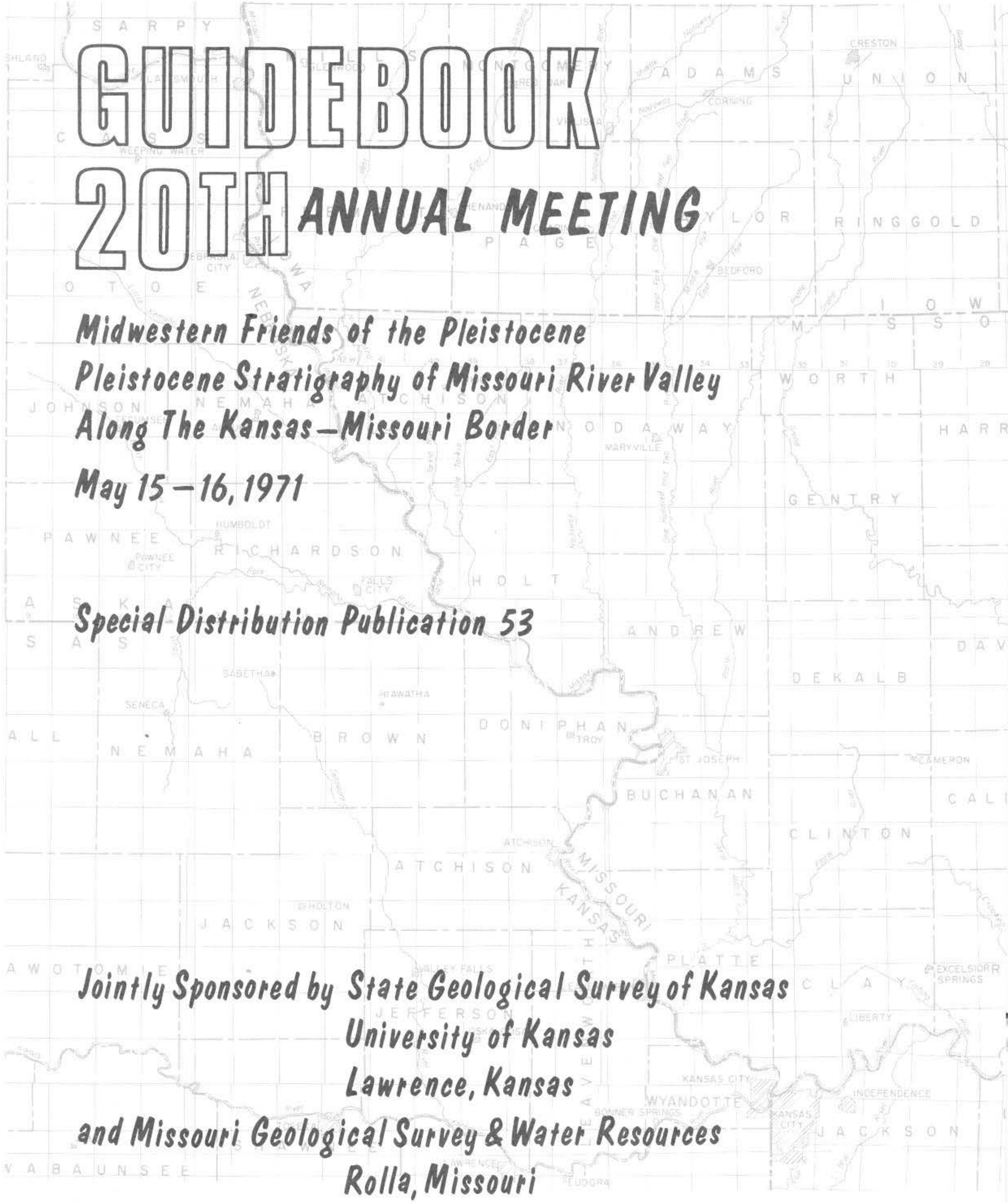
GUIDEBOOK
20TH ANNUAL MEETING

Midwestern Friends of the Pleistocene

Pleistocene Stratigraphy of Missouri River Valley Along The Kansas–Missouri Border

May 15 – 16, 1971

Special Distribution Publication 53



Jointly Sponsored by State Geological Survey of Kansas
University of Kansas
Lawrence, Kansas
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A Listing of Former Meetings

MIDWEST FRIENDS OF THE PLEISTOCENE

Compiled by H. E. Wright

		Location	*Leaders*
1	1950	Eastern Wisconsin	S. Judson
2	1951	Southeastern Minnesota	H. E. Wright and R. V. Ruhe
3	1952	Northwestern Illinois	P. R. Shaffer, Wayne Scholtes, and others
4	1953	Northeastern Wisconsin	F. T. Thwaites
5	1954	Central Minnesota	H. E. Wright and A. F. Schneider
6	1955	Central Ohio	R. P. Goldthwait
7	1956	Northern Michigan	J. H. Zumberge and others
8	1957	Southern Indiana	W. J. Wayne and W. D. Thornbury
9	1958	Eastern North Dakota	Wilson Laird and others
10	1959	Western Wisconsin	R. F. Black
11	1960	Eastern South Dakota	Allen F. Agnew and others
12	1961	Eastern Alberta	C. Gravenor and others
13	1962	Western Ohio	R. P. Goldthwait and others
14	1963	Western Illinois	J. C. Frye and H. B. Willman
15	1964	Eastern Minnesota	H. E. Wright and E. J. Cushing
16	1965	Northeastern Iowa	R. V. Ruhe
17	1966	Eastern Nebraska	E. C. Reed and others
18	1967	South-Central South Dakota	Lee Clayton and T. Freers
	1968	None	
19	1969	Cypress Hills, Saskatchewan, Alberta	Walter Kupsch and others
	1970	None	

Pleistocene Stratigraphy of Missouri River Valley Along the Kansas-Missouri Border

Prepared cooperatively by

State Geological Survey of Kansas
and
Missouri Geological Survey and Water Resources
for the
20th Annual Meeting of the Midwest Friends of the Pleistocene

Field Trip Leaders
C. K. Bayne and H. G. O'Connor, *Kansas*
S. N. Davis and W. B. Howe, *Missouri*

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The University of Kansas
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Pleistocene Stratigraphy of Missouri River Valley Along the Kansas-Missouri Border

INTRODUCTION

This publication has been prepared for the 20th Annual Meeting of the Midwest Friends of the Pleistocene, an informal organization of scientific and professional workers who have active interests in Pleistocene geology in the midwestern part of the United States. Planning and preparation of the guidebook and the 20th Annual Meeting have been under the joint sponsorship of the State Geological Survey of Kansas and the Missouri Geological Survey and Water Resources. A listing of earlier Midwest Friends of the Pleistocene meetings appears on the inside front cover.

Until the mid-1960's, little work was done in northeastern Kansas to modify the stratigraphic concepts of John C. Frye and A. Byron Leonard in their classic publication, "Pleistocene Geology of Kansas" (1952). During the decade of the 1960's, much new information concerning Pleistocene deposits in northeastern Kansas was obtained through studies of Brown and Doniphan counties by C. K. Bayne, Atchison County by J. R. Ward, and through studies of pits and quarry exposures along the Missouri River valley by Wakefield Dort, Jr. In 1966, James Thorp, C. K. Bayne, and H. G. O'Connor spent six weeks studying and describing Pleistocene deposits in northeastern Kansas. Of particular importance has been the recognition of the more complex nature of the early Pleistocene deposits. Evidence is presented in this report which supports the interpretation of two Kansan tills separated by an interstadial paleosol and framed by the Afton Soil below and the Sangamon Soil above. Additionally, evidence is presented for division of the Nebraskan Stage into two substages or stades on the basis of a widespread and distinctive Afton Soil and an older interstadial paleosol.

In Missouri, work by S. N. Davis on the Pleistocene geology of Platte County and a program of test drilling in northwestern Missouri by the Missouri Geological Survey and Water Resources in the 1950's marked the beginning of expanded studies of Pleistocene deposits in this area. The results of Missouri's drilling program have been published in a series of preliminary reports on the ground-water resources for counties in northwestern Missouri. Much new information on Pleistocene drainage patterns and bedrock topography was obtained and described by G. E. Heim and W. B. Howe (1963a, 1963b).

Many new exposures of Pleistocene deposits, particularly late Pleistocene deposits, have resulted from construction activities in northwestern Missouri since the mid-1960's and have been studied by S. N. Davis and W. B. Howe. The classification and description of these late Pleistocene deposits have been emphasized in Missouri sections described in this report.

In order that current concepts of Pleistocene stratigraphy of the Missouri River valley along the Kansas-Missouri boundary might be shared with a larger audience than could attend the 20th Annual Meeting of the Midwest Friends of the Pleistocene, the Kansas Geological Survey has published this guidebook as a part of its Special Distribution Series. The publication is available from both the State Geological Survey of Kansas and the Missouri Geological Survey and Water Resources.

ACKNOWLEDGMENTS

Appreciation is expressed to E. C. Reed, V. H. Dreeszen, S. J. Tuthill, James Thorp, C. W. Hibbard, F. C. Greene, Gomer Jenkins, F. C. Foley, and William Herndon for their helpful discussions of stratigraphic and correlation problems in the field, and assistance in the planning of this Friends of the Pleistocene meeting and guidebook.

Special thanks are expressed to V. H. Dreeszen, R. R. Burchett, and R. J. Pauken for their papers prepared especially for this guidebook.

TABLE 1.—Stratigraphic units of the Pleistocene, northeastern Kansas and northwestern Missouri.

	KANSAS			MISSOURI		
Stage	Substage	Rock Unit	Soil Formation	Substage	Rock Unit	Soil Formation
Recent *		Fluvial deposits	XX	- - -	Fluvial deposits	XX
Wisconsinan		Bignell Formation		Valderan	Bignell Loess	
	Bradyan	- - -	X	Twocreekan	- - -	X
		Peoria Formation		Woodfordian	Peoria Loess	
		Gilman Canyon Fm.	X	Farmdalian	Roxana ? Silt	XX
		- - -		Altonian(?)		
Sangamonian	- - -		XXXXX	- - -		XXXXX
Illinoisan		Loveland Fm. / Fluvial deposits		Late Illinoian	Loveland Loess	
				Medial Illinoian	Fluvial deposits	XX
				Early Illinoian		
Yarmouthian	- - -		XXX	- - -	Ferrelview Fm.	XX
Kansan	Upper Kansan	Loess, fluvial and lacustrine deposits		Late Kansan		
	Medial Kansan	Cedar Bluffs Till	XX	Medial Kansan	Undifferentiated Kansan till	XX
		Fluvial deposits				
	Lower Kansan	Nickerson Till		Early Kansan	Atchison sand	
		Atchison Formation				
Aftonian	- - -		XXXX	- - -		XX
Nebraskan	Upper Nebraskan	Iowa Point Till	X	- - -	Nebraskan till	
	Lower Nebraskan	Fluvial and lacustrine deposits			Fluvial deposits	

* Assigned to Holocene Series in Missouri

no scale intended

REGIONAL PLEISTOCENE STRATIGRAPHY

By C. K. Bayne,[1] S. N. Davis,[2] W. B. Howe,[3] and H. G. O'Connor[1]

Introduction

Pleistocene deposits and Pleistocene history are of considerable importance to Kansas and Missouri. The widespread and generally favorable influence of Pleistocene deposits upon the character of agricultural soils of northwestern Missouri and northeastern Kansas combined with the plentiful supply of potable groundwater generally associated with the deposits that occupy the preglacial valleys are of enormous importance to the general economy of the region. Northern Missouri and northeastern Kansas were glaciated during early Pleistocene (Nebraskan and Kansan) time, but escaped glaciation during middle and late Pleistocene time. Pleistocene till and associated deposits covered most of the area north of the Missouri and Kansas rivers and extended south at several localities. Extensive alluvial and eolian deposits of middle and late Pleistocene age were formed in the northern part of the region. Pleistocene deposits in Kansas and Missouri include glacial, fluvio-glacial, lacustrine, and eolian deposits that range in age from early Nebraskan to Recent (Table 1). Extensively developed and widely recognized paleosols are, in many localities, the principal basis for division of the Pleistocene succession. Some carbon-14 dates are also available for late Pleistocene deposits. Compared with surrounding states, Missouri is one in which relatively little modern detailed Pleistocene stratigraphy has been done. In contrast, Pleistocene deposits in Kansas have been studied for more than 30 years.

The preglacial topography of the region is important in the interpretation of Pleistocene history. Because of the considerable information available through water well and test drilling work, it has been possible to delineate the principal preglacial drainageways (see separate report by Dreeszen in this publication). Most of the buried valley systems were inherited from topography that presumably developed during the late Tertiary. The present drainage system in the region is a composite of exhumed ancient valleys and superposed valleys associated with streams that developed upon Pleistocene till plains. Floors of the lower reaches of the principal buried valleys lie as much as 100 feet below the beds of present-day streams.

Much of the interest in the bedrock of preglacial topography in the region has been associated with the search for increased ground-water supplies. Test drilling has shown that in some localities the buried valleys are completely filled or are blocked by glacial till, while other valleys contain sand and gravel deposits capable of producing large quantities of potable water. In some northernmost counties in both Kansas and Missouri, interpretation of cross sections prepared from well records and test holes indicates that the bedrock surface was generally covered with outwash sand and gravel deposits that were later buried by glacial till and/or scoured by glacial ice. Knowledge of the distribution of the various types of glacial deposits and their relationship to the bedrock topography is limited. The wide variety of types of deposits that may be encountered is recognized; however, sufficient information about their distribution is not available for satisfactory mapping and description. The delineation of the buried and exhumed topography on the bedrock surface is fairly well defined, but knowledge of the bedrock topography is only a part of the answer to the problems that exist with water supply. Moreover, many details of the stratigraphic succession have yet to be determined. The general succession of deposits and their interrelationships are fairly well defined and can be demonstrated in the area.

The Pleistocene Succession

Essential features of the stratigraphic succession of the Pleistocene Series in northwestern Missouri and northeastern Kansas are discussed in the following paragraphs under subheadings identified by stage (age) terms. Order of the units in this discussion is from oldest to youngest.

NEBRASKAN STAGE

Oldest tills and alluvial materials encountered in extreme northeastern Kansas and in Missouri north of St. Joseph have been considered by most workers to be Nebraskan. The complexity of early Pleistocene stratigraphy is becoming more evident as studies progress in various parts of the world. The subdivision of the Pleistocene into a simple series of four major glacial advances has been abandoned by a large number of modern workers. Early Pleistocene deposits along the Missouri River reflect many of the complexities reported from other regions. The traditional classification of the Pleistocene of the Midwest has, nevertheless, been retained in the discussions that follow.

Thick Nebraskan deposits are undoubtedly present

[1] State Geological Survey of Kansas.
[2] University of Missouri at Columbia.
[3] Missouri Geological Survey and Water Resources.

in many of the buried channels in northeastern Kansas and northwestern Missouri. Reliable criteria for the differentiation of these deposits from overlying Kansan till and outwash, however, are generally lacking.

The principal basis for recognition of Nebraskan till is its association in sequence with one or more overlying tills (Kansan) and an intervening soil profile (Afton). Till of Nebraskan age has been recognized in outcrops in the Moberly and Macon areas in north-central Missouri; in southern Iowa, near Hopkins, Missouri; and in outcrops in Kansas near Iowa Point, Doniphan County, along the Missouri River bluffs. Nebraskan till also appears to be present at many widely scattered points in the north-central and northwestern Missouri areas, where carefully logged test drilling records are available. No evidence of Nebraskan till has been found south of the buried valley of the ancient St. Joseph River between St. Joseph and Gallatin, Missouri. This valley may have been marginal to Nebraskan ice.

