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Part II: *Zoology and Wildlife Management*

Part III: *Geography and Geology*

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(*1955 Meeting*)

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GEOLOGY

VERTEBRATE FOSSILS FROM THE MEADE FORMATION OF SOUTHWESTERN KANSAS

CLAUDE W. HIBBARD

University of Michigan

THE remains of fossil mammals collected from the Meade formation in Meade County, Kansas, and the adjoining region form the basis of this report, which includes the recording of two new local faunas. These faunas contribute to an understanding of the Pliocene-Pleistocene boundary in the nonglaciated part of the Plains region and the succession of Pleistocene faunas in North America (Fig. 1).

The fossils are in the collections of the University of Kansas and the University of Michigan. The names of these institutions and of others referred to in this report are abbreviated as follows: KUMVP (Kansas University Museum of Vertebrate Paleontology); UMMP (University of Michigan Museum of Paleontology); UMMZ (University of Michigan Museum of Zoology); USNM (United States National Museum). When catalogue numbers are given without identification, they are those of the University of Michigan Museum of Paleontology.

The field party of the University of Michigan Museum of Paleontology consisted in the summer of 1953 of William G. Melton, Jr., Michael O. Woodburne, H. George Golden, Eugene O. Bowser, Faye Hibbard, and myself. The members of the 1954 party were Arthur J. Jelinek, Logan Mahaffey, Eugene O. Bowser, John W. Duane, Michael O. Woodburne, Thomas M. Oelrich, Faye Hibbard, and myself.

THE MEADE FORMATION

History of the term "Meade formation."—Cragin (1896) described the Meade gravels as a formation and noted their occurrence in both Clark and Meade counties (see Hibbard, 1949a), but this formation and the younger deposits noted by Cragin were forgotten for nearly forty years. The drought and the dust bowl of the thirties brought the area once again to the attention of geologists. Their chief concern was with ground water, which required the study of the stratigraphy of the region. Dust storms due to the drought had blown acres of land bare, and much of the vegetation had died, so that any rain sufficient to cause runoff exposed new areas of fossil-bearing beds.

Accounts of the geological and paleontological reconnaissance in this region can be found in papers by Hibbard (1938, 1940, 1941a, 1941b, and 1944), H. T. U. Smith (1940), Frye (1942), and Frye and Hibbard (1941).

STRATIGRAPHIC SUCCESSION OF PLEISTOCENE FAUNAS IN MEADE COUNTY, KANSAS

DIAGRAMMATIC SECTION	ROCK UNITS	TIME UNITS (Tentative correlation based on four major glaciations)	LOCAL FAUNA NAME	REFERENCE
VANHEM Fm.	VANHEM FORMATION	WISCONSIN 4th glacial	JONES RANCH (cool, moist)	Downs, 1949, 1954 Goodrich, 1940 Hibbard, 1940, 1949b Leonard, 1948 Tihen, 1942
KINGSDOWN Fm.	KINGSDOWN FORMATION	SANGAMON 3rd interglacial	CRAGIN QUARRY JINGLEBOB (warm, moist)	Hibbard, 1939, 1949a van der Schalie, 1953 Oelrich, 1953; Rinker, 1949; Tihen, 1954
		ILLINOIAN 3rd glacial	UNNAMED (cool, moist)	Taylor, 1943
CROOKED CREEK Fm.		YARMOUTH 2nd interglacial	Buried caliche BORCHERS (warm, semiarid)	Hibbard, 1941a, 1942, 1954
	PEARLETTE ASH MEM.	KANSAN 2nd glacial	CUDAHY (Yarmouthian molluscan) (cool, moist)	Hibbard, 1944, 1949a Frye, *et al.*, 1948 Leonard, 1950 Frye and Leonard, 1952
	STUMP ARROYO MEMBER		SEGER GRAVEL PIT probably pre-Kansan	Hibbard, 1951b
MEADE Fm.	MISSLER MEMBER	AFTONIAN 1st interglacial	SANDERS (warm, moist) This report Buried caliche zone DEER PARK (warm)	Hibbard, 1949a, 1949b
		NEBRASKAN 1st glacial	DIXON (cool, moist)	This report Frye and Leonard, 1952
	MEADE GRAVELS MEMBER		UNNAMED probably pre-Nebraskan	Hibbard, 1949a

FIG. 1

The term "Meade formation" has been used in various ways and for various formations in the area for the past fourteen years (see Hibbard, 1949a, 1950, 1955, for correlation charts).

Members of the State Geological Survey of Kansas and I (Frye and Hibbard, 1941) agree that the type section of the Rexroad formation is directly overlain by the Meade formation. Only at this locality is our use of the term "Meade formation" synonymous.

Frye (1945, p. 77) says: "Stratigraphically, the Rexroad beds are believed to rest conformably upon beds generally considered to be of Middle Pliocene age, and they are separated from the overlying Meade formation by a distinct unconformity. This unconformity can be seen at the type locality of the Rexroad and along canyons for ten miles north of that locality; but at the type locality of the Meade formation, although the Rexroad beds are believed to be absent, the unconformity at the base of the Meade formation is less clearly recognizable in the field."

The unconformity recognized by Frye (1945) approximately ten miles north of the type locality of the Rexroad formation is the unconformity between the Crooked Creek and Meade formations (Hibbard, 1949a) and not that between the Meade and Rexroad formations as exposed at the type locality of the Rexroad. Another distinct unconformity at the same location approximately ten miles north of the type locality of the Rexroad formation is, however, equivalent to the unconformity exposed at the type locality of the Rexroad. These stratigraphic relationships were demonstrated and discussed during a field conference in 1947 (Hibbard, 1950, p. 117). Frye and Leonard (1952, pp. 84-85) still regarded the deposits of the Meade formation at the locality ten miles north of the type locality of the Rexroad as the Rexroad ("Blanco") formation. However, they (1952, pp. 65, 103) considered the Rexroad formation at its type locality as redescribed by Frye and Hibbard (1941) to be their "Blanco formation." They also affirm that their Meade formation occurs unconformably on the Blanco (Rexroad) formation at many localities in western Kansas. I know of no place in western Kansas where the Meade formation of Frye and Leonard (1952), based on sediments in their restricted type locality (the Crooked Creek formation of Hibbard), occurs unconformable on the Rexroad ("Blanco") formation. It must be kept clearly in mind that "Blanco formation" as used by Frye and Leonard (1952) in Kansas outside of the type area of the Rexroad formation applies to younger sediments that stratigraphically underlie their Meade formation, as based on its restricted type locality by Frye, Swineford, and Leonard (1948).

Frye, Swineford, and Leonard (1948, p. 521) restricted the Meade formation to sediments exposed in NW. ¼ Sec. 21 T. 33 S., R. 28 W., in Meade County, that contain the Pearlette ash (Crooked Creek formation, Hibbard, 1949a). Yet in their figure 3 (p. 520) they show the Meade formation resting on the Rexroad formation at its type section.

It is therefore evident that they consider the Pleistocene consolidated sand and gravel directly overlying the Rexroad formation at its type locality to be equivalent in age to the Pleistocene sand and gravel in the restricted type area of their Meade formation. It is not the same sand and gravel. The Pleistocene sand and gravel in the restricted type area of the Meade formation of Frye, Swineford, and Leonard is the base of the Crooked Creek formation that overlies unconformably the true Meade formation. How can the type section of a formation consist of distinctive and younger sediments, which contain younger faunas, than the formation to which the name applies?

Moore (1949, p. 1279, fig. 1) considered the Meade formation to rest on the Rexroad formation. His Meade formation was not a single formation but two early Pleistocene formations, the Meade and the later Crooked Creek formation, both of which contain distinctive faunas and sediments. The failure of Moore to recognize two distinct Pleistocene formations in what he was calling the Meade formation allowed him to place the Upper Pliocene Rexroad formation in the lower Pleistocene. The term "Meade formation" as used by the Kansas Geological Survey embraces two distinct cycles of sedimentation and their faunas.

Frye and Leonard (1952, p. 151, fig. 6) listed a number of fossil mollusk faunas as occurring in Nebraskan deposits in southwestern Kansas. The fauna from the SW. ¼ Sec. 36, T. 34 S., R. 31 W., Seward County, Kansas, is part of the Saw Rock Canyon fauna (Hibbard, 1953b), which is considered by me to be lower Upper Pliocene in age and which could be called upper Middle Pliocene in age (see footnote by R. C. Moore in McLaughlin, 1946, p. 33). The SW. ¼ Sec. 35, T. 34 S., R. 30 W., Meade County, is the Fox Canyon locality of the Upper Pliocene Rexroad fauna. The SW. ¼ Sec. 22, T. 33 S., R. 29 W., is the Rexroad fauna locality No. 3, and the NW. ¼ Sec. 19, T. 32 S., R. 28 W., is the Big Springs Ranch locality of the Rexroad fauna.

Only one other Nebraskan local fauna listed by Frye and Leonard (1952) is pertinent in the discussion of the Meade formation; that is the local fauna (here named the Dixon local fauna) from the SW. ¼ Sec. 12, T. 29 S., R. 8 W., Kingman County, Kansas. This fauna occurs in deposits equivalent to the Meade formation that overlies the Rexroad ("Blanco") formation and is overlain unconformably by sand and gravel of the Crooked Creek formation (Grand Island member, *fide* Frye and Leonard, 1952, p. 63, pl. 3B).

I agree with Frye and Leonard (1952) that this fauna can be considered Nebraskan in age. Dwight W. Taylor, after examination of the mollusks in the fauna, and I, after a study of the associated mammals, regard it as latest Nebraskan. J. A. Tihen (1955), who has studied the amphibians of the Pliocene and Pleistocene of Kansas, believes the fauna to be interglacial, on the basis of the salamander remains. Taylor, Tihen, and I agree as to the characters of the faunal assemblage but disagree on where a glacial fauna ends and an interglacial fauna begins, since this fauna is a transitional fauna.

Frye and Leonard did not make a thorough collection of the molluscan fauna at this locality. A snail, *Gyraulus pattersoni* Baker, occurs in the fauna. This snail has been considered an "index fossil" by Frye, Swineford, and Leonard (1948) and Leonard (1950) for faunas of Yarmouth age, and by Frye and Leonard (1952) for faunas of Kansan age. It was on the basis of this snail that Frye, Swineford, and Leonard (1948), Leonard (1950), and Frye and Leonard (1952) correlated the local Sand Draw fauna (late Nebraskan) from Nebraska with the younger, well-known Cudahy fauna of late Kansan age.

Definition and occurrence.—The Meade formation consists of the earliest known Pleistocene sediments in this region. It contains stream-laid sand and gravel of Rocky Mountain origin at the base, and this grades upward into sandy silt, silt, clay, buried *caliche*, clay to

silt, and sandy silt. The base of the Meade formation rests unconformably on the Rexroad formation at the type locality of the Rexroad and at the type locality of the Meade proposed by Hibbard (1949a). To the west, the northwest, and the north of the type locality of the Rexroad, the Meade formation is overlain unconformably by the Crooked Creek formation.

The Meade formation is widespread in southwestern Meade County, west of Crooked Creek, and in southeastern Seward County, as well as in northern Beaver County north of Mocane, Oklahoma, where it is exposed along the breaks in the south valley wall of the Cimarron River. Sediments equivalent in age occur eastward in Kansas, for example, those at the locality in Kingman County from which the Dixon local fauna was recovered and the sediments named the Chase Channel formation by Fent (1950, p. 64).

Spring Creek section.—The following geological section was started approximately in the center of the N. ½ Sec. 18, T. 32 S., R. 28 W., Big Springs Ranch, Meade County (in the area of the proposed type locality of the Meade formation, Hibbard, 1949a), in the bed of a tributary of Spring Creek, and was measured south and westward along the valley slope.

	Thickness in feet
Topsoil	
Crooked Creek formation	
12. Sandy silt (covered)	
Stump Arroyo ("Grand Island") member	
11. Sand and gravel	19.0
Unconformity	
Meade formation	
Missler member	
10. Clay, reddish to light brown, with mollusks and vertebrates in lower part (Sanders fauna)	1.5
9. Sandy silt, gray, with fossils in top foot (Sanders fauna, Locality UM–K1–53)	4.0
8. Sandy silt, tan to gray, with calcium carbonate concretions. Locally cemented at top to form "mortar bed" (*caliche* zone, when present, is at top of this bed)	11.0
Meade gravels member	
7. Sand and gravel, cemented. Partly covered	8.25
Unconformity	
Rexroad formation	
6. *Caliche*	1.0
5. Very fine sand and sandy silt, yellowish streaked with gray	8.5
4. Fine sand, locally cemented	1.0
3. Sandy silt, gray, with shells and bone, Rexroad fauna	2.5
2. Sandy silt, reddish, with some bone	3.0
1. Sandy silt, reddish gray, with a few nodules of *caliche;* concentration of *caliche* stringers and nodules 6½ feet from bottom of exposure. Base not exposed	7.25

About one-fourth mile to the west, in the next valley, is a more complete section of the Crooked Creek formation that is continuous with the measured section. Near the top of the section is the Pearlette ash, and the Cudahy fauna is present below the ash. This is one of the few continuous geological sections exposed in this region that contains the Rexroad and the Sanders invertebrate and vertebrate faunas, the associated Pearlette ash, and the Cudahy invertebrate and vertebrate fauna.

Section at Sanders-Fauna Locality UM-K2-53.—The section below begins in the bed of the draw on the consolidated Meade gravels member, near the center of Sec. 23, T. 32 S., R. 29 W., Big Springs Ranch, Meade County, Kansas.

	Thickness in feet
Topsoil	
Crooked Creek formation	
Stump Arroyo ("Grand Island") member	
8. Sand and gravel (slump and slope wash)	
Unconformity	
Meade formation	
Missler member	
7. Fine, sandy, micaceous silt, yellowish to light tan, grading upward into gray sandy silt and local lenses of brown clay, with *caliche* nodules	12.5
6. Clay, reddish gray to reddish brown, with shells; a few calcium carbonate nodules at base	1.0
5. Sandy clay, pinkish gray to blue-gray, with shells at top (Sanders fauna, Locality UM–K2–53)	3.5
4. Sandy silt, pinkish tan, with *caliche* nodules	5.5
3. *Caliche*, massive	0.75
2. Sandy silt, pinkish tan, with *caliche* nodules; grading upward into a light-reddish buff to gray, mottled with nodules of *caliche*	17.0
Meade gravels member	
1. Sand and gravel, consolidated at base; covered interval grading upward into fine unconsolidated sand (base of formation not exposed)	13.0

THE LOCAL FAUNAS OF THE MEADE FORMATION

Vertebrate fossil remains are scattered throughout the formation, except in the *caliche* zone (Pl. I, Fig. 1). Concentrations occur at three horizons, and these fossil assemblages have been given local faunal names—Dixon, Deer Park, and Sanders. Two of them, the Dixon and the Sanders, are here reported for the first time; they consist of associated mollusks and vertebrates. Only a few vertebrates have been taken from the Meade gravels member; these are listed with the other local faunas but are not assigned a local faunal name. The following list indicates the occurrence of the mammals in the Meade formation.

