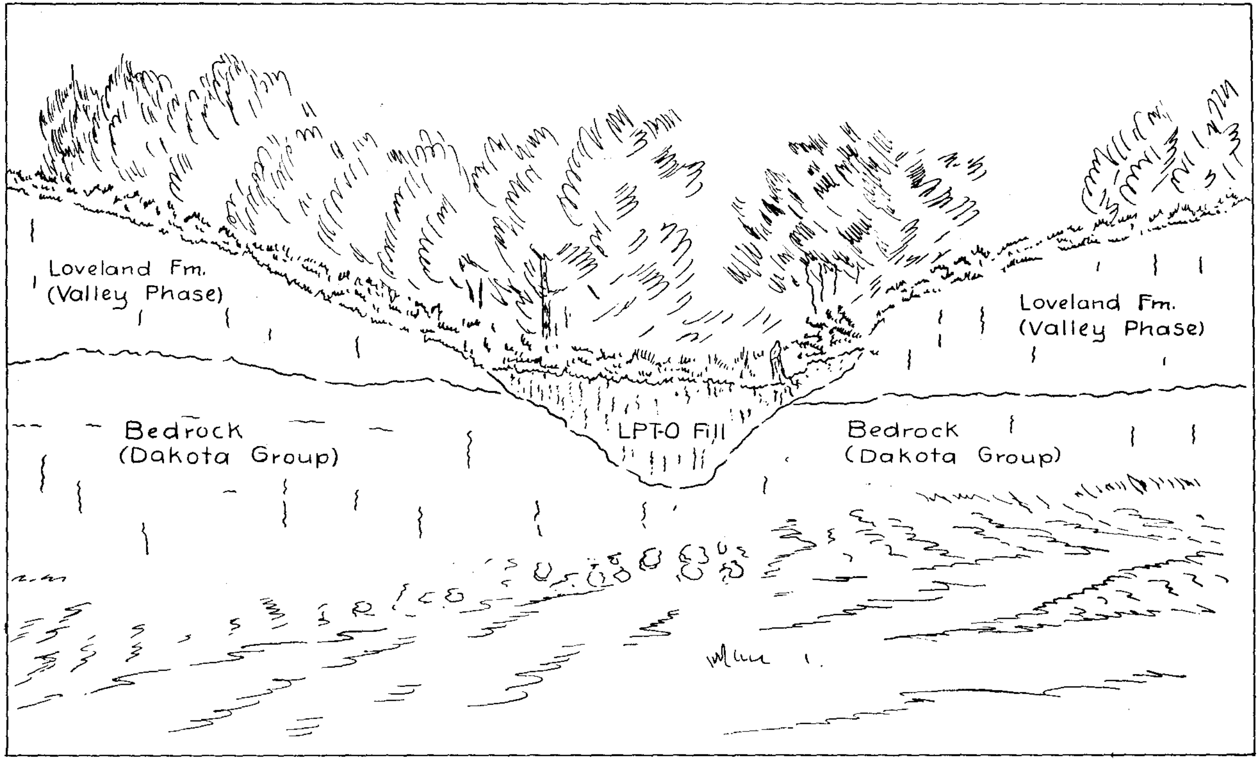

FIG. 14. Ash Grove Lime and Cement Quarry exposure described in Profile Section No. 10.

of the "Peorian." The general lithological evidence would seem to warrant the classification as given in the diagrams, for it seems probable that at this place the Todd Valley formation has been removed by erosion. The "Peorian," particularly south of Ashland, has this lighter color. This is also true at a number of other places along the south bluffs of the Platte River between Ashland and Plattsmouth.

The valley phase of the Loveland appears here, as at Ashland, to consist largely of reworked sandstone from the nearby exposures of the "Dakota group." The lithology of the valley phase of the Loveland differs considerably from one locality to another. Wherever it has been identified in this area, it has a characteristic red or reddish-brown color. The coarser materials, when present, always consist of rock materials derived from close at hand. For example, in an exposure five miles west and one and one-half miles north of Ceresco, near the center of sec. 2, T. 13 N., R. 6 E., (aerial photograph descriptive location: 6–15–40, UM–4A–29, $x = 6.0$, $y = 8.5$), the valley phase Loveland consists of silty, red clay mixed with gravels, cobbles, and boulders. Some of the boulders are as much as three feet in diameter. At this locality, the source of the material was a very stony till under adjacent slopes.

SECTION NO. 11 (ASHLAND-SALT CREEK SECTION)

Location

About one-half mile southwest of Ashland, SW¼, sec. 2, T. 14 N., R. 9 E. Aerial photograph description of location: 7–18–40, UM–5A–27, $x = 5.7$, $y = 6.0$.

Discussion

This profile section (see Fig. 15, upper enlarged circle) is based on an exposed perpendicular face of a terrace that stands 40 feet above Salt Creek. Equivalents of this terrace were traced westward as far as Greenwood. The terrace appears to be well developed upstream, but detailed study was not carried out further west than the town of Greenwood.

Section

	Feet
1. Sandy, loess-like material	18
2. Dark brown clayey layer	1

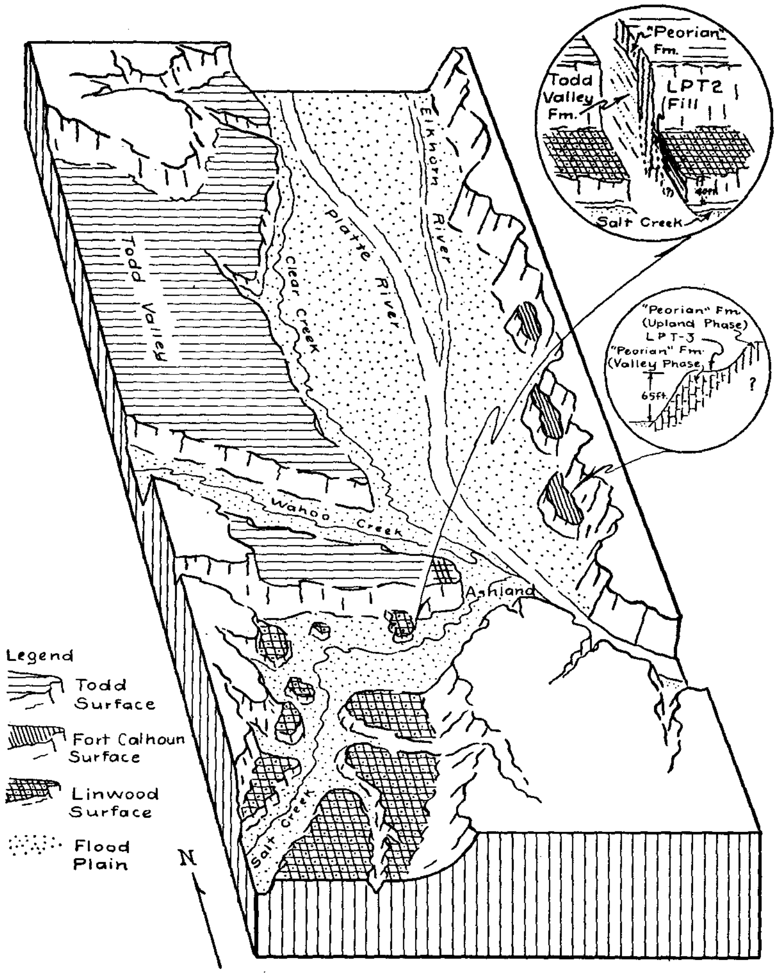

FIG. 15. Location of exposures near Ashland described in Profile Sections Nos. 11 and 12. Approximate dimensions of block 7 x 14 miles.

3. Gray sand, stratified in beds several inches thick............. 7
4. Covered vertical interval.. 14

The base of the section is at the water level of Salt Creek.

CONCLUSIONS

This terrace has the same height and also has essentially the same lithologic characteristics as the terrace at Linwood (South ½, sec. 16, T. 17 N., R. 5 E. Aerial photograph descriptions of location: 9–8–40, UM–6A–176, x = 3.0, y = 7.0. It is believed to be the Linwood terrace (LPT-2) equivalent.

SECTION NO. 12 (ASHLAND-DONALD GRAHAM SECTION)

LOCATION

The southwest extreme outskirts of Ashland on the Donald Graham farm, the SE¼ of the NW¼, sec. 2, T. 13 N., R. 9 E. Aerial photograph description of location: 7–18–40, UM–5A–28, x = 2.5, y = 7.0.

DISCUSSION

This exposure occurs along an erosional escarpment at the southern edge of Todd Valley. Figure 16 diagrammatically illustrates some local details of this exposure. The overlying "Peorian" formation is a clayey, buff-colored silt. It is quite sandy in a number of places. This formation lies unconformably on the gray-white, fine sands of the Todd Valley formation. The bedding planes in these sands are approximately parallel to the contact, which has at this place a vertical relief of 4½ feet in 12 feet of horizontal distance. A differential level profile (hand level) was made, starting at the point described above for Figure 17. This is point A in Figure 17. Points BCD are also on the profile, which extends one-fourth mile east from point A. The points are on the unconformable contact between the "Peorian" and the Todd Valley formation.

CONCLUSIONS

The unconformable contact of the "Peorian" formation on the Todd Valley formation is a profile of a loess-mantled sand dune topography. The larger areas of the Todd surface are, in most places, gently undulating. Aerial photographs definitely reveal that these are not arranged in drainage patterns. The Todd surface

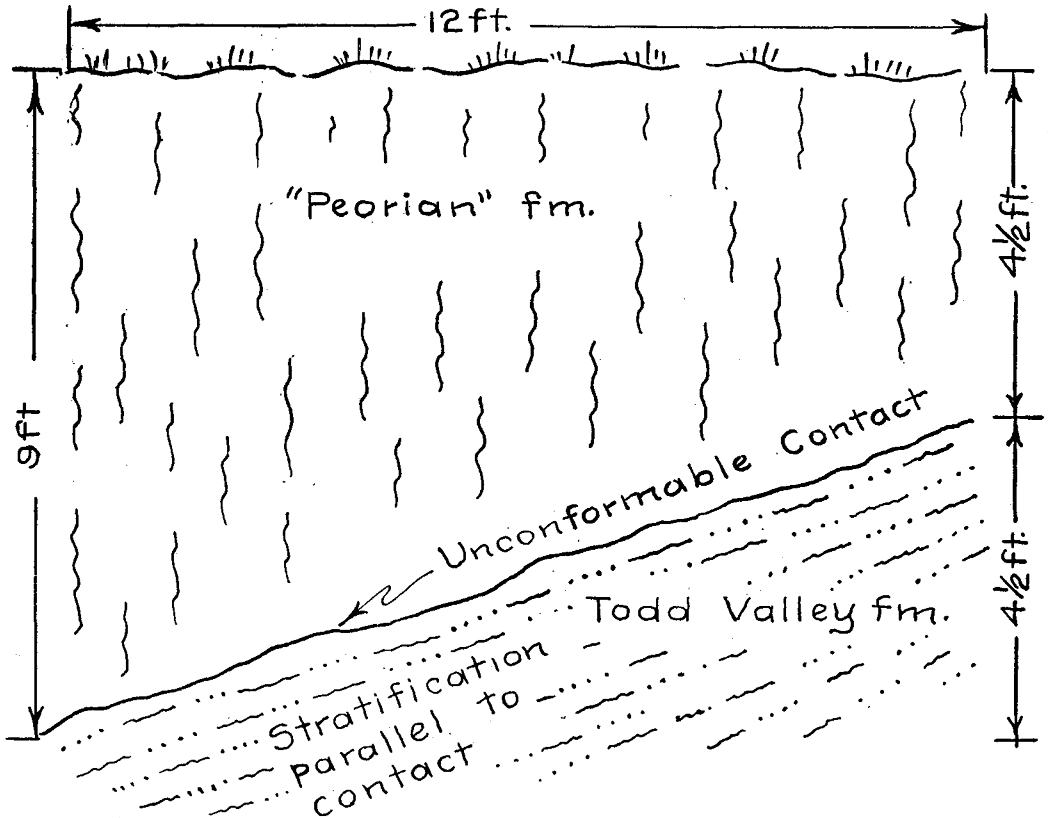

FIG. 16. Diagram showing local details of the contact between the "Peorian" and Todd Valley formations.