Basal till containing few or no northern erratics is moderately common in northwestern Missouri and northeastern Kansas. Davis (1955) described similar material from Platte County, Missouri, where he identified it as a "local" facies of the Kansan till of that area. Glaciers advancing over sedimentary rocks incorporated a preponderance of easily eroded local materials into the basal part of the ice. The lowest till emplaced would, therefore, be dominated by local rock types. Later, overriding ice would not be in contact with as much bedrock and would deposit till containing a greater percentage of northern erratics. Thus, an upward increase of northern erratics within an outcrop of till would not necessarily indicate two episodes of glaciation separated by a significant span of time. Dort (1966) discusses some of the problems in the assignment of ages to tills of various lithologies. Bayne and O'Connor (1967) and Bayne (1968) refer such tills exposed near Doniphan, Kansas, to the Kansan Stage. Such "basal" till facies presumably might be associated with till of either Nebraskan or Kansan age.

A number of exposures of Nebraskan silt, sand, and gravel are found in quarries along the Missouri River in Doniphan County, Kansas. Some of these exposures are described in a later section of this report. Comparable outcrops are not seen on the Missouri side of the river, although silts in St. Joseph and north of St. Joseph along Interstate 29 (Howe, 1968) may be Nebraskan. Further studies in northwestern Missouri may show that periglacial silt of Nebraskan age is more widespread than present knowledge would suggest.

AFTONIAN STAGE

New exposures along Interstate 29 north of St. Joseph include one of the few exposures of a well-defined paleosol known in northwestern Missouri that can be even provisionally referred to the Aftonian. At the Interstate 29 locality, the paleosol in question is not associated with glacial till, but is underlain and overlain by silt tentatively regarded as periglacial deposits of Early Nebraskan and Early Kansan age, respectively.

Afton Soil developed over Nebraskan till was well exposed a few years ago in the overburden of a limestone quarry in southern Iowa just north of Hopkins, Missouri, and has also been identified in exposures at Iowa Point in northeastern Kansas (Frye and Leonard, 1949) and in exposures near Doniphan and Wathena in Doniphan County, Kansas. Gray leached material above glacial till and below calcareous till referred to the Kansan is recorded in logs of test holes scattered over northern and northwestern Missouri. This probably represents the Aftonian paleosol.

KANSAN STAGE

Most till in northeastern Kansas and northern Missouri is classed as Kansan. At present there is no basis for division of the Kansan tills in Missouri as has been accomplished in Nebraska by Reed and Dreeszen (1965) who identify two distinct till deposits. Two Kansan tills are also recognized in northeastern Kansas, as reported by Bayne and O'Connor (1967) and Bayne (1968). According to current interpretation, Kansan glaciers overrode the area affected by Nebraskan glaciers in Kansas and Missouri and extended far to the south where they locally blocked the ancient Kansas River forcing it to develop alternate routes generally marginal to the glacial front.

Kansan glaciation tended to obliterate most of the pre-existing topography in northern Missouri and northeastern Kansas. The early stages of the post-Kansan drainage systems, which presumably were the precursors of those currently in existence, are not clear. Part of the buried sand and gravel fill in some of the early Pleistocene valleys in northeastern Kansas and northwestern Missouri, however, is undoubtedly pre-Kansan material.

Outwash-derived alluvium developed during recessive stages of Kansan glaciation undoubtedly is associated with valley fill in the ancient Kansas River valley and the Missouri River valley below Kansas City which, for the most part, is the locus of the modern Missouri River. Lacustrine and accretion-gley deposits that are provisionally identified as very late Kansan and Yarmouthian in age are widespread in upland regions in Platte, Clay, Clinton, and Caldwell counties in Missouri, and in Atchison, Brown, Doniphan, and Jefferson counties in northeastern Kansas. These deposits may have incorporated considerable quantities of late Kansan loess, as well as volcanic ash, and are a composite of lacustrine and accretion-gley types. They have been named the Ferrelview Formation in Missouri (Howe and Heim, 1968) and have, in Kansas, been referred to as "Nortonville clay."

YARMOUTHIAN STAGE

The Yarmouthian Stage is represented in Missouri by a soil profile, the Yarmouth Soil, and by parts of the composite lacustrine and accretion-gley deposits identified as Ferrelview which were deposited at the same time that the Yarmouth Soil was being developed. Well-defined and clearly differentiated Yarmouth Soil is known in only a few localities in northeastern Kansas and northwestern Missouri. A possible reason for this is that the next younger deposits, the Loveland Loess, (although of widespread distribution) is generally thin and in many places incorporated completely in the profile of the next younger soil (Sangamon). Development of the Sangamon Soil was so intense that, in most areas where the intervening Loveland Loess was deposited, soil-forming influences extended all the way through the Loveland and into the underlying Yarmouth. Where the Loveland is absent through nondeposition, the Sangamon is superposed upon the Yarmouth and may represent a continuation of soil-forming processes (Wright and Ruhe, 1965, p. 31; Howe and Heim, 1968, p. 18). In the absence of the Loveland Loess, the Yarmouth Soil is not commonly distinguishable in northeastern Kansas and Missouri, although its presence is inferred at many points. New exposures seen in July 1968 at Kansas City International Airport (under construction) and in Jefferson County, Kansas, indicate clearly that weathering of the till and some accumulation of resistant erratics took place prior to deposition of the Ferrelview Formation.

ILLINOISAN STAGE

Illinoisan glaciers are not known to have reached Kansas or northwestern Missouri, although Illinoisan till is present at St. Louis. Alluvial deposits preserved as terraces have been recognized at a number of points, and as indicated in a preceding section, extensive loess deposits (the Loveland Loess) are recognized. Colluvium of probable Illinoisan age is also common on many hill slopes. Three lines of evidence suggest that the valley of the modern Missouri River between Kansas City and St. Joseph, Missouri, may have been cut principally during Illinoisan time. First, the valley is relatively narrow and youthful looking. Second, till-bedrock contacts along the bluffs facing the river are generally more than 50 feet above the modern floodplain, suggesting that dissection was post-Kansan. Third, tributary valleys along this part of the Missouri River have well-developed late Illinoisan terraces but no indication of earlier terraces. This implies that the stream valleys were graded to the Missouri River by late Illinoisan time but were not carved until after the last advance of Kansan ice.

SANGAMONIAN STAGE

The Sangamonian Stage is represented by one of the most intensely developed and most widespread of the Pleistocene paleosols. The Sangamon is recognized over large areas in northern Kansas and Missouri. As already indicated, the Sangamon profile may be intimately associated with older profiles so that the identification of the older one may be in doubt. The paleotopography during Sangamonian time was such that the Sangamon Soil developed on an erosional surface that in places transected an older one associated with the Yarmouth. The general relationship in northeastern Kansas and northwestern Missouri is the development of the Sangamon profile over a wide variety of indurated and nonindurated rock types with the profile itself being overlain by Wisconsinan loess, principally the Peoria Loess.

At several localities in northwestern Missouri and northeastern Kansas, slope-site exposures of till with the Sangamon profile developed on it include typically a prominent "lag" or "stone-line" accumulation of resistant erratics which occurs within the Sangamon paleosol or possibly within a composite Sangamon-Yarmouth paleosol.

WISCONSINAN STAGE

Wisconsinan deposits in northwestern Missouri and northeastern Kansas include early Wisconsinan loess, identified in Kansas as Gilman Canyon and in Missouri as Roxana?, overlain by younger loesses identified as Peoria and Bignell. Current thinking about the identification and nomenclature of Wisconsinan loesses in the northwestern Missouri and northeastern Kansas region is not in accord with respect to the materials older than those uniformly regarded as Peoria (Peorian). Area geologists have recognized a post-Sangamon, pre-Peoria succession for many years, generally with a tentative assignment to the "Farmdale." This material was given the name Gilman Canyon in Nebraska by Reed and Dreeszen (1965, p. 42), and the name was subsequently adopted in Kansas (Bayne and O'Connor, *in* Zeller, 1968, p. 62). The difference in viewpoint between Missouri and Kansas geologists relates to both the age of and the appropriate names for this material. In Missouri the term Roxana is being utilized for similar deposits in the St. Louis area and appears to be applicable at Kansas City. In southwestern Iowa, Frye, Willman, and Glass (1968), and Glass, Frye, and Willman (1968) identify loess at this position as Roxana, and note that a weakly developed Farmdale soil caps the loess. This disposition of the matter appears to best fit the relationships in northwestern Missouri and is utilized in a provisional sense, subject to more detailed studies. The material previously identified as Farmdale? is tentatively correlated with the Roxana (of Altonian age), with the overlying paleosol (Farmdale) being the only record of the Farmdalian Substage. In Kansas the same material is identified as Gilman Canyon and thought to be of Farmdalian rather than Altonian age. Radiocarbon dating will ultimately be the deciding factor in resolving the issue, but presently available evidence is inconclusive. In northwestern Missouri only one carbon-14 date (Martin and Williams, 1966, p. 26) is relevant, and it (indicating an age of 25,000 ± 2,200 years BP) relates to material collected *at the top* of silt referred to the "Farmdale," rather than *within it*. Wood determined to be 24,500 ± 800 years BP old from a southwestern Iowa exposure (Ruhe, Rubin, and Scholtes, 1957) was described as having been ". . . extracted from the A horizon of a buried soil in a loess sheet 3 to 4 feet thick that overlies Loveland loess . . ." (p. 676). The authors identified the associated loess sheet as Farmdale (p. 674, 677). It is likely that the deposit involved is comparable with that noted by Frye, Willman, and Glass (1968) and the Gilman Canyon (Kansas) or Roxana? (Missouri) of this report. The fact that the dated material came from the uppermost part of the deposit at the Iowa locality interjects a factor of doubt about the age of the deposit as a whole. Reported Gilman Canyon dates (Dreeszen, 1970) in Nebraska (23,000—34,900 BP) may also be inconclusive. At present Kansas geologists prefer to assign the early Wisconsinan loess to the Farmdalian Substage rather than to the Altonian as is done on a provisional basis in Missouri. More attention to this problem is needed in both states.

The Wisconsinan loesses are present in maximum aggregate thickness of at least 100 feet along the Missouri River valley bluffs and are widely distributed in northeastern Kansas and northwestern Missouri. Thick exposures of light-colored loess almost invariably show darker color bands which are subparallel to the topography. Some of the color bands may be caused by post-depositional accumulations of iron and manganese staining from subsurface water. Many of the color bands, however, are made of material which is leached of carbonates and contains more clay than the normal loess. These bands are interpreted as buried soils even though the soil profile is not well developed. Better exposures show at least five post-Sangamon "soils." Work is still needed in order to correlate Wisconsinan loesses in this region with better known sections in Nebraska and Illinois. Despite uncertainties, the names Gilman Canyon (Kansas), Roxana? (Missouri), Peoria, and Bignell are used for the loesses. The bulk of the loess deposits are correlated with the Peorian Loess in Illinois. A somewhat poorly defined overlying loess is correlated with the Bignell Loess of Nebraska. The Bignell is profusely fossiliferous at most localities along the bluffs of the Missouri River (see separate report by Pauken in this publication). The Peoria is also fossiliferous at many places where complete leaching has not taken place.

Wisconsinan alluvial deposits appear to compose most of the sand and gravel fill in the valley of modern streams such as the Kansas, Missouri, and Grand rivers. In areas where the modern stream occupies a valley that existed during or even before early Pleistocene time, the alluvial fill is undoubtedly a composite of both early and late Pleistocene materials.

DETAILED DISCUSSION OF SELECTED PLEISTOCENE EXPOSURES IN NORTHEASTERN KANSAS AND NORTHWESTERN MISSOURI

By C. K. Bayne, S. N. Davis, W. B. Howe, and H. G. O'Connor

Introduction

A generalized four-fold history of continental glaciation has long been accepted in the United States. Generally the uppermost till was correlated with the youngest glaciation and the underlying till was correlated with the next younger glaciation. In areas where only early Pleistocene glaciations occurred, this same method was often practiced. Recognition of a more complex system of advances and retreats of ice in the Wisconsinan Stage led to the adoption of substage or stade division of this stage.

Each of the glacial stages is separated from the succeeding glacial stage by an interglacial stage. The interglacial stage was one of relative stability under comparatively warm conditions during which extensive interglacial soils were developed in the periglacial regions as well as the glaciated regions.

Recent studies have indicated that early Pleistocene glaciations were more complex than formerly believed and instead of a single advance and retreat of ice, several advances and retreats of the ice occurred within each of the stages (Reed and Dreeszen, 1965; Bayne, 1968).

Northeastern Kansas and northern Missouri were glaciated during the early Pleistocene (Kansan and Nebraskan), but escaped glaciation during middle and late Pleistocene. Early Pleistocene till and associated deposits cover most of this area. Extensive eolian deposits of middle and late Pleistocene age overlie the early Pleistocene deposits in much of the area. Alluvial deposits of middle Pleistocene age occur in tributaries of the Missouri River but have not been recognized in the St. Joseph area of the Missouri River valley. Late Pleistocene alluvial deposits are present in all the stream valleys.

Frye and Leonard (1949, 1952) described an exposure of two tills in a quarry in the Missouri River bluffs near Iowa Point in northwestern Doniphan County, Kansas. A well-developed soil on a lower till was indicative of a long period of weathering prior to the deposition of the upper till. Partly on this basis the two tills were correlated with the Nebraskan and Kansan glaciations respectively. More recently Dort (1966) has reported on studies of other pits and quarries in the Missouri River bluffs, and Bayne (1968) reported on studies by Bayne, H. G. O'Connor, and James Thorp in 1966 on pits and quarries in the same area. These later studies are primarily concerned with deposits of early Pleistocene age. Howe (1968) and Davis (1955) have reported on the extensive eolian deposits in northwestern Missouri. In each of these reports the presence and degree of development of interglacial or interstadial soils has been an important factor in the correlation and classification of the Pleistocene deposits.

On the following pages are descriptions and diagrams of Pleistocene deposits exposed in pits and quarries in the Missouri River bluffs or in nearby exposures in northwestern Missouri and northeastern Kansas. In no single exposure is a complete Pleistocene section exposed, and no two of the exposures are exactly alike, but distinctive features in some part of the exposure are present which permit correlation with similar features in one or more other exposures and lead to an overall correlation of the Pleistocene se-

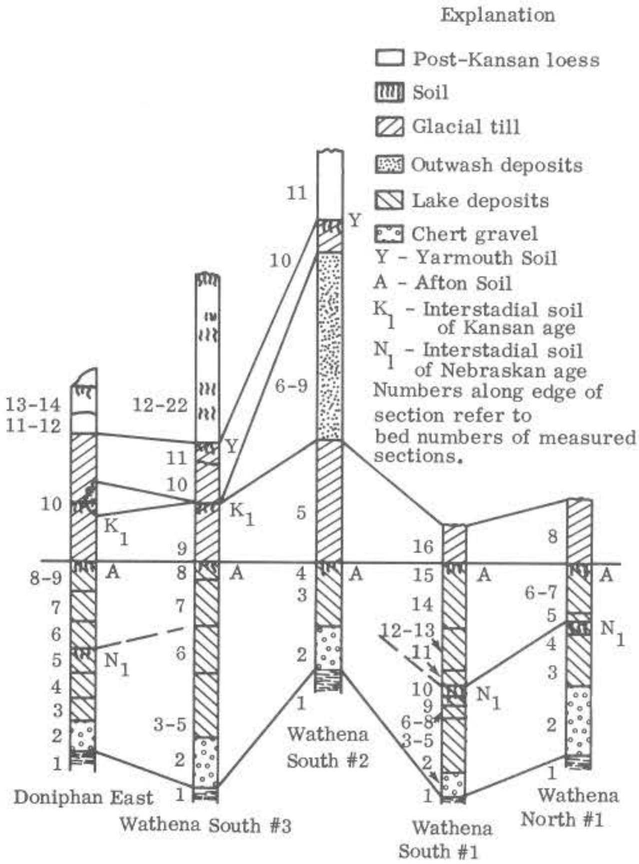


FIGURE 1.—Tentative correlation of lower Pleistocene deposits in northeastern Kansas.

quence in this area. In Figure 1 the descriptions of lower Pleistocene deposits in five pits in northeastern Kansas are illustrated. In this figure a well-developed soil which has been interpreted as the Afton Soil is developed in silty clay deposits of lacustrine and fluvial origin and is below a till. Using the Afton Soil as a base line, units above and below are correlated.