Mammal	*Meade gravels member*	*Dixon*	*Deer Park*	*Sanders*
INSECTIVORA				
Sorex sp.	..	×	..	..
Sorex leahyi, sp. nov.	..	×	..	..
Sorex dixonensis, sp. nov.	..	×	..	..
Sorex sandersi, sp. nov.	..	..	..	×
Blarina sp.	..	×	..	..
CARNIVORA				
Mustelid sp.	..	×	×	..
Mustela sp.	..	..	..	×
Taxidea cf. taxus (Schreber)	..	..	×	..
Canis sp.	..	..	×	..
RODENTIA				
Cynomys meadensis, sp. nov.	..	..	×	..
Citellus sp.	..	×	×	..
Procastoroides ?	..	×	..	..
Procastoroides sweeti Barbour and Schultz	..	..	×	..
Perognathus cf. pearlettensis Hibbard	..	..	..	×
Prodipodomys sp.	..	..	..	×
Geomys quinni McGrew	..	..	×	..
Geomys (Parageomys) tobinensis Hibbard	..	..	..	×
Geomys sp.	..	×	..	..
Bensonomys meadensis, sp. nov.	..	..	..	×
Peromyscus sp.	..	×	..	..
Sigmodon cf. intermedius Hibbard	..	..	..	×
Ogmodontomys or Mimomys (Cosomys) sp.	..	..	×	..
Pliophenacomys meadensis, sp. nov.	..	×	..	×
Pliopotamys meadensis Hibbard	..	×	×	..
Pliolemmus antiquus Hibbard	..	×	×	×
Synaptomys (Synaptomys) rinkeri, sp. nov.	..	×	..	..
Zapus sandersi, sp. nov.	..	..	..	×
PROBOSCIDEA				
Stegomastodon sp.	×	..	×	..
Rhynchotherium sp.	..	..	×	..
LAGOMORPHA				
Hypolagus sp.	..	..	×	..
ARTIODACTYLA				
Platygonus sp.	..	..	×	..
Camel sp.	×	..	×	×
PERISSODACTYLA				
Equus (Plesippus) simplicidens Cope	×	..	×	×
Equus (Asinus ?) sp.	×	..	..	..
Nannippus phlegon (Hay)	×	..	×	×

AGE AND CORRELATION OF FAUNAS

The Meade formation is Pleistocene. I use the term "Pleistocene" as synonymous with "Ice Age." This usage allows recognition of Pleistocene floras and faunas in North America south of the glaciated region on the basis of evidence of a climatic change in the area under study.

Only tentative correlation exists at the present time in North America between the glacial deposits and the nonglacial deposits outside the glaciated region, especially in southwestern Kansas. The assumption that only four major continental glaciations and three major interglacial intervals existed during the Pleistocene in North America is the basis on which the tentative correlation of deposits in southwestern Kansas has been made. Four distinct post-Rexroad formations occur there. Our studies over the past nineteen years show that each of the three oldest of these formations contains two distinctive faunas. The lower, or older, fauna in each formation exhibits forms that indicate that the fauna lived in that region during a much cooler and more moist climate than now exists there. Fossils of the younger faunas show that the faunas lived under milder conditions than did the faunas that preceded them. The fossils of the fourth, or youngest, formation indicate that at the time the fauna lived it was cooler and more moist in that region than at present (see Fig. 1).

The Upper Pliocene Rexroad formation contains two faunas, the Saw Rock Canyon being the older, and the Rexroad the younger. Both these faunas indicate that at the time they lived in that region the climate was rather moist and mild-temperate. The marked faunal change occurs between the Rexroad fauna and the Dixon and Deer Park faunas.

On the assumption that there were only four major glaciations, the Meade formation can be tentatively considered Nebraskan and Aftonian in age. References, throughout this paper, to deposits and faunas from Meade County in relation to time units based on the events in the glaciated region are also tentative.

The vertebrate fossils from the Meade gravels member are the oldest. The Dixon fauna is considered latest Nebraskan. The Deer Park fauna, which was previously regarded by me as a "cool" fauna and tentatively labeled Nebraskan, I now believe to be a "warmer" fauna, Aftonian in age. This conclusion is based upon the vertebrate fossils recovered from Meade County, Locality 1, in the summer of 1954, and upon the mammals found in the Sanders interglacial fauna. The Sanders local fauna occurs above the buried *caliche* zone and near the top of the formation. Both the invertebrates and the vertebrates in this fauna indicate that they lived during an interglacial time, regarded as late Aftonian.

The Dixon fauna can be correlated with the Sand Draw fauna of Nebraska, which is considered late Nebraskan (see Taylor, 1954). On the basis of the rodents, I am of the opinion that the Sand Draw fauna of Nebraska and the Hagerman fauna of Idaho occur in deposits equivalent in age to part of the Meade formation and that they are closely related to the Dixon and Deer Park faunas. The Grand View local fauna of Idaho is equivalent to the younger Sanders fauna or the Borchers fauna from the Crooked Creek formation. The Holloman fauna from Frederick, Oklahoma, which was considered by Grayson Meade (1953) to be Aftonian in age, is younger than the faunas found in the Meade formation. In my opinion, the fauna comes from sediments equivalent in age to part of the Crooked Creek formation.

I believe all faunas in North America that contain the microtine rodent *Mimomys* (*Cosomys*) to be younger than the Rexroad fauna. *Cosomys* is regarded by some workers as a synonym of the European *Mimomys* or as a subgenus of that group. The lack of knowledge concerning the late Pliocene and early Pleistocene faunas of North America does not permit *Mimomys* (*Cosomys*) to be taken as an "index fossil" for the Pleistocene. There is a marked break between the microtine rodents in the Rexroad fauna and those in the Dixon and Deer Park faunas of that region. The hiatus represented by the erosional unconformity between the Rexroad formation and the Meade formation, as well as the faunal differences, suggests that a considerable period elapsed between the two formations. Without doubt, deposition occurred in other regions of North America at this time, and such deposits as the Coso Mountains and Hagerman could be post-Rexroad sediments and pre-Meade formation in age. On the basis of the microtine rodents, the Villafranchian faunas are certainly post-Rexroad fauna and compare well with the Hagerman, Sand Draw, Dixon, and Deer Park faunas. No microtine rodent has been reported from the Pliocene deposits of Europe that is as primitive as *Ogmodontomys* from the Saw Rock Canyon and Rexroad faunas (see Fig. 8*C*)

I regard the Pliocene-Pleistocene boundary in southwestern Kansas as occurring between the Rexroad and Meade formations. This opinion is supported by lithological, stratigraphical, and faunal evidence, as well as by evidence of a cooling climate in that region.

PALEOECOLOGY OF FAUNAS

Dixon fauna.—This local fauna consists of forty-one species of mollusks, the remains of fishes, amphibians, reptiles, and birds, and six identifiable species of mammals. In an unpublished manuscript on the molluscan fauna, Dwight W. Taylor says: "Local conditions probably included a permanent pond and connecting stream or else a large, slow stream, abundant vegetation in shallow water, and shoreline vegetation of trees and shrubs."

The one *Blarina* species, the three of *Sorex*, and the four species of micro tines indicate a marshy habitat along the water's edge; *Blarina* indicates, also, the presence of trees and shrubs.

On the basis of an analysis of the molluscan fauna and a comparison with the Sand Draw fauna of Nebraska and

with other Pleistocene faunas in Kansas, Dwight W. Taylor says: "Paleoecological indications are that the fauna lived in a moist climate of mild summers and winters which were not excessively cold. This climate was cooler than that indicated by the Sanders local fauna but milder than that of the Cudahy fauna, and seems to represent a glacial-interglacial transition. The Dixon local fauna is therefore considered late Nebraskan."

The absence of *Synaptomys* (*Mictomys*) from the fauna indicates that it was slightly warmer in the region at that time than when the Cudahy fauna (late Kansan) lived there. The absence of the numerous Cricetinae, when compared with their abundance in the Rexroad fauna, points to a cooler climate than the Rexroad fauna enjoyed.

Deer Park fauna.—This local fauna is known from the remains of reptiles, birds, and mammals recovered from a dendritic artesian-spring system whose outlets lie in a basin eroded during Meade time. The habitat in the neighborhood of these springs can be considered to have been similar to that characteristic of the same springs in Meade County today. The area of discharge is a death trap of boiling quicksand, and the entire basin is a bog, in places choked with water cress and other aquatic plants that cover outlets of a part of the earlier dendritic pattern. The basin grades into a marsh that supports sedges and associated vegetation. Around the edges of the marsh and along the banks of the outlet area are trees, shrubs, and grapevines. This habitat furnishes not only a home for rodents and shrews but also a watering and feeding place for the larger grazers and browsers and for some carnivores. The remains consist chiefly of those of horses, mastodons, camels, and peccaries. The large grazers and browsers had probably ventured out too far from the edge of the basin while feeding.

The climate at the time this fauna lived is regarded as interglacial because of the presence in it of the large land turtle *Testudo*, which could have inhabited the region only during a mild-temperate time.

Sanders fauna.—The Sanders local fauna consists of twenty-three species of mollusks, amphibians, reptiles, and birds and thirteen species of mammals. The habitat of the Sanders fauna, as indicated by the sediments and fossils, appears to have been a broad flood plain that was chiefly a marsh area. Dwight W. Taylor, in his unpublished manuscript concerning the Sanders molluscan fauna, says: "The Sanders fauna lived in and near shallow subpermanent ponds or else a small, slow-moving stream of local origin. The absence of genera usually associated with bushes or trees bordering such a habitat may possibly indicate semiannual grassland ponds or streams." He remarks of the climate: "The Sanders fauna probably lived in a climate of mild summers, warm winters and moderate rainfall. This climate seems to me more interglacial than glacial. Increase in rainfall since the interglacial maximum may indicate a change toward glacial conditions."

The climate was warmer than at the time the Dixon fauna lived, for the mammal fossils contain fewer species of *Sorex* and include the cotton rat (*Sigmodon*), *Bensonomys*, and *Prodipodomys*, a kangaroo rat. That a more moist condition then prevailed in the area than exists at the present time is indicated by *Zapus* and the great numbers of micro tine rodents. The paucity of cricetine rodents may be due in part to the habitat, but it is in contrast to their abundance in the warm-temperate Rexroad fauna.

SYSTEMATIC ACCOUNT OF THE MAMMALS

MEADE GRAVELS MEMBER

The Meade gravels member is generally cemented (Pl. I, Fig. 2), and provides a prominent stratigraphic marker where exposed. No pocket, or concentration, of fossils has been found in the member; in fact, fossils are rare. More vertebrate remains have been collected from this member in Clark County, in SE. ¼ Sec. 12, T. 30 S., R. 23 W., and SW. ¼ Sec. 7 and NW. ¼ Sec. 18, T. 30 S., R, 22 W., than in the entire area worked by us in Meade and Seward counties. A few isolated horse teeth and limb bones have been taken in Meade County at the Sanders sand and gravel pit on the Big Springs ranch, in Sec. 7, T. 32 S., R. 28 W. Here the sand and gravel is only partly cemented. The other fossils in this member have been found at a few scattered localities in Meade County. The mammals are described below.

Order Proboscidea

Family Gomphotheriidae

Stegomastodon sp.

Fragmentary remains of this mastodon are common in Clark County in the area cited above. In Meade County fragments of molars are found, but even these are rare.

Hibbard (1944, pl. II, fig. 1) figured a molar from the "Meade formation." At that time both the Meade formation and the overlying Crooked Creek formation (Hibbard, 1949a) were included by me in the Meade. The present molar was taken from the gravel pit developed in the Stump Arroyo member of the Crooked Creek formation, on the north side of the road north of Bluff Creek, near the west line of Sec. 20, T. 30 S., R. 23 W., just east of the A. E. Esplund house, in Clark County.

Order Artiodactyla

Family Camelidae

Only fragmentary remains of camels have been taken from these sand and gravel deposits. The material is not complete enough for generic identification.

Order Perissodactyla

Family Equidae

Nannippus phlegon (Hay)

Only isolated teeth of this horse have been recovered from the sand and gravel. Most of these were collected in Clark County.

Discussion.—O. P. Hay (1917, p. 42) described *Hipparion cragini* on the basis of an upper molar or premolar collected by Cragin in 1891 along the upper part of Bluff Creek, Clark County, east of Minneola, on the Thomas ranch. In 1942 the Clark County engineer (M. M. Mayse) wrote to me concerning the location of the Thomas ranch as follows: "The only Thomas land that I have been able to locate in Clark County is the SW. ¼ Sec. 36, T. 30 S., R. 24 W." (Hibbard, 1944, p. 716). I was never able to locate an exposure in this section from which the tooth could have been taken. Later, Mr. George Taylor, whose family was one of the first to settle Clark County and who lived in Sec. 20, T. 30 S., R. 23 W., told me: "The old Thomas ranch was just west across the north-south road and up Bluff Creek from my place." An examination of this area in 1954 revealed good exposures of the Stump Arroyo member of the Crooked Creek formation in the NW. ¼ Sec. 30, T. 30 S., R. 23 W., and the NE. ¼ Sec. 25, T. 30 S., R. 24 W. It is from this area that the tooth was apparently taken. Mr. A. E. Esplund, of Bloom, Kansas, who lives in the E. ½ Sec. 19, T. 30 S., R. 23 W., cheeked the county records concerning the Thomas land and wrote to me on December 4, 1954: "Mr. Thomas homesteaded in 1886 the place just west of me. It is now owned by Melencamp and Randall."

This later Pleistocene age for the holotype of *Nannippus cragini* is further confirmed by the fact that in the summer of 1954 one half of an upper premolar or molar, UMMP No. 31805, of this horse was recovered from the same sand and gravel pit in the Crooked Creek formation just east of the A. E. Esplund house from which the *Stegomastodon* tooth figured by me (1944) was taken. Teeth of *Equus* (*Plesippus*) were also taken from this pit.

Equus (*Plesippus*) *simplicidens* Cope

(Fig. 2*G*)

Isolated teeth and limb bones of this zebrine horse are nearly as rare in these sand and gravel deposits as those of *Nannippus*. Figure 2*G* is of a lower molar taken from the Sanders gravel pit, in Sec. 7, T. 32 S., R. 28 W., Meade County.

It seems best to refer the isolated teeth of the zebrine horse from the Upper Pliocene Rexroad formation and the Pleistocene Meade and Crooked Creek formations to the species *simplicidens*. Many species of the subgenus *Plesippus* have been described, but better material is needed before the refinement of the species of *Plesippus* is attempted. The zebrine horse teeth from the younger Crooked Creek formation show some differences from the teeth taken from the Rexroad and the Meade formations.