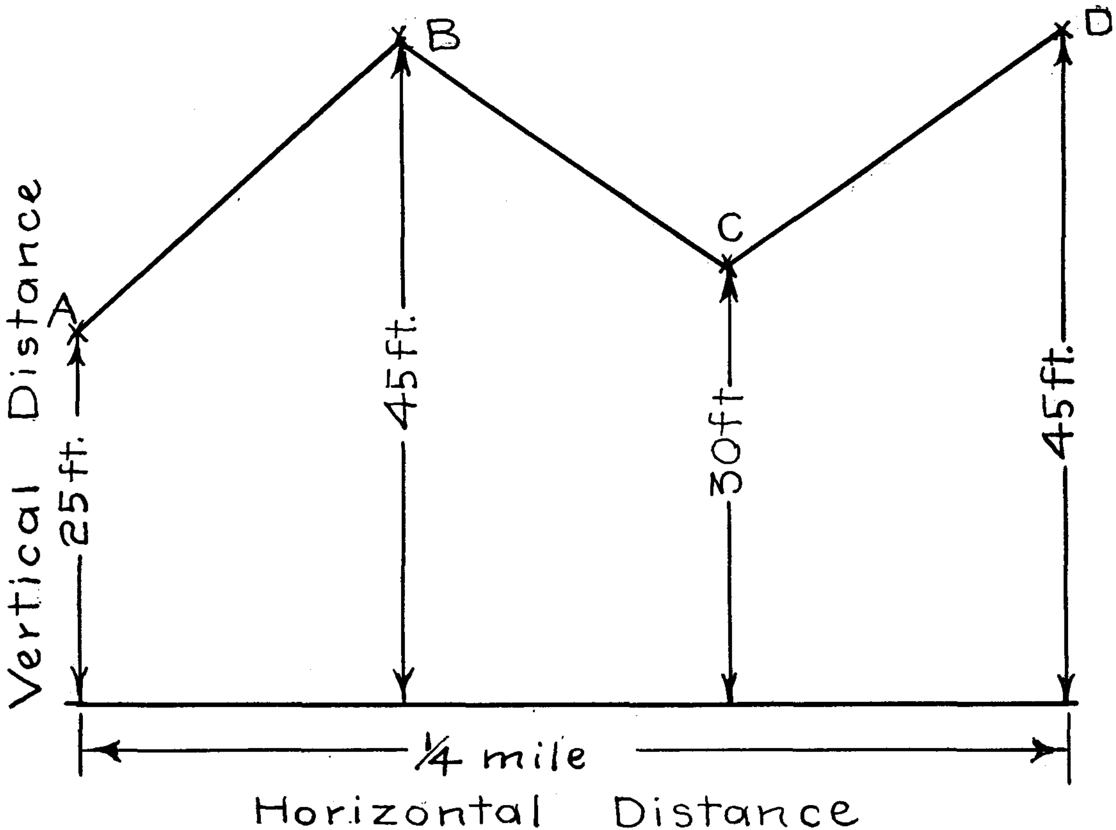

FIG. 17. Differential level profile showing the undulatory characteristics of the "Peorian" and Todd Valley formations contact. Datum level is the average level of the base of the terrace.

has a very characteristic mottled appearance. The knobs or hills are believed to be the sand dunes and the depressions the interdune areas.

If this loess-mantled contact were a surface which had been produced by stream erosion and then mantled with loess, an integration of these depressions would exist and would be evident. Also, if the difference of relief had been produced by water erosion, the bedding planes would not be parallel to the unconformity (See Fig. 16). The conclusion therefore is that the Todd surface was a sand dune area prior to the deposition of the "Peorian" loess.

In some places, the Todd surface has a pronounced topographic "grain." An excellent example of this is afforded in the area between the Elkhorn River and Cuming Creek east of Crowell in the northern part of Dodge County. This "grain" consists of irregularly shaped parallel ridges that have a very pronounced northwest-southeast trend. These ridges have been shaped, no doubt, by the drifting of the Todd Valley formation sands in response to prevailing northwest winds.

The loess-mantled interdune depressions form the small "wet weather" ponds on the Todd surface. The average "basin" or "depression" is perhaps no larger than three or four acres. However, considerable variation exists in the size of these knobs and depressions. The average height of the knobs is approximately 5 to 15 feet, but some higher knobs, 30 to 40 feet, are found in the northern part of Todd Valley. Some of the relief of the Todd surface may have been produced in part by the irregular deposition of the "Peorian" loess. The origin of several isolated knobs and landmarks such as Pahok Hill which is located on the upland two and one-half miles northeast of Cedar Bluffs (sec. 22, T. 17 N., R. 7 E) an Indian Mound located in the northeast outskirts of Ithaca (SW, sec. 21, T. 14 N., R. 8 E) appear to have had this origin.

The mottled appearance of the Todd surface in the aerial photographs has been used by the writer as one of the criteria for mapping this surface. Small areas cannot be identified by this criterion for an area must be large enough to show and contain these characteristic features.

In some of the valleys small areas of the Todd Valley formation are found as erosional remnants. No doubt, in many other places, these have not been identified because they are small rounded ter-

race shoulders and are not large enough in area to show the characteristic "mottling" or "grain" revealed in the aerial photographs of large Todd surface areas.

SECTION NO. 13 (ELKHORN VALLEY-GRETNA SECTION)

LOCATION

Approximately three miles southwest of Gretna. This is a composite section of a terrace. Exposures intermittently show along a north-south county road extending from a position one and one-half miles west of Gretna to a location three miles south (Fig. 15, lower enlarged circle).

DISCUSSION

Well-developed exposures of this terrace are located at a number of places along the road defined above and also at a point on the south side of a county road between sections 11 and 14, T. 13 N., R. 10 E.

This terrace is made up of buff, silty, loess-like material, and in some of the exposures it is faintly stratified. In other exposures, the stratification is very clearly shown. Sand lenses are also common. The lithological and textural characteristics appear to be identical with the Fort Calhoun terrace described in Profile Sections Numbers 4 and 8. The elevation of this terrace above the flood plain of the Platte-Elkhorn Valley is 65 feet. It is therefore approximately 5 feet higher than the equivalent terrace one-half mile west of Fontanelle and it is approximately 15 feet lower than the Fort Calhoun terrace along the bluffs of the Missouri River Valley in Washington County. These differences are due to the fact that the vertical interval between alluvial terraces on a main stream and a corresponding interval on a tributary is always larger on the main stream. It can be shown for the terraces in this area that these differences of vertical intervals to the flood plains are consistently gradational.

The above described section is located approximately midway between the Fontanelle exposures in the Elkhorn River Valley and the exposures in the Missouri River Valley in Washington County. The location of this terrace is very strategic in tracing the continuity of this old surface.

CONCLUSIONS

The lithologic characteristics and the elevation above the flood plain indicates that this is the Fort Calhoun terrace. The material which constitutes the fill of this terrace consists of the valley phase of the "Peorian" formation. The exposures in this profile section and Profile Section No. 3 definitely prove that the Platte-Elkhorn Valley was eroded prior to the deposition of the valley phase of the "Peorian" formation. The height of this terrace is only 15 to 25 feet lower than the Todd terrace. This indicates that the Fort Calhoun, or "Peorian," alluviation nearly filled the valley to the elevation of the Todd surface.

SECTION NO. 14 (WAHOO-TODD TERRACE SECTION)

LOCATION

Approximately three-fourths mile east of Wahoo and one-fourth mile north of Sunrise Cemetery, SW¼, sec. 2, T. 14 N., R. 7 E. Aerial photograph description of location: 8–30–40, UM–6A–123, $x = 5.0$, $y = 4.9$.

DISCUSSION

Sand Creek flows in a valley that is entrenched into Todd Valley. Outcrops are found in a short gully tributary to Sand Creek. At the extreme head of this gully, erosion has exposed 16 feet of the "Peorian" formation (upland phase). It is an unstratified, buff-colored, clayey silt. It lies unconformably on 15 feet of exposed Todd Valley formation which consists of gray-white, cross-bedded, fine sand. The contact between the two formations shows a relief at this location of 2½ feet. An exposure that appears to be the valley phase of the "Peorian" formation 30 feet in thickness can be seen at the mouth of this gully. This is a fill and forms a terrace with its surface 20 feet below the average local surface level of Todd Valley. The terrace level stands approximately 35 feet above the water level of Sand Creek. This fill consists of dark buff stratified material which is similar to the upland phase of the "Peorian."

Two lower levels are located at the mouth of this gully. The higher terrace is 10 feet and the lower 5 feet in elevation above the water level of Sand Creek. The higher terrace constitutes the broad flood plain level of Sand Creek and is underlain with gray, sandy alluvium. The lower fill consists of dark humic alluvium. These

relationships are graphically summarized in the right enlarged circle of Figure 18.

Silver Creek is another stream which has entrenched itself into Todd Valley. It flows diagonally across Todd Valley in a north-south direction. Exposures along this drainage were measured and studied one and one-half miles north of Ithaca in sec. 16, T. 14 N., R. 8 E, UM–6A–168, x = 1.5, y = 6.5 (aerial photograph descriptive location). These exposures reveal terrace fills which have the same lithologic characteristics and the same vertical sequence as those in Sand Creek. It is therefore obviously unnecessary to describe the exposures in Silver Creek Valley.

CONCLUSIONS

The elevation above stream level, the lithology of the materials constituting the fills and the terraces noted above along Sand and Silver creeks identify them in order from the lowest to the highest, respectively as LPT-0, LPT-1, and LPT-3. The terrace fill LPT-2 appears not to be represented along either Sand Creek or Silver Creek. If it ever was deposited, all remnants appear to have been swept out by erosion. Attention should be called to the fact that the writer was able to identify LPT-2 only in the valleys of major drainages such as the Platte River, Elkhorn River, Pebble Creek, and Logan Creek (see the accompanying plate). This terrace appears to have had a restricted development because the entrenchment which preceded the alluviation of LPT-2 was a minor one. The exposure one-half mile northwest of Fontanelle (Section 3) indicates that the vertical distance of entrenchment at this location, along a major drainage, was only 15 feet. Streams during this cycle, therefore, may not have developed headward far enough, in many areas, to produce valleys in which the LPT-2 could be deposited.

The exposures of this section reveal that the initial erosion of both Sand Creek and Silver Creek antedated the deposition of the valley phase of the "Peorian" formation. This also affords proof that Todd Valley did not function as a Platte River Valley during the time of this erosion because Silver Creek could not flow diagonally across a valley occupied by a river such as the ancient Platte River. This, therefore, is proof that the Platte River abandoned Todd Valley after the deposition of the Todd Valley formation and before the erosion of Sand Creek and Silver Creek. Therefore,

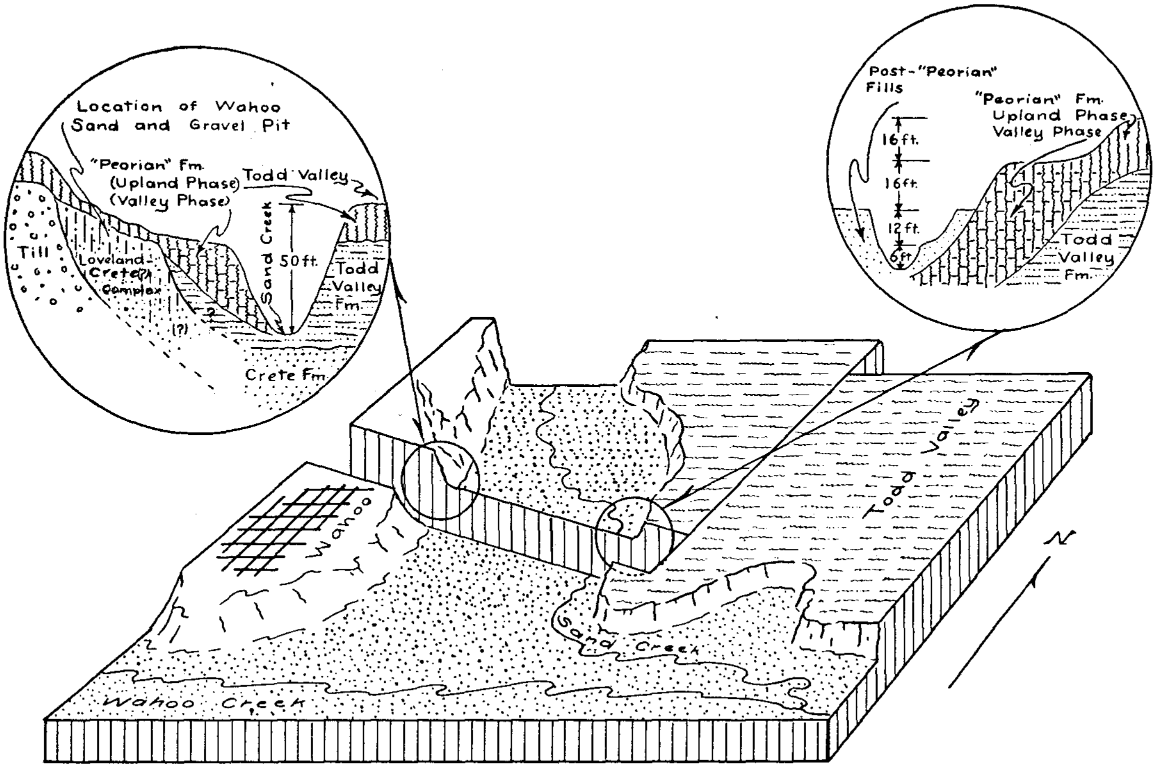

FIG. 18. Location of exposures near Wahoo described in Profile Sections Nos. 14 and 15. Approximate dimensions of block 1 x 1 mile.

erosion of the Fremont section of the Platte River Valley, which came about at this time, represents an epoch of long duration and deep cutting which took place after the deposition of the Todd Valley formation and before the deposition of the "Peorian" formation. This also supplies evidence that the "Peorian" sedimentation was not a continuation of the Todd Valley alluviation as some have suggested. The two sedimentations were separated by a time of major erosion—namely, the time when the Fremont part of the Platte River Valley was eroded and entrenched.