Buried profiles of weathering or fossil soils are probably the most usable criteria for stratigraphic correlation and classification of Pleistocene deposits in Kansas and Missouri. The top of a buried soil is unmistakably an unconformity and where deep well-developed soil profiles occur, a significant interval of nondeposition and only slight erosion is indicated. Interpretation of the soils within the Pleistocene sequence involves the evaluation of the soil horizons as interglacial or interstadial and may lead to errors in correlation. The strength of soil development is believed to be the most important factor in this interpretation. Pronounced zones of clay enrichment in the "B" horizon, considerable depth of leaching, great depth of oxidation, and significant thickness of secondary lime accumulation are believed to be better indicators of the interglacial nature of soils than the thickness of the humic "A" horizon which often has been removed by erosion or scour. Stratigraphic position and lithologic character of deposits are important aids in correlation and classification of the Pleistocene.

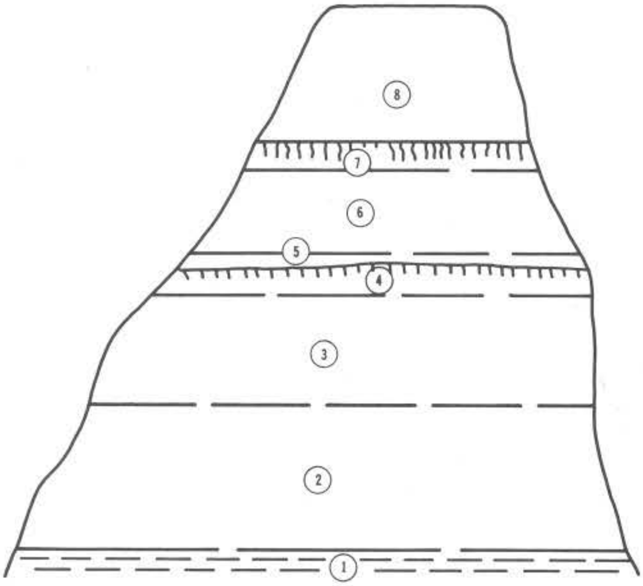
Kansas Stratigraphic Sections

WATHENA NORTH #1 SECTION

Pleistocene deposits exposed in a small gravel pit 1.3 miles N of Wathena on the Missouri River, or 0.45 mile NE of the SW corner sec. 22, T 3 S, R 22 E, Doniphan County, Kansas.

Discussion

This site exposes deposits considered to be of early Pleistocene age that include the Afton Soil where it has a reddish "B" horizon with a zone of lime accumulation below it indicating good internal drainage with aeration while it was forming. This site contrasts with similar deposits exposed in pits south of Wathena in which the Afton Soil developed under conditions of poor drainage. The Afton Soil is overlain by Kansan till and overlies silty clay deposits in which an interstadial Nebraskan soil is recognized. Fluvial deposits of chert and limestone gravel containing a few northern erratics comprise the lowermost Pleistocene deposits.



WATHENA NORTH #1 SECTION

Tentative correlation of Pleistocene units

Unit 8—Kansan till
Units 5, 6, and 7—Late Nebraskan clays and silts
Units 3 and 4—Early Nebraskan clays and silts
Unit 2—Early Nebraskan gravels

Description of Lithologic Units

Section measured by James Thorp, C. K. Bayne, and H. G. O'Connor, July 1966

Unit number	*Description*	*Thickness, feet*
8	Calcareous, oxidized till. Stony clay loam texture containing many erratics but few northern derived erratics.	10+
7	Massive clay, reddish-brown mottled with grayish brown. Contains vertical joints formed by shrinkage. "B" horizon of Afton Soil.	1.5
6	Reddish-brown (moist) to light reddish-brown (dry) fine blocky clay with thin clay skins on blocks. Part of "B" horizon of Afton Soil. Noncalcareous.	6.3
5	Reddish-brown (5 yr 4/4, 5/4) fine blocky silty clay with thin clay skins on blocks. Many decayed lime concretions. Mass calcareous. "C" horizon.	1.0
4	Pink (7.5 yr 7/4, 8/4) silty clay. Noncalcareous except few concretions. "B" horizon of interstadial soil.	1.8
3	Brown (m) to pale brown (d) (10 yr 5.5/3, 6.5/3) weakly stratified silt loam. Very calcareous. "C" horizon of interstadial soil.	8.2
2	Chert and limestone gravel with few northern type erratics.	10.8
1	Pennsylvanian shale.	

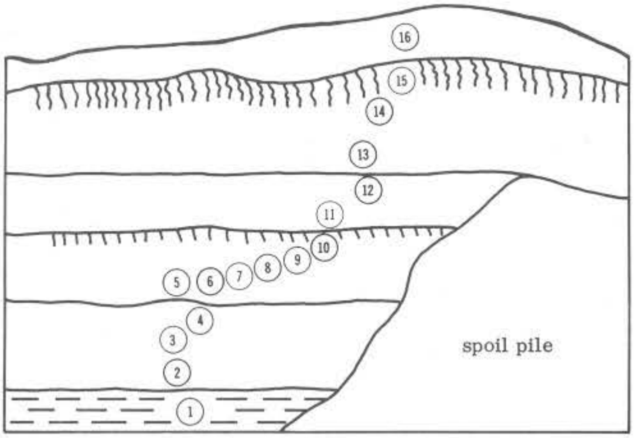
WATHENA SOUTH #1 SECTION

Pleistocene deposits exposed in a small gravel pit about 0.7 miles SSW of Wathena on the river road or 0.3 mile S and 0.4 mile W of the NE corner sec. 33, T 3 S, R 22 E, Doniphan County, Kansas.

Discussion

In this exposure about 37 feet of Nebraskan fluvial and lacustrine deposits overlie Pennsylvanian shale and are overlain by Kansan till. The basal deposits are chert and limestone gravel and sand containing a few northern erratics. An accretion-gley (interstadial) soil divides the deposits near the middle of the exposure and a well-developed Afton Soil is developed in the upper silts and clays. The Afton Soil at this site was developed under conditions of poor internal drainage and all or nearly all of the bedding planes have been obliterated by swelling and shrinking of the clays with the formation of slickenside faces. Well-defined clay skins appear on the blocks of the old "B" horizon. Glacial till of Kansan age overlies the Afton Soil.

The Pleistocene deposits below the interstadial soil contain both invertebrate and vertebrate faunas. This is the only known site in Kansas in which deposits considered to be of Nebraskan age include a vertebrate fauna, and are overlain by glacial till. The site has been collected and is being studied but an interpretative report on the vertebrates has not been published. Hopefully, the vertebrate fauna will prove useful in stratigraphic correlation of the glaciated and nonglaciated areas of Kansas.



WATHENA SOUTH #1 SECTION

Tentative correlation of Pleistocene units

Unit 16—Nickerson Till (Early Kansan)
Units 11, 12, 13, 14, and 15—Late Nebraskan lacustrine and fluvial deposits
Units 2, 3, 4, 5, 6, 7, 8, 9, and 10—Early Nebraskan lacustrine and fluvial deposits

Description of Lithologic Units

Section measured by James Thorp, H. G. O'Connor, and C. K. Bayne, July 1966

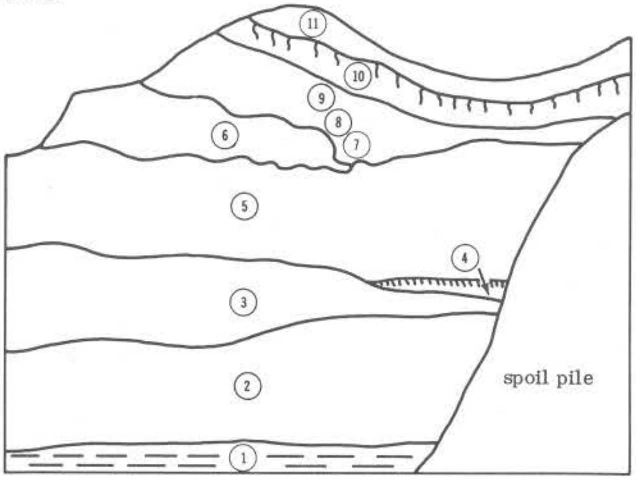
Unit number	*Description*	*Thickness, feet*
16	Yellowish-brown to reddish-brown calcareous, stony clay till.	6+
15	Silty clay, heavy compact, vertical shrinkage cracks, slickensided joints with clay skins on joint faces. Mass noncalcareous. "B" horizon of Afton Soil.	1.2
14	Grayish-brown (m) to light grayish-brown (d) (2.5 yr 5/2, 6/2) silty clay. Noncalcareous, blocky structure, with slickensides and clay skins. Some gray and black mottling.	5.0
13	Light brown (m) to pink (d) (7.5 yr 6/3, 7/3) silty clay with faint mottles. Blocky structure with clay skins on slickenside joints.	4.0
12	Same as above with wider spacing on joints and some gypsum in joints. Contains a few calcium carbonate concretions and has faint stratification but no horizontal cleavage. Mass noncalcareous.	6.5
11	Pinkish-gray (7.5 yr 6/2) silty clay with faint gray and brown mottles. Becomes grayer with depth. Noncalcareous.	2.3
10	Light brownish-gray (m) to light gray (d) (2.5 yr 6/2, 7/2) compact silty clay-containing fine black specks of decayed vegetation. Noncalcareous except in joints. "A" horizon of an accretion-gley soil.	1.0
9	Very dark grayish-brown (m) to dark grayish-brown (d) (2.5 yr 3/2, 4/2) compact clay containing much humus. Sandy at base. "B" horizon.	0.8
8	Very dark gray (m) to dark gray (d) (10 yr 3/1, 4/1) massive silty clay with much humus. Noncalcareous except a few etched snail shells. Contains vertebrate remains. "C" horizon.	0.4
7	Gray (10 yr 5/1, 6/1) calcareous, weakly stratified silty clay.	0.3
6	Stratified, calcareous, organic rich silty clay with several fine sand partings. Contains many broken snail shells. "C" horizon.	2.5
5	Bedded fine silty sand. Calcareous. "C" horizon.	1.7
4	Bedded chert and limestone gravel with few northern type erratics.	1.7
3	Sand fine to medium, bedded, strongly calcareous.	5.2
2	Chert and limestone gravel containing a few erratics.	4.0
1	Pennsylvanian shale.	

WATHENA SOUTH #2 SECTION

This site is about 150 yards S of Wathena South #1 Section in the W face of a gravel pit. Located 0.4 mile S and 0.4 mile W of the NE corner sec. 33, T 3 S, R 22 E, Doniphan County, Kansas.

Discussion

In this exposure the Nebraskan deposits are thinner, and fewer units are recognized than in the nearby Wathena South #1 Section, but the Afton Soil can be recognized in the face of the pit at the north end of the exposure. Above the Afton Soil are two Kansan tills separated by outwash deposits. The lower till is identified as the Nickerson Till (Early Kansan) and the upper till is identified as the Cedar Bluffs Till (Medial Kansan). A partial Yarmouth Soil is developed in the upper till and this is overlain by Loveland loess.



WATHENA SOUTH #2 SECTION

Tentative correlation of Pleistocene units

Unit 11—Loveland Formation
Unit 10—Cedar Bluffs Till
Units 6, 7, 8, and 9—Medial Kansan outwash
Unit 5—Nickerson Till
Units 2, 3, and 4—Nebraskan lacustrine and fluvial deposits

Description of Lithologic Units

Section measured by C. K. Bayne and H. G. O'Connor, July 1966

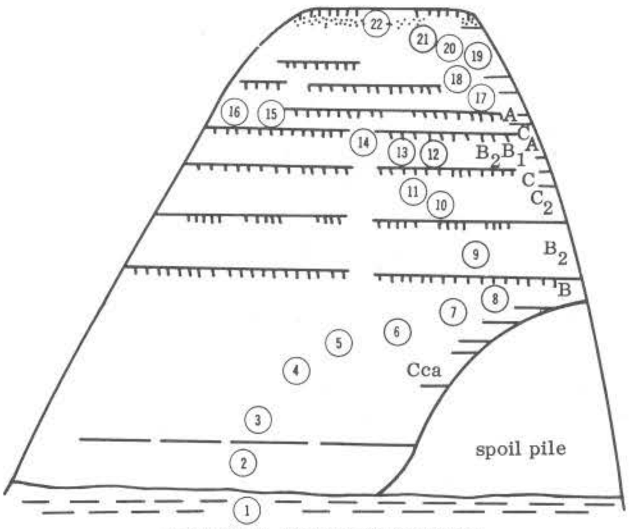
Unit number	*Description*	*Thickness, feet*
11	Silt, buff, noncalcareous. (loess)	11+
10	Silty clay till reddish-brown and buff. Contains caliche nodules in upper part and many northern type erratics. Cedar Bluffs Till.	5.0
9	Sand and gravel with much silt and clay, calcareous. Contains many cobbles and boulders. Granitic types badly decomposed. (outwash)	13.0
8	Dense dark gray till. (transported block)	2.0
7	Same as bed 9.	2.0
6	Sand and gravel like bed 3 with inclusions of dark gray till and a large block of fine to very fine sand similar to Atchison Formation type sand.	13.0
5	Gray to dark gray clay till, very compact and hard, containing cobbles and boulders almost entirely of local origin. Nickerson Till.	19.0
4	Massive vertically jointed noncalcareous clay with slickensides poorly exposed in north end of pit. Afton Soil.	0-4
3	Bedded well-graded silt and sand and tannish-gray clay beds. Noncalcareous.	10
2	Chert and limestone gravel and sand containing a few northern type erratics. (A bone from an early Pleistocene deer-like animal was taken 1.5 feet below the top of this bed.)	7.0
1	Pennsylvanian shale.	

WATHENA SOUTH #3 SECTION

Borrow area for earth-fill dam on a small stream. About 1,500 feet ESE of center of W line sec. 33, T 3 S, R 22 E, Doniphan County, Kansas. Located about 200 feet W of river road, on SW facing exposure.

Discussion

In this section three incipient soils in Wisconsinan loesses occur below the modern soil. A well-developed Sangamon Soil is present lying on a truncated Yarmouth Soil. A truncated interstadial soil (Kansan) may be represented in bed 9, the lower of two Kansan tills. The paleosol developed in the lake clays beginning with bed 8 represents a long period of soil formation under wet conditions and poor internal drainage and is identified as the Afton Soil. The "A" horizon of the Afton Soil has been stripped off by the overriding glacier. Early Nebraskan water-laid gravels are the basal Pleistocene deposits.