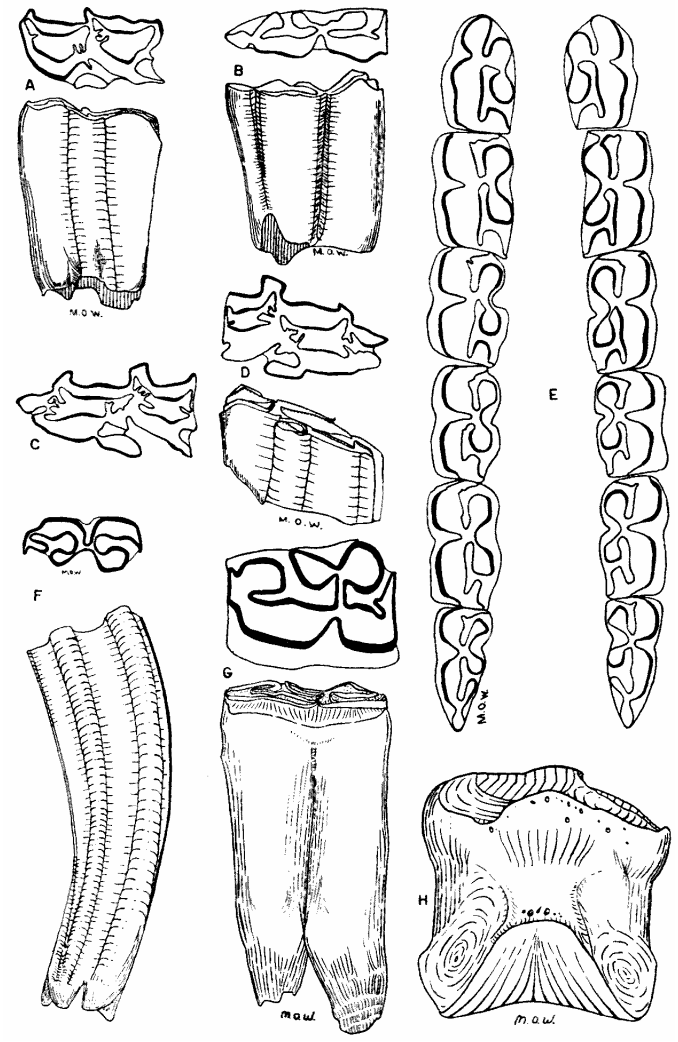

FIG. 2

EXPLANATION OF FIGURE 2

A-F, teeth of *Nannippus phlegon* (Hay): *A*, UMMP 31742, LDP^3; *B*, UMMP 31740, LDP_2, occlusal and lingual views; *C*, UMMP 31741, LDP^2, occlusal view; *D*, UMMP 31743, RDP^2, occlusal and lingual views; *E*, UMMP 31730, left and right P_2-M_3, occlusal view; *F*, UMMP 24389, LM_2, occlusal and lingual views. *G*, *Equus* (*Plesippus*) *simplicidens* Cope, UMMP 31367, right premolar or molar, occlusal and labial views. *H*, *Equus* (*Asinus* ?) sp., UMMP 31366, second phalanx. All X 1

Equus (*Asinus* ?) sp.

(Fig. 2*H*)

A second phalanx, No. 31366, of a medium-sized horse (Fig. 2*H*) was collected at the Sanders sand and gravel pit. The greatest length is 40.5 mm., and the greatest width is 38.0 mm. The only *Equus* remains known from the early Pleistocene deposits of southwestern Kansas that are similar to this specimen in size are those of *E.* (*Asinus*) *calobatus* Troxell (Hibbard, 1953a), taken from the Crooked Creek formation.

DIXON LOCAL FAUNA

The name "Dixon local fauna" is used for an association of mollusks and vertebrates collected on the Dixon farm in the SW. ¼ Sec. 12, T. 29 S., R. 8 W., Kingman County, Kansas, from the Meade formation (Pl. II, Fig. 2). This fauna was considered by Frye and Leonard (1952), on the basis of an incomplete molluscan fauna, to be of the same age as, and a part of, the Saw Rock Canyon fauna (lower Upper Pliocene) and the Rexroad fauna (Upper Pliocene). The fauna occurs in a clay and sandy silt exposed along the bank of a small draw on the Dixon farm. A systematic discussion is given here of the mammals only. The invertebrate fauna is being reported by Dwight W. Taylor, the amphibians by J. A. Tihen (1955), and the birds by Byron E. Harrell.

Class Mammalia

Order Insectivora

Family Soricidae

Sorex sp.

Parts of three fragmentary jaws, No. 31973, of a small shrew intermediate in size between *Sorex cinereus* Kerr and *S. vagrans* Baird were taken with the Dixon fauna. One of the fragments contains M_1, and the other two contain M_2 and M_3.

Sorex leahyi, sp. nov.

(Fig. 3)

Holotype—UMMP 31969, part of a right lower jaw, with M_2 and M_3. Collected in the summer of 1954 by Claude W. Hibbard and party. Paratypes: No. 31970, part of a left lower jaw, with M_1-M_3, and No. 31972, part of a left lower jaw, with M_1 and M_2.

Horizon and type locality.—Lower Pleistocene (late Nebraskan), Meade formation, Dixon farm, SW. ¼ Sec. 12, T. 29 S., R. 8 W., Kingman County, Kansas.

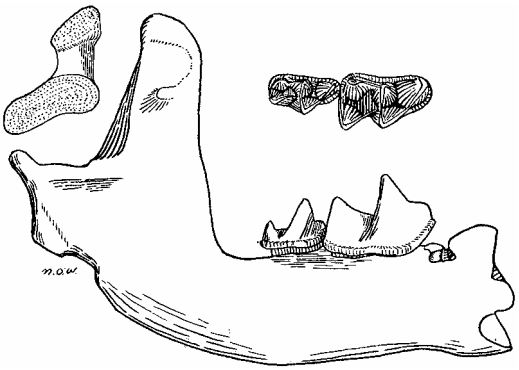

FIG. 3. *Sorex leahyi*, sp. nov., holotype, UMMP 31969, right lower jaw, M_2 and M_3, lateral and occlusal views and posterior view of condyle, X 10

Diagnosis.—A shrew the size of *Sorex arcticus* Kerr. *Sorex leahyi* is distinguished from other fossil and Recent species of *Sorex* by a narrower and distinctly developed posterointernal ramal fossa and a broad, flattened posterior border on the coronoid process of the ascending ramus, similar to the condition observed in *S. durangae* Jackson (UMMZ 99979).

Description of holotype.—The lower jaw is broken anterior to the alveoli of M_1. The anteroposterior length of M_2-M_3 is 2.3 mm. There is a well-developed coronoid spicule (see Gaughran, 1954, pl. 2), which is more ventral on the side of the ascending ramus than in *Sorex taylori* Hibbard. This process is missing in the specimens of *S. arcticus* examined. It was present in other species studied, and its shape and position appear to be characteristic for different species groups of *Sorex*.

The cingulum forms a prominent band on the anterior base of M_2 and M_3. These teeth are slightly narrower than the M_2 and M_3 of *Sorex taylori*.

Sorex leahyi is named for Mr. Dave Leahy, Director of the Kansas Forestry, Fish and Game Commission, who has been greatly interested in the promotion of research.

Description of paratypes.—Specimen No. 31970 consists of the horizontal ramus, which contains M_1-M_3. The characters of M_2 and M_3 are like those of the holotype. M_1 is slightly narrower than that tooth in *Sorex taylori*, and it has a better-developed anterior cingulum. The anteroposterior length of M_1-M_3 in the paratype is 3.6 mm. The second fragment, No. 31972, with M_1 and M_2, is from an old individual. The anterior cingulum of M_1 is not so pronounced as in the other specimens. Except for this, the teeth agree with those of the holotype and the other paratype.

Sorex dixonensis sp. nov.

(Fig. 4)

Holotype.—UMMP 31968, the posterior part of a left lower jaw, bearing M_1-M_3. Collected in the summer of 1954 by Claude W. Hibbard and party.

Horizon and type locality.—Lower Pleistocene (late Nebraskan), Meade formation, Dixon farm, SW. ¼ Sec. 12, T. 29 S., R.8 W., Kingman County, Kansas.

Diagnosis.—A large shrew, intermediate in size between *Sorex obscurus* Merriam and *S. pacificus* Coues. *Sorex dixonensis* differs from other species of *Sorex* in that M_1 and M_2 are more rectangular. This is due in a measure to the development of the cingulum along the anterior part of the teeth. The external reëntrant valley between the hypoconid and the protoconid of M_2 is shallower than in specimens of other species exhibiting comparable dental wear.

Description of holotype.—The anterior part of the lower jaw is missing. The dental pattern indicates that the jaw is that of an adult animal; it exhibits moderate occlusal wear. The anteroposterior length of M_1-M_3 is 4.0 mm. In comparison with Recent species of *Sorex*, the first and second molars of *S. dixonensis* have a narrow width for their anteroposterior length. This condition is due chiefly to the reduced width of the trigonid of these two teeth. The posterior border of the coronoid process above the condyle is shaped as in *S. obscurus*. The coronoid spicule is situated well down on the labial side of the

ascending ramus, and its position consequently differs from that observed in other species of *Sorex*. The development of this process is more like the condition found in *S. pacificus*. *Sorex dixonensis* is distinguished from other known fossil species of *Sorex* in North America by its larger size. The posterointernal ramal fossa is like that of *S. obscurus* and *S. pacificus*, not constricted as in *S. leahyi*.

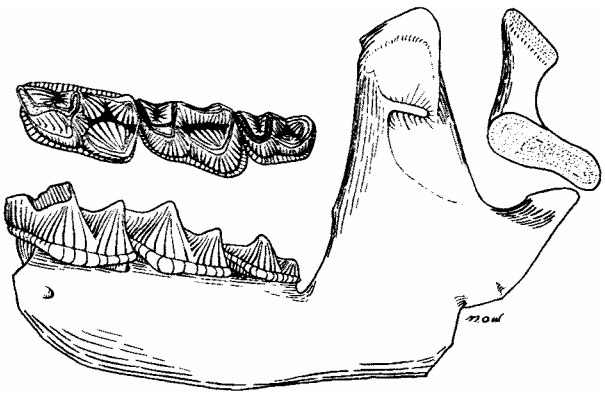

FIG. 4. *Sorex dixonensis*, sp. nov., holotype, UMMP 31968, left lower jaw, M_1-M_3, lateral and occlusal views and posterior view of condyle, X 10

Blarina sp.

Part of a right maxillary, No. 31966, with M^1 and M^2, and part of a left lower jaw, No. 31967, with alveoli of M_2 and M_3, of this large, short-tailed shrew were taken.

Order Carnivora

Family Mustelidae

Mustelid sp.

In the collection is a left DP_4, No. 32067, of a mustelid, slightly larger than any DP_4 of the Recent badger (*Taxidea taxus*) in the collection of the University of Michigan Museum of Zoology.

Order Rodentia

Family Sciuridae

Citellus sp.

Seven isolated teeth, No. 32038, were found. They are from rather large ground squirrels. One M_3 is similar to that tooth in *Sciurus*.

Family Castoridae

A fragment of a beaver tooth, No. 32039, similar in size to a tooth of a small individual of *Procastoroides*, was found.

Family Geomyidae

Geomys sp.

(Fig. 11*A*)

A number of isolated teeth, No. 32040, of a pocket gopher were taken. No. 32042 is a right DP_4 (Fig. 11*A*), smaller than the DP_4 of *Pliogeomys buisi* Hibbard from the Ogallala (Upper Middle Pliocene) of Beaver County, Oklahoma.

Family Cricetidae

Peromyscus sp.

An isolated RM_1, No. 32045, of a species of *Peromyscus* was recovered that was larger than that tooth in *P. leucopus* (Rafinesque).

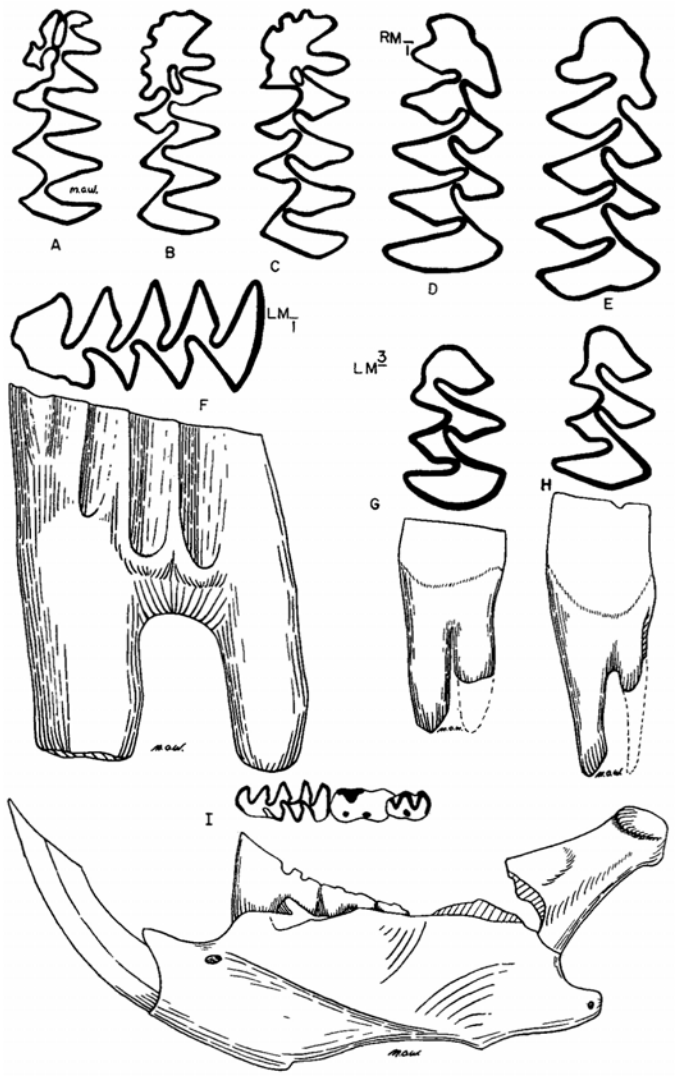

FIG. 5

EXPLANATION OF FIGURE 5

Teeth of *Pliopotamys meadensis: A-C*, immature patterns, UMMP 32056 a-c, LM_1; *D-E*, adult patterns, UMMP 32056 d-e, RM_1, occlusal views; *F*, UMMP 32055, LM_1, labial and occlusal views; *G*, UMMP 32047, LM^3; *H*, UMMP 32054, LM^3, anterior and occlusal views; *I*, KUMVP 9921, left lower jaw, M_1-M_3, lateral and occlusal views. *A-H*, all X 8; *I*, X 3