Sand Creek and Silver Creek could have developed only after the Platte River entrenchment was well under way. This provides additional evidence that there was a long interval of time separating the deposition of the Todd Valley and the "Peorian" formations.

SECTION NO. 15 (WAHOO CONCRETE PRODUCTS COMPANY SAND AND GRAVEL PIT SECTION)

LOCATION

Northeast outskirts of Wahoo, extreme south center of sec. 34, T. 15 N., R. 7 E. Aerial photograph description of location: 6–2–40, UM–2A–119, x = 4.4, y = 1.7.

DISCUSSION

This exposure has been made in part by the excavations of the Wahoo Concrete Products Company. The elevation of the top of the exposure is approximately the same as the floor of Todd Valley across Sand Creek Valley to the east, and the elevation of the base is approximately the same as the water level of Sand Creek which flows 50 feet below the level of Todd Valley. The "Peorian" formation (upland phase), consisting of 0-10 feet of unstratified buff clayey silts, mantles gravel and till on the west side of Sand Creek Valley. The "Peorian" formation grades down into a terrace remnant 30 feet high above the water level of Sand Creek. The material of the terrace consists of the valley phase of the "Peorian." It is a stratified, buff, clayey silt and ranges in thickness from 0-25 feet. The thickness of the gravel exposure ranges from 0-33 feet. It may be a complex consisting of gravels representing several different alluviations. The gravel does not appear to underlie the upland west of this exposure (north part of Wahoo). Dr. G. E. Condra [28] reported that test wells drilled for a water survey revealed no evi-

[28] Personal communication, December 1946.

dence of the existence of this gravel west of this location. The absence of the gravel in the upland seems to indicate that it is not an intertill gravel, but that it is related to Todd Valley more closely than to the tills. The tentative stratigraphic relationship of the formations in this exposure are graphically suggested in the left enlarged circle of Figure 18.

CONCLUSIONS

It appears that at least part of the gravel exposed in this gravel complex is equivalent to the Crete formation, which is known to underlie the Todd Valley formation in Todd Valley (see footnote Profile Section No. 2). The lithologic characteristics of these gravels also strongly suggest the equivalence of the Crete formation. More evidence derived from strategic drilling would be desirable and would either confirm or rule out the above interpretation. If these gravels are part of the Crete formation, as they seem to be, this is proof of a great thickness of gravel alluviation during Crete time and also a long post-Crete formation pre-Todd Valley formation erosion which isolated the gravels in this exposure as a Crete formation terrace remnant.

SECTION NO. 16 (BARTEK BROTHERS FARM SECTION)

LOCATION

About two and one-half miles west of Weston, center of NE¼, sec. 12, T. 14 N., R. 5 E. Aerial photograph description of location: 8–30–40, UM–6A–134, x = 6.4, y = 3.6.

DISCUSSION

An unnamed tributary of Wahoo Creek has cut into a hill on the outside of a local meander loop (see Fig. 19). The exposure is graphically represented by the enlarged rectangle A′B′C′D′ in Figure 19.

SECTION

	Feet
1. "Peorian" formation (valley phase). Buff-colored, faintly stratified, clayey silt	0–15
2. Loveland (valley phase). Brown-red, silty sand, faintly stratified	10
3. Soil zone. Gray, humic silt	1
4. Silty sand, greenish-buff in color	5

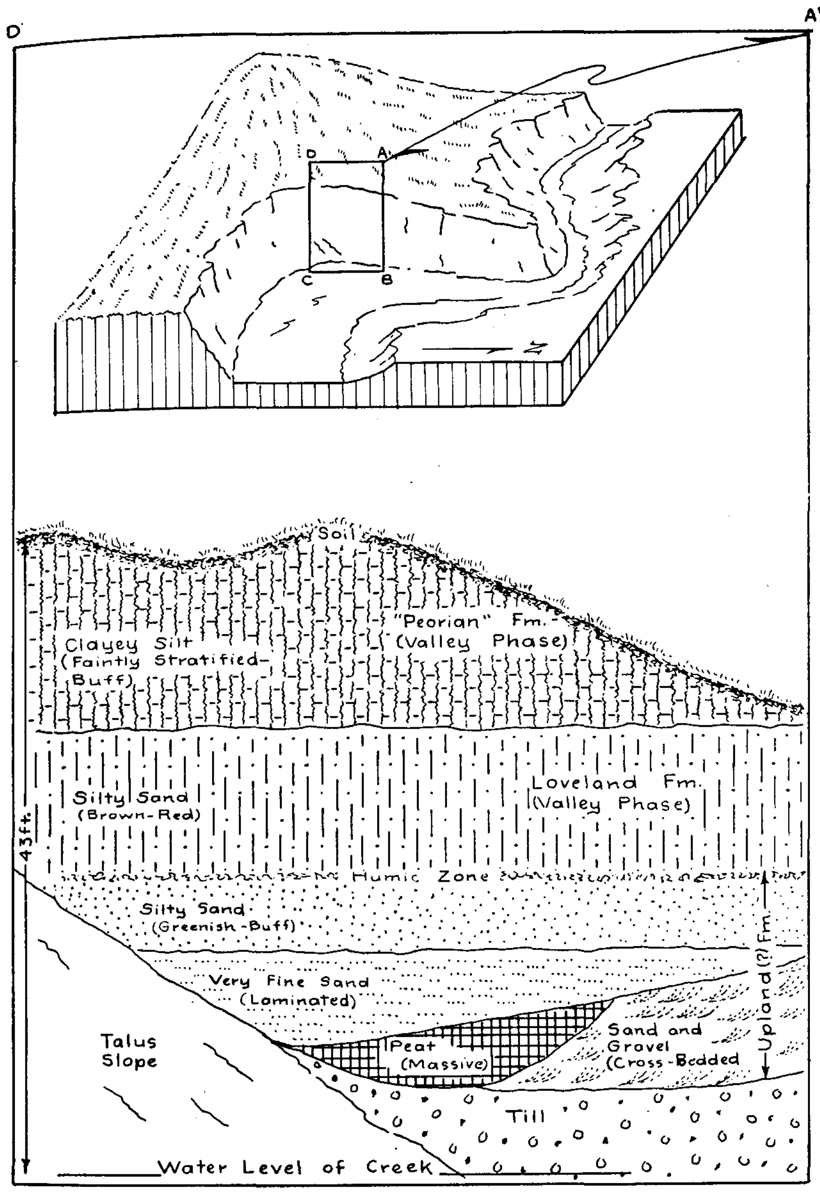

FIG. 19. Location of Profile Section No. 16 near Weston. Approximate dimensions of block 1/8 x 1/8 mile.

5. Very fine sand, prominently stratified, horizontal laminations	1–4
6. Peat	0–3
7. Sand and gravel, prominently cross-bedded	0–7
8. Till	6

The total thickness of the exposure is 43 feet and the base of it is approximately 180 feet lower than the upland hills. Supplemental information to the above section is shown in Figure 20. It is a modified pen-tracing of a projected Kodachrome showing the fill, LPT-0, as exposed by an entrenched meandering stream. The location is one-fourth mile east of Profile Section No. 16. The aerial photograph descriptive location of this point is UM–6A–133, $x = 4$, $y = 2$. Two terraces are shown in the drawing. The higher terrace stands 25 feet above the water level of the stream. This terrace consists of a buff-colored, silty clay. The lower terrace consists of dark, humic silt and is definitely a valley fill. The top of this terrace stands 10 feet above the stream level.

CONCLUSIONS

Beds numbers 3, 4, 5, and 6 in the above described section appear to be a complex and are provisionally assigned to the Upland formation. Bed 7 may possibly represent the equivalent of the Grand Island gravels. In terms of age they can be definitely assigned as younger than the till, Nebraskan (?) or Kansan (?), and older than the Loveland. The humic zone appears to be a soil zone, which indicates that the surface of the silty, greenish, buff sand was exposed for a long time to soil-forming conditions. This bed in particular has the lithologic characteristics of the Upland formation, and if it is the Upland formation the evidence of an intensive erosion in the post-Kansan pre-Upland time is conclusive, because this bed is a fill deposited in a channel cut 180 feet below the top of the present day upland levels. If the upland phases of both the "Peorian" and the Loveland formations have a total approximate thickness under the upland levels of 50 feet (this estimate is purposely placed high) this post-Kansan pre-Upland erosion in this valley represents a vertical entrenchment of at least 130 feet below the Kansan till surface.

The "Peorian" rests unconformably on the valley phase of the Loveland. The typical gray-white, fine sands of the Todd Valley formation are not present in this exposure. They appear to have

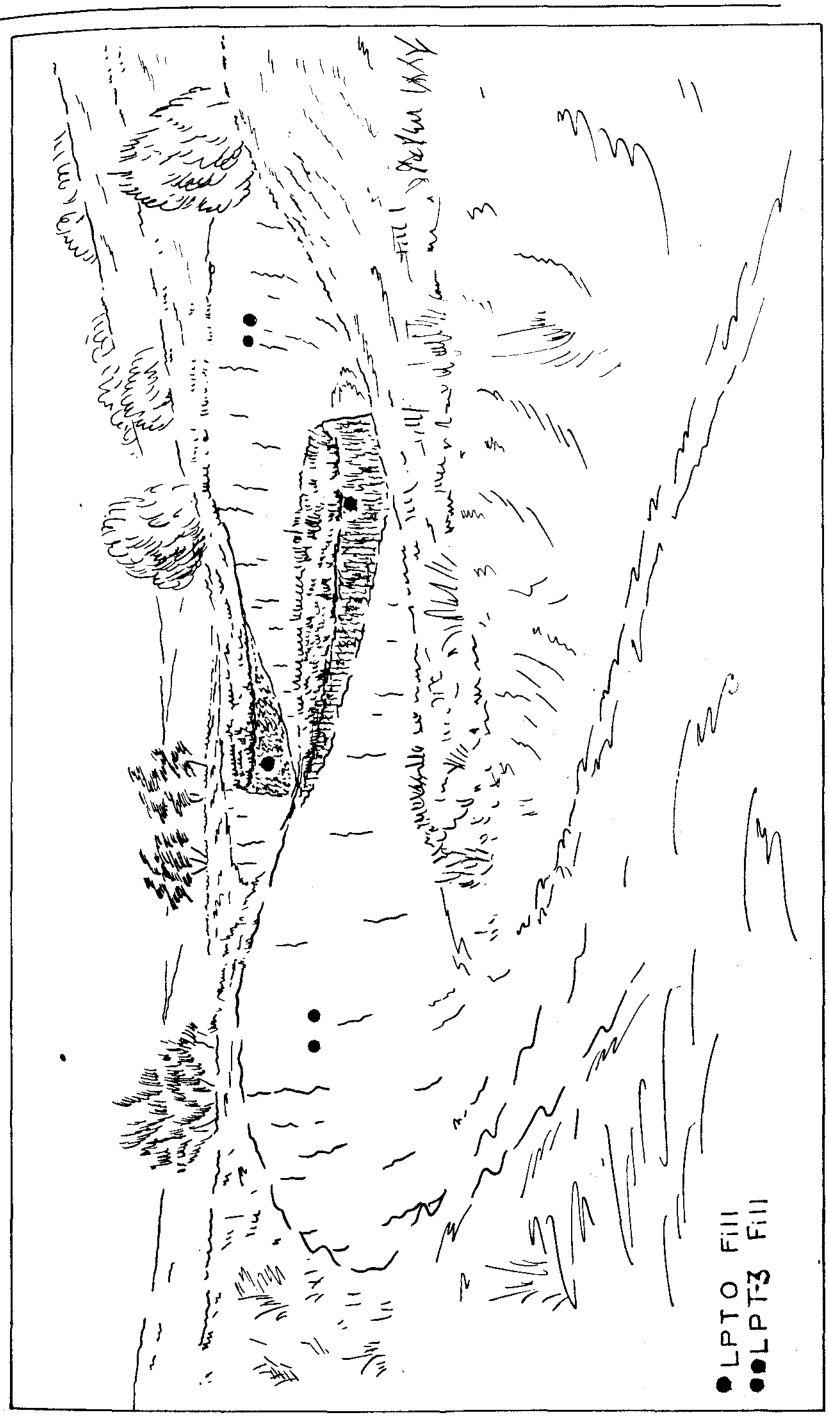

FIG. 20. View of exposures near the Bartek Brothers farm described in Profile Section No. 16.

been removed by erosion. Topographically, higher isolated terrace shoulder remnants are located on the sides of the valley. These small terrace remnants likely are loess-mantled remains of the Todd Valley formation.