WATHENA SOUTH #3 SECTION

Tentative correlation of Pleistocene units

Units 20, 21, and 22—Bignell Formation
Units 17, 18, and 19—Peoria Formation(?) or Bignell Formation(?)
Units 15 and 16—Gilman Canyon Formation
Units 12, 13, and 14—Loveland Formation
Units 10 and 11—Cedar Bluffs Till
Unit 9—Nickerson Till
Units 2, 3, 4, 5, 6, 7, and 8—Nebraskan lacustrine and fluvial deposits

Description of Lithologic Units

Section measured by James Thorp and C. K. Bayne, July 1966

Unit number	*Description*	*Thickness, feet*
22	Grayish-brown (m) to light gray (d) (10 yr 4/2, 6/2) friable silt. Partly eroded "A" horizon of modern soil.	0.6
21	Brown (m) to very pale brown (d) (10 yr 5/3, 7/3) friable noncalcareous silt. "Color-B" horizon contains no illuvial clay.	3.0
20	Finely mottled (10 yr 6/3, 8/3) and (7/1, 9/1) friable silt, calcareous with thin bands of "loess puppets."	5.0
19	Pale brown (m) to very pale brown (d) (10 yr 6/3, 7/3) friable noncalcareous silt. Calcareous on faces of joints.	2.0
18	Mottled very pale brown, pale yellow and black friable calcareous silt.	2.0
17	Light yellowish-brown (m) to very pale brown (d) (10 yr 6/4, 7/4) structureless silt. Lower 1 foot calcareous.	4.5
16	Brown (m) to very pale brown (d) (10 yr 5/3, 7/3) noncalcareous friable silt. "A" horizon of Gilman Canyon Soil.	1.1
15	Same color as above but calcareous. "C" horizon of above soil.	2.1
14	Grayish-brown (m) to light gray (d) (10 yr 5/2, 7/2) noncalcareous platy friable silt. "A" horizon of well developed Sangamon Soil.	1.8
13	Grayish-brown (m) to light brownish-gray (d) (10 yr 5/2, 6/2) subangular blocky silty clay. Thin clay skins on blocks. Noncalcareous. "B_1" horizon.	2.0

Unit number	Description	Thickness, feet
12	Yellowish-brown (m) to very pale brown (d) (10 yr 5/4, 7/4) subangular, blocky, clayey silt. Some clay skins. Mass noncalcareous. "B_2" horizon developed in loess.	2.0
11	Brownish-yellow (m) to yellow (d) (10 yr 6/5, 7/5) finely blocky clay till, noncalcareous except for a few lime concretions. Mottled with gray and black spots. "C_1" horizon of truncated Yarmouth Soil. Contains inclusions of black clay from lake clays below.	2.8
10	Oxidized and strongly weathered calcareous till with many large lime concretions. Contains rounded inclusions of brownish-yellow sand. "C_2" horizon.	6.6
9	Light olive-brown (m) to pale yellow (d) (2.5 yr 5/3, 7/3) massive to coarsely blocky calcareous till. Contains much limestone and few northern erratics. Contains a few lime concretions in upper part. Part of a paleosoil from which "A" and "B" horizons have been removed by overriding ice.	9.0
8	Brownish-yellow (m) to yellow (d) (10 yr 5.5/6, 6/5.6) light mottled clay. Noncalcareous with slickensided joints. Upper part of "B" horizon of lake clay soil (Afton).	3.2
7	Gray (m) to light gray (d) (2.5 yr 5.5/1, 7.5/1) coarse blocky clay with clay skins on blocks. Some pinkish-gray mottles.	3.0
6	Grayish-brown (m) to light gray (d) sharply blocky clay with clay skins on blocks.	2.6
5	Light gray (m) to white (d) blocky clay with mottles of light brown.	1.5
4	Same as bed 5, carbonate in plates and irregular masses in joints. "C_{ca}" horizon.	7.3
3	Light brownish-gray (m) to white (d) laminated silty clay.	10.1
2	Brown water-laid chert gravel.	8.2
1	Pennsylvanian shale.	

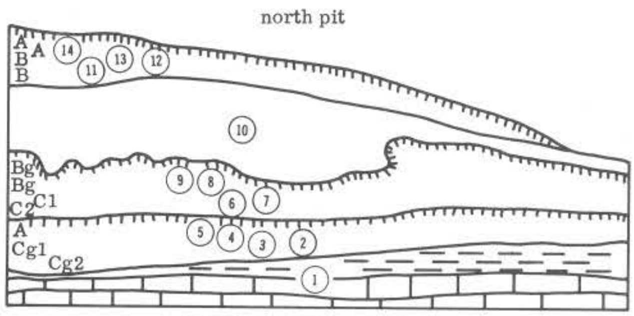
DONIPHAN EAST SECTION

Pleistocene deposits exposed about 90 feet above the Missouri River floodplain in an Oread Limestone quarry in the river bluff. Located 250 feet S and 1,900 feet W of the NE corner sec. 9, T 5 S, R 21 E, Doniphan County, Kansas.

Discussion

This section exposes a Sangamon paleosol developed in Loveland loess and some underlying "lag" material that is partly water laid. At the north end of the pit where this section was measured, the next lower material is calcareous oxidized boulder clay till that is identified as Nickerson Till.

At the south end of this exposure the Nickerson Till has a weak interstadial soil developed at the top and is overlain by a wedge of outwash sand and gravel and a younger till (Cedar Bluffs). Below the Nickerson Till are about 31 feet of lacustrine and fluvial deposits containing the Afton Soil in the upper part and an interstadial soil near the middle. The two paleosols beneath the till have little or no true soil structure. The clays break with a starchy fracture, and have developed many intersecting slickenside faces in the past with periodic changes in moisture content. The clays shrink markedly with drying. The silty clay material below the Nickerson Till might be interpreted as gumbotil by some workers, but visual evidence of horizontal bedding would indicate the material is lacustrine.



DONIPHAN EAST SECTION

Tentative correlation of Pleistocene units

Units 11, 12, 13, and 14—Loveland Formation and Illinoisan gravels
Unit 10—Nickerson Till
Units 6, 7, 8, and 9—Late Nebraskan lacustrine and fluvial deposits
Units 2, 3, 4, and 5—Early Nebraskan lacustrine and fluvial deposits

Description of Lithologic Units

Section measured by James Thorp and H. G. O'Connor, August 1966 (north end north pit)

Unit number	Description	Thickness, feet
14	Brown (m) to very pale brown (d) (10 yr 5/3, 7/3) silt. Friable when moist, noncalcareous Loveland Loess. "A" horizon of Sangamon Soil.	1.4
13	Yellowish-brown (m) to pale brown (d) (10 yr 5/4, 7/4) massive silt. Friable when moist. Noncalcareous Loveland Loess. "A" horizon.	2.8
12	Yellowish-brown (m) to very pale brown (d) (10 yr 5/4, 7/4) blocky clay containing some sand and gravel. Noncalcareous mass with discontinuous clay skins on blocks. "B_1" horizon of Sangamon Soil developed in partly water-worked material.	1.0
11	Brownish-yellow (m) to very pale brown (d) (10 yr 5/5, 7/5) blocky clay with some white and brown mottles. Thin clay skins. "B" horizon.	2.0
10	Strongly calcareous oxidized boulder clay till containing many secondary lime concretions in upper part and many northern erratics.	20-25
9	Grayish-brown (m) to light gray (d) (10 yr 5/2, 7/2) silty clay. Plastic when wet and very hard with vertical joints when dry. "B_g" horizon of Afton Soil. Original structure destroyed and few clay skins on surface of blocks. Scattered pebbles.	2.4

Unit number	Description	Thickness, feet
8	Gray (m) to light gray (d) (7.5 yr 5/1, 6/1) silty clay with coarsely blocky structure and slickenside structure in moist conditions. "B_g" horizon.	3.0
7	Brown (m) to pinkish-gray (d) silty clay. Shatters to fine blocks when dry but same structure as bed 8 when moist. No clay skins. "C_1" horizon.	4.5
6	Brown (m) to very pale brown (d) (10 yr 5/3, 7/3) silty clay with a few lighter streaks. Some evidence of bedding but same fracture as above. Base of upper soil in lake sediments. "C_2" horizon.	4.5
5	Very dark brown (m) to brown (d) (7.5 yr 3/2, 5/2) massive silty clay. "A_1" horizon of a buried low-humic gley soil developed in a permanently wet site.	4.0
4	Same as above bed except color is dark brown (m) to brown (d) and contains scattered chert and quartz pebbles. Transition zone.	4.0
3	Similar to bed 4 except color is brown (m) to pale brown (d) (10 yr 5/3, 6/3). "C_{g1}" horizon.	3.5
2	Gray (m) to light gray (d) sandy clay horizontal bedding with manganese streaks. Contains as much as 6 inches of chert gravel in lower part. "C_{g2}" horizon.	5.0
1	Pennsylvanian limestone and shale.	

NEWTON FARM SECTION

Pleistocene deposits exposed along an E trending gully S of driveway into the Newton farm, SE SE NW sec. 12, T 3 S, R 21 E, Doniphan County, Kansas.

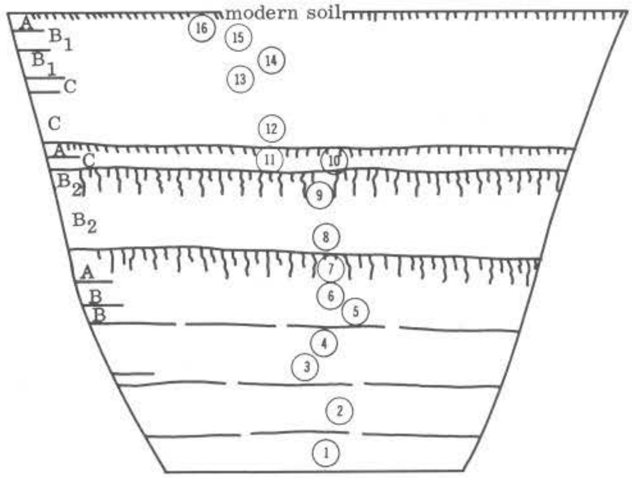
Discussion

The Newton Farm site exposes two well-defined soils, the upper of which is capped by a thin laminated silt with a humic soil a few inches thick at its top. The lowermost soil, developed in silty material overlying leached Kansan till over calcareous Kansan till is interpreted as a Yarmouth Soil (bed 7) because there is an erosion pavement of pebbles and boulders between the leached till and the silty clay part of the profile. This erosion pavement could have formed after the deposition of the later of two Kansan tills. The erosion pavement and the till immediately below contain much Sioux Quartzite and other igneous and metamorphic rocks. In contrast the till in contact with the clay at the Wathena South sites has mostly local rocks and relatively few erratics.

The oldest paleosol at the Newton Farm site is best classed as a low-humic gley. It is silty but contains much clay and some sand, especially in the lower part. The material was laid in a low place and probably was laid partly by water and partly by wind. That it was not completely saturated, though, is attested by the presence of burrow-fills (crotowinas) in its "B" horizon. The paleosol is judged to be of Yarmouthian age. The next older paleosol (bed 9) is in silty clay material and is much like the oldest one. It is judged to be of Sangamon age.

The laminated gray silt (bed 10) with dark humic layer above it (bed 11) was judged by E. C. Reed to represent the Gilman Canyon Formation (with soil) of Wisconsinan age, corresponding to Farmdale of Illinois. Carbon-14 analysis of this soil in Nebraska gives dates of 25,000-28,000 years BP.

One of the interesting things seen at this site is the redder buried soils of the same age which lie up the valley from the original site described. In this area the "B" horizon of the Sangamon Soil is quite red except for grayish mottles that have developed under the influence of percolating water since the paleosol was mantled by Peoria loess. This is an excellent site to illustrate paleo-soil catenas.



NEWTON FARM SECTION

Tentative correlation of Pleistocene units

Units 12, 13, 14, 15, and 16—Peoria Formation
Units 10 and 11—Gilman Canyon Formation
Units 8 and 9—Loveland Formation
Units 3, 4, 5, 6, and 7—Late Kansan loess and fluvial deposits
Units 1 and 2—Kansan till (Cedar Bluff Till?)

Description of Lithologic Units

Section measured by James Thorp, H. G. O'Connor, and C. K. Bayne, August 1966

Unit number	Description	Thickness, feet
16	Dark grayish-brown (m) to light grayish-brown (d) (10 yr 4/2, 6/2) friable silt with fine crumbly structure. "A" horizon of modern soil.	0.8
15	Brown (m) to pale brown (d) friable silt. "B_1" horizon modern soil.	2.0
14	Same color as above, blocky silty clay with thin clay skins and a few dark brown mottles. "B_1" horizon.	2.0
13	Transition to "C" horizon. Black and yellow silt mottled brown.	0.8

Unit number	Description	Thickness, feet
12	Light gray (m) to nearly white (d) (10 yr 6.5/1, 8/1) friable structureless silt, coarsely mottled brown to reddish-yellow (7.5 yr 5/8, 6/8). "C" horizon.	4.2
11	"A_1" horizon of a humic-gley soil (Gilman Canyon) dark gray (m) to gray (d) (10 yr 4/1, 6/1). Fine blocky silty clay with clay skins on some blocks.	1.3
10	Light gray (m) to white (d) friable laminated silt, noncalcareous, "C_2" horizon of above soil. Depositional break with bed below.	0.8
9	Light brownish-gray (m) to very light gray (d) (10 yr 6/1.5, 8/1.5) weakly blocky silty clay with very thin clay skins and dark brown mottles. "B_{21}" horizon of Sangamon Soil.	1.5
8	Coarsely mottled gray (m) to nearly white (d) and reddish-brown (m) to light brown (d) blocky heavy silty clay with some clay skins on blocks. "B_{22}" horizon of Sangamon Soil.	5.0
7	Grayish-brown (m) to light grayish-brown (d) (10 yr 5/1.5, 6/1.5) nearly massive heavy silty clay. "A" horizon Yarmouth Soil. Contains a few lime concretions in a noncalcareous mass.	2.5
6	Brown (m) to very pale brown (d) (10 yr 5/3, 7/3) mottled strongly brown (7.5 yr 5/6) silty clay, weakly blocky, noncalcareous mass but contains many lime concretions.	1.5
5	Colors as above. Weakly blocky silt loam containing a few black manganese spots.	1.3
4	Light brownish-gray (m) to very light gray (d) friable silt mottled with black manganese (loess).	4.8
3	Noncalcareous bedded fine sand with manganese spots. Erosion pavement of pebbles and boulders.	0.5
2	Leached and oxidized clay till with enfolded sand and gravel.	3.8
1	Black (m) to light gray (d) (2.5 yr 3/0.5, 6/0.5) strongly calcareous till with many kinds of erratics.	3.0

Missouri Stratigraphic Sections

KEY TO SYMBOLS USED IN DIAGRAMS OF MISSOURI STRATIGRAPHIC SECTIONS

Well-developed soil (Sangamon Soil)	Angular blocks of rock or modern rubble
Soil horizon	Natural stones (gravel & cobble size)
Incipient soil	Calcareous concretions
Color band - darker color than above or below may also be incipient soil	Fossil gastropods
Sharp contact between lithologic units	Shale
Indistinct contact between lithologic units	Limestone

WYETH PARK SECTION

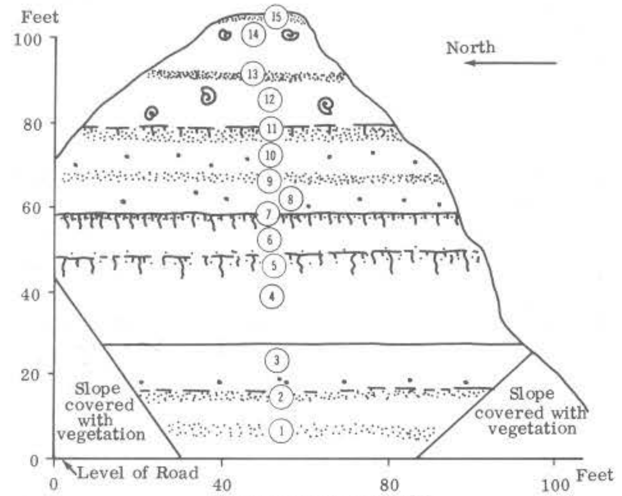
Pleistocene deposits (Wyeth Park locality) above MacArthur Drive, N of the foot of Jule Street in St. Joseph, Missouri, east-central part of sec. 7, T 57 N, R 35 W.