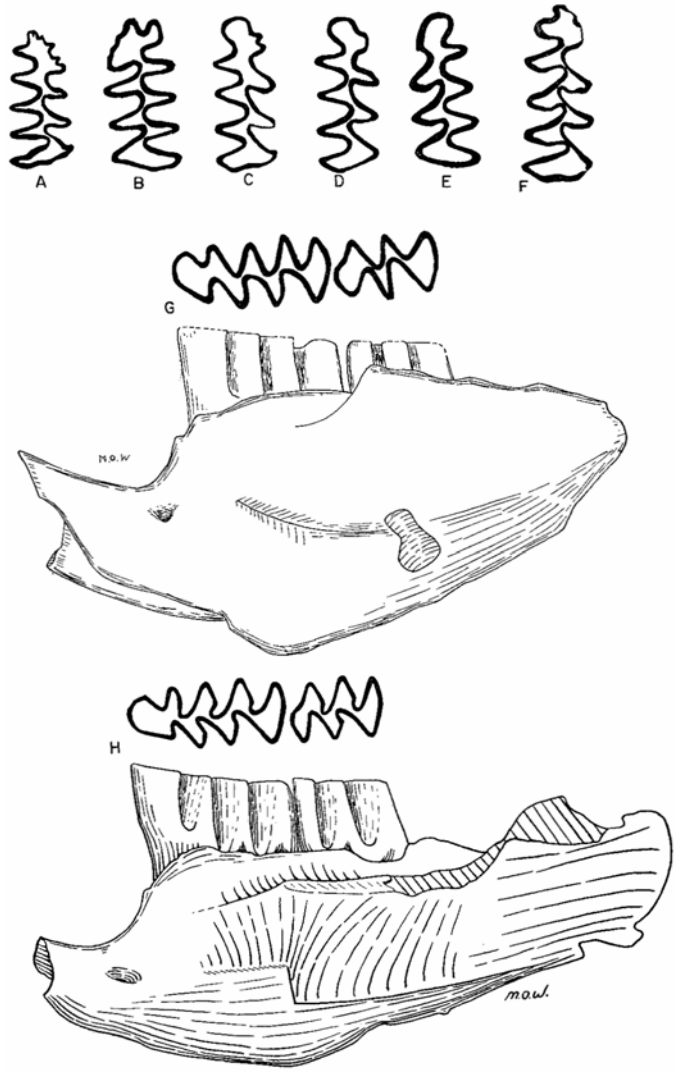

FIG. 6. *Pliophenacomys: A-F, P. meadensis*, UMMP 32051, Dixon fauna, occlusal views of first lower molars; *G*, UMMP 32053, left jaw, M_1-M_2, lateral and occlusal views; *H*, *P. parvus* (Wilson), holotype, Calif. Inst. Tech. 1369, left jaw, M_1-M_2. All X 8

Pliophenacomys meadensis Hibbard

(Figs. 6 *A-G*)

Numerous isolated teeth of this vole, a new species described in the portion of the present paper concerned with the Sanders fauna (see p. 187), were recovered. Parts of thirty-one individuals were taken, according to a count of specimens of the right M_1. Twenty-six examples of LM_1 were found. Part of a left ramus, No. 3&053, contains M_1 and M_2 (Fig. 6*G*). These teeth compare in size and dental patterns with those of the holotype, UMMP 32019. Age and individual variation in the pattern of M_1 is shown in Figures 6 *A-F*.

Pliopotamys meadensis Hibbard

(Figs. 5 *A-F, H*)

This medium-sized vole is a common member of the Dixon fauna. Only isolated teeth were found, but they represent seven individuals, since there are seven left lower first molars. M_1 consists of a posterior loop, five alternating triangles, and an anterior loop that varies in complexity according to the stage of wear (Figs. 5 *A-F*). The anteroposterior length of the occlusal surface of five lower first molars is (in millimeters): 4.55, 4.1, 4.5, 5.1, and 4.5. The M_1 with the shortest occlusal surface is that from a young animal (Fig. 5*A*), and the tooth with the greatest anteroposterior length is that of an old adult (Fig. 5*E*). The teeth increase slightly in transverse width with wear.

M^1, M^2, and M^3 (Fig. 5*H*) each have three well-developed roots. *Pliopotamys meadensis*, No. 32047, from the Sand Draw fauna of Nebraska also has three distinct roots on M^3 (Fig. 5*G*).

Pliolemmus antiquus Hibbard

(Figs. 15 *B-E*)

Two fragmentary lower jaws, each with M_1 and M_2, and numerous isolated teeth were taken. Parts of at least eleven individuals of this vole were found. Variation due to age was observed in the tooth pattern of M^3; the occlusal pattern of immature teeth is shown in Figures 15 *D, E*. The anteroposterior occlusal length of M_1 and M_2, No. 32064 (Fig. 15*C*), is 4.55 mm. The occlusal length of these teeth in No. 32065 (Fig. 15*B*) is 4.3 mm. This vole is a common faunal element in the Sanders fauna (see p. 191).

Synaptomys (Synaptomys) rinkeri, sp. nov.

(Figs. 7 *A, B*)

Holotype.—UMMP 32069, part of a right lower jaw, with incisor, M_1, and M_2. Collected in the summer of 1953 by Claude W. Hibbard and party.

Horizon and type locality.—Lower Pleistocene (late Nebraskan) Meade formation, Dixon farm, SW. ¼ Sec. 1, T. 29 S., R. 8 W., Kingman County, Kansas.

Diagnosis.—A bog lemming that is the size of a large individual of *Synaptomys cooperi* Baird. It differs from the Recent forms of *Synaptomys* (*Synaptomys*) in that the diastemal region is broader and the anterior loop of M_1 more pointed (Fig. 7 *A*). It differs from *S. landesi* Hibbard, from the Borchers fauna, in that the first and second alternating triangles of M_1 and M_2 are closed.

Description of holotype.—The lower jaw is that of an adult. It is broken just posterior to M_1. The diastemal region is broad and flat, so that the outline of the mental foramen is hidden in dorsal view. This opening is closer to the anterior root of M_1 than in *Synaptomys cooperi*.

The molar teeth are of the ever-growing type, and cement is present in the reëntrant angles. M_1 consists of a posterior loop, three alternating closed triangles, and an anterior loop. The apex of the second inner reëntrant angle and that of the third outer reëntrant angle meet, making a distinct anterior loop. The enamel band forming the apexes of the inner reëntrant angles is more uniform in thickness (not thinned), than it is in Recent specimens of *Synaptomys cooperi*. The outer triangle is one half the size of the first alternating inner triangle. M_2

consists of a posterior loop, two alternating closed triangles, and an anterior loop. As in the Recent *S. cooperi*, the occlusal pattern of M_1 and M_2 is interrupted. This is due to the absence of enamel along the sides of the teeth in the areas of some of the apexes of the alternating triangles and the anterior and posterior loops. The anteroposterior occlusal length of M_1 and M_2 is 5.35 mm.

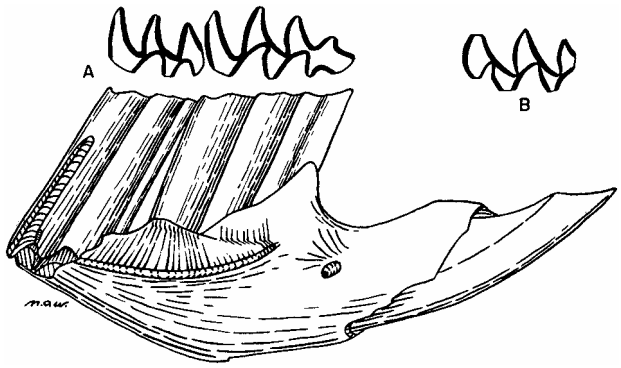

FIG. 7. *Synaptomys* (*Synaptomys*) *rinkeri*, sp. nov.: A, holotype, UMMP 32069, part of right ramus, M_1-M_2, lateral and occlusal views; *B*, paratype, UMMP 32070, LM^1, occlusal view. Both X 6

Among the isolated teeth of this lemming recovered, there is a left M_1 that is the same size and of the same occlusal pattern as the M_1 of the holotype. There are two examples of left M^1 (Fig. 72?), the occlusal pattern of which is like those of the Recent *Synaptomys cooperi*. All the isolated teeth of this lemming have cement in the valleys of the reëntrant angles.

The species is named for George C. Rinker, who spent a number of summers collecting fossils in southwestern Kansas and who has contributed to the knowledge of both fossil and Recent mammals.

Discussion.—The presence of cement in the reëntrant angles of the teeth of specimens of *Synaptomys* (*S*.) *rinkeri* which were taken in association with teeth of *Pliopotamys*, *Pliophenacomys*, and *Pliolemmus* lacking cement indicates that its absence in these three forms is not a matter of preservation.

The presence of this species of *Synaptomys* in the early Pleistocene deposit indicates that the development of ever-growing teeth and the accumulation of cement on the teeth became characteristic of the genus before that epoch. This record is the earliest known for *Synaptomys*. Its ancestral stock has not been determined, but should be looked for in deposits of Pliocene age.

Synaptomys (*S*.) *rinkeri* is distinct from the aberrant *S. vetus* Wilson, from Grand View, Idaho, and *S. landesi* Hibbard, from the Borchers fauna of southwestern Kansas. These last two species have some characters of the subgenus *Mictomys*, and are assigned to the subgenus *Synaptomys*. They represent a side branch that split off from the *Synaptomys* stock during the Pliocene.

I find no characters in *Synaptomys* (*S*.) *rinkeri* that would keep it from being the ancestral stock of the Recent *S. cooperi* or from being ancestral to other later Pleistocene forms of the subgenus *Synaptomys*, exclusive of the *S. vetus* group.

THE DEER PARK FAUNA

The Deer Park local fauna occurs in the Missler member of the Meade formation. The quarry (Meade County, Locality 1) from which this fauna was taken is located in the Meade County State Park near the west edge of the SE. ¼ Sec. 15, T. 33 S., R. 29 W. Because of the presence of *Nannippus* and *Equus* (*Plesippus*), I included the members of this fauna, collected in the summer of 1936 by a field party from the University of Kansas Museum of Paleontology, in the Upper Pliocene Rexroad fauna (Hibbard, 1938, 1941b).

The site has never been thoroughly worked because of the character of the deposits containing the fossils, which are found in flour-sand pockets and tubes developed in the silt and silty clay by an old, now-dry, artesian-spring system. The type of deposition was not understood when the quarry was first worked in 1936. At that time we spent just two days there and sifted only the sand removed by members of a Civilian Conservation Corps camp from one of the large sand pockets and from a small pocket about one foot in diameter and two and one-half feet deep. Part of a beaver jaw, the holotype of *Eocastoroides lanei*, other small jaws, and numerous horse teeth were recovered. The quarry was not worked again until the summer of 1944 when Allen Graffham and Richard Rinker, members of our field party, spent two more days there. They found numerous horse teeth, fragments of other teeth, and a lower jaw of *Pliopotamys meadensis*. Isolated specimens exposed by erosion have subsequently been picked up at the site.

In 1954, near the close of the summer field work, we started on the floor of the small draw and dug two trenches about sixty feet apart, directly into the exposure. Both of these trenches ran into a large flour-sand deposit about two feet wide, from which the sand-filled pockets and tubes containing most of the fossil remains branch upward. To what depth the sand extends is unknown. The basin formed by the spring when it was flowing has not been found, and it appears to have been eroded away before the deposition of the overlying silt and clay.

It is impossible to make a detailed geological section at the site because of the development of the present basin to the north and northwest, slump, slope-wash, and vegetation. The Meade formation at this locality was involved in the development of the present artesian basin in the Meade County State Park. The regional dip of the Cenozoic deposits in the area is eastward toward Crooked Creek. The Meade sand and gravel in the southeast corner of the buffalo pasture (previously known as Deer Park) occurs considerably lower

topographically than it does near the center of the west side of the pasture, a half-mile away, where the rock was quarried for the dam of Lake Larrabee.

The top of the consolidated Meade gravels member is well exposed just west of the quarry in the buffalo pasture, but in the quarry, at Locality 1, the top of this member is forty-five feet below the quarry floor. The quarry is in a reddish sandy silt containing nodules of *caliche*, and it is in this silt that the fossil-bearing pockets and tubes occur.

A blue-gray silty clay from eight to thirty inches thick caps the former spring surface. Above this clay are two feet of reddish sandy silt, overlain by twelve feet of gray sandy silt that is covered with grass. Some large pebbles occur on the surface. It is not known whether these are residual pebbles from the overlying Crooked Creek formation or whether they are due to slope-wash from the west consisting of material from both the Meade gravels and the younger Crooked Creek formation.

The small fossil remains occur in pockets which contain coarse sand and polished fragments of enamel. The matrix around the fossils often consists chiefly of fine polished enamel from the numerous teeth that have been ground by the churning water. Fossil bone is seldom found, for it has been largely destroyed by the abrasion of the harder teeth; most of what is found is badly abraded and polished.

Remains of the large slug *Deroceras aenigma* Leonard were collected in the sand pockets with the vertebrate fossils, but no mollusks were observed in the silt or clay. None of the matrix was washed, for the procedure at this locality was to sift the fossil-bearing sand.

Class Reptilia

A piece of the carapace, No. 31961, of a large species of *Testudo* was taken. A few snake vertebrae were also found, although reptile remains have been rare in the deposit.

Class Aves

Only a few bird bones were collected, most of them fragmentary.

Class Mammalia

Order Carnivora

Family Mustelidae

Mustelid sp.

A left M^1 was found belonging to a mustelid species heretofore not recovered from deposits in this area. The tooth, which is nearly rectangular and has a transverse width of 11.5 mm., came from an animal the size of the fisher (*Martes pennanti* Erxleben). The lingual heel, however, is not so broad as the heel of M^1 of the fisher. The anteroposterior width of the lingual part of the tooth is 6.0 mm. The width of M^1 in the fisher used for comparison is 8.0 mm.

Taxidea cf. *taxus* (Schreber)

A left M^1, No. 31943, of an immature badger was taken. The tooth consists only of the unworn crown. Roots had not started to develop. It is the size of the LM^1 in UMMZ 76984, an immature Recent female specimen. The fossil differs from this tooth only in that the posterior oblique row of conules is larger.

Family Canidae

Canis sp.

A right and a left M^1, No. 31945, of a canid the size of the coyote *Canis latrans* Say, were taken. The teeth show different degrees of occlusal wear and appear to be from two different individuals. Associated with them were two examples of left M_2, one slightly larger than the other, also from a canid the size of the coyote.

Order Rodentia

Family Sciuridae

Cynomys meadensis, sp. nov.

(Fig. 8*A*)

Holotype.—No. 31963, University of Michigan Museum of Paleontology, a right M_1 and M_2 (Fig. 8*A*). Collected in the summer of 1954 by the University of Michigan field party.

Horizon and type locality.—Early Pleistocene, Missler member of the Meade formation, Meade County State Park, SE. ¼ Sec. 15, T. 33 S., R. 29 W., Locality 1, Meade County, Kansas.

Diagnosis.—A prairie dog with lower molar teeth smaller than those of *Cynomys ludovicianus* (Ord). M_1 and M_2 are distinguished from the same teeth in other known prairie dogs by the presence of a small, round conulid, instead of a transverse mesolophid, on the lingual side of the talonid basin.

Description of holotype.—The molars are from a young animal and are about the size of those of *Cynomys leucurus* Merriam. They are not so high-crowned as the molars of prairie dogs today. The conulid in the talonid basin is developed on the entoconid side of the basin wall. It is round and has no enamel ridge connecting it posteriorly or lingually to the side of the tooth. The greatest anteroposterior length of M_1 is 3.0 mm., that of M_2 is 3.3 mm.