POST-KANSAN HISTORY

A chronological order of events can now be stated based on the various "Jig saw" pieces of evidence shown in the profile sections which have been described. The order of events will be given chronologically from the time immediately following the melting of the Kansan ice sheet in this area, up to the present time. Figures 21 through 28 graphically illustrate this history. It should be clearly understood that these diagrams are composites and as such, therefore, do not represent any one valley or place in this area. Vertical and horizontal scales have not been included in these diagrams because the cross-sectional areas of some of the beds have been necessarily exaggerated, for if drawn to the same scale as the larger beds they would be microscopically small.

POST-KANSAN PRE-CRETE CYCLE

It can be assumed that the Kansan till sheet had some initial topographic relief prior to its erosion. This relief could have been caused by the irregular deposition of the till, and some irregularities may have been due to the incomplete filling and leveling of the pre-Kansan topography. The first valleys that were developed on the Kansan till in this area, were likely those made by eroding streams which flowed from the melting Kansan ice sheet. The first task of erosion was to form continuity of drainage from one low depression to another. Adjustments and entrenchments continued until a well-developed mature topography resulted, initiating even then some of the smallest tributaries which today are less than one-fourth mile long. See Gas Pipe Line Profile Section No. 1. This exposure contains an Upland valley fill below the valley phase of the Loveland. It might be proposed that the fill assigned as the equivalent of the Upland (?) is the Crete formation. The texture and color of this fill, however, closely resembles the description of the Upland formation as defined by Lugn.[29] It is unlike the typical coarse-textured gravels of the Crete formation. If this fill is the Upland formation, as it quite definitely seems to be, then the

[29] Lugn 1935, op. cit., p. 26.

erosion into the Kansan till forming the valley in which this fill is contained must have taken place in post-Kansan pre-Upland time. The evidence given by the Bartek Brothers Farm exposure (see Section No. 16) indicates that the post-Kansan pre-Upland erosion was a profound one. This erosion and subsequent alluviation constitutes the "Post-Kansan pre-Crete" cycle. Graphically this cycle is illustrated by the composite profile in Figure 21. What is here termed the Upland (?) may include Grand Island gravels at the base.

THE CRETE-LOVELAND CYCLE

Erosion and entrenchment followed the post-Kansan pre-Crete cycle. Some of the valleys that had been eroded and filled during the post-Kansan pre-Crete cycle were almost washed clean of the Upland (?) formation. Such streams as Elm Creek eroded down at least as far as into the till, and it appears likely to have eroded into the David City formation. The David City formation, while not exposed at the location of the outcrops described in Section No. 2, is exposed at the base of the mouth of Elm Creek, one-eighth mile northeast of this location. Exposures described in Profile Sections Nos. 1, 2, 5, 7, 10 and 16 give proof of the erosion and alluviation which constitute this cycle. Evidence given in these exposures substantiates Dr. Lugn's statement pertaining to the intensiveness of the pre-Loveland erosion. However, the writer is not fully in agreement with Lugn [30] that the initial erosion of the lower Platte River Valley from Columbus to Plattsmouth occurred in the post-Loveland pre-Peorian interval (Iowan age of glaciation). This age designation appears to be correct if applied only to the reopening of the Platte Valley during the Todd Cycle.

An earlier Platte Valley antedated the deposition of the Todd Valley formation, because the Crete formation is also well developed in the Todd Valley under the Todd Valley formation (see Profile Section Nos. 2 and 5). The Todd surface can be traced westward from the north end of Todd Valley to a point at least as far as 10 miles northwest of Columbus. This surface is represented on the north side of the Platte River Valley as a broad and almost unbroken terrace. Due to shortage of time, the writer was not able to work on the problems of the continuity of the Crete formation and the valley phase of the Loveland in its position under the

[30] A. L. Lugn, "The Pleistocene History of Nebraska," *The Compass of Sigma Gamma Epsilon,* XXII, No. 2, November, 1941.

Todd formation in contiguous areas. There is no reason, however, to suppose that the stratigraphic sequence in the terrace on the north side of the Platte River Valley westward from Todd Valley to Columbus is any different than in Todd Valley. The Platte River from Ashland to Plattsmouth flows in a narrow valley because the river has entrenched itself in hard bed rock. The river, because of its narrow valley, has, therefore, swept away the Todd fill which once may have been present.

If the initial erosion of Todd Valley took place prior to the deposition of the Crete formation, it must be concluded that the lower Platte from a point 10 miles northwest of Columbus to Plattsmouth, with the exception of the part of the valley from Ames to Gretna, was eroded prior to the deposition of the Crete formation. It seems reasonable to visualize the initial erosion of the Platte River Valley to have taken place in Yarmouth time by a Missouri River tributary eroding headwardly across the till border. Headward erosion appears to have progressed until capture of some of the drainages west of the till border took place. A Platte River tributary, for example, appears to have captured the parallel flowing northwest-southeast flowing tributaries of the Loup River. Sharp elbows of capture are indicated at the points of junction of these present-day tributaries of the Loup River. The drainage pattern of the modern-day Loup River strongly suggests that the branches of the Loup River, before piracy, were the headwaters of the Blue River System.

Deposition of the Crete formation followed the period of intensive erosion which took place in the early part of the Crete-Loveland Cycle. The Crete formation, according to Condra and Reed,[31] in places, grades vertically up into the valley phase of the Loveland, and the deposition of the valley phase of the Loveland was contemporary with the upland phase loess of the Loveland. The Crete formation, therefore, represents the early part of the Crete-Loveland alluviation cycle. It has already been noted that the "Crete" formation is the "Valley Phase" of the Loveland, as first described by Lugn. He also suggested that it may have been contemporaneous in age with the Illinoian glaciation.

The coarse texture of the Crete formation and some of the valley phase deposits of the Loveland is proof of the vigor of erosion and

[31] Condra and Reed, (In manuscript) Correlation of the Pleistocene Deposits of Nebraska. To be published by the Nebraska Geological Survey.

of the high competency of the tributaries of the Crete-Loveland drainage systems. It indicates a much higher competency than streams have today in this region. Some of these sediments consist of boulder gravel which may have been deposited during "flash flood" conditions when high gradient tributaries were competent to move this coarse material. The source of sediments was the local material at hand—Figure 22 is the graphic summary of this cycle.

TODD CYCLE

The alluviation of the Crete–Loveland Cycle was followed by a period of vigorous and widespread erosion. This erosion removed large amounts of the former valley fills. Todd Valley well logs show a considerable variation of depth of the Todd-Crete contact (see footnote 24 Profile Section No. 2, and Profile Section No. 5). Evidence shown in the Crowell exposure (Section No. 10) indicates that even small, short tributaries, such as are found at this location, were reopened prior to the deposition of the Todd Valley formation.

The erosion of the Todd Cycle was followed by the deposition of the Todd Valley formation. This formation, wherever recognized, consists of fine, gray-white sands, and nowhere was the writer able to identify coarse-textured materials in the Todd Valley formation. These uniform, fine-textured sands indicate a time of deposition when streams had a uniform, selective competency. Flash floods, therefore, appear not to have occurred.

A soil zone (*Citellus* zone soil) was formed during an interval following the deposition of the upland phase of the Loveland and prior to the erosion that preceded the deposition of the "Peorian" in the next cycle. (Profile Section No. 6). This soil is commonly found developed on the top of the upland phase of the Loveland, and it was deeply eroded and widely removed before the deposition of the "Peorian" loess. For a graphic summary of the Todd Cycle see the composite profile of Figure 23.

FORT CALHOUN OR "PEORIAN" CYCLE

This cycle is characterized by a profound erosion and an equally great alluviation which followed the erosion. The depth of erosion in this cycle in such valleys as the Platte and the Elkhorn was at least to as great a depth as that of the valleys of the present day. This is definitely known because the terrace fill materials of this cycle (valley phase of the "Peorian") occur *in situ* on the present-

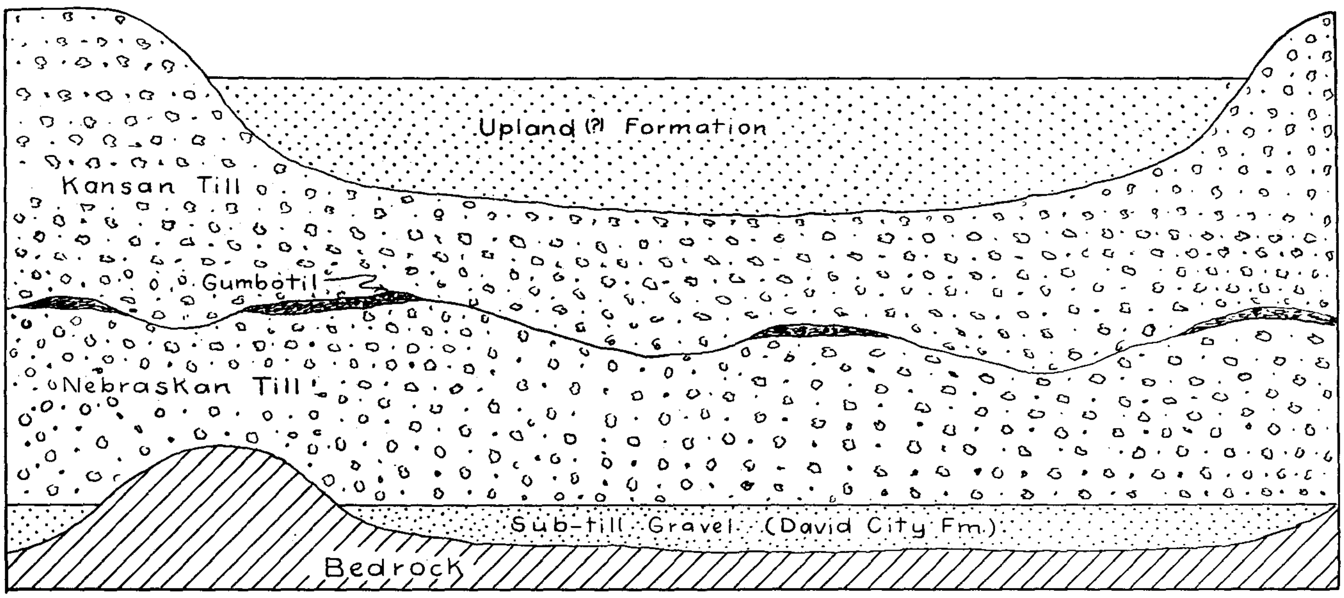

FIG. 21. Post-Kansan Pre-Crete Cycle. (1) Erosion. (2) Deposition of the Upland (?) Formation. The Grand Island Formation may also be represented in what is here termed Upland (?) Formation. A soil was developed in places on this Upland (?) Formation.