Discussion

The Wyeth Park locality is important to students of the Pleistocene in Missouri because of the exceptional thickness of the Pleistocene succession that is exposed and the large number of depositional and paleosol units that are represented. Many of the interrelated factors involved in the interpretation of such a succession are illustrated at this stop. One of these is the importance of information about the topography prior to deposition of the various units. An early Pleistocene valley is assumed to have occupied a position within the area of the modern Missouri River valley at this point, and probably represented part of an upstream segment of a prominent east-trending buried valley (St. Joseph Valley of Heim and Howe, 1963a) extending to the east from the southern part of St. Joseph. Basal silt seen at this locality may represent ponded sediment deposited during a period of drainage blockage during Nebraskan or Kansan time. The silt closely resembles Nebraskan silt present at approximately the same elevation at a point almost directly across the Missouri River in Doniphan County, Kansas. The overlying sand probably represents a remnant of Illinoian terrace deposits that occur along an essentially modern course of Missouri River above Kansas City. The loess sequence and associated paleosol above the Illinoian(?) terrace material were deposited or developed upon increasingly precipitous bluffs at the edge of the Missouri River valley. The lateral variations along the bluff are typical. Among the interesting features is the evidence of slump and landslide structures, part of which developed prior to Late Wisconsinan time.

The unit tentatively referred to the Roxana is the only depositional record of the relatively long period following the development of the Sangamon Soil and preceding the beginning of Peoria Loess deposition. It is probably correlative with the Wisconsinan Roxana sequence (Frye and Willman, 1960) of western Illinois (see regional discussion).

In addition to the ancient colluvial deposits, loess mixed with modern rubble can be seen at various localities in the southern part of the exposure. Holes have been drilled to bedrock 1,200 feet southeast of the Wyeth Park section. The silt exposed in the base of the cliff is probably underlain by alluvial sand and gravel. Till was not encountered in the drill holes.



WYETH PARK SECTION

Tentative correlation of Pleistocene units

Units 14 and 15—Bignell Loess
Units 8, 9, 10, 11, 12, and 13—Peoria Loess
Units 6 and 7—Roxana? Loess
Units 4 and 5—Illinoian sand
Units 1, 2, and 3—Nebraskan or Kansan silt

Description of Lithologic Units

Section measured by S. N. Davis, 1970

Unit number	*Description*	*Thickness, feet*
15	Silt, grading from dark yellowish-brown at top to pale yellowish-brown at bottom. Eroded modern "A" and "B" horizons.	1.0
14	Silt, pale yellowish-brown. Calcareous, some gastropod remains. Very porous and not as compact as units below.	13.0
13	Silt, pale yellowish-brown, but *slightly* darker than units above and below. Slightly calcareous.	1.5
12	Silt, pale yellowish-brown. Calcareous, some gastropod remains.	11.5
11	Silt, pale yellowish-brown but darker than units above or below. Not calcareous.	3.0
10	Silt, moderate yellowish-brown. Calcium carbonate concretions. Silt matrix not calcareous. Strongly developed vertical jointing.	9.0
9	Silt, moderate yellowish-brown. *Slightly* darker zone than above or below.	1.0
8	Silt, moderate yellowish-brown. Calcium carbonate concretions. Silt matrix not calcareous. Strongly developed vertical jointing.	8.0
7	Silt, some clay, moderate yellowish-brown. Not calcareous. Closely spaced cracks give fine, blocky appearance.	2.5
6	Silt, few sand grains, moderate yellowish-brown. Not calcareous.	7.5
5	Silt, sandy, some clay, moderate brown. Not calcareous but with relict concretions.	5.0
4	Sand, fine to medium, pale yellowish-brown.	20.0
3	Silt, some clay, yellowish-brown. Few large (maximum diameter 6 inches) calcium carbonate concretions near base.	9.0
2	Silt, clayey, yellowish-brown, slightly darker than units above or below. Not calcareous.	2.0
1	Silt, some clay, yellowish-brown. Not calcareous. Slightly darker band in about middle of this unit.	12.0

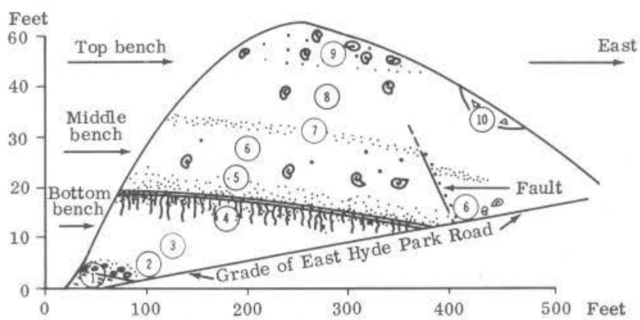
EAST HYDE PARK SECTION

Loess exposure at East Hyde Park near the intersection of Hyde Park and King Hill roads in the southern part of St. Joseph, Missouri, east-central part of sec. 31, T 57 N, R 35 W.

Discussion

The East Hyde Park section is similar to the Wyeth Park section except the buried soils at Hyde Park are not as prominent. Only the lower soil (Sangamon?) is clearly exposed. Other zones of incipient soil development are, however, suggested by the degrees of leaching and scarcity of fossil gastropods at various horizons. An interesting "fault" is exposed in the eastern part of the roadcut. Great care must always be exercised in working with Pleistocene deposits along the bluffs of the Missouri River. Almost all large exposures show some evidence of ancient mass movements.

The difficulties encountered in trying to identify the Bignell Loess are well illustrated at the Hyde Park section. A well-defined Brady soil is only rarely found along the Missouri River. Most commonly the Bignell Loess can be recognized by (1) non-compact, porous texture, (2) lack of a deeply weathered modern soil at the surface, (3) abundant content of fossils, and (4) high carbonate content. A few hundred yards from the bluff line the loess is leached of most carbonates and the Bignell Loess cannot be distinguished from the underlying Peoria Loess.



EAST HYDE PARK SECTION

Tentative correlation of Pleistocene units

Unit 9—Bignell Loess
Units 6, 7, and 8—Peoria Loess
Unit 5—Roxana? Formation
Units 3 and 4—Loveland Formation. Unit 4 is a well-developed Sangamon Soil.
Unit 2—Illinoian colluvium

Description of Lithologic Units

Section measured by S. N. Davis, 1970

Unit number	*Description*	*Thickness, feet*
10	Silt and rubble. Modern gully filling.	2.0
9	Silt, porous, calcareous, with fossil gastropods and scattered concretions, moderate yellowish-gray. Upper part of this unit has been removed artificially.	6.0
8	Silt, compact, very few fossil gastropods, moderate yellowish-gray, calcareous.	11.0
7	Silt, compact, no fossils, small zones of manganese staining, moderate yellowish-brown, only slightly calcareous.	2.0
6	Silt, abundant fossil gastropods at base, scattered calcareous concretions, moderate to pale yellowish-brown	9.0
5	Silt, some clay near base, suggestion of incipient soil at top of unit, moderate yellowish-brown, not calcareous.	4.5
4	Silt, considerable clay, few grains of sand, light brown.	5.0
3	Silt, some grains of sand, compact, moderate yellowish-brown, not calcareous.	16.0
2	Silt mixed with limonite, chert, and limestone fragments.	2.0
1	Shale (Pennsylvanian)	1.0

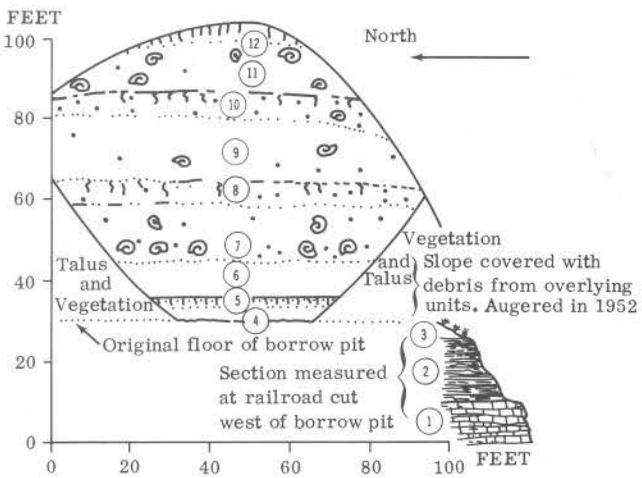
IATAN SECTION

Loess and bedrock at Iatan, Missouri (Platte County), near center of sec. 9, T 54 N, R 36 W.

Discussion

The Iatan exposure is the east face of an old borrow pit which was developed about 40 years ago. The stability of the loess cliff is indicated by the fact that scars of the original power-shovel operation can still be seen in parts of the face. A rich fauna of fossil gastropods from several different horizons has been collected from this site. All the fossils are late Wisconsinan and do not suggest significant ecological changes during the periods of loess deposition.

The type locality for the Iatan limestone is along the railroad cut just west of the exposure of loess. The Iatan Formation is in the uppermost part of the Missourian Series, Pennsylvanian System.



IATAN SECTION

Tentative correlation of Pleistocene units

Units 11 and 12—Bignell Loess
Units 7, 8, 9, and 10—Peoria Loess. Unit 10 may be a poorly developed Brady soil.
Unit 6—Roxana? Formation
Units 4 and 5—Loveland Formation. Unit 4 may be a truncated Sangamon Soil.

Description of Lithologic Units

Section measured by S. N. Davis, 1954

Unit number	*Description*	*Thickness, feet*
12	Silt, yellowish-gray, slightly blocky structure but well-defined soil horizons not present, leached of calcium carbonate.	5
11	Silt, yellowish-gray, poorly compacted, calcareous, abundant gastropod shells, few small calcareous concretions.	12
10	Silt, yellowish-gray, slight amount of clay, many calcareous concretions, maximum diameter 40 mm, matrix of loess is leached except along joint surfaces and in lowest part of unit, a few gastropod fragments can be found.	6
9	Silt, yellowish-brown, fewer concretions than unit 10, matrix of loess is slightly calcareous, scattered fragments of gastropods.	16
8	Silt, yellowish-brown, more clay than units 7 or 9, partly leached matrix, calcareous concretions up to 100 mm diameter, no gastropod remains.	6
7	Silt, yellowish-brown, few calcareous concretions, maximum diameter 60 mm, abundant fossil gastropods.	14
6	Silt, coarse, sandy in basal part, yellowish-brown, leached of calcium carbonate.	9
5	Silt, sandy, and clayey, moderate yellowish-brown, leached of calcium carbonate.	2
4	Sand, silty, yellowish-brown, leached of calcium carbonate, bottom of this unit not penetrated completely by auger.	4+
3	Not exposed and not penetrated by auger.	5
2	Shale (Pennsylvanian, Douglas Group).	15
1	Limestone (Pennsylvanian, Pedee Group, Iatan Formation) bottom not exposed.	10

KANSAS CITY INTERNATIONAL AIRPORT SECTION

Ferrelview Formation at the entrance to the Kansas City International Airport and adjacent to Highway I-29, near center of S line, NW NE sec. 26, T 52 N, R 34 W, Platte County, Missouri.

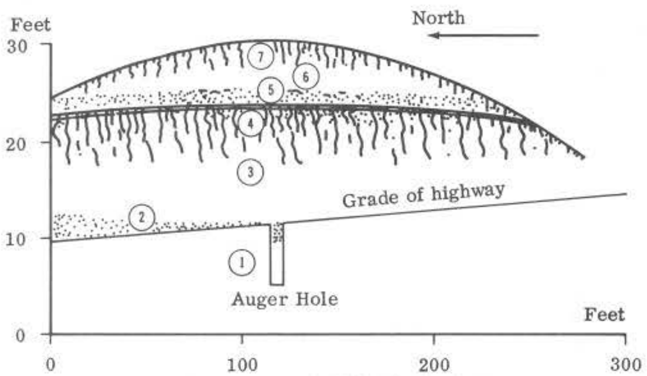
Discussion

The Ferrelview Formation, a post-Kansan(?) silty clay, has been exposed in numerous excavations for airports and highways during the past 20 years. Unfortunately, a given exposure does not remain in good condition for more than two or three years. The descriptions given here, nevertheless, are typical of the deposits underlying the broad upland areas north of the Missouri River in Platte and Clay counties, Missouri.

The Ferrelview Formation is of interest for at least two reasons. First, the formation is composed of material which has been called "gumbotil." The petrology and thickness of the deposit as well as a stone line separating the Kansan till from the "gumbotil," however, argue against the interpretation that the "gumbotil" is the result of normal weathering of till. Second, the clay and silt of the Ferrelview Formation may represent an accretion-gley deposit composed of increments from Kansan till, Kansan loess, and minor amounts of other material.

Drill holes in this vicinity generally show the following succession (after Howe and Heim, 1968):

	Range of thickness, feet
WISCONSINAN STAGE	
Peoria Loess (some Roxana? and Bignell included)	
1. Modern "A-B" horizon	1 to 3
2. Loess	5 to 10
ILLINOIAN STAGE	
Loveland Loess	
3. Silt, clayey, "B" horizon Sangamon soil	4 to 7
4. Silt, clayey	5 to 15
YARMOUTHIAN STAGE(?)	
Ferrelview Formation	
5. Clayey silt	5 to 20
KANSAN STAGE	
Kansan till	
6. Sandy clay	10 to 40
PRE-PLEISTOCENE BEDROCK	
7. Limestone and/or shale, up to 1 foot weathered material on top of rock	



KANSAS CITY INTERNATIONAL AIRPORT SECTION

TENTATIVE CORRELATION OF PLEISTOCENE UNITS

Units 6 and 7—Bignell and Peoria Loess
Unit 5—Roxana? Loess
Units 3 and 4—Loveland Formation
Units 1 and 2—Ferrelview Formation

DESCRIPTION OF LITHOLOGIC UNITS

Section measured by S. N. Davis, 1970

Unit number	*Description*	*Thickness, feet*
7	Silt, grading from dark yellowish-brown at top to moderate yellowish-brown at bottom. Not calcareous. Modern "A" and "B" horizons.	2.5
6	Silt, moderate yellowish-brown. Not calcareous.	2.0
5	Silt, mottled moderate yellowish-brown, and some dark yellowish-brown. Not calcareous.	1.5
4	Silt, clayey, light brown. Not calcareous.	4.0
3	Silt, some clay, moderate yellowish-brown. Not calcareous.	7.0
2	Silt, clayey, mottled pale yellowish-brown and moderate yellowish-brown. Not calcareous.	3.0
1	Clay, silty, pale yellowish-brown. Not calcareous. Very few widely scattered siliceous pebbles.	5.0

Lower 6.0 feet of this section augered. Lower two units are also exposed in a grader ditch 200 feet north of measured section.