This is the earliest fossil record of a prairie dog from the area under study, for the other fossil specimens taken have been from very late Pleistocene deposits and are indistinguishable from animals now living in the region.

Citellus sp.

In the summer of 1954 three teeth, No. 31953, of a ground squirrel were taken with teeth of *Cynomys*.

FIG. 8. *A, Cynomys meadensis*, sp. nov., holotype, UMMP 31963, RM_1-M_2, labial and occlusal views, X 4. *B, Ogmodontomys* or *Mimomys* (*Cosomys*), UMMP 31952, RM_1, labial and occlusal views, X 8. *C, O. poaphagus*, UMMP 32036, RM_3, Rexroad fauna, occlusal, labial, and anterior views, X 8. *D, Hypolagus* sp., UMMP 31955, LP_3, occlusal view, X 6. *E, Mimomys* (*Cosomys*) primus, UMMP 31419, Hagerman fauna, LM^3, occlusal, lingual, and anterior views, X 8. *F Geomys quinni*, KUMVP 4576, left jaw, P_4-M_2, lateral and occlusal views, X 3

Family Castoridae

Procastoroides sweeti Barbour and Schultz

Procastoroides sweeti Barbour and Schultz, 1937. Am. Mus. Novitates, No. 942: 6, fig. 3.
Eocastoroides lanei Hibbard, 1938. Kans. Acad. Sci., Trans., 40 (1937): 244, fig. 2.

This beaver is known from the holotype of *Eocastoroides lanei* which is part of a left lower jaw collected in 1936; a maxillary, KUMVP 4577 (Hibbard, 1944, pl. II, fig. 1), and three upper teeth, No. 31950, were recovered in the summer of 1954. The specimens from the present locality are smaller than those reported by Barbour and Schultz (1937).

Family Geomyidae

Geomys quinni McGrew

(Fig. 8*F*)

Part of the left lower jaw, KUMVP 4576, of a large gopher was taken in the summer of 1937 at Locality 1. The incisor, which is 3.3 mm. wide, and P_4-M_2 are present (Fig. 8*F*). There is a deep pit between M_3 and the ascending ramus.

Family Cricetidae

Pliolemmus antiquus Hibbard

This vole is known in the Deer Park fauna only from the holotype (part of a right lower jaw with M_1 and M_2) and isolated finds of LM_1 and RM_1—all taken in the summer of 1936.

Specimens of this form were not recovered again until the summer of 1953, when the vole was found to be a part of the Dixon fauna described in the present paper. A detailed description of the genus is given under the Sanders fauna, since nearly perfect upper and lower dentitions were recovered with that fauna in the summer of 1954.

The misidentification of this form (Hibbard, 1938) as a lemming was one of the reasons for considering the Deer Park fauna a "cool" fauna.

Ogmodontomys or *Mimomys* (*Cosomys*) sp.

(Fig. 8*B*)

In August 1954, a right M_1, No. 31952, of an adult vole, the size of M_1 of *Ogmodontomys poaphagus* Hibbard, was taken from a sand pocket in association with the teeth of *Pliopotamys meadensis*. The occlusal pattern of the M_1 is the same as that of *Ogmodontomys* and of *Mimomys* (*Cosomys*) (Fig. 8*B*).

Ogmodontomys is distinguished from the subgenus *Cosomys* (Fig. 8*E*) by the presence of a grooved upper incisor and an M^3 with three distinct and well-developed roots (Fig. 8*C*). The lower incisor in *Ogmodontomys* ends on the labial side of the jaw opposite the dental foramen. There is no enlargement for the base of the incisor. The occlusal pattern of M_1 is similar in *Ogmodontomys* and *Mimomys* (*Cosomys*).

Material collected in the summer of 1953 indicates that the vole from the Saw Rock Canyon fauna that I assigned (Hibbard, 1953b) to *Cosomys primus* Wilson on the basis of occlusal pattern of M_1 was misidentified. It has a grooved upper incisor and an M^3 with three distinct roots, and is therefore *Ogmodontomys*.

Pliopotamys meadensis Hibbard

(Fig. 5*I*)

The type locality of this vole was given by me (1938) as Meade County, Locality No. 2. At the time specimens were being drawn to illustrate the Rexroad fauna (Hibbard, 1938), a number of small ones were misplaced and a beaver tooth and a microtine lower jaw were lost

by the artist. It was evident that specimens had been switched in the containers, but further field work was needed to clear up certain discrepancies.

Localities No. 2 and No. 2a were reworked, but no teeth or jaws of *Pliopotamys* were recovered. I clearly remembered taking the large vole in association with *Pliolemmus* at Locality No. 1. In 1944, at Locality 1, we found another lower jaw of *Pliopotamys* (Fig. 51), and in the summer of 1954 nine isolated teeth of this form were taken at the same site. I am certain that the two specimens of *Pliopotamys meadensis* KUMVP 3846 and 3847 were from Locality 1 in Meade County, and not Locality 2, as declared by me in 1938. In the extensive collecting since then, we have never found *Pliopotamys* in the Rexroad formation.

Following is a description of specimen KUMVP 9921 collected in the summer of 1944 at Locality 1. It is the left lower jaw of an old adult. The jaw was damaged in the process of collection, the coronoid process being broken at the dental foramen. The mental foramen is more dorsal on the diastemal region than in *Ondatra annectens* Brown (USNM 12044) and in Recent *Ondatra*. In *Ondatra* the mental foramen is on the labial side of the jaw, and the opening is not seen in dorsal view. In KUMVP 9921 no pit exists between the ascending ramus and M_2 and M_3 such as is seen in specimen KUMVP 3847. The development of this part of the jaw corresponds to that in *Pliopotamys idahoensis* (Wilson), with the lower incisor ending on the labial side slightly above the dental foramen. The swelling for the reception of the base of the incisor is not so well developed as in Recent *Ondatra*, and there is no cement in the reëntrant angles of the lower molars of this specimen or in the isolated teeth taken from this locality.

M_1 consists of a posterior loop and five alternating triangles. The first four are closed, but the fifth opens widely into the anterior loop. M_2 is badly worn, and only the enamel islands remain on the base of the crown. M_3 has a posterior loop and four alternating triangles; the enamel on the labial side of the molar has worn away. The anteroposterior length of M_1-M_3 is 9.65 mm. The transverse width of the incisor is 1.75 mm. Among the isolated teeth collected is a right M^2 with three pronounced roots. In these specimens the two posterior roots are better developed than in Recent *Ondatra*.

The genus *Pliopotamys* is considered distinct from *Ondatra* because of the absence of cement in the reëntrant valleys of the molars and because of the lack of a better-developed pit between M_2 and M_3 and the ascending ramus. In Recent *Ondatra* this pit is formed partly by the ridge caused by the incisor, which blocks the posterior section of the valley between the lower cheek teeth and the ascending ramus. The isolated second and third (Figs. 5 *G, H*) upper molars of *Pliopotamys* have three well-developed roots. Furthermore, in *Pliopotamys* the interrupted occlusal enamel pattern found in fossil and in Recent *Ondatra* does not occur.

The small muskrat-like voles present a taxonomic problem; better specimens are needed for study. These small forms occurred in this area as late as the Borchers (Yarmouth?) fauna, and lack cement in the reëntrant angles of the teeth, to judge from specimen No. 32046, taken in the summer of 1952 in association with the Borchers fauna.

Ondatra occurs in the Cudahy, Kentuck, Berends, and Jinglebob faunas. Cement is present in the reëntrant angles of the teeth in members of this genus, and the occlusal enamel pattern is interrupted during some stage of wear.

Order Proboscidea

Family Gomphotheriidae

Stegomastodon sp.

A second molar, KUMVP 7060, of this mastodon was taken in the summer of 1944. The anteroposterior length of the crown is 108.0 mm. The greatest width, across the posterior loph, is 72.0 mm.

Also in the collection is a milk premolar, No. 7303. Owing to the lack of comparative material, generic identification of this tooth is not possible.

Rhynchotherium sp.

In the summer of 1954 fragments of a large tusk, No. 31958, bearing a longitudinal enamel band, were taken from the flour sand. This record is the first for *Rhynchotherium* from the Pleistocene of Kansas.

Four milk teeth of a mastodon were found. It is not known to what genus they belong.

Order Lagomorpha

Family Leporidae

Hypolagus sp.

(Fig. 8*D*)

A small left P_3, No. 31955, of this rabbit was taken, along with two unidentifiable upper premolars or molars.

Order Artiodactyla

Family Tayassuidae

Platygonus sp.

Only isolated teeth, No. 31948, of a large peccary were found. The teeth are larger than those recovered in the Rexroad fauna, in Keefe Canyon (Hibbard and Riggs, 1949).

Family Camelidae

Isolated camel teeth, representing two sizes of camels, have been taken with the other material from the Deer Park quarry. It is not possible to assign them with certainty to definite genera.

Order Perissodactyla

Family Equidae

Nannippus phlegon (Hay)

(Figs. 2 *A*-*F*)

The teeth of this little horse are next to those of *Equus* (*Plesippus*) in abundance, and more of them have been recovered from the Deer Park quarry than from all the other localities investigated in southwestern Kansas.

In August 1954 a nearly complete pair of lower jaws, No. 31730 (Fig. 2*E*), was found in the flour sand. The following measurements, in millimeters, are taken from this specimen; they give the length of each tooth in the premolar-molar series from the tip of the longest root to the top of the crown: P_2, 45.0; P_3, 49.0; P_4, 60.0; M_1, 57.0; M_2, 68.0; and M_3, 67.0. The distance between the left P_2 and the right P_2 is 22.0. The occlusal length of P_2-M_3 is 107.0; the occlusal length of P_2-P_4 is 54.0; and the occlusal length of M_1-M_3 is 53.0.

The lower jaws are different in outline from those of other Pleistocene and Recent horses observed. The jaws are quite deep below the crowns of M_1 and M_2, measuring approximately 63.0 mm. The jaw tapers anteriorly until it has a depth of 22.0 mm. at the symphysis. The mental foramen is situated 26.0 mm. anterior to P_2. In the jaws of a large domestic jack, the foramen is only 14.0 mm. anterior to P_2. No canines are present, so the jaws are probably those of a female. From the shape of the alveoli of the incisors it appears that they were less procumbent than in *Equus*.

Equus (*Plesippus*) *simplicidens* Cope

Teeth of this zebrine horse are the most common fossils found in the deposit. A palate of a foal, one to three days old, was recovered from the flour sand of the large fissure. It was ground so thin and was so fragmentary that we could save only the six milk premolars, No. 31962. They were not polished, and the cement remains over the crowns of the teeth.

SANDERS LOCAL FAUNA

The name “Sanders local fauna” is applied to the fossils from a zone that occurs above the buried *caliche* in the Meade formation (Pl. II, Fig. 1). This zone is exposed in outcrops extending for over two miles along the valley of Spring Creek and its tributaries on the Big Springs Ranch, south of Meade, Kansas.

A systematic account is given here only of the mammals. The mollusks are being reported by Dwight W. Taylor, the amphibians by J. A. Tihen, and the birds by Byron E. Harrell.

Class Mammalia

Order Insectivora

Family Soricidae

Sorex sandersi, sp. nov.

(Fig. 9)

Holotype.—UMMP 31976, a right lower jaw, with C-M_3. Collected in the summer of 1954 by Claude W. Hibbard and party.

Horizon and type locality.—Lower Pleistocene (Aftonian), Meade formation, Big Springs Ranch, Locality UM-K2-53, SE. ¼ Sec. 23, T. 32 S., R. 29 W., Meade County, Kansas.

Diagnosis—A. shrew that is slightly larger than *Sorex taylori* and intermediate in size between *S. leahyi* and *S. dixonensis*. *Sorex sandersi* is distinguished from other species of *Sorex* by the shape of the canine and the premolar. The apex of the crown of the canine is close to the anterior edge of the premolar, as in *Microsorex* and *Notiosorex*. The shape of the condyle and posterointernal ramal fossa is like that of *Sorex*.

Description of holotype.—The lower jaw lacks the incisor. The labial side of the incisor extended farther posteriorly on the side of the jaw than in *Sorex obscurus*, and nearly on a line with the posterior edge of the premolar. The mental foramen is situated under the anterior edge of M_1 (Fig. 9). The shape of the canine is like that of *Microsorex*. The premolar lacks a posterior cingular cusp. M_3 has a well-developed talonid. The anteroposterior length of C-M_3 is 5.2 mm. The anteroposterior length of M_1-M_3 is 3.8 mm. *Sorex sandersi* is larger than either *S. cudahyensis* Hibbard or *Microsorex pratensis* Hibbard, and smaller than *S.* (*Neosorex*) *lacustris* Hibbard, all of which occur in the younger Cudahy fauna of the area.

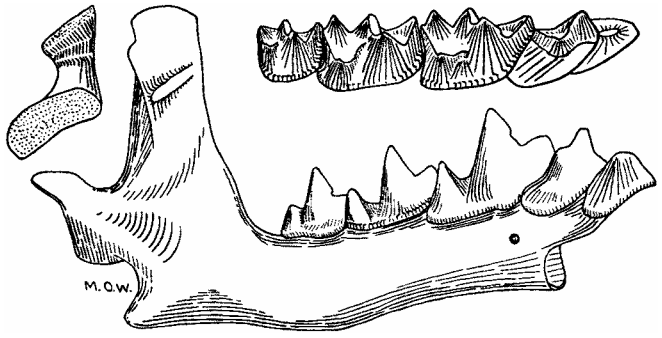

FIG. 9. *Sorex sandersi*, sp. nov., holotype, UMMP 31976, right lower jaw, C-M_3, lateral and occlusal views and posterior view of condyle, X 10

This species is named for Mr. Arthur D. Sanders, of Meade, Kansas, on whose ranch the fossil-bearing deposits occur. Mr. Sanders has helped in all possible ways to make our study of the region a success.

Order Carnivora

Family Mustelidae

Mustela sp.

In the collection from Locality UM-K2-53 is a left M_1, No. 31977, of a weasel. The tooth is larger than the M_1, No. 30243, of *Mustela rexroadensis* Hibbard.

Order Rodentia

Family Heteromyidae

Perognathus cf. *pearlettensis* Hibbard

(Fig. 10)

Parts of three lower jaws of a small pocket mouse are referred to this species. The best specimen is the left horizontal ramus, No. 31978, of an adult, with the incisor and P_4-M_3 (Fig. 10). The anteroposterior length of the tooth row is 2.85 mm. The second specimen, No. 31979, in which the ascending ramus and M_1 are missing, is from a younger individual. The anteroposterior length of P_4-M_3 is 3.2 mm. The third lower jaw, No. 31980, is broken just posterior to M_1.