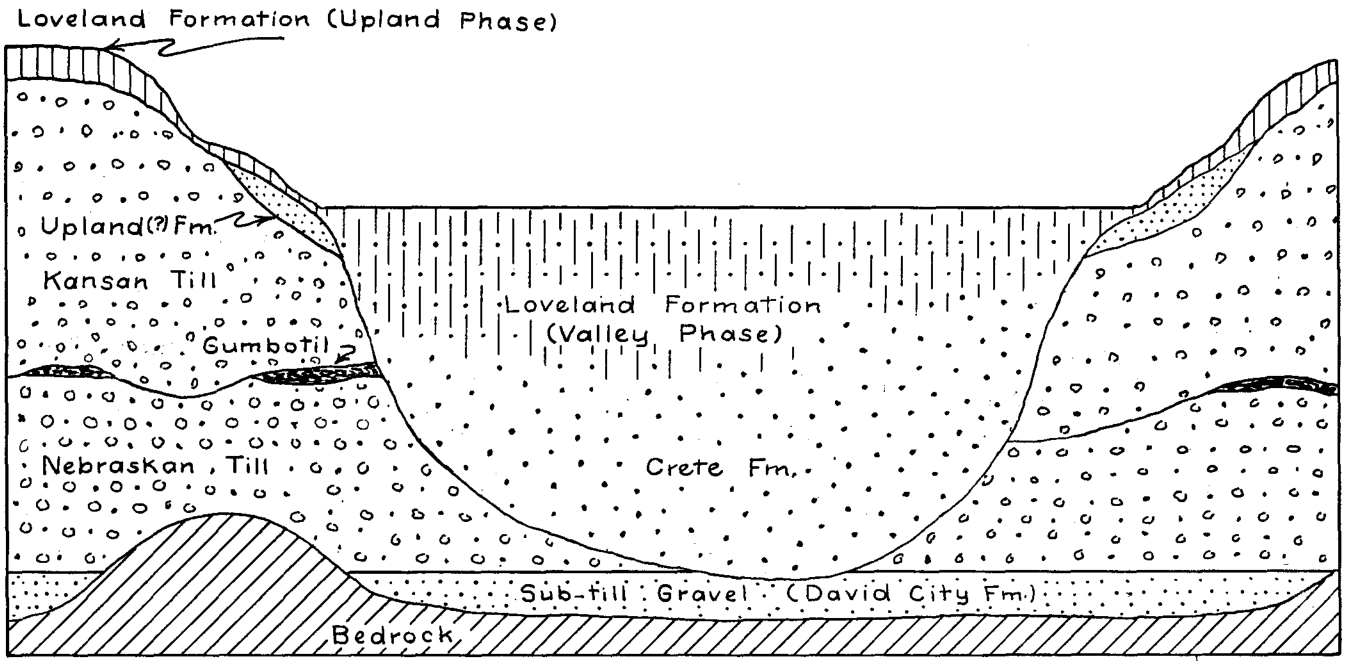

FIG. 22. Crete-Loveland Cycle. (1) Erosion. (2) Deposition of the Crete and Loveland Formations.

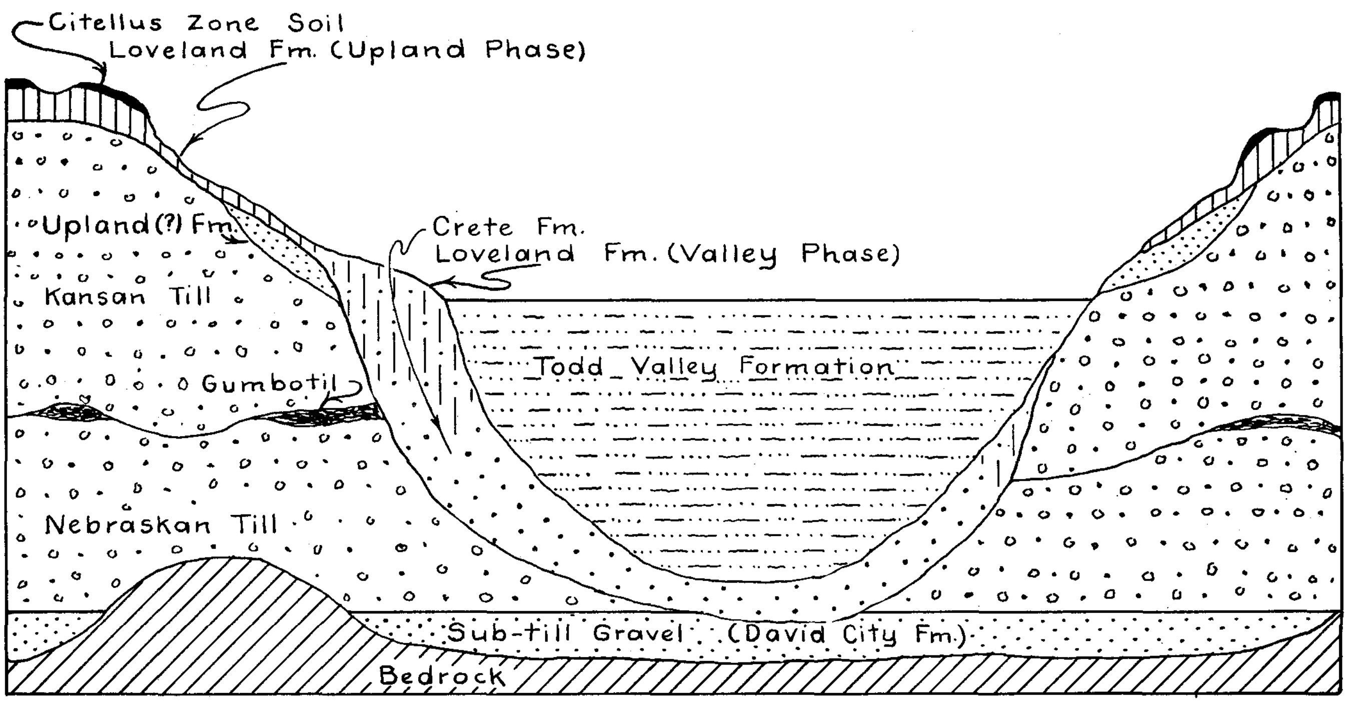

FIG. 23. Todd Cycle. (1) Erosion and contemporaneous (?) development of the Citellus Zone Soil. (2) Deposition of the Todd Valley Formation.

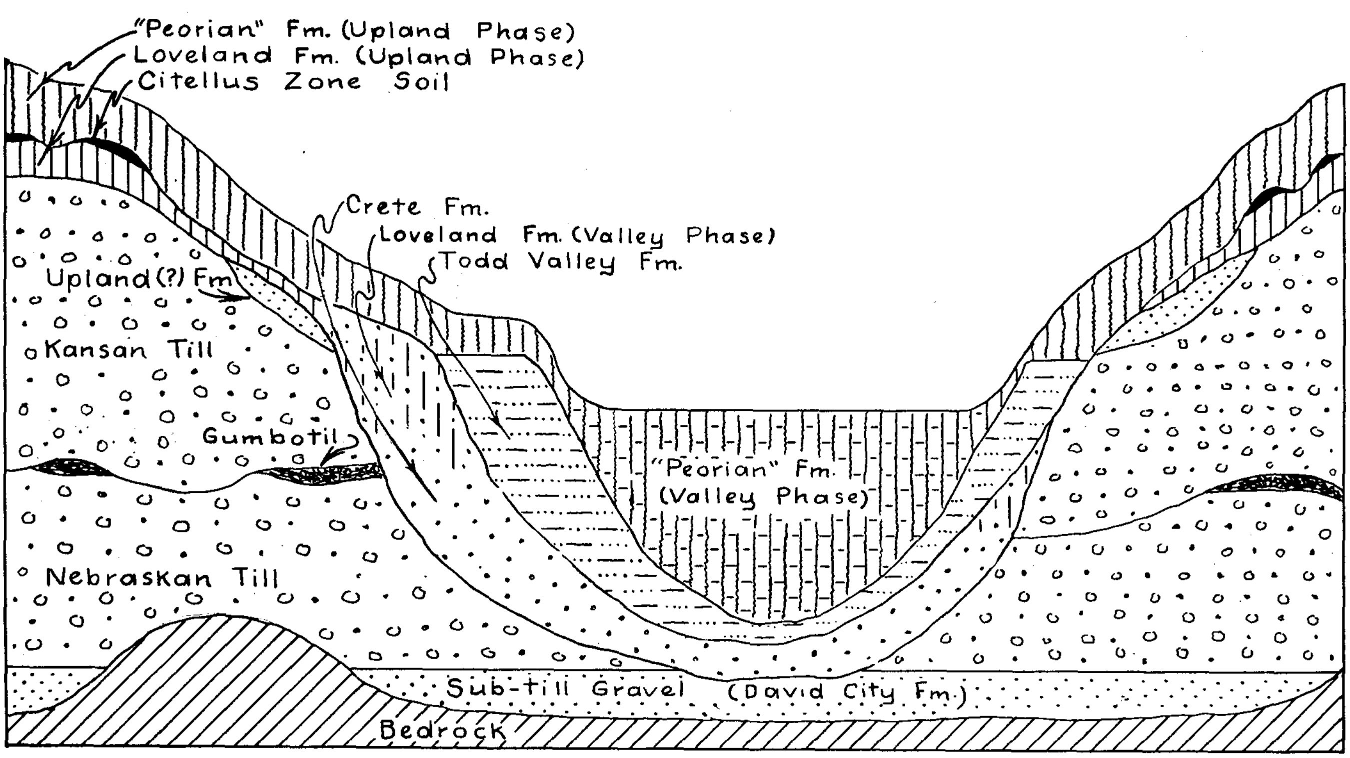

FIG. 24. "Peorian" or Fort Calhoun Cycle. (1) Erosion. (2) Deposition of the "Peorian" Formation.

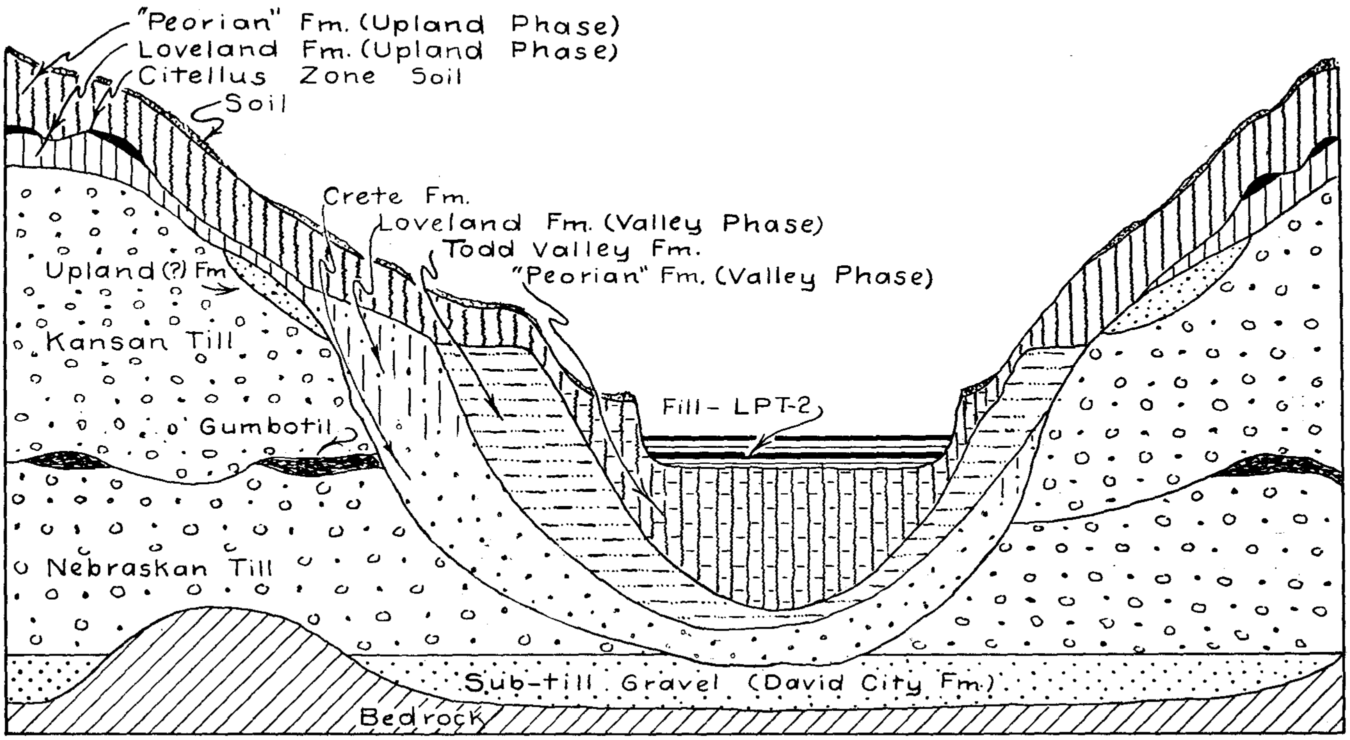

FIG. 25. Linwood Cycle. (1) Erosion. (2) Deposition of the fill which constitutes the material of Lower Platte Terrace No. 2 (LPT-2). Soil development and some erosion. The soil at the top of the "Peorian" is in places overlain by a younger loess, capped by later soil.