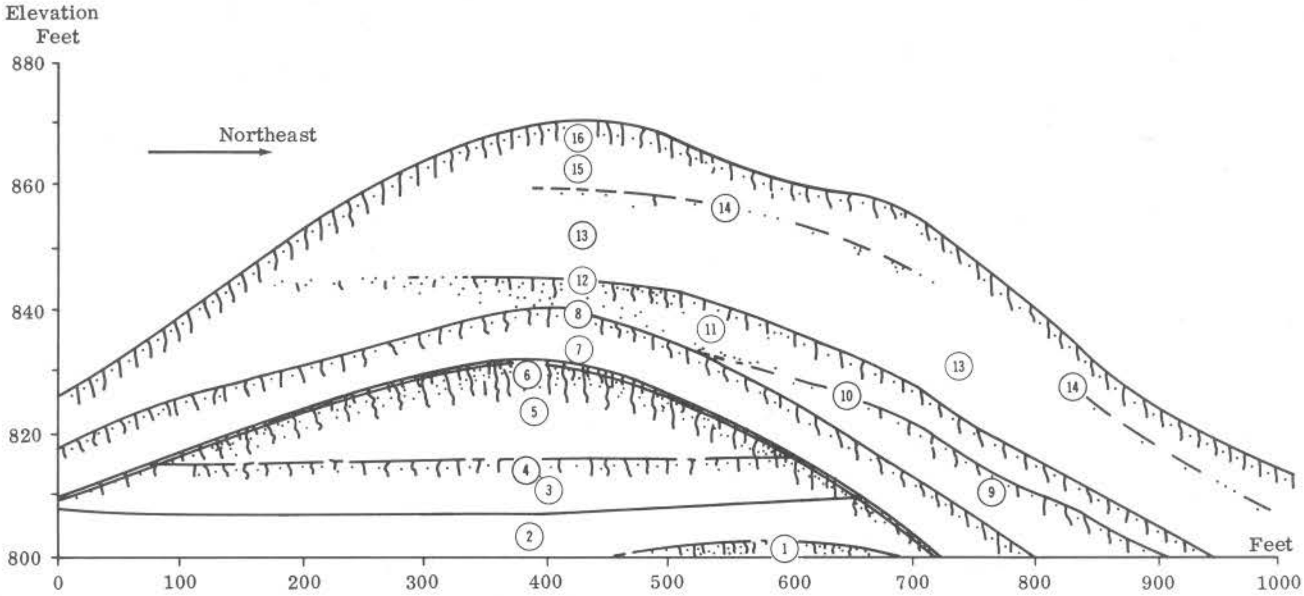
RANDOLPH SECTION

Glacial outwash and loess near Randolph, Missouri, at the intersection of highways I-435 and State 210, SE SW NE sec. 9, T 50 N, R 32 W.

DISCUSSION

Exposures of loess near Randolph are some of the most complete and extensive in the State of Missouri. Unfortunately, the loess is leached of most carbonates and the recognition of zones of partially weathered loess is difficult. A few calcium carbonate concretions are present, but fossil gastropods have not, as yet, been found. The most distinctive feature of the exposures is the large number of buried "soils" which can be seen. Most of the "soils" appear as dark bands in the outcrop. The dark color is, in part, caused by closely spaced shrinkage cracks which in turn are related to the clay content that is greater than adjacent, less weathered loess.

The Missouri State Highway Department has drilled several test holes in the vicinity of the road cuts at Randolph. Most holes encountered 10 to 25 feet of weathered till underlying the glacial(?) sands and gravels and resting directly on Pennsylvanian bedrock.



RANDOLPH SECTION

Tentative correlation of Pleistocene units

Units 15 and 16—Bignell Loess
Units 9, 10, 11, 12, 13, and 14—Peoria Loess. Unit 14 may be a poorly defined Brady Soil.
Units 7 and 8—Roxana? Formation
Units 5 and 6—Loveland Formation. Unit 6 is a well-developed Sangamon Soil.
Units 2, 3, and 4—Late Kansan sand and silt
Unit 1—Medial Kansan silt
Medial Kansan till—Sand and gravel not exposed, but penetrated in drill holes.

Description of Lithologic Units

Section measured by S. N. Davis, 1970

Unit number	*Description*	*Thickness, feet*
16	Silt, dark yellowish-brown at top to moderate yellowish-brown at bottom. Not calcareous. "A" and "B" horizons of modern soil.	2.5
15	Silt, pale yellowish-brown, not calcareous.	5
14	Silt, pale yellowish-brown, not calcareous. Slightly darker and contains more clay than units above or below.	1
13	Silt, pale yellowish-brown, not calcareous.	14
12	Silt, moderate yellowish-brown, not calcareous. More clay coatings on silt grains than found above or below this unit.	2.5
11	Silt, pale yellowish-brown, not calcareous.	2.5
10	Silt, moderate yellowish-brown, not calcareous. More clay coatings than in units above or below.	1.5 1.5
9	Silt, pale yellowish-brown, not calcareous.	25
8	Silt, moderate yellowish-brown, not calcareous, more clay than in units above or below.	3.5
7	Silt, pale yellowish-brown at top grading to pale brown (7.5 yr 5/4, dry) at bottom, not calcareous. Relic casts of former concretions.	14
6	Silt, clayey, moderate brown, not calcareous.	5
5	Silt, few sand grains, moderate yellowish-brown, not calcareous.	11
4	Sand, medium grain size, some silt and clay, moderate yellowish-orange, not calcareous.	2.5
3	Sand, fine grain size, considerable silt, scattered pebbles at base of this unit, not calcareous.	5
2	Silt, some fine sand, horizontal bedding few millimeters thick is prominent in central part of unit, yellowish-gray, calcareous concretions but matrix has little or no reaction to acid.	7
1	Silt, some clay, dark yellowish-orange mottled with some gray near base of exposure. Small manganese-rich concretions scattered in upper part.	5

The Missouri State Highway Department has drilled 10 test holes to bedrock in the interchange area of the highway. All except two of the holes penetrated from 10 to 25 feet of weathered to unleached till before entering bedrock. The hole nearest the measured section penetrated 20.8 feet of till starting about 20 feet below road level.

REFERENCES

BAYNE, C. K., 1968, Evidence of multiple stades in the lower Pleistocene of northeastern Kansas: Trans. Kansas Acad. Sci., v. 71, no. 3, p. 340-349.

———, and O'CONNOR, H. G., 1967, Two tills of Kansan age in northeastern Kansas *in* Geological Survey Research—Regional Geology: U.S. Geol. Survey, Prof. Paper 575, p. A77.

———, and ———, 1968, Quaternary System *in* The Stratigraphic Succession in Kansas, Zeller, D. E., Ed.: Kansas Geol. Survey Bull. 189, p. 59-67.

DAVIS, S. N., 1955, Pleistocene geology of Platte County, Missouri: Unpub. Ph.D. dissertation, Yale Univ., New Haven, Connecticut.

DORT, WAKEFIELD, JR., 1966, Nebraskan and Kansan stades; complexity and importance: *Science*, v. 154, no. 3750, p. 771-772.

DREESZEN, V. H., 1970, The stratigraphic framework of Pleistocene glacial and periglacial deposits in the Central Plains *in* Pleistocene and Recent Environments of the Central Great Plains: Univ. Kansas Dept. Geology Spec. Pub. 3, Univ. Press of Kansas, p. 9-22.

FRYE, J. C., and LEONARD, A. B., 1949, Pleistocene stratigraphic sequence in northeastern Kansas: Am. Jour. Sci., v. 247, p. 883-899.

———, and ———, 1952, Pleistocene geology of Kansas: Kansas Geol. Survey Bull. 99, 230 p.

———, and WILLMAN, H. B., 1960, Classification of the Wisconsinan Stage in the Lake Michigan Glacial Lobe: Illinois State Geol. Survey Circ. 285, 16 p.

———, ———, and GLASS, H. D., 1968, Correlation of Midwestern loesses with the glacial succession *in* Loess and Related Eolian Deposits of the World: Cong. Int. Assoc. for Quat. Research (INQUA), Proc. VII, v. 12, p. 3-21.

GLASS, H. D., FRYE, J. C., and WILLMAN, H. B., 1968, Clay mineral composition, a source indicator of Midwest loess *in* The Quaternary of Illinois: Ill. Univ. College of Agriculture Spec. Pub. 14, p. 35-40.

HEIM, G. E., and HOWE, W. B., 1963a, Pleistocene drainage and depositional history in northwestern Missouri: Trans. Kansas Acad. Sci., v. 66, no. 3, p. 378-392.

———, and ———, 1963b, Map of the bedrock topography of northwestern Missouri: Missouri Geol. Survey and Water Resources, one sheet.

HOWE, W. B., 1968, Guidebook to Pleistocene and Pennsylvanian formations in the St. Joseph area, Missouri: Association Missouri Geologists, 15th Annual Field Trip, 45 p.

———, and HEIM, G. E., 1968, The Ferrelview Formation (Pleistocene) of Missouri: Missouri Geol. Survey and Water Resources, Rept. Inv. 42, 32 p.

MARTIN, J. A., and WILLIAMS, J. H., 1966, Stratigraphic section *in* The Grundel Mastodon by Mehl, M. G.: Missouri Geol. Survey and Water Resources, Rept. Inv. 35, p. 26-28.

REED, E. C., and DREESZEN, V. H., 1965, Revision of the classification of the Pleistocene deposits of Nebraska: Nebraska Geol. Survey Bull. 23, 65 p.

RUHE, R. V., RUBIN, MEYER, and SCHOLTES, W. H., 1957, Late Pleistocene radiocarbon chronology in Iowa: Am. Jour. Sci., v. 255, p. 571-689.

WRIGHT, H. E., and RUHE, R. V., 1965, Glaciation of Minnesota and Iowa *in* Geology of the Quaternary of the United States—A review volume for the VII Congress of INQUA, Part I: Princeton Univ. Press, p. 29-41.

BURIED VALLEYS IN THE LOWER PART OF THE MISSOURI RIVER BASIN

By Vincent H. Dreeszen[1] and Raymond R. Burchett[2]

Continental ice sheets, streams, and wind combined forces during the Pleistocene to reshape the land surface in the lower part of the Missouri River Basin. Prior to glaciation a drainage system largely unrelated to the river system now draining the area had developed on the bedrock surface. Although parts of this surface were modified repeatedly during the Pleistocene, most of the buried valley system probably developed during the late Tertiary and early Pleistocene. Some segments of bedrock valleys may be much older; e.g., the valley now occupied by the Platte River in Nebraska from Ashland to its mouth at Plattsmouth is believed to have been trenched first by west-flowing drainage during the Cretaceous (Dakota). Glacial, alluvial, and eolian deposits now mantle much of the bedrock topography and fill many of the old valleys to depths ranging up to several hundred feet. The depositional sequence—particularly of Nebraskan and Kansan age—is discontinuous and often masked by loess and alluvial deposits of Illinoian and Wisconsinan age. Definition of the system of buried valleys is basic to correlation of deposits filling them and is basic also to an understanding of the age and sequence of events that produced trenching and gave rise to the systems of past and present major valleys.

The drainage history of the area, the pattern of occurrence and nature of the buried bedrock, and the stratigraphic succession of the Pleistocene deposits have been subjects of study and speculation for many years. Exploratory test drilling by public and private interests for water, limestone, oil and gas, sand and gravel, and engineering data have increased significantly the geologic- and economic-resource knowledge gained from a long history of surface study in the lower Missouri River Basin. The state geological surveys, individually and in cooperation with federal and other state agencies, have investigated much of the area with systematic test drilling. The results of most of these investigations have been published in interpretive reports that include bedrock topographic maps.

A bedrock topographic map of northwestern Missouri was prepared by Heim and Howe (1962) and a comprehensive review of the Pleistocene history of the area was presented by Heim and Howe (1963). The bedrock topography of southwestern Iowa was mapped and discussed by Hershey, Brown, Van Eck, and Northrup (1960), Sendlein, Henkel, and Hussey (1968) and Sendlein and Henkel (1970). Cagle and Steinhilber (1967) and Cagle (1969) mapped the bedrock surface in south-central Iowa. The Kansas Geological Survey has published a series of county and regional reports relating to the glacial geology and occurrence of buried valleys in northeastern Kansas. A map showing the bedrock topography in northern Kansas and southern and eastern Nebraska is presented in Reed, Dreeszen, Bayne, and Schultz (1965). Burchett and Dreeszen (*in* Burchett and Carlson, 1966) mapped the configuration of the bedrock surface in southeastern Nebraska and Burchett (1970) depicted the trend of bedrock valleys in that area and the adjacent parts of Iowa and Missouri.

Sufficient surface and subsurface data were available to permit these various workers to map the bedrock surface at 50-foot contour intervals. Alternative interpretations of buried valley trends can be made in some places where control is limited. For example, only limited systematic subsurface investigation has been done in the Missouri River valley.

The authors utilized published bedrock topographic maps to infer the probable preglacial drainage (Fig. 1, p. 24-25) in the lower Missouri River Basin where the four states of Iowa, Kansas, Missouri, and Nebraska adjoin. Also utilized was an unpublished bedrock topographic map of northeastern Kansas contributed by Charles K. Bayne and Howard G. O'Connor of the Kansas Geological Survey. Supplemental data for southern Iowa were provided by Orville Van Eck of the Iowa Geological Survey and Joseph Cagle of the U.S. Geological Survey at Iowa City. Wallace B. Howe of the Missouri Geological Survey and Stanley N. Davis of the University of Missouri at Columbia, together with Charles Bayne and Howard O'Connor of the Kansas Geological Survey, reviewed a first draft of the map and offered suggestions but had no opportunity to review the final map.

Heim and Howe (1963) applied the names of modern rivers to buried valleys in northwestern Missouri where they deemed it possible. For those valleys that were not indicated to be related to the modern drainage system, they selected place names. Their name—Grand River Valley, after the Grand River in Missouri—has been used in Iowa by Sendlein, Henkel, and Hussey (1968) for the extension of that buried valley into Iowa. The authors accept that name in this report if for no other reason than that the "Grand

[1] Director, Conservation and Survey Division, University of Nebraska, Lincoln, Nebraska.

[2] Research Geologist, Conservation and Survey Division, University of Nebraska, Lincoln, Nebraska.

River Valley" appears to be the "grand" valley of the system. The practice of applying the names of modern rivers to major buried valleys seems to be questionable because the relation of buried valleys to modern streams is generally only coincidental. Place names or other descriptive names for major buried valleys and for segments of buried valleys would seem preferable. The name Lower Kansas River Valley was applied by Heim and Howe (1963) to the buried valley from Kansas City east to the Grand River Valley. That name is also applied in this report to the segment approximately coincident with the Kansas River in Kansas.

Dominant features on the map are: the Grand River Valley and the Lower Kansas River Valley of Heim and Howe (1963); the present Big and Little Blue River valleys in Kansas; the several west-to-east major tributary valleys which cross the Missouri River valley and enter the Grand River Valley from the west; and several south-trending tributary valleys which enter the Grand River Valley from the north. Each of these "buried" valleys, with two possible exceptions, is believed to have developed prior to and during early Pleistocene time. The exceptions are the Big and Little Blue River valleys in the Kansas portion of the area, which may have developed as ice-marginal valleys in early Kansan time. The drainageway from below Atchison, Kansas, to Kansas City is probably an ancient major tributary to the Lower Kansas River Valley that now is occupied by the Missouri River.