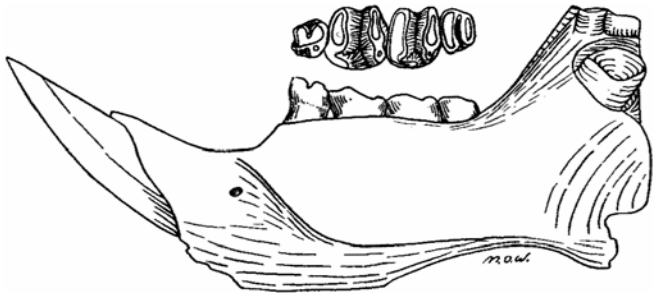

FIG. 10. *Perognathus* cf. *pearlettensis*, UMMP 31978, part of left lower jaw, P_4-M_3, lateral and occlusal views, X 8

Prodipodomys sp.

(Fig. 11*I*)

Three isolated teeth of a kangaroo rat were taken at Locality UM-K2-53. Two of the teeth are P_4 with roots. The third is an unworn molar with two well-developed roots. No. 32035 (Fig. 11*I*) is a left P_4 of a young adult slightly larger than *Prodipodomys rexroadensis* Hibbard.

There is no evidence of a wedge-shaped dentine tract along the sides of the teeth. The enamel base of the crown of the tooth in this kangaroo rat does not extend so far down on the labial and lingual sides of the roots as it does on the anterior and posterior sides.

Family Geomyidae

Geomys (*Parageomys*) *tobinensis* Hibbard

(Figs. 11 *B-H, J-K*)

A number of isolated teeth and the rostral parts of the skull of this medium-sized gopher were found. In the collection are three lower jaws, Nos. 31990, 31991, and 31992, that contain the incisor and P_4-M_3. The occlusal length, in millimeters, of P_4-M_3 in these jaws is: 5.8, 5.4, and 5.1. Several deciduous premolars were also found (Figs. 11 *B-H*).

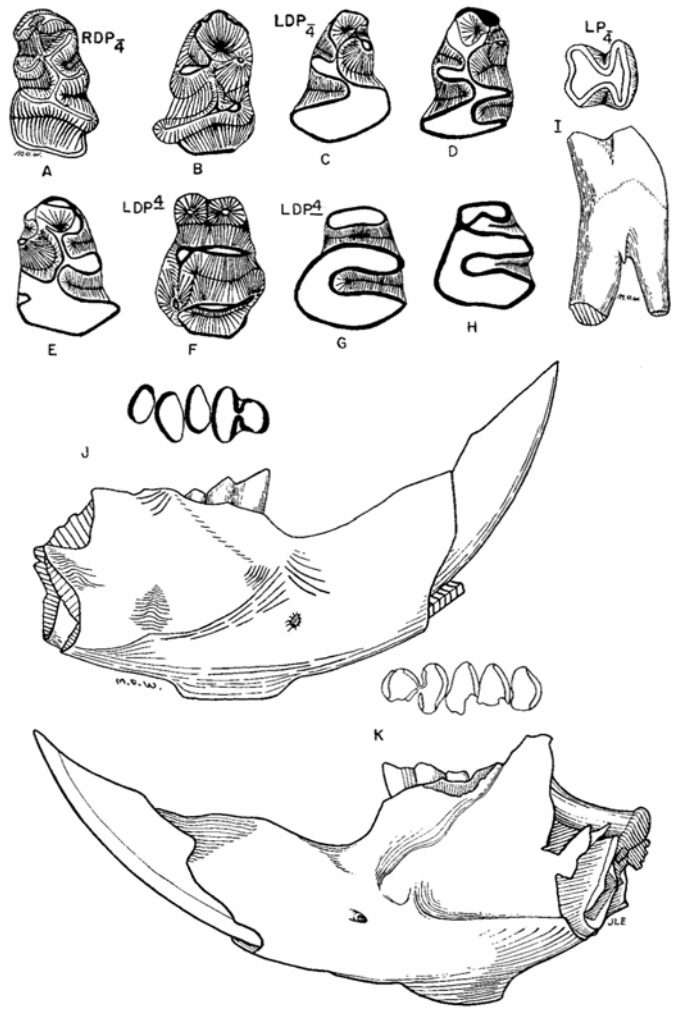

FIG. 11. Geomyidae. *A-H, Geomys: A*, UMMP 32042; *B-H*, UMMP 32352, occlusal views of deciduous premolars, X 10. *I*, *Prodipodomys* sp., UMMP 32035, LP_4, labial and occlusal views, X 8. *J-K*, *Geomys tobinensis: J*, UMMP 31991; *K*, UMMP 31990, lateral and occlusal views, X 4

Geomys tobinensis is distinguished from the Recent species of *G. bursarius* (Shaw) and *G. breviceps* Baird by the shallower, though prominent, pit between M_3 and the ascending ramus. The presence of the well-developed pit distinguishes it from *Nerterogeomys* (from the Rexroad fauna), in which the pit is nearly lacking. The pit is shallower and anteroposteriorly longer than in *G. quinni* McGrew. *Geomys tobinensis* is also distinguished from *G. quinni* by its smaller size and by the position of the dental foramen, which is closer to the posterior border of the pit, as in *G. breviceps*. In *G. quinni* this foramen is more posterior. In young adult specimens of *G. tobinensis* the enamel pattern of P_4 is not interrupted by the dentine tracts, which are present but which occur below the enamel of the occlusal surface of the tooth (Fig. 11*J*). The closed enamel pattern of P_4 has not been observed in *G. quinni* or in Recent specimens of *Geomys* of comparable age.

Discussion.—The genus *Parageomys* is considered to be of sub-generic rank for those species of *Geomys* that retain a closed enamel pattern on P_4 in young adult specimens. In the genotype of *P. tobinensis*, the dentine tracts are present on the sides of P_4. With a little wear, the tract on the labial side of the posterior loph would form a part of the occlusal surface. The tracts on the sides of the anterior loph are farther down on the sides of the tooth than those of the posterior loph.

Family Cricetidae

Genus *Bensonomys* Gazin

Bensonomys Gazin, 1942, U. S. Nat. Mus., Proc, 92 (3155): 489.

The following generic characters of *Bensonomys* were given by Gazin: "Near *Eligmodontia* with knoblike process at anterior extremity of masseteric crest on lower jaw, last lower cheek tooth reduced, and sulcus between capsular and coronoid processes. Removed from *Eligmodontia* in having deeper lower jaw, dorsally placed mental foramen closer to process at extremity of masseteric crest, more brachydont cheek teeth, notch on anterior lobe of first lower cheek tooth better developed, lower incisor more procumbent."

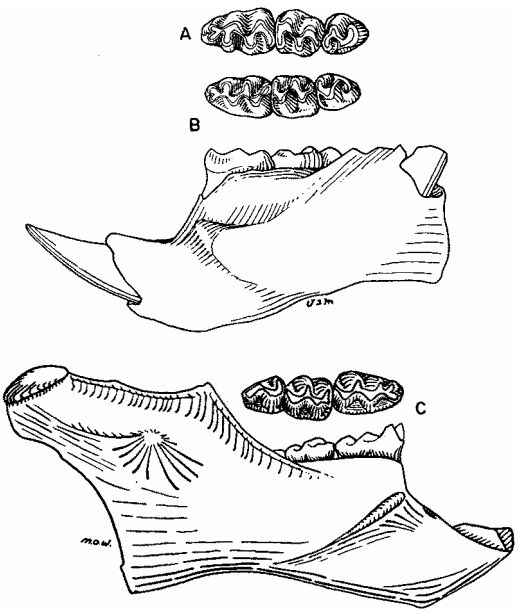

FIG. 12. *Bensonomys: A, B. eliasi*, KUMVP 4551, M_1-M_3, occlusal view; *B, B. arizonae* (Gidley), holotype, USNM 10503, lateral and occlusal views; *C, B. meadensis,* sp. nov., holotype, UMMP 31981, part of right lower jaw, M_1-M_3, lateral and occlusal views. All X 6

Bensonomys arizonae (Gidley)

(Fig. 12*B*)

This mouse is known from the holotype (Fig. 12*B*) and three other specimens from the Benson fauna of Arizona. The holotype is part of a left jaw (USNM 10503), with incisor and M_1-M_3. The anteroposterior length of M_1-M_3 is 3.62 mm. Specimen USNM 10504 is that of an older individual. M_1 is split transversely and filled with silt or calcite, which gives a slightly greater anteroposterior length to the tooth. The anteroposterior length of M_1-M_3 is 3.84 mm.

Bensonomys eliasi (Hibbard)

(Fig. 12*A*)

Peromyscus eliasi Hibbard, 1938, Kans. Acad. Sci., Trans., 40 (1937): 246-247, pl. 1, fig. 4.
Eligmodontia ? arizonae Gidley, Hibbard, 1941, Univ. Kans., Sci. Bull., 27 (6): 88.
Eligmodontia ? arizonae Gidley, Hibbard, 1941, Kans. Acad. Sci., Trans., 44: 283-284, pl. 2, fig. 6.
Bensonomys arizonae (Gidley), Hibbard and Riggs, 1949, Geol. Soc. Am., Bull., 60: 859.
Bensonomys arizonae (Gidley), Hibbard, 1950, Univ. Mich. Mus. Pal., Contrib., 8 (6): 148-149, pl. 1.

This species was first taken from the Rexroad formation at Locality 2, Meade County, Kansas. Later collecting at Localities 2 and 3 has furnished additional specimens, and these have been compared with the holotype and the paratype of *Bensonomys arizonae*. It was found that *B. eliasi* is a valid species. In both young adult and adult specimens the lower incisor of *B. eliasi* has a greater transverse width than the lower incisor of *B. arizonae*. M_1 in *B. eliasi* is more rectangular than the M_1 of *B. arizonae*, which tends to be triangular, with the apex of the triangle at the anteroconid. The reëntrant valleys of M_1 and M_2 in *B. eliasi* are broader than those of *B. arizonae*.

The holotype of *Peromyscus eliasi* (KUMVP 3941) is a fragmentary left lower jaw, with M_1-M_3, of a very old adult. The teeth are worn down to their bases, and only the outlines of a few of the reëntrant angles and cusps remain. The age of the animal is reflected in the anteroposterior length of M_1-M_3, which is 3.51 mm. The lower jaws of adult specimens with M_1-M_3 later recovered from Locality 3 agree with the holotype in the shape of the jaw and in the development and position of the masseteric ridge and the mental foramen. In specimen KUMVP 4551, which is that of a young adult (Fig. 12*A*), the anteroposterior length of M_1-M_3 is 3.8 mm. In the summer of 1953 a right lower jaw, No. 31099, with incisor and M_1-M_3, was taken at Locality 3 in association with a left lower jaw, No. 31098, that contained M_1-M_3. The anteroposterior lengths of M_1-M_3 in the two are 3.8 mm. and 3.85 mm.

Bensonomys meadensis, sp. nov.

(Fig. 12*C*)

Holotype—UMMP 31981, a right lower jaw with M_1-M_3, but with the incisor missing. Paratypes: No. 31982, part of a right lower jaw with incisor, M_1, and M_2; No. 31983, part of a left lower jaw with incisor and M_1.

Horizon and type locality.—Lower Pleistocene (Aftonian), Meade formation, Big Springs Ranch, Locality UM-K2-53, SE. ¼ Sec. 23, T. 32 S., R. 29 W., Meade County, Kansas.

Diagnosis.—A mouse smaller than *Bensonomys eliasi* and distinguished from *B. arizonae* by the position of the masseteric crest. The anterior end of the masseteric

crest in *B. meadensis* is more dorsal and more posterior from the mental foramen.

Description of holotype.—The lower jaw is that of a young adult mouse (Fig. 12*C*). The mental foramen is dorsal on the diastemal part of the jaw. The sulcus between the coronoid and the capsular process is very shallow compared to the deep sulcus in *Bensonomys eliasi*. The incisor has a narrower transverse width than in *B. eliasi*. The anteroconid of M_1, consisting of two distinct conulids, is divided equally by a deep groove that extends down the anterior face of the tooth. The protoconid and the anteroconid are connected by the cingulum, which forms a slight depression at the bases of the two cusps. The cusps of the teeth are alternate. The anteroposterior length of M_1-M_3 is 3.5 mm.

The dental pattern and the characters of the lower jaws of the paratypes agree with those of the holotype. In paratype No. 31982 the anteroposterior length of M_1-M_2 is 2.7 mm., and the transverse width of the incisor is 0.5 mm.

Sigmodon cf. *intermedins* Hibbard

(Fig. 13)

The cotton rat is a common element in the fauna. Three lower jaws containing M_1-M_3 and a number of fragmentary lower and upper dentitions were found. The lower jaws are the size of those of the cotton rat from the older Rexroad fauna and larger than those of *Sigmodon hilli* Hibbard from the Borchers (Yarmouth?) interglacial fauna. The specimens from the Sanders fauna appear to have slightly higher crowns on the teeth than specimens exhibiting comparable wear from the Rexroad fauna, but a better series of remains is needed for a comparative study of these rats from the two faunas. The anteroposterior length of M_1-M_3 in specimen No. 31996 (Fig. 13) is 5.42 mm. In two other specimens from Locality UM-K2-53 this length is 5.6 mm. and 5.65 mm. Specimen No. 31999, a right lower jaw from Locality UM-K1-53, with M_1-M_3, has an anteroposterior tooth length of 5.85 mm.

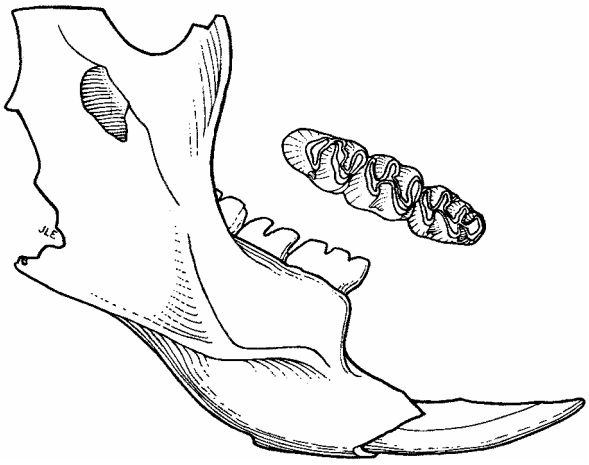

FIG. 13. *Sigmodon* cf. *intermedins*, UMMP 31996, right lower jaw, M_1-M_3; lateral and occlusal views, X 5

Pliophenacomys meadensis, sp. nov.

(Figs. 14 *A-I, K-M*)

Holotype.—UMMP 32019, a nearly complete left lower jaw, with only M_3 missing (Fig. 14*M*). Collected in the summer of 1954 by Claude W. Hibbard and party. Paratypes: No. 32020, part of a left lower jaw with the incisor; Nos. 32021 and 32022, parts of right lower jaws with M_1 and M_2; No. 32009, a left maxillary with M^1-M^2.

Horizon and type locality.—Lower Pleistocene (Aftonian), Meade formation, Big Springs Ranch, Locality UM-K2-53, SE. ¼ Sec. 23, T. 32 S., R. 29 W., Meade County, Kansas.