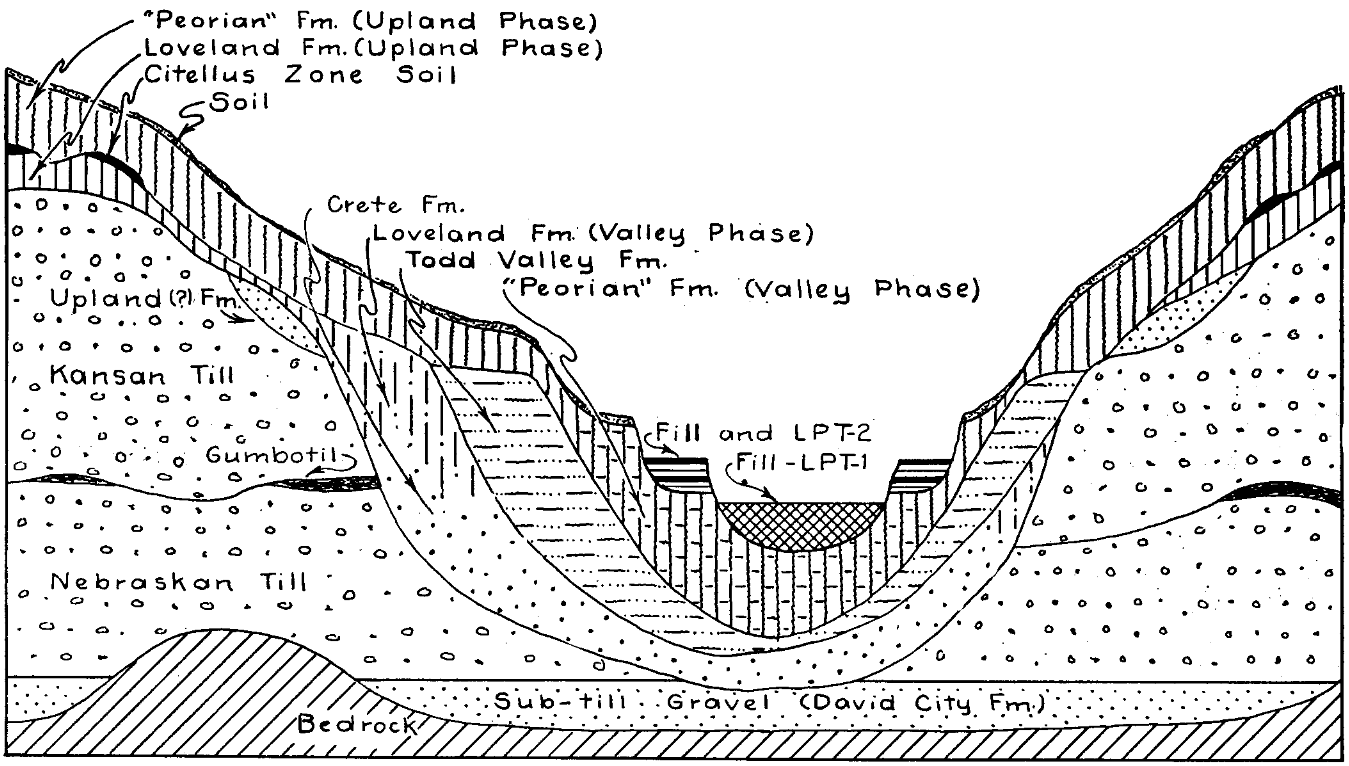

FIG. 26. Fremont Cycle. (1) Erosion. (2) Deposition of the fill which constitutes the material of Lower Platte Terrace Number 1 (LPT-1).

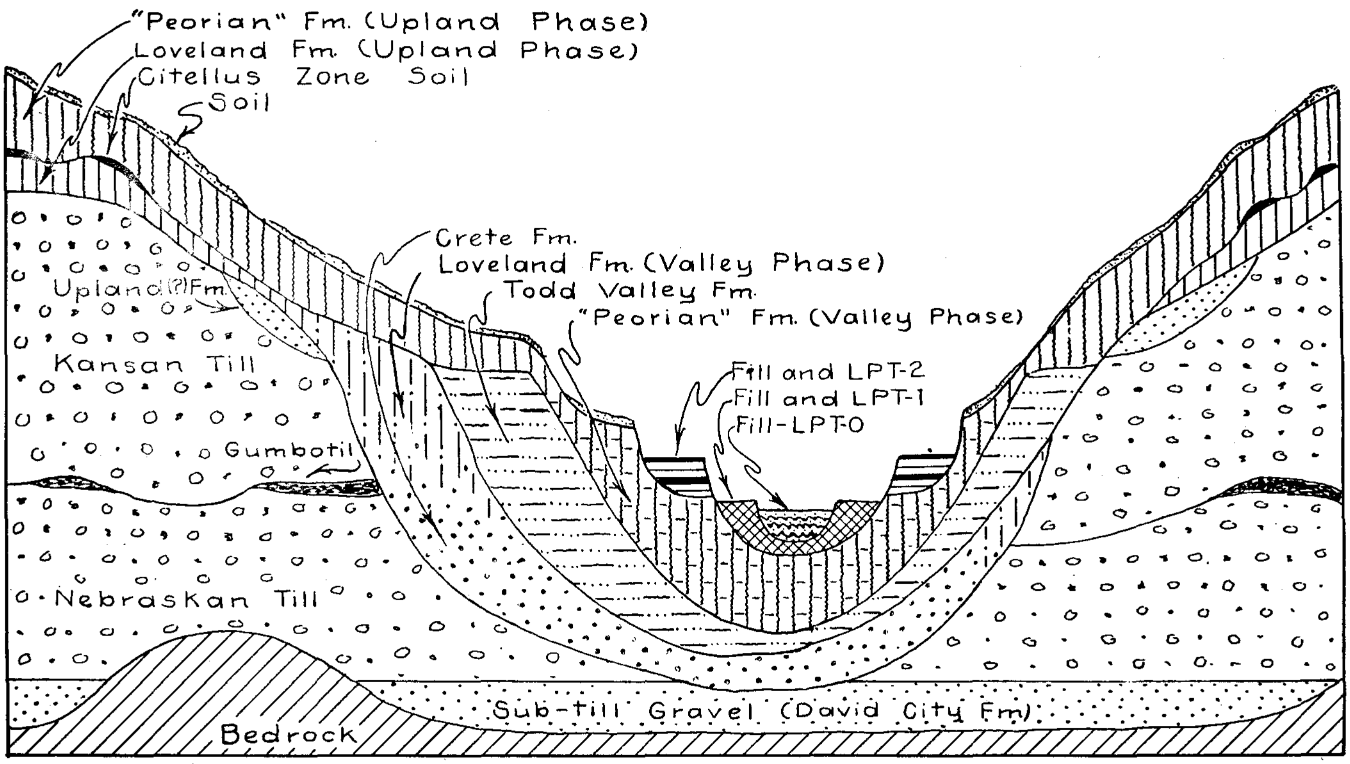

FIG. 27. Elm Creek Cycle. (1) Erosion. (2) Deposition of the fill which constitutes the material of Lower Platte Terrace Number 0 (LPT-0).

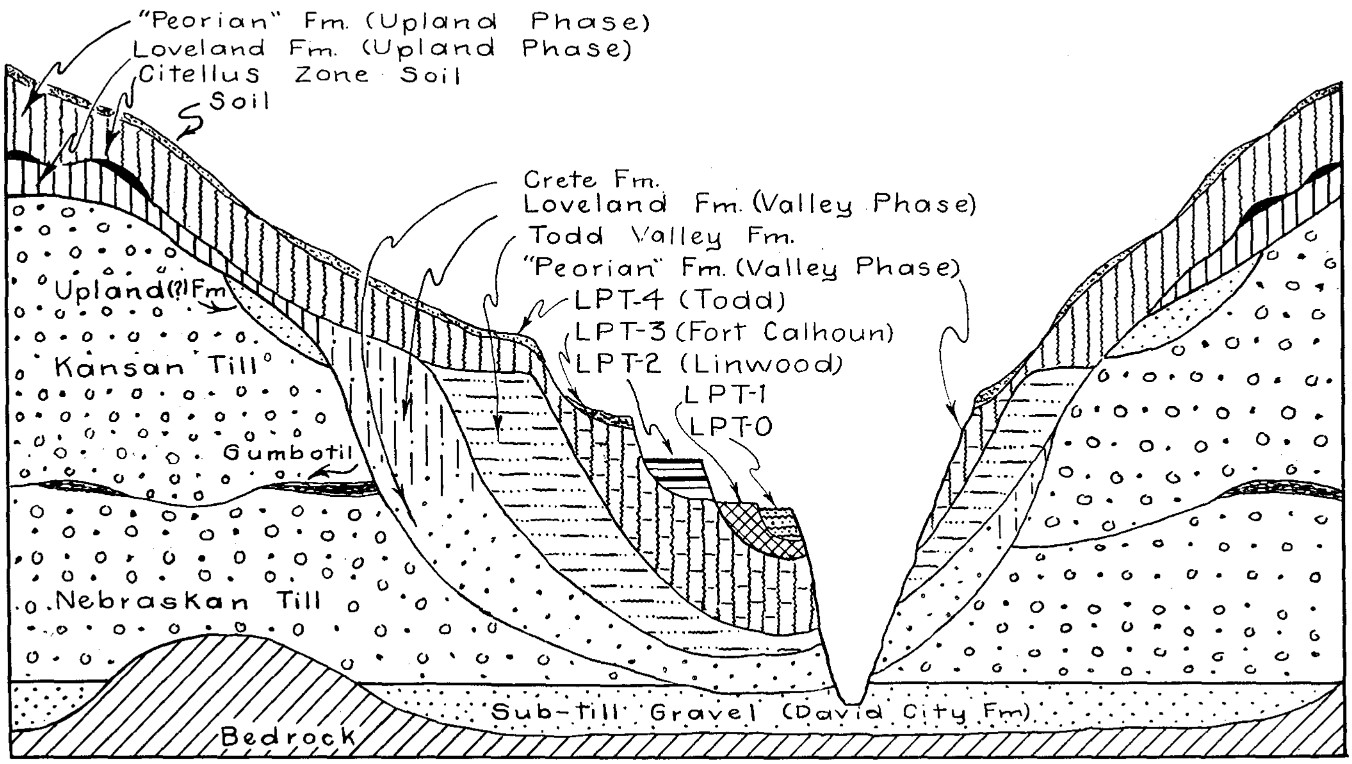

FIG. 28. The Present Cycle. (1) Erosion.

day flood plain level of these streams. The Fremont section of the Platte Valley was eroded some time during the erosional interval of this cycle. This is proved by the facts that at the Fontanelle exposure (sec. 3) and at Linwood the remnants of the valley phase of the "Peorian" are found at the flood plain level in the Platte Valley as "foundations" on which the LPT-2 fill rests. The Platte, therefore, must have been entrenched to this depth at these places before the deposition of the valley phase of the "Peorian."

There is no evidence of a post-Todd Valley cycle Platte River entrenchment in Todd Valley, and, consequently, it must be concluded that the Platte River during this cycle was flowing in the Fremont part of the Platte Valley and was then entrenched to a level as deep as the Fremont section of the Platte is entrenched today. The diversion of the Platte River appears to have taken place in the early part of this erosional cycle. (See the conclusions stated in connection with Profile Section No. 14.)

By headward erosion of one of the tributaries of the Elkhorn a break was made through the low-lying divide which separated the Elkhorn system from the Todd Valley Platte River. This break was relatively easily accomplished because streams were flowing on their highly alluviated beds which were then approximately 60 feet higher than the levels of the streams of today. The divide between the two drainages was, perhaps, less than 30 feet high. The breakthrough was facilitated by the erosion of the Platte against the east side of its valley at the sharp meander bend which was located at this place.

A similar broken-down divide or "gate" is found at the Todd surface level between the Maple Creek and the Platte River, approximately 10 miles northeast of the town of North Bend. It appears that during at least part of the Todd Cycle the upper Maple Creek system flowed into the Platte. A tributary of the Elkhorn worked headward and captured this stream. The elbow of capture is located at a point approximately nine miles northwest of the town of North Bend.

The alluviation of this cycle was of major proportions. The Missouri River Valley (see Profile Secion No. 8) was alluviated with a fill at least 85 feet in thickness. The Platte and Elkhorn river valleys experienced a similar alluviation (see Profile Sections Nos. 2, 3, 4, 7, 10, and 13). Alluviation extended to the extreme upper

ends of small, short gullies, where the fills grade into the upland phase of the "Peorian" formation. The immediate source of this material was the upland phase of the "Peorian" loess which was locally reworked. The source of the loess, at least in large part, appears to have been the alluviated flood plains of the Sand Hills Region of Nebraska. Climatic conditions which caused alluviation in this cycle in the lower Platte River Valley area no doubt also caused streams to alluviate in the Sand Hills Region. The source of the alluvial material of the Sand Hills streams in this cycle was the Tertiary formations (mainly Ogallala formation) from which the streams selectively eroded a clayey silt.

The events of the "Peorian" or Fort Calhoun cycle in the lower Platte River Valley area are graphically depicted in the composite profile in Figure 24.