At this time we can only speculate in regard to the northward extension of the Grand River Valley into Iowa and Nebraska. Sendlein *et al.* (1968) and Sendlein and Henkel (1970) mapped the buried valley extension of the Grand River Valley system approximately 110 miles north into Iowa from the Iowa-Missouri border. Although the evidence is not complete it appears that two major buried valleys join the Grand River Valley in south-central Mills County, Iowa, with one branch continuing on north into Iowa and the other branching to the northwest into Nebraska. Two other major tributaries that have been mapped into central Nebraska join this branch south of Omaha and near Plattsmouth, Nebraska. However, the main buried valley continues many miles northwestward into the Elkhorn River Basin, which is outside the map area. Possibly a major tributary or even the main valley of the Grand River system extends northward coincident with the Missouri River valley. Although bedrock control is inadequate to support this conjecture, one line of evidence—the broadening of the Missouri River valley a few miles north of Omaha, Nebraska, and Council Bluffs, Iowa—does support this possibility. The great width of the valley of the Missouri River in this area is due primarily to, but is not explained fully by, the less resistant nature of the bedrock (Cretaceous sandstone and shale and Pennsylvanian shale and thin limestones) than that in the area to the south. Todd (1898) suggested the relation of valley width to the character of the bedrock in an interesting discussion on the ages of the terraces and trough of the Missouri River.

The buried valleys shown in southeastern Nebraska have been traced westward more than halfway across the state and, presumably, are a part of the Rocky Mountain drainage system. For example, the most southerly of these buried valleys (at various times mistakenly referred to as the "Ancestral Republican River") extends upgradient into Kansas near Chester, Nebraska, and back into Nebraska near Superior. For 15 miles westward from Superior this "buried" valley is coincident with the present Republican River valley and then branches. One branch has been mapped to the northwest and the other is approximately coincident with the present Republican River valley.

Some major and tributary preglacial valleys retain, at least in part, their original valley fills of early to medial Pleistocene age, whereas other of these valleys were reopened, deepened, and subsequently refilled. Both the buried and the modern drainage systems are composite. Generally, modern valleys are wider where they cross buried drainageways. Several examples of this can be seen on soils and topographic maps along the Missouri River between Plattsmouth, Nebraska, and St. Joseph, Missouri. Also, where present rivers have occupied segments of partly filled "buried" valleys, the modern valley tends to be wider than might normally be expected. Examples of such rivers, referred to as "misfit" rivers, are the present Thompson River and the Gallatin-Chillicothe segment of the present Grand River (Heim and Howe, 1963) in northwestern Missouri. The major example of coincidence of modern streams and a major preglacial valley is the Kansas River from Manhattan, Kansas, to Kansas City and the Missouri River eastwardly from Kansas City. An interesting example of a major tributary "buried" valley that probably has been almost completely exhumed is the Nemaha River in extreme southeastern Nebraska. The authors speculate that this buried valley is the northwestward extension of the buried valley north of St. Joseph, Missouri—the Amazonia Valley of Heim and Howe (1963).

The direction of movement and extent of continental ice sheets were controlled in part by the slope and configuration of the land surface over which they rode. Definition of the surface overridden by each advancing ice sheet will be difficult to accomplish but should be attempted if we are to understand more fully the succession of deposits left by, or derived from, the glaciers. Possibly the surface least difficult to define will be the bedrock surface prior to glaciation.

Selected References

BURCHETT, R. R., 1965, Correlation of the formations drilled in test holes for Interstate 480 Bridge between Omaha, Nebraska and Council Bluffs, Iowa: Nebraska Geol. Survey Paper 17, 30 p.

———, (Compiler), 1969, Geologic bedrock map of Nebraska: Nebraska Geol. Survey: Scale 1:1,000,000.

———, 1970, Guidebook to the geology along the Missouri River bluffs of southeastern Nebraska and adjacent areas: Nebraska Geol. Survey Guidebook, 21 p.

———, and CARLSON, M. P., 1966, Twelve maps summarizing the geologic framework of southeastern Nebraska: Nebraska Geol. Survey, Rept. Inv. 1, 14 p.

———, and REED, E. C., 1967, Centennial guidebook to the geology of southeastern Nebraska: Nebraska Geol. Survey Guidebook, 83 p.

CAGLE, J. W., 1969, Availability of ground water in Wayne County, Iowa: Iowa Geol. Survey Water Atlas 3, 33 p.

———, and STEINHILBER, W. L., 1967, Availability of ground water in Decatur County, Iowa: Iowa Geol. Survey Water Atlas 2, 28 p.

FRYE, JOHN C., and WALTERS, K. L., 1950, Subsurface reconnaissance of glacial deposits in northeastern Kansas: Kansas Geol. Survey Bull. 86, pt. 6, p. 143-158.

HEIM, GEORGE E., and HOWE, WALLACE B., 1962, Map of the bedrock topography of northwestern Missouri: Missouri Geol. Survey and Water Resources: Scale 1:250,000.

———, and ———, 1963, Pleistocene drainage and depositional history in northwestern Missouri: Trans. Kansas Acad. Sci., v. 66, no. 3, p. 378-391.

HERSHEY, H. G., BROWN, C. N., VAN ECK, O., and NORTHRUP, R. C., 1960, Highway construction materials from the consolidated rocks of southwestern Iowa: Iowa Highway Research Board Bull. 15, 151 p.

HORBERG, LELAND, 1950, Bedrock topography of Illinois: Illinois Geol. Survey Bull. 73, 111 p.

IOWA GEOLOGICAL SURVEY, 1969, Geologic map of Iowa: Scale 1:500,000.

KANSAS GEOLOGICAL SURVEY, 1964, Geologic map of Kansas: M-1, scale 1:500,000.

MCCRACKEN, MARY H., (Compiler), 1961, Geologic map of Missouri: Missouri Geol. Survey and Water Resources: Scale 1:500,000.

REED, E. C., DREESZEN, V. H., BAYNE, C. K., and SCHULTZ, C. B., 1965, The Pleistocene in Nebraska and northern Kansas *in* The Quaternary of the United States, Wright, H. E., Jr., and Frey, D. G., Eds.: Princeton Univ. Press, p. 187-202.

SENDLEIN, LYLE V. A., and HENKEL, DONALD E., 1970, [abs.] Preglacial bedrock topography of southwestern Iowa: Geol. Soc. America, Abstracts with Programs, v. 2, no. 6, p. 405.

———, ———, and HUSSEY, KEITH M., 1968, Geology of the Regolith Aquifers of the Nishnabotna Basin: Dept. of Earth Science Completion Report Project No. A-012-IA, 29 p.

TODD, J. E., 1898, The moraines of southeastern South Dakota and their attendant deposits: U.S. Geol. Survey Bull. 158, 171 p.

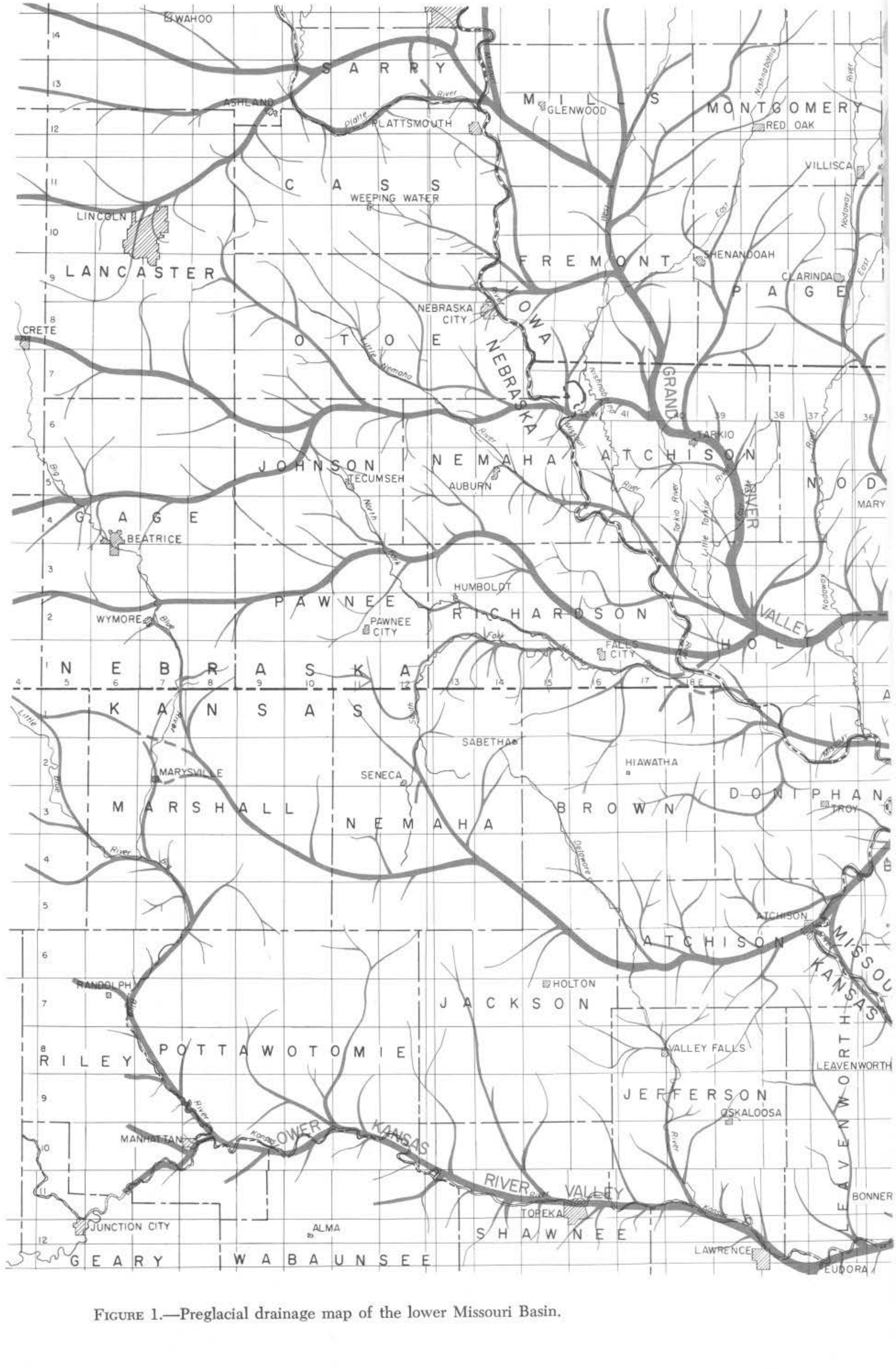
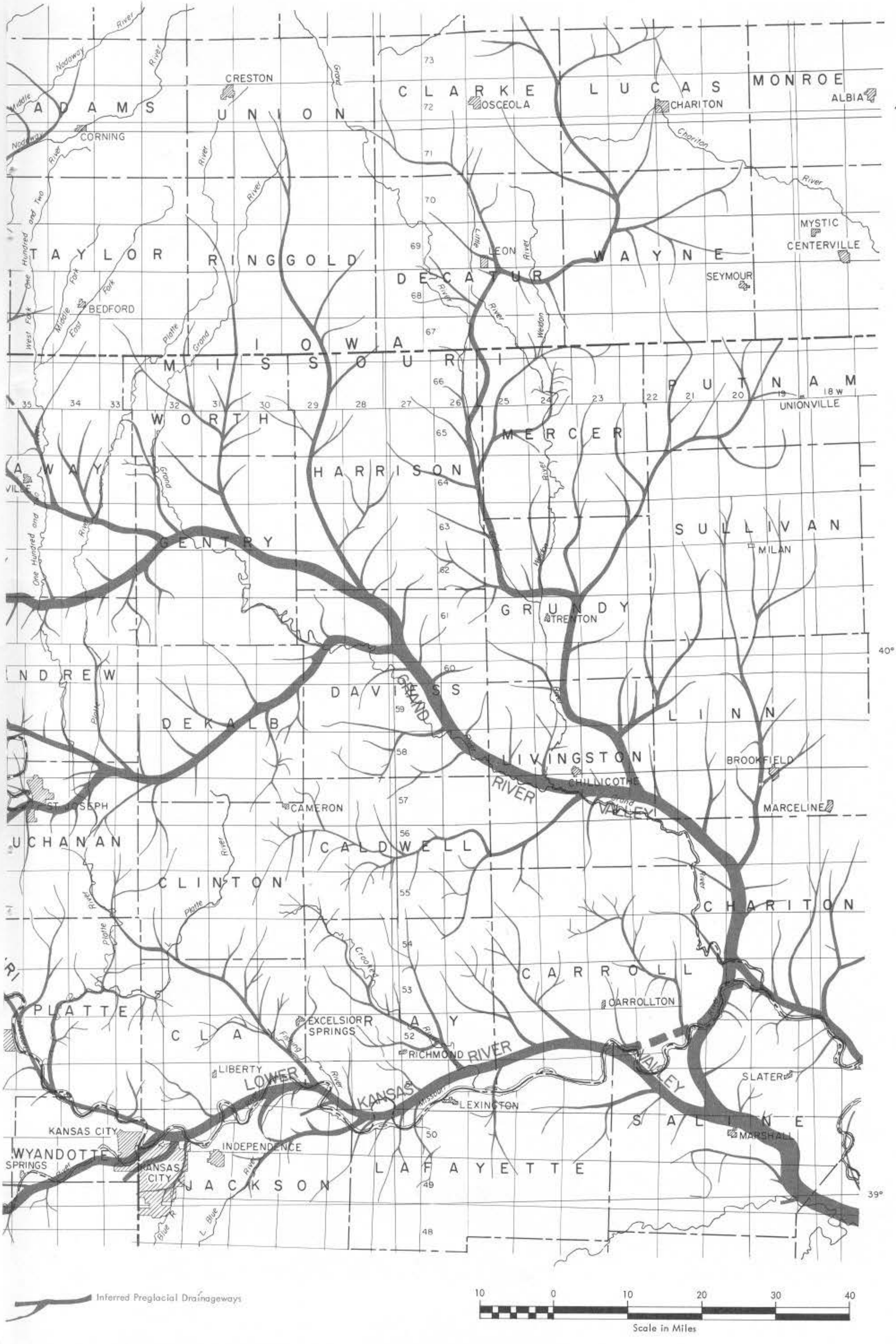


FIGURE 1.—Preglacial drainage map of the lower Missouri Basin.