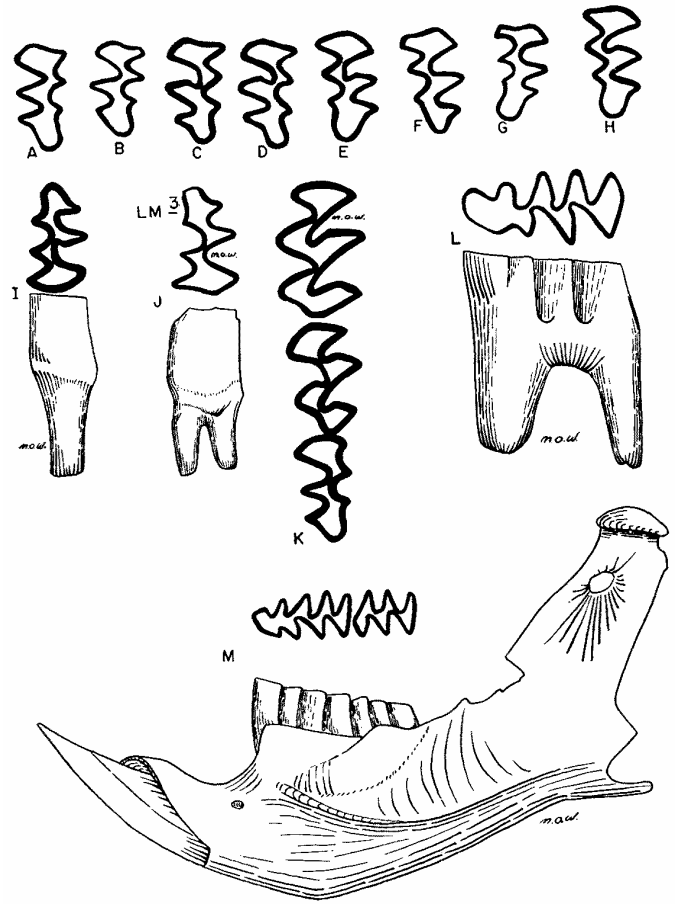

FIG. 14. *A-I*, *Pliophenacomys meadensis*, sp. nov., paratypes, UMMP 32008 a-h, M^3: *A-H*, occlusal views; *I*, anterior and occlusal views. *J, P. primaevus*, UMMP 32037, LM^3, anterior and occlusal views. *K, P. meadensis*, paratype, UMMP, 32009, M^1-M^3, occlusal view. *L, P. meadensis*, UMMP 32016, LM_1, labial and occlusal views. *M, P. meadensis*, holotype, UMMP 32019, left lower jaw, M_1-M_2, lateral and occlusal views. *A-L*, X 8; *M*, X 5

Diagnosis.—*Pliophenacomys meadensis* is larger than *P. primaevus* Hibbard and *P. parvus* (Wilson). The mental foramen is not so dorsal as in *P. primaevus*, and the capsular process for the base of the incisor on the coronoid process of the ascending ramus is better developed. The number of roots of M^2 varies from two to three; M^3 is two-rooted. In *P. primaevus* M^2 has three roots, and M^3 generally has two, although three roots are sometimes present (Fig. 14*J*). The posterior loop of M^3

in *P. meadensis* is more hook-shaped, like that of *P. parvus* (Wilson), than the posterior loop in *P. primaevus*, which is rounded.

Description of holotype.—The lower jaw is nearly complete. Its diastemal area is like that in *Phenacomys*, and the mental foramen is located in a slight depression on the labial side, as in *Phenacomys*. The position of the mental foramen distinguishes the lower jaw from those of *Ogmodontomys* and *Pliolemmus*; in these genera the mental foramen is more dorsal on the diastemal region. In *Pliophenacomys meadensis* there is no pit between M_2-M_3 and the ascending ramus. The base of the incisor ends above the dental foramen on the labial side of the jaw, in a prominent capsular process. Between the capsular and the coronoid process is a shallow sulcus. The development of the capsular process separates *Pliophenacomys* from all other known fossil and Recent voles in North America except *Pliolemmus*, in which this part of the jaw is unknown. The incisor passes from the lingual side to the labial side of the jaw posterior to M_2 and beneath the anterior root of M_3.

M_1 consists of a posterior loop, five alternating triangles, and an anterior loop. The posterior loop is closed off from the first triangle, and a narrow dentine tract connects the second, third, and fourth ones. The third and fourth triangles are confluent and open widely into the anterior loop. It has been observed that the fourth and fifth triangles are often confluent, a variation that occurs in *Pliophenacomys primaevus*, but not so frequently as in *P. meadensis*.

M_2 has a closed posterior loop and four alternating triangles. The first, second, and third triangles are connected by a narrow tract of dentine, and the third and fourth are confluent. The enamel of the teeth is uniform.

The alveolar length of M_1-M_3 is 6.5 mm. The occlusal length of M_1-M_2 is 4.6 mm. The greatest width of M_1 is 1.3 mm. The distance from the anterior part of the alveolus of the incisor to the posterior edge of the articular condyle is 16.2 mm.

Description of paratypes and associated teeth.—Nos. 32021 and 32022 are right lower jaws from individuals older than the holotype (the occlusal surface of the teeth becomes wider with wear). The anteroposterior length of M_1-M_2 in both of these paratypes is 4.7 mm.

There is considerable variation in the pattern of the anterior loop of M_1. In the teeth of immature animals and young adults the pattern is more complicated (Figs. 6 *A*-*F*). In immature teeth the posterior loop of M_1 is joined with the rest of the alternating triangles by a tract of dentine (Figs. 6 *A*-*C*). In adult teeth, as a rule, the first, second, and third triangles are closed in M_1, and the first and second are closed in M_2. In specimens from old adults M_1 has been worn to a pattern similar to what is found in *Ogmodontomys*; that is, M_1 consists of a posterior loop, three alternating triangles, generally closed, and an anterior loop.

I observed no variation in the occlusal pattern of M_2. Its inner triangles are like those of M_1 in that they are larger than the outer triangles.

M_3 consists of a posterior loop and four alternating triangles. The first and second are nearly closed, and the third and fourth are broadly confluent. The outer triangles are reduced and much smaller than the inner ones. The lower molars have two roots.

Paratype No. 32009, the left maxillary, is that of an adult vole. The occlusal length of M^1-M^3 is 6.15 mm. (Fig. 14*K*). M^1 consists of an anterior loop and four alternating triangles. This loop is connected with the first triangle by a very narrow tract of dentine. Triangles one and two are confluent. The third is closed off from the second. The third and fourth are connected by dentine. M^1 is three-rooted. The anterior root is the largest and supports the anterior loop. The third root is the smallest and supports the first inner triangle. The second root supports the posterior loop.

M_2, which may have either two or three roots, consists of an anterior loop and three alternating closed triangles. In teeth from immature animals and young adults, the roots were just beginning to develop and there is evidence only of a large anterior root and a small posterior one. As the anterior root lengthens with age, a deep vertical groove develops on its posterior face. The dentine on the inner side of the groove forms a ridge and grows to the anterointernal wall of the root canal, separating it into two canals. The smaller canal, or opening, is on the inner side of the tooth. Among nine teeth from young adults, eight had a broad anterior root with a deep groove on the posterior side, and two root canals. One specimen had an anterior root without the groove and with only a single canal opening. Teeth of five old adults were examined. Four of them had three roots.

The occlusal pattern of M^3 (Figs. 14 A-H) is similar to that in *Pliophenacomys primaevus* except that the posterior loop is more hook-shaped, rather than rounded as in *P. primaevus*. I did not find the variation in the occlusal pattern of this tooth that I found in M_1. In the teeth of immature animals or very young adults the anterior loop is rectangular (Figs. 14 *B, G*) as shown by Wilson (1933, p. 129, fig. 5a) for *P. parvus*. I did not examine the isolated teeth reported by Wilson, but it appears that the tooth figured by him is that of a young adult vole.

Discussion.—*Pliophenacomys meadensis* is closely related to *P. parvus* (Fig. 6*H*). If *P. primaevus* is ancestral to *P. meadensis*, then considerable time elapsed between the period when the Rexroad fauna lived in that area and the period when the Pleistocene Dixon and Sanders faunas lived. So far, there is no evidence to support the theory that *P. primaevus* is the immediate ancestor. In North America *Pliophenacomys* was probably widespread northward during the late Pliocene. A more advanced northern species could have given rise to *P. meadensis*, but *Pliophenacomys* is

too specialized (in the development of the capsular process for the base of the incisor) to be considered an ancestral stock for any of the living voles in North America. This vole is not known from the later Cudahy and Borchers faunas.

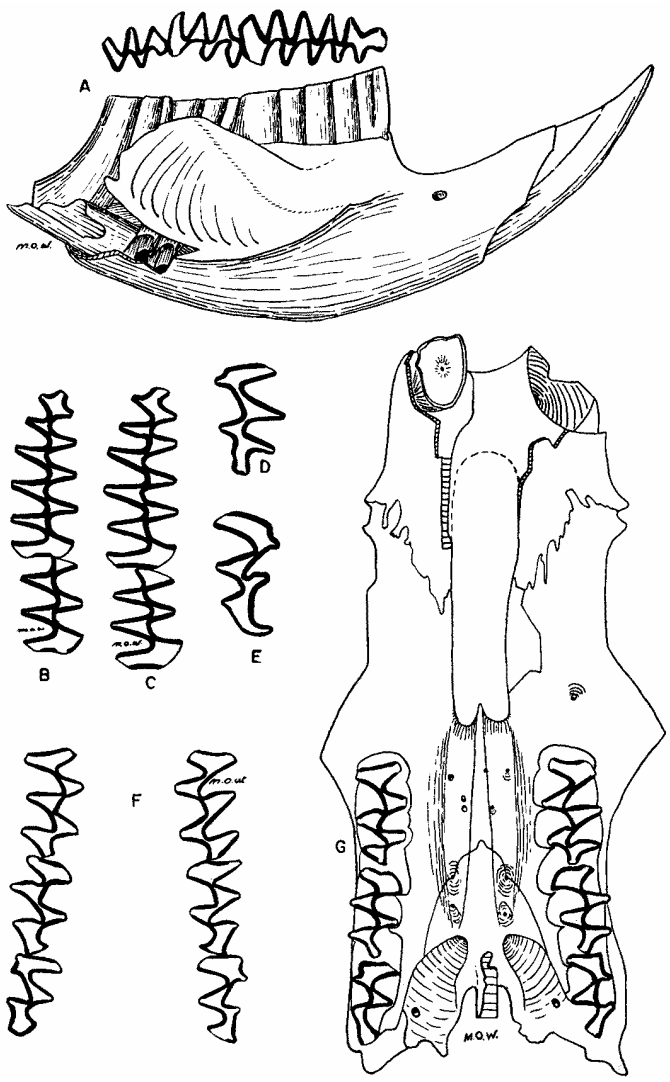

FIG. 15. *Pliolemmus antiquus: A*, UMMP 32025, part of right lower jaw, M_1-M_3, lateral and occlusal views; *B-C*, UMMP 32065 and 32064, RM_1-M_2, occlusal views; *D-E*, UMMP 32066, occlusal views of upper third molars; *F*, UMMP 32024, occlusal view of upper molars; *G*, UMMP 32023, palatal view. *A, F, G,* X 6; *B-E*, X 8

Pliolemmus antiquus Hibbard

(Figs. 15 *A, F, G*)

Generic characters.—A vole the size of *Microtus* (*Pedomys*) *ochrogaster* (Wagner), with an interrupted enamel pattern on upper and lower molars in old-adult stage of wear. The posterolateral palatine pits are large, and the median posterior palatine process is free from the median borders of the pits. M^3 consists of an anterior loop, a closed lingual triangle, and a posterior loop, rectangular to hourglass in shape. Cheek teeth are of the ever-growing type and without cement in the reëntrant angles. M_1 consists of a posterior loop, seven alternating triangles, and an anterior loop. M_2 is curved labially and rests against the side of the jaw.

Description of specimens.—No. 32023 is the palatal and diastemal region of the skull of an adult vole (Fig. 15*G*). The incisors are broken, leaving only the roots, and the anterior border of the anterior palatine foramina is missing. The foramina are broad and rectangular posteriorly, and were at least 4.7 mm. long. They end 0.5 mm. anterior to the alveoli of M^1. Whether the large size of the foramina is due in part to age is not known. Quay (1954, p. 39) found that the incisive (anteropalatine) foramina become larger with age in some species of micro tines and smaller in others. The lateral palatal grooves extend posteriorly from each of the foramen and end in a posterior palatal foramen opposite the posterior border of M_1. The posterolateral palatine pits are large and extend a short distance under the dorsal shelf of the palate. The median posterior palatine process is free from the median borders of the roof of the pits. The development of the pits and the "spine" is far greater than in any of the Recent genera of North American micro tines. *Synaptomys* is the only genus that has pits and a "spine" that resemble, in part, the specialized condition found in *Pliolemmus*.

M^1 consists of an anterior loop and four alternating closed triangles. In adult specimens—for example, No. 32023—the occlusal enamel pattern is interrupted as in old individuals of *Ondatra* and in some old individuals of *Dicrostonyx*. The enamel is lacking from both the labial and the lingual tips of the salient angles. The posterior triangle is flattened where it joins M^2, and there is no enamel along the flattened surface.

M^2 consists of an anterior loop and three alternating closed triangles. The tip of the outer salient angle of the anterior loop lacks enamel, just as does the tip of the first inner triangle. The posterior face of the third triangle is more flattened where it joins M^3 than is that of M^1 where it joins M^2. A faint salient angle has developed along the posterolingual border of the tooth.

The occlusal pattern of M^3 is distinct from that in other micro tines. The tooth consists of an anterior loop, a closed lingual triangle, and a large posterior loop, hourglass to rectangular in shape. In teeth of young adult specimens the posterior loop is slightly constricted near the center, which produces an occlusal pattern similar to the shape of an hourglass. The posterior face of M^3 lacks the enamel.

Specimen No. 32024 is the palate of a younger individual, with M^1-M^3 (Fig. 15*F*). Associated with it are the upper incisors, both strongly curved, and the left premaxillary. A marked depression is present just anterior to the border of the infraorbital foramen on the dorsolateral surface of the premaxillary. The enamel patterns of the teeth are not so interrupted as are those in the older specimen.

The lower jaws lack the angular and ascending ramus. It is not known how far the incisor extended beyond M_3. The diastemal area of the jaw is wider than in

Synaptomys cooperi and *Microius ochrogaster*. The mental foramen is anterior to the labial edge of M_1, and on the dorsal surface of the diastemal area instead of on the side. The masseteric ridge ends on a line with the anterior edge of M_1 (Fig. 15*A*). Between M_3 and the ascending ramus is a shallow pit. The incisor crosses over to the labial side of the jaw between M_2 and M_3, and this side is slightly enlarged because M_2 is greatly curved, with its base resting against the inner wall. M_3 is slightly displaced lingually, and a capsular process is developed on the inner side of the jaw.

In young specimens the alternating triangles of M_1 are connected by narrow tracts of dentine, but with wear these triangles become tightly closed (Figs. 15 *B, C*), and in adult specimens, where the tooth has worn down, the seventh alternating triangle opens into the anterior loop. The enamel pattern becomes interrupted in adult specimens.