LINWOOD CYCLE

Erosion in this cycle next removed materials down to a level approximately 15 to 25 feet above the present-day flood plains of the main streams. This is clearly shown by the terrace at Fontanelle (see Profile Section No. 3) and also at the Linwood terrace, two miles east of Linwood. In both cases, the LPT-2 fill rests on a "foundation" of valley phase "Peorian." The thickness of this "foundation" above the flood plain ranges from 15 to 25 feet. This is proof that the erosion of this cycle was not as vigorous or as prolonged even in major drainages, such as the Platte and Elkhorn river valleys, as in previous cycles and did not cut down as far as the level of the present-day flood plains. Erosion, resulting in the reopening of older valleys, appears not to have developed headward in many parts of the upland area. The writer was able to find evidence of this cycle along the major drainages only.

The erosion of this cycle was followed by the deposition of the fill designated as LPT-2 fill. (See Profile Sections Nos. 3 and 22.) The thickness of this fill is approximately 15 to 25 feet in the main drainages.

Evidence is not conclusive, only suggestive, that this alluviation may have been contemporary with a time of loess accumulation. The loess mantle has a darker color at the top of some of the west bluffs of the Missouri River Valley. At one place in particular immediately north of the highway in SE¼, sec. 20, T. 18, N., R. 12 E., (aerial photograph description of location: 11–12–41, UP–3B–36, x = 3.7,

y = 7.3), the upper ten feet of loess is separated from the valley phase "Peorian" by the one-foot oxidized band. The material above the oxidized band is massive and dark buff in color, and it is loess-like in texture. The valley phase of the "Peorian" is exposed below the oxidized band. It is definitely stratified and has a lighter color. This is evidence of a loess which is younger than the valley phase of the "Peorian."

An exposure near Winslow (Profile Section No. 5) also contains evidence of a recent loess accumulation.

A graphic summary of this cycle is shown in Figure 25.

FREMONT CYCLE

A new cycle of erosion followed the Linwood Cycle which removed materials to a depth slightly below the present-day flood-plain level in the Platte River Valley and along other main drainages. Evidence for this is that the LPT-1 surface constitutes part of the present-day flood-plain level of streams in this area.

This erosion was followed by an alluviation. The LPT-1 fill, which is a dark, buff material similar to the valley phase of the "Peorian," but of a darker color, was deposited at this time. It is most easily identified where it is exposed in the same profile with the "Peorian," for then the darker shade of color is more evident.

The graphic summary of this cycle is given in Figure 26.

ELM CREEK CYCLE

This cycle is represented by a minor erosion. Evidence of this erosion is found in the exposures of upland tributaries, where the average depth of erosion in this cycle was probably less than ten feet. The erosion was followed by alluviation when the LPT-0 fill was deposited. It consists of a dark carbonaceous or humic fill in the upland valleys. It is believed to be of recent origin since pieces of Indian pottery have been found in this fill at a number of places. Every upland tributary contains this fill unless more recent erosion has removed it. (See Profile Sections Nos. 2, 6, 7, 10, and 16.) Figure 27 is a graphic summary of this cycle.

PRESENT CYCLE

The present is a time of active erosion. Erosion is not only taking place as sheet and soil erosion, but valleys are now in the process of being reopened and are being lengthened and deepened by

headward and downward erosion. Aerial photographs clearly reveal the evidence of a "wave" of headward erosion in the valleys. Field evidence is convincing that erosion is today the dominant geologic process. Erosion is easily accomplished in the unconsolidated "valley" or terrace fills.

Man's methods of farming facilitate erosion. Today an erosional soil conservation problem confronts society not only because of some faulty agricultural practices but also because fundamentally the present is a geological time of active erosion and regional reduction. Streams may again and probably will actively alluviate their valleys at some future time.

Figure 28 graphically shows the present cycle of erosion.

SUMMARY

The post-Kansan history of the lower Platte Valley area is summarized in the following ouline.

1. Post-Kansan Pre-Crete Cycle.
   (1) Erosion.
   (2) Deposition of the Upland formation, with perhaps some Grand Island gravels at the base. A soil is developed at the top of the Upland.
2. Crete-Loveland Cycle.
   (1) Erosion.
   (2) Deposition of Crete formation. This is a valley fill.
   (3) Deposition of the Loveland formation.

      The upland phase is a loess and the valley phase is a fluviatile deposit. The two phases are essentially contemporaneous. The Crete formation represents an earlier alluviation of this sedimentation cycle. It grades up into the true valley phase of the Loveland.
   (4) Development of the *Citellus* zone soil.

      This took place in the interval sometime between post-Loveland and pre-"Peorian" time.
3. Todd Cycle.
   (1) Erosion.
   (2) Deposition of the Todd Valley formation.
4. "Peorian" or Fort Calhoun Cycle.
   (1) Erosion.
   (2) Deposition of the Tazewell-Cary portion of the "Peorian" formation.

The upland phase is a loess and the valley phase is a fluviatile deposit consisting mainly of reworked upland phase "Peorian." The two phases are essentially contemporaneous.

5. Linwood Cycle.
   (1) Erosion.
   (2) Deposition of Lower Platte Terrace-Number Two (LPT-2) fill. Some loess was deposited in faborable situations on the uplands.
6. Fremont Cycle.
   (1) Erosion.
   (2) Deposition of Lower Platte Terrace-Number One (LPT-1) fill.
7. Elm Creek Cycle.
   (1) Erosion.
   (2) Deposition of Lower Platte Terrace-Number Zero (LPT-0) fill.
8. Present Cycle
   (1) Erosion.

Figure 29 graphically summarizes the cyclic nature of erosion and deposition. It is only semiquantitative and is intended to be mainly suggestive of possible correlations of events. Sufficient quantitative data are not at present available on which to base a more precise interpretation. Definite assignments for the several erosions and depositions are not given. The writer has sought to present the events in the post-Kansan geological history of the Lower Platte River Valley area in a chronological order. A by-product of this research is that the sequence of events is cyclic. The correlation of the geomorphological cycles in this area with the events of the Pleistocene recognized elsewhere would be most desirable and may sometime be possible.

The basis for the tentative correlation of post-Kansan events suggested in Figure 29 is noted below. Streams today are actively eroding. It appears that the present is an interglacial time. A great interval of erosion took place after the melting of the Kansan ice sheet. This erosion occurred in the Yarmouth interglacial age. The evidence in these two cases indicates that interglacial ages are times when streams actively erode. Kay [32] determined the age of the Love-

[32] G. F. Kay, "Loveland Loess: Post-Illinoian, Pre-Iowan in Age," *Science*, New Series, LXVIII, 1928, pp. 482–483.

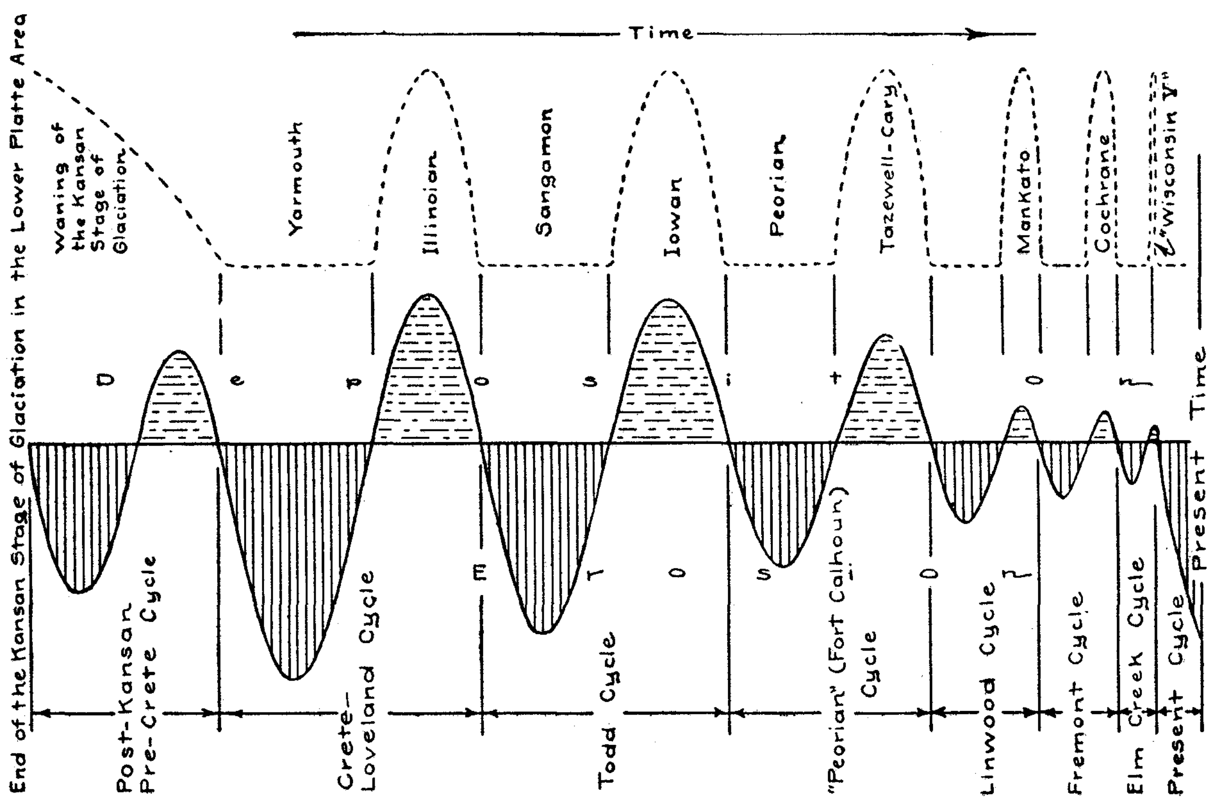

Fig. 29. Cyclic erosion-deposition curve showing the tentative correlation of events in the lower Platte River Valley area with the standard Pleistocene time classification.

land does to be post-Illinoian gumbotil erosion and pre-Iowan, and if we consider the Loveland loess deposition to have taken place contemporary with the waning of the Illinoian ice sheet, three control points for correlating the cyclic erosion-deposition curve with glacial and interglacial ages of the Pleistocene are available, as indicated in Figure 29.

If the post-Kansan pre-Crete Cycle is considered to be contemporary with the receding Kansan ice sheet, and if the Loveland formation is assigned to the time of the receding Illinoian glacier, then the aggradations of the Todd, "Peorian," Linwood, and Fremont Cycles become contemporary with the Iowan, Tazewell-Cary, Mankato, and Cochrane glaciations respectively.

The correlation seems to imply a cause other than a glacial climate for the deposition which occurred during the Elm Creek Cycle (LPT-0 fill). This alluviation is quantitatively insignificant when compared with the size of the other alluviations and may not have had a true glaciation as a climatic cause. Behre,[33] Ray [34] and Bryan,[35] however, have presented evidence in the Rocky Mountains of a very late glacial sub-stage ("Wisconsin V"). The evidence for this sub-stage has been referred to as a "protalus rampart" or a "nivation ridge." This sub-stage represents a cool period when the cirques were filled with a semi-permanent glacial snow mass, but precipitation was not adequate to produce a glacial tongue. The change in climate representing "Wisconsin V" may be contemporary with the deposition of the LPT-0 fill.

The correlation in Figure 29 indicates that the time of deposition of the "Peorian" formation (loess) was contemporaneous with the Tazewell-Cary glaciation. Conventionally, this formation is assigned to the "Peorian" interglacial age or to the waning of the Iowan glaciation. The writer's reason for separating the "Peorian" formation from the Iowan is that evidence presented in this paper (see conclusions of Profile Section No. 14, also Fort Calhoun or "Peorian" Cycle) indicates that an important erosinal interval separates the "Peorian" formation from the Todd Valley formation.

[33] C. H. Behre, Jr., 1933, "Talus Behavior above Timber in the Rocky Mountains," *Journal of Geology*, XLI, pp. 622–635.

[34] Louis L. Ray, 1940, "Glacial Chronology of the Southern Rocky Mountains," *Bul., Geological Society of America*, LI, pp. 1862–1863.

[35] Kirk Bryan, 1934, "Geomorphic Processes at High Altitudes," *Geographical Review*, XXIV, pp. 655–656.

It was during this period of erosion and entrenchment that the Fremont section of the Platte River Valley was developed. If the Todd Valley formation is Iowan in age,[36] and if the "Peorian" formation is "Peorian" in age it is necessary to recognize a deposition, an interval of erosion, and then another deposition, all taking place during one glacial and one interglacial age. If the "Peorian" formation (loess) is assigned to the waning of the Iowan glaciation, then two depositions separated by an erosion must all have transpired in one glacial age, the Iowan, which would make it a much longer time interval than many students of the subjects would concede.

The correlation in Figure 29 is based on the concepts that in geological time streams normally develop through a cycle of erosion (youth, maturity, old age) and that glaciations are climatic accidents which cause streams to aggrade. If these concepts are correct, then interglacial times are normal times of degradation. Stream deposition, during a glacial age, seems to have been caused by the overloading of the streams. A low mean temperature would cause a sparse vegetative covering and this condition in turn would favor intensive sheet erosion and rock mantle creep. In this correlation, times of loess deposition are postulated to be contemporaneous with glaciations or waning glaciations.