ADAMS
UNION
CLARKE
LUCAS
MONROE
CRESTON
CORNING
OSCEOLA
CHARITON
ALBIA
TAYLOR
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BEDFORD
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WORTH
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PUTNAM
UNIONVILLE
GENTRY
SULLIVAN
MILAN
GRUNDY
TRENTON
DAVIESS
DEKALB
LINN
LIVINGSTON
CHILLICOTHE
BROOKFIELD
MARCELINE
GRAND RIVER VALLEY
ST. JOSEPH
CAMERON
CALDWELL
CLINTON
CHARITON
CARROLL
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PLATTE
CLAY
EXCELSIOR SPRINGS
RICHMOND
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MARSHALL
KANSAS CITY
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Inferred Preglacial Drainageways
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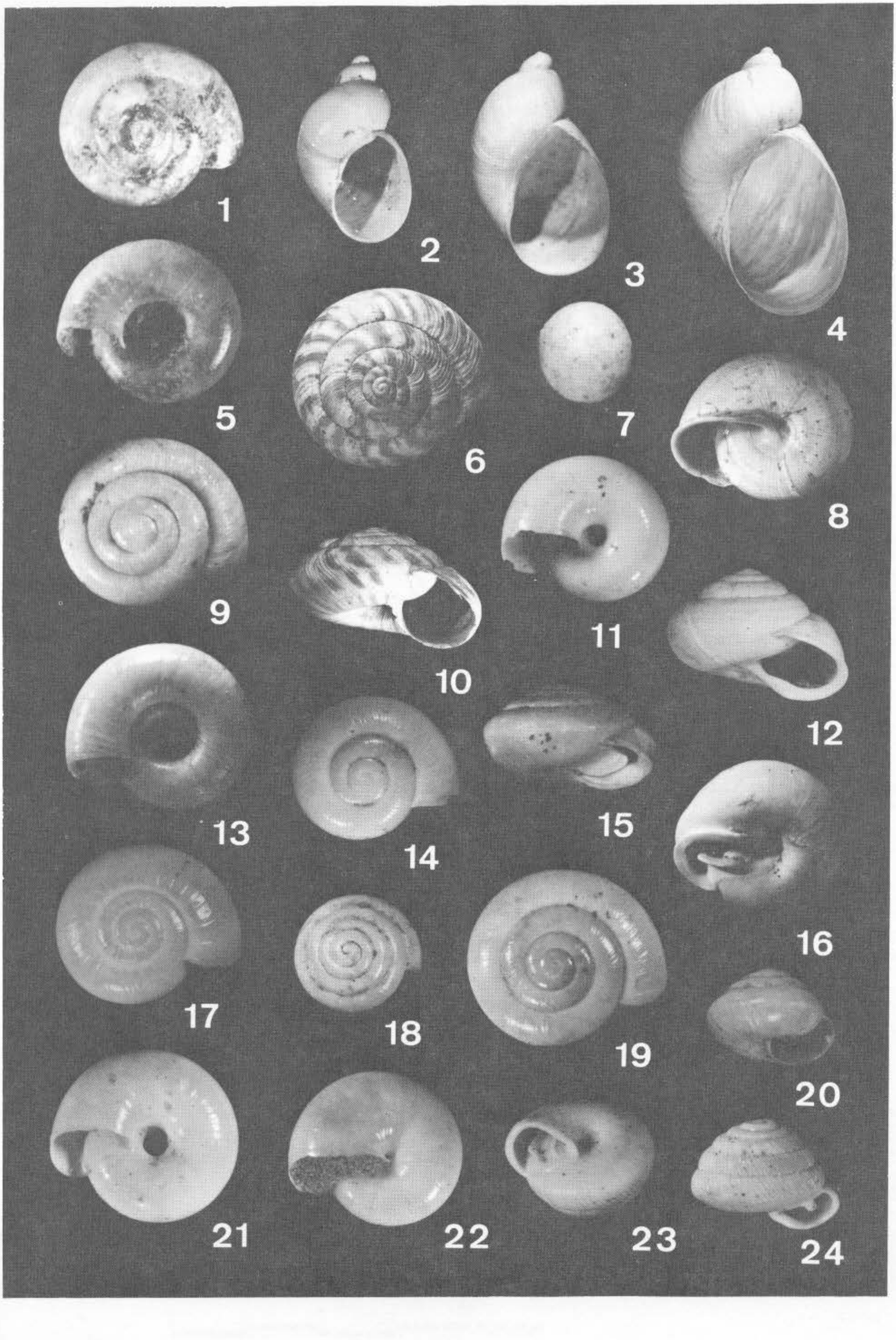
Scale in Miles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PALEONTOLOGICAL CONSIDERATIONS OF THE LOESS DEPOSITS OF WESTERN MISSOURI

By Robert J. Pauken[1]

Many of the Missouri loess deposits occurring in proximity to the Missouri River floodplain contain abundant and diverse Pleistocene pulmonate gastropod faunas (Plates 1 and 2). The most abundant and well-preserved faunas occur in deposits of calcareous loess developed on the eastern banks in areas where the river flows primarily north-south. In areas where the river flows east-west the loess is typically thin and unfossiliferous.

Faunas were collected by channel-sampling through the entire thickness of each outcrop. This consisted of taking 1 cubic foot of material from each 2-foot interval. These samples typically yielded over 1,000 specimens each.

A bioassociational analysis (Valentine and Mallory, 1965) was performed to determine whether or not faunal groupings could be derived which would be useful for environmental and/or stratigraphic interpretations. This analysis produced two major faunal associations that are primarily related to regional climatic trends and do not appear to be restricted to any specific stratigraphic horizons. It has been proposed that climatic changes associated with the various stages of loess deposition resulted in regional alteration of the species content of the gastropod populations living during those times such that they could be used for biostratigraphic correlation of the loess (Leonard and Frye, 1960). This was not found to be the case in Missouri. Although certain gastropod species tend to occur in greater abundance in either the Bignell or Peoria loess, their occurrence in one of these deposits does not exclude them from occurring in the other.

[1] Mobil Research Laboratory, Dallas, Texas.

One of the faunal associations mentioned above is typical of an uplands forest environment such as exists today in many parts of Missouri and the other is representative of a prairie, prairie-forest border situation as in eastern Kansas and parts of western Missouri. The most common faunal elements of these two fossil associations are as follows:

Prairie-Forest Ecotone	Deciduous Forest
Anguispira alternata	*Carychium exile canadense*
Cionella lubrica	*Discus cronkhitei*
Gastrocopta armifera	*D. shimeki*
G. contracta	*Euconulus fulvus*
G. holzingeri	*Hendersonia occulta*
G. pentodon	*Nesovitrea electrina*
G. procera	*Punctum minutissimum*
Haplotrema concavum	*Strobilops labyrinthica*
Hawaiia minuscula	*Succinea gelida*
Helicodiscus parallelus	*S. grosvenori*
H. singleyanus	*S. ovalis*
Pupoides albilabris	*Triodopsis multilineata*
Stenotrema hirsutum	*Vertigo gouldi hubrichti*
S. leai	*V. modesta*
Vallonia parvula	

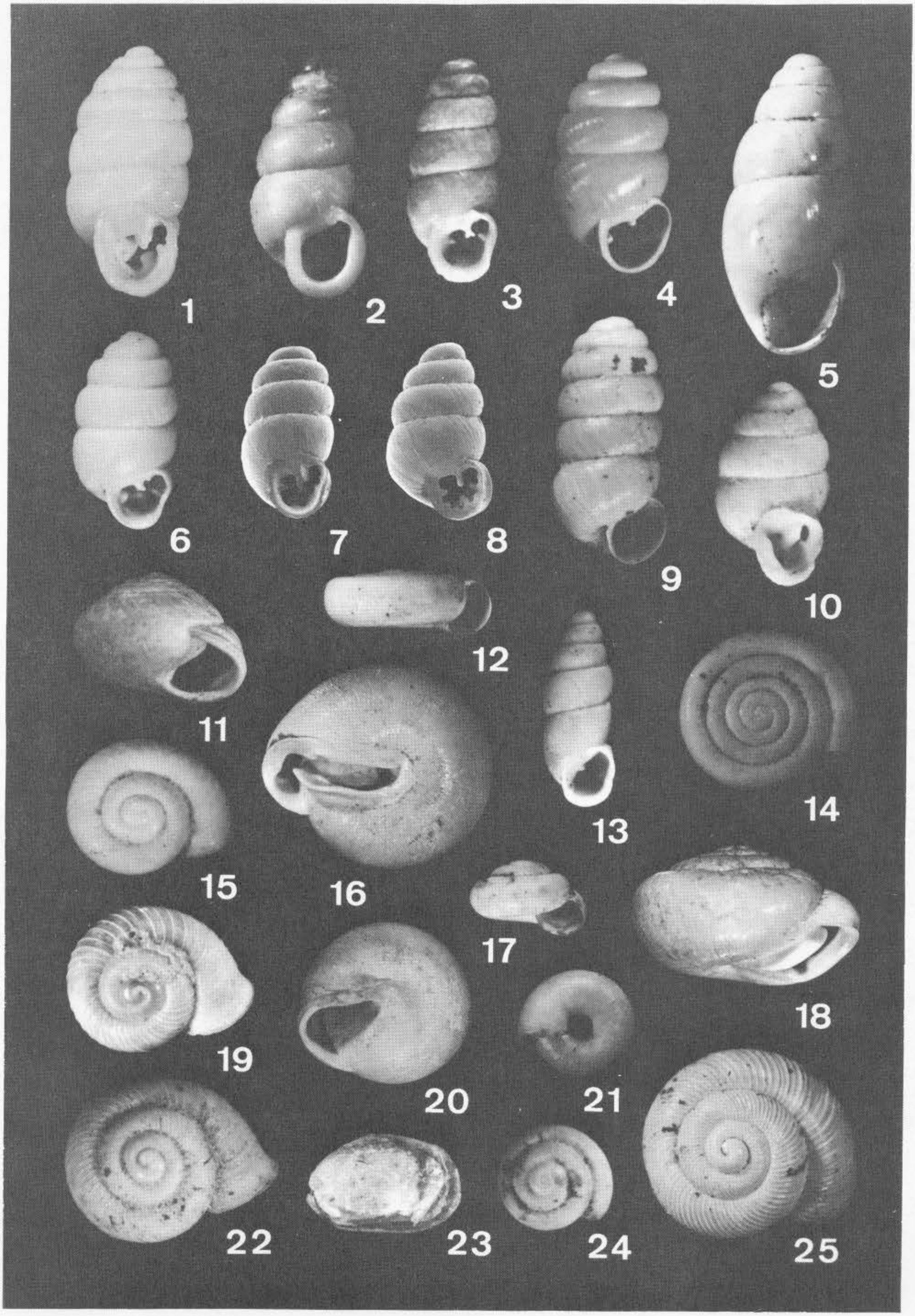
The uplands forest fauna commonly occurs in samples collected throughout Missouri and from all the stratigraphic intervals. The prairie, prairie-forest border fauna occurs more often in samples collected from the western part of the state and in samples collected from the younger loesses, e.g., Bignell. These relationships were further substantiated by calculating the species diversity (Beerbower and Jordan, 1969) and a habitat-moisture index for all the samples.

The habitat-moisture index calculated from the species content of each sample and based on the habitat preferences of living representatives of the species indicates increasing aridity in a westerly direction across Missouri during latest Wisconsinan.

EXPLANATION OF PLATE 1

Common Pleistocene pulmonate gastropods occurring in the loess deposits of western Missouri.

Figure	
1, 5.	*Helicodiscus singleyanus* (Pilsbry). 1, Apical view; 5, Umbilical view. ×18
2.	*Succinea gelida* (Baker). 2, Apertural view. ×5
3.	*Succinea grosvenori* Lea. 3, Apertural view. ×4
4.	*Succinea ovalis* Say. 4, Apertural view. ×3
6, 10.	*Anguispira alternata* (Say). 6, Apical view; 10, Apertural view. ×1.8
7.	Snail egg. 7. ×15
8, 12.	*Triodopsis multilineata* (Say). 8, Umbilical view; 12, Apertural view. ×1.8
9, 13.	*Hawaiia minuscula* (Binney). 9, Apical view; 13, Umbilical view. ×18
11, 14.	*Nesovitrea electrina* (Gould). 11, Umbilical view; 14, Apical view. ×11
15, 16.	*Stenotrema leai* (Binney). 15, Apertural view; 16, Umbilical view. ×5
17, 22.	*Nesovitrea indentata* (Say). 17, Apical view; 22, Umbilical view. ×11
18, 20.	*Euconulus fulvus* (Müller). 18, Apical view; 20, Apertural view. ×11
19, 21.	*Zonitoides arboreus* (Say). 19, Apical view; 21, Umbilical view. ×11
23, 24.	*Strobilops labyrinthica* (Say). 23, Umbilical view; 24, Apertural view. ×11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This trend existed during Woodfordian time, increased in intensity during the Valderan, and reached its peak during the altithermal period when many of the extensive deciduous forests which developed earlier in the Wisconsinan when the climate was cooler and more moist than today gave way to grasslands and prairies which have since remained as relicts due to the decline in temperature and increase in available moisture since that time. Many of the samples, especially those of Peoria loess, contain gastropod species which have modern representatives that are restricted to more northern latitudes today, e.g., *Carychium exile, Discus cronkhitei,* and *Vallonia gracilicosta,* indicating that at least during Woodfordian time the climate in Missouri was somewhat cooler than today. Also, in samples of Peoria and Bignell loess the species diversity increases toward the west and is a reflection of the increased occurrence of the grasslands fauna coexisting with the uplands forest fauna in this direction. In addition, the grasslands assemblage composes a larger proportion of the fauna in samples of Bignell than of Peoria loess (Pauken, 1969).

In consideration of the above discussion, I propose that from late Pleistocene to present, an upland forest-prairie ecotone has existed in Missouri and has shifted east and west in response to changing climate. The record of these changes has been preserved in detail by the gastropod faunas trapped in loess deposits formed during this interval.

References

BEERBOWER, J. R., and JORDAN, D., 1969, Application of information theory to paleontologic problems: Taxonomic diversity: Jour. Paleontology, v. 43, no. 5, p. 1184-1198.

LEONARD, A. B., and FRYE, J. C., 1960, Wisconsin molluscan faunas of the Illinois Valley region: Illinois State Geol. Survey Circ. 304, 32 p.

PAUKEN, R. J., 1969, A population study of the Pleistocene molluscan faunas in the loess of the Missouri River basin in Missouri: Unpub. Ph.D. dissertation, Univ. Missouri at Columbia, 192 p.

VALENTINE, J. W., and MALLORY, R., 1965, Recurrent groups of bonded species in mixed death assemblages: Jour. Geol., v. 73, no. 5, p. 683-701.

EXPLANATION OF PLATE 2

Common Pleistocene pulmonate gastropods occurring in the loess deposits of western Missouri.

Figure	
1.	*Gastrocopta armifera* (Say). 1, Apertural view. ×11
2.	*Pupoides albilabris* Adams. 2, Apertural view. ×11
3.	*Gastrocopta procera* (Gould). 3, Apertural view. ×11
4.	*Vertigo modesta* (Say). 4, Apertural view. ×18
5.	*Cionella lubrica* (Müller). 5, Apertural view. ×11
6.	*Vertigo gouldi hubrichti* Pilsbry. 6, Apertural view. ×18
7.	*Gastrocopta holzingeri* (Sterki). 7, Apertural view. ×23 Scanning electron micrograph
8.	*Gastrocopta pentodon* (Say). 8, Apertural view. ×23 Scanning electron micrograph
9.	*Columella alticola* (Ingersoll). 9, Apertural view. ×18
10.	*Gastrocopta contracta* (Say). 10, Apertural view. ×18

Figure	
11, 20.	*Hendersonia occulta* (Say). 11, Apertural view; 20, Umbilical view. ×5
12, 14.	*Helicodiscus parallelus* (Say). 12, Apertural view; 14, Apical view. ×11
13.	*Carychium exile canadense* Clapp. 13, Apertural view. ×18
15.	*Vallonia perspectiva* Sterki. 15, Apical view. ×16
16, 18.	*Stenotrema hirsutum* (Say). 16, Umbilical view; 18, Apertural view. ×5
17, 21, 24.	*Punctum minutissimum* (Lea). 17, Apertural view; 21, Umbilical view; 24, Apical view. ×16
19.	*Vallonia parvula* Sterki. 19, Apical view. ×16
22.	*Vallonia gracilicosta* Reinhardt. 22, Apical view. ×16
23.	*Deroceras laeve* (Müller). 23, Apical view. ×11

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SARPY
PLATTSMOUTH
CASS
WEEPING WATER
MILLS
GLENWOOD
MONTGOMERY
RED OAK
VILLISCA
ADAMS
CORNING
CRESTON
UNION
FREMONT
SHENANDOAH
CLARINDA
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RINGGOLD
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OTOE
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NEBRASKA
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ATCHISON
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JOHNSON
TECUMSEH
NODAWAY
MARYVILLE
HARR
GENTRY
PAWNEE
PAWNEE CITY
HUMBOLDT
RICHARDSON
FALLS CITY
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HIAWATHA
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KANSAS CITY
WYANDOTTE
BONNER SPRINGS
KANSAS CITY
INDEPENDENCE
JACKSON
TOPEKA
ALMA
SHAWNEE
LAWRENCE
EUDORA
ABAUNSEE
Missouri River
Platte River
Nishnabotna
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Kansas River
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