The role of diastrophism in the complex history of stream erosion and deposition in the lower Platte River Valley area is a matter for speculation. It no doubt was a factor, and obviously the region initially had to be raised high enough to facilitate erosion. It seems possible that diastrophic uplift may have taken place more or less continuously at a slow rate. This uplift would have served to give streams a continuously renewed erosive power during normal or non-glacial times. To postulate that diastrophism was the controlling factor which caused cyclic erosion and deposition in this area would call for a fantastic sequence of rhythmic movements. If diastrophism was the controlling factor, sedimentational evidence would show a uniform gradational change of texture in the various fills, but field evidence does not indicate this. It is concluded that diastrophic control was of minor importance while climatic control exercised the major influence in the cyclic events which transpired in the lower Platte River Valley area in post-Kansan time.

[36] A. L. Lugn, 1935, op. cit.

GENERAL CONCLUSIONS

1. Erosion and deposition have been cyclic in the lower Platte River Valley area since the melting of the Kansan ice sheet.

2. Each cycle consists of an erosion or valley-cutting followed by an interval of deposition or valley-filling.

3. The cycles were not identical repetitions because the competency and erosive actions of streams varied from cycle to cycle.

4. Due to the repeated alluviations and entrenchments that have taken place, five different terrace levels have been developed in the lower Platte River Valley area. These are definite and recognizable morphological features.

5. The larger terrace surface areas, as mapped by the use of photogrammetric methods, reveal a very close correlation with the Waukesha silt loam as shown by the soil maps of Dodge, Washington, Douglas, Sarpy, Cass, and Saunders counties. The soil maps of these six counties, however, show no differentiation of the Waukesha silt loam with the exception of Dodge County. This soil map shows a lower and an upper phase of the Waukesha silt loam.

6. The valleys of today have been made by the reopening of older alluviated valleys.

7. The present is a time of erosion, and down-cutting is the dominant action of streams.

8. The cyclic repetition of degradation and aggradation of streams in this (periglacial) region appears to have been due mainly to the cyclic changes caused by the waxing and waning of the post-Kansan glaciers of the Pleistocene.

BIBLIOGRAPHY

ALBRITTON, CLAUDE C. JR., AND BRYAN, KIRK, 1939, Quaternary Stratigraphy in the Davis Mountains, Trans-Pecos, Texas, *Bulletin, Geological Society of America*, L, pp. 1423–1474, 11 pls., 13 figs.

ALDEN, WILLIAM C., *et al*, 1932, Glacial Geology of the Central States, *Guidebook 26, Excursion C-3, XVI Session, International Geological Congress.* (Map by Frank Leverett.)

———, 1932, Physiography and Glacial Geology of Eastern Montana and Adjacent Areas, *Professional Paper 174, United States Geological Survey.*

AUGHEY, SAMUEL, 1880, Physical Geography and Geology of Nebraska, Omaha: Daily Republican Book and Job Office.

BARBOUR, E. H., 1903, Report of the State Geologist, *Publications, Nebraska Geological Survey,* First Series, I.

BEHRE, C. H., JR., 1933, Talus Behavior above Timber in the Rocky Mountains, *Journal of Geology,* XLI, No. 6, pp. 622–635, 10 figs.

BRYAN, KIRK, 1934, Geomorphic Processes at High Altitudes, *Geographical Review,* XXIV, No. 4, pp. 655–656.

———, 1941, Correlation of the Deposits of Sandia Cave, New Mexico, with the Glacial Chronology, *Smithsonian Miscellaneous Collections,* XCIX, No. 23 (Appendix), pp. 45–64, pl. 15, figs. 8–9.

———, 1945, Glacial versus Desert Origin of Loess, *American Journal of Science,* CCXLIII, No. 5, pp. 245–248.

———, AND RAY, L. L., 1940, Geologic Antiquity of the Lindenmeier Site in Colorado, *Smithsonian Miscellaneous Collections,* XCIX, No. 2, pp. 1–76, pls. 1–6, 13 figs.

CHAMPE, JOHN L., 1946, Ash Hollow Cave, a Study of Stratigraphic Sequence in the Central Great Plains, *University of Nebraska Studies,* New Series, No. 1, December.

CONDRA, G. E., 1903, An Old Platte Channel, *American Geologist,* XXXI, pp. 361–369, map.

———, 1908, Geology and Water Resources of a Portion of the Missouri River Valley in Northeastern Nebraska, *Water-Supply Paper 215, United States Geological Survey.*

———, 1908, The Sand and Gravel Resources and Industries of Nebraska, *Nebraska Geological Survey,* First Series, III, Part 1.

———, 1930, The Conservation of Nebraska's Water Resources, *Bulletin 3, Conservation Department of the Conservation and Survey Division, Nebraska Geological Survey,* University of Nebraska.

———, 1934, Geological Phases of Soil Erosion Investigation and Control in Nebraska, *Paper 6, Nebraska Geological Survey.*

———, AND REED, EUGENE C., 1943, The Geological Section of Nebraska, *Bulletin 14, Second Edition, Nebraska Geological Survey.*

———, REED, EUGENE C., AND GORDON, E. D., 1947, Correlation of the Pleistocene Deposits of Nebraska, *Bulletin 15, Nebraska Geological Survey, in press.*

DOW, C. L., 1933, The Upper North Platte River Valley of Nebraska. A Geographical Interpretation, *unpublished Ph.D. thesis, University of Nebraska Library, Lincoln, Nebraska.*

ELIAS, M. K., 1945, Loess and Its Economic Importance, *American Journal of Science,* CCXLIII, No. 5, pp. 227–230.

FISK, HAROLD N., 1944, Geological Investigation of the Alluvial Valley of the Lower Mississippi River, *Mississippi River Commission, Vicksburg, Mississippi, U. S. War Department, Corps of Engineers.*

FRYE, JOHN C., 1946, Review of Studies of Pleistocene Deposits in Kansas, *American Journal of Science,* CCXLIV, No. 6, pp. 403–416, fig. 1.

KAY, GEORGE F., 1928, Loveland Loess: Post-Illinoian, Pre--Iowan in Age, *Science* (N. S.), LXVIII, No. 1768, November 16, pp. 482–483.

———, 1929, Significance of Post-Illinoian, Pre-Iowan Loess, *Science* (N.S.), LXX, No. 1811, pp. 259–260.

———, 1931, Classification and Duration of the Pleistocene Period, *Bulletin, Geological Society of America,* XLII, No. 1, pp. 425–466, 9 figs.

———, AND APFEL, EARL T., 1928, The Pre-Illinoian Pleistocene Geology of Iowa, Part I of the Pleistocene Geology of Iowa, *Iowa Geological Survey, Special Report,* pp. 1–304, pls. 1–3, figs. 1–63.

———, AND GRAHAM, JACK B., 1941, The Illinoian and Post-Illinoian Pleistocene Geology of Iowa, *Part 2* of The Pleistocene Geology of Iowa, *Special Report, Iowa Geological Survey (Annual Report* 1940–1941, XXXVIII.)

———, AND PEARCE, J. N., 1920, The Origin of Gumbotil, *Journal of Geology,* XXVIII, No. 2, pp. 89–125, map.

LEIGHTON, M. M., 1931, The Peorian Loess and the Classification of the Glacial Drift Sheets of the Mississippi Valley, *Journal of Geology,* XXXIX, No. 1, pp. 45–53, 3 figs.

———, 1933, The Naming of the Subdivisions of the Wisconsin Glacial Age, *Science* (N.S.), LXXVII, p. 168.

LEVERETT, FRANK, 1898, The Peorian Soil and Weathered Zone (Toronto Formation?), *Journal of Geology,* VI, pp. 244–249.

LUENINGHOENER, GILBERT, 1940, A Survey of the Water-Bearing Formations at Fremont, Nebraska. (A special report made to the Department of Utilities at Fremont, Nebraska, based on test drilling operations cooperatively done by the Conservation and Survey Division of the University of Nebraska [Nebraska Geological Survey] and the Department of Utilities at Fremont, Nebraska.)

LUGN, A. L., 1934, Outline of Pleistocene Geology of Nebraska, *Bulletin, University of Nebraska State Museum,* I, No. 41, Part 1.

———, 1935, The Pleistocene Geology of Nebraska, *Bulletin 10, Nebraska Geological Survey.*

———, 1939, Nebraska in Relation to the Problems of Pleistocene Stratigraphy. *American Journal of Science,* CCXXXVII, pp. 851–884, figs. 1–7.

———, 1941, The Pleistocene History of Nebraska, *The Compass of Sigma Gamma Epsilon, Lincoln, Nebraska,* XXII, No. 2, pp. 11–37, figs. 1–14.

OBRUCHEV, VLADIMIR, 1945, Loess Types and Their Origin, *American Journal of Science,* CCXLIII, No. 5, pp. 256–262.

RAY, LOUIS L., 1940, Glacial Chronology of the Southern Rocky Mountains, *Bulletin, Geological Society of America,* LI, No. 12, Part 1, pp. 1851–1917, pls. 1-6, figs. 1–12.

REED, E. C., 1944, Groundwater Survey of Area North of O'Neill, Holt County, Nebraska, *Paper 2, Nebraska Water Survey, University of Nebraska Conservation and Survey Division, Nebraska Geological Survey.*

SHARP, H. O., 1936, Photogrammetry. Ann Arbor, Michigan: Edward Brothers, Inc.

SCHULTZ, C. BERTRAND, 1934, The Pleistocene Mammals of Nebraska, *Bulletin, University of Nebraska State Museum,* I, No. 41, Part 2.

———, 1943, Some Artifact Sites of Early Man in the Great Plains and Adjacent Areas, *American Antiquity,* VIII, No. 3, pp. 242–249, 291–295, 1 pl.

———, AND STOUT, THOMPSON M., 1941, Guide for a Field Conference on the Tertiary and Pleistocene of Nebraska, *University of Nebraska State Museum, Special Publication.*

———, AND STOUT, THOMPSON M., 1945, Pleistocene Loess Deposits of Nebraska, *American Journal of Science,* CCXLIII, No. 5, pp. 231–244, pls. 1–2, figs. 1–3.

———, AND STOUT, THOMPSON M., 1947, Pleistocene Mammals and Terraces in the Great Plains, *Bulletin, Geological Society of America (Symposium on the Pleistocene of the Great Plains), in press.*

SHIMEK, B., 1909, Aftonian Sand and Gravel in Western Iowa, *Bulletin, Geological Society of America,* XX, pp. 399–408, pls. 33–37.

———, 1919, Geology of Harrison and Monona Counties, Iowa, *Iowa Geological Survey,* XX, pp. 271–485.

STRONG, WILLIAM DUNCAN, 1935, An Introduction to Nebraska Archeology, *Smithsonian Miscellaneous Collections,* LXLIII, No. 10.

SWINEFORD, ADA, AND FRYE, JOHN C., 1945, A Mechanical Analysis of Windblown Dust Compared with Analyses of Loess, *American Journal of Science,* CCXLIII, No. 5, pp. 249–255, fig. 1.

TODD, JAMES EDWARD, 1889–1890, The Terraces of the Missouri, *Proceedings, Iowa Academy of Sciences,* 1887–1889, pp. 11–12.

———, 1892, Volcanic Dust from Omaha, Nebraska, *American Geologist,* X, pp. 295–296.

———, 1895, Volcanic Ash Bed Near Omaha, *American Geologist,* XV, p. 130.

———, 1899, The Moraines of Southeastern South Dakota and Their Attendant Deposits, *Bulletin 158, United States Geological Survey.*

United States Department of Agriculture, 1941, Soil Survey of Cass County, Nebraska.

———, 1918, Soil Survey of Dodge County, Nebraska.
———, 1915, Soil Survey of Douglas County, Nebraska.
———, 1939, Soil Survey of Sarpy County, Nebraska.
———, 1913, Soil Survey of Saunders County, Nebraska.
———, 1917, Soil Survey of Washington County, Nebraska.

WARD, FREEMAN, 1922, The Geology of a Portion of the Badlands, *Bulletin 11, South Dakota Geological and Natural History Survey.*

WENZEL, L. K., CADY, R. C., AND WAITE, H. A., 1946, Geology and Ground-water Resources of Scotts Bluff County, Nebraska, *Water-Supply Paper 943, United States Department of the Interior, Geological Survey.*

WILLIAMS, B. H., 1945, Sequence of Soil Profiles in Loess, *American Journal of Science,* CCXLIII, No. 5, pp. 271–277, fig. 1.

ZEUNER, FREDERICK E., 1945, The Pleistocene Period. London: Ray Society Publications.