M_2 consists of a posterior loop and four alternating triangles. It is strongly curved labially and rests against the side of the incisor.

M_3 is slightly displaced lingually and rests along the lingual side of the incisor. The tooth consists of a posterior loop and three alternating triangles, the second of which is considerably smaller than the other two.

Discussion.—-The generic name *Pliolemmus* is very misleading for this vole. Originally it was thought to be of Pliocene age, and, owing to the curvature and position of M_2, the fragmentary jaw of the holotype was considered to be that of a lemming.

Pliolemmus is a specialized vole. So far as is known, the genus did not survive the second glacial advance, for it has never been found among the Cudahy or later faunas of the region. The specialized characters point to a long evolution, before the first glaciation. Its ancestors should be sought in preglacial deposits of northern North America.

Family Zapodidae

Zapus sandersi, sp. nov.

(Fig. 16)

Holotype.—UMMP 31984, the anterior part of a left lower jaw of a jumping mouse, with M_1. Collected in the summer of 1954 by Claude W. Hibbard and party.

Horizon and type locality.—Lower Pleistocene (Aftonian), Meade formation, Big Springs Ranch, Locality UM-K2-53, SE. ¼ Sec. 23, T. 32 S., R. 29 W., Meade County, Kansas.

Diagnosis.—A jumping mouse near the size of *Zapus burti* Hibbard from the Borchers fauna. In *Z. sandersi*, M_1 has a broader external reëntrant angle. *Zapus sandersi* is smaller than *Z. rinkeri* Hibbard, from the Rexroad fauna, in which the anterior part of M_1 is broader (Hibbard, 1951a).

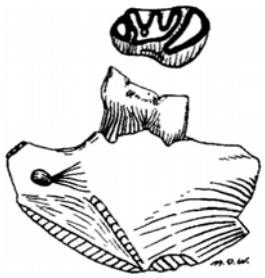

FIG. 16. *Zapus sandersi*, sp. nov., holotype, UMMP 31984, part of left lower jaw, M_1, lateral and occlusal views, X 8

Description of holotype.—The holotype is the anterior part of a lower jaw, with M_1. The incisor is missing and the jaw is broken just posterior to the anterior alveolus of M_2 (Fig. 16). The diastemal area is wider than that of *Zapus hudsonius* (Zimmerman), and the tooth has a slightly shorter crown. The masseteric crest ends anteriorly on a line with the anterior edge of M_1. The anteroposterior length of M_1 is 1.5 mm. The tooth has a narrower transverse width anteriorly than posteriorly, but it is not so narrow anteriorly as the M_1 of *Z. hudsonius*. The external reëntrant valley is much broader than that of *Z. burti*, although it is not so broad as that of *Z. rinkeri*, from the Pliocene. A cingulum, which is not present in *Z. hudsonius* and *Z. burti*, occurs along the base of the broad valley in *Z. sandersi*, where it is better developed than in *Z. rinkeri*.

This species is named for Mr. Jack T. Sanders, who lives on the Big Springs ranch and who made it possible for us to prospect the Spring Creek drainage outcrop areas for exposures containing this fauna.

Order Artiodactyla

Family Camelidae

A distal end of an ulna, No. 31359, of a medium-sized camel was taken from the quarry at Locality UM-K1-53. It was found in association with numerous mollusks, isolated rodent teeth, and other larger vertebrates, including fragments of a large mastodon tooth.

Order Perissodactyla

Family Equidae

Nannippus phlegon (Hay)

The only remains of this little horse taken from the Sanders faunal horizon in the Missler silt member above the *caliche* zone was the distal end of a metapodial. No. 31362, which was recovered from the quarry at Locality UM-K1-53. A badly shattered and weathered skull and lower jaws were found about one-half mile east of Locality UM-K2-53 on the south side of Spring Creek. Only one good tooth (No. 31350) was recovered; it was found in the Missler silt below the *caliche* zone seventeen feet below the Sanders faunal horizon.

Numerous mollusks are present in the Sanders faunal zone at this locality. Here the Meade formation is overlain by the sand and gravel of the Stump Arroyo member of the Crooked Creek formation.

Equus (*Plesippus*) *simplicidens* Cope

Part of a femur, No. 31363; astragali, Nos. 31361 and 31351, and a lower M_3, No. 31360, of this horse were taken at Locality UM-K1-53. The only specimen recovered at Locality UM-K2-53 was the distal end of a tibia.

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HIBBARD PLATE I

FIG. 1. Buried *caliche*, near top of Meade formation, SE. ¼ NW. ¼ Sec. 33, T. 32 S., R. 29 W., Meade County, Kansas

FIG. 2. Consolidated Meade gravels member resting on the Rexroad formation, Big Springs Ranch, Meade County, Kansas

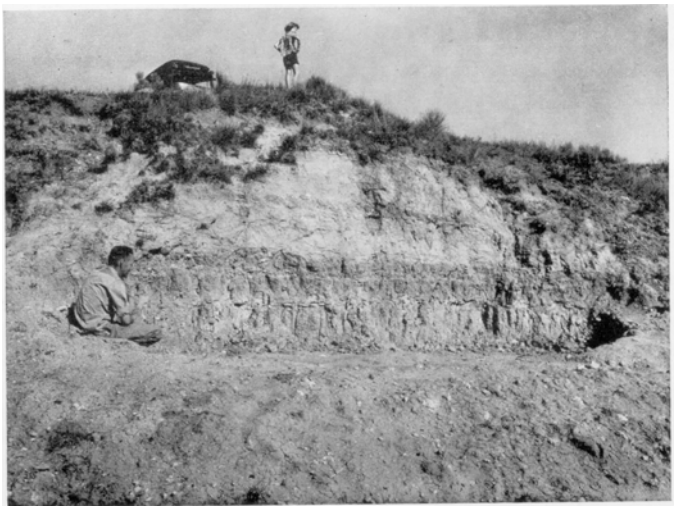

FIG. 1. Sanders fauna, Locality UM-K2-53, Big Springs Ranch, Meade County, Kansas

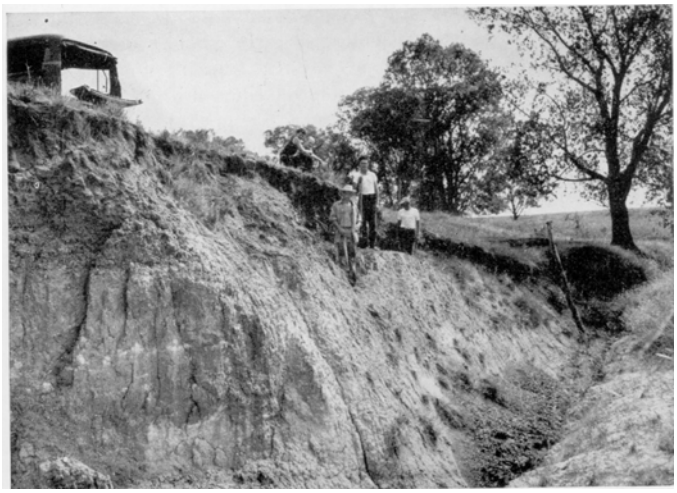

FIG. 2. Dixon-fauna locality, Dixon farm, Kingman County, Kansas

CRETACEOUS INVERTEBRATES OF THE AURORA LIMESTONE

LEWIS B. KELLUM

University of Michigan

THIS study of Cretaceous invertebrates is based on fossils collected during the summer of 1953 from the Aurora limestone in the Sierra de Tlahualilo, Coahuila, Mexico. Fossils were obtained at forty-nine localities scattered for fifteen miles along the western front of the range, which is situated on the boundary line between the states of Coahuila and Durango, about fifty-six miles northeast of the city of Torreon. The purpose of the study was to determine the age of the Aurora limestone in this area and to correlate it with sediments laid down elsewhere in Mexico and in Texas.

Large collections were obtained from a very persistent layer about four hundred feet below the top of the Aurora limestone. The distribution and elevation of the outcrop of this layer were mapped with plane table and alidade. Its geographic distribution in three separate areas is shown in Figure 1. In the Ojo de Agua and Guayule embayments at the south it crops out along canyons within the range. In the central part of the area it is present along the western flank of the Villareal uplift. Farther north it is widely distributed in the Gonzalez Basin, which is a synclinal depression between the Villareal uplift on the south and the Barro uplift on the north. These three areas of outcrop are separated by faults along the western margin of the range, north and south of the Villareal uplift.

All specimens are deposited in the Museum of Paleontology of the University of Michigan and bear catalogue numbers of the Museum. Both the field and the laboratory work were conducted under the auspices of the Museum of Paleontology.

PRESERVATION OF FOSSILS

The fossils, though abundant, are for the most part in a poor state of preservation, and the more fragile shells are badly weathered or incomplete. The poor condition of the specimens has limited the degree to which they could be identified.

The fossils were collected both in place and from the float, where they had weathered out and were loose on the surface. Those in place were better preserved, but more difficult to collect. The larger number—notably the brachiapods, gryphaeas, and pectens, as well as the echinoids—have retained their original shell material; the gastropods, cephalopods, and most of the pelecypod genera are preserved as casts. In some specimens there has been a calcite replacement of the shell.

FOSSIL LOCALITIES

All the localities listed below (see Fig. 1) are in the *Gryphaea mucronata* zone except numbers 21 and 50, which are in the *Lima wacoensis quadrangularis* zone. The directions “right” and “left” refer to the observer's right and left as he faces downstream.

1. On left side of tributary of Arroyo Guayule, about 1,200 feet southeast of Camp 531.
2. On right side of tributary of Arroyo Guayule, about ¼ mile upstream from Locality 1.
3. In saddle on divide between two tributaries of Arroyo Guayule, about 2,300 feet east of Camp 531.
4. On top of ridge on right side of tributary of Arroyo Guayule, upstream from and about 2,100 feet northeast of Camp 531.
5. Near top of ridge on left side of tributary of Arroyo Guayule, about 1,400 feet northeast of Camp 531.
6. On right side of canyon tributary to Arroyo Guayule and about 225 feet west of Locality 5.
7. On crest of ridge on south side of tributary to Arroyo Guayule, about 2,000 feet northeast of Camp 531.
8. On crest of ridge on south side of tributary to Arroyo Guayule, about ½ mile northeast of Camp 531.
9. About 100 feet east of Locality 8, on crest of same ridge on south side of tributary of Arroyo Guayule.
10. Near crest of ridge on left side of tributary of Arroyo Guayule, about 3,600 feet northeast of Camp 531.
11. Near crest of ridge overlooking canyons to the east which are tributary to Arroyo Guayule, about 4,600 feet northeast of Camp 531.
12. On side of next knob west of Locality 11, between tributaries of Arroyo Guayule, about 4,600 feet northeast of Camp 531.
13. On side of small outlying knob between tributaries of Arroyo Guayule, about 5,100 feet northeast of Camp 531.
14. On top of ridge between tributaries of Arroyo Guayule, about ¾ mile northeast of Camp 531.
15. On top of ridge between tributaries of Arroyo Guayule, about 800 feet west of Locality 14 and about ¾ mile northeast of Camp 531.
16. On right side of tributary of Arroyo Guayule, about 4,600 feet northwest of Camp 531.
17. On rim of hill on tributary of Arroyo Ojo de Agua, about 3,200 feet southeast of Camp 531.
18. On left side of canyon tributary to Arroyo Ojo de Agua, opposite Locality 17, about 3,800 feet south-southeast of Camp 531.
19. In the Guayule embayment on side of knoll carved by stream erosion, about 4,785 feet northeast of Camp 531.
20. At southeast corner of outlying hill of limestone, west of principal mountain front, about 1½ miles west-northwest of Camp 531. (The fauna, mostly ostreidae, is not diagnostic of age.)
21. On crest of hill on left side of canyon of Arroyo Guayule, about 900 feet east of Camp 531. (Zone of *Lima wacoensis quadrangularis*.)
22. On west flank of Villareal uplift, on right side of westward draining canyon, 3½ miles and about 130 feet northwest of Camp 531.
23. Outcrop along right side of bed of Arroyo Gonzalez, about 2,000 feet east of Camp 532.
24. On nose of hill on right side of mouth of Arroyo Gonzalez, about 760 feet northeast of Camp 532.
25. Outcrop along left side of bed of Arroyo Gonzalez, about 400 feet upstream from Locality 23 and about 2,350 feet southeast of Camp 532.
26. Outcrop bench along left side of tributary of Arroyo Gonzalez, 1½ miles and about 100 feet southeast of Camp 532.
27. On hillside on left of canyon tributary to Arroyo Gonzalez, about 100 feet above stream bed, 1½ miles and about 625 feet east-southeast of Camp 532.
28. Outcrop bench along right side of tributary of Arroyo Gonzalez, 1½ miles and about 925 feet southeast of Camp 532.
29. On crest of ridge, at western front of Sierra de Tlahualilo, west of Tlahualilo fault scarp, about 3,000 feet southeast of Camp 532.
30. On nose of ridge, at western front of Sierra de Tlahualilo, about 950 feet southeast of Locality 29 and about 3,960 feet southeast of Camp 532.
31. In northern part of Gonzalez Basin, on hillside at left of draw which drains about S. 45° W., approximately 5,100 feet northeast of Camp 532.
32. In saddle on top of ridge, on opposite side of draw from Locality 31, about 4,700 feet northeast of Camp 532.
33. About 530 feet southwest of Locality 32, on same ridge.
34. On left side of tributary of Arroyo Gonzalez, about 860 feet southwest of Locality 28, on opposite side of stream bed.
35. On right side of tributary of Arroyo Gonzalez, about 600 feet upstream from Locality 28.
36. On north side of Guayule embayment, on left side of canyon draining southwest-ward, about 5,000 feet northwest of Camp 531.
37. On west flank of Villareal uplift, on right side of stream bed of arroyo which drains westward, 2½ miles and about 1,900 feet northwest of Camp 531.
38. About 1,450 feet northeast of Camp 531, opposite Locality 6.
39. Same location as Locality 31, but fossils collected from float at somewhat lower stratigraphic position.
40. In northern part of Gonzalez Basin, about 400 feet southwest of Locality 33.
41. One mile and about 1,385 feet west-northwest of Camp 531, on limestone hill, 400 feet northeast of site of Candelilla camp.
42. Top of limestone ridge, about 1,650 feet northeast of Camp 531.
43. On left side of canyon of Arroyo Guayule, about 1,650 feet northeast of Camp 531.
44. On western front of Sierra de Tlahualilo, about 2,500 feet southeast of Camp 532.
45. On top of limestone hill, 1½ miles and about 230 feet southeast of Camp 532.
46. On south side of Gonzalez Basin, on top of ridge, 1½ miles and about 1,400 feet southeast of Camp 532.
47. On west side of Villareal uplift, 3 miles and about 400 feet northwest of Camp 531.
48. On nose of ridge at left side of mouth of canyon of Arroyo Gonzalez, about 800 feet east of Camp 532.
49. On right side of canyon tributary to Arroyo Ojo de Agua, about 3,430 feet south-southwest of Camp 531. (Zone of *Lima wacoensis quadrangularis*.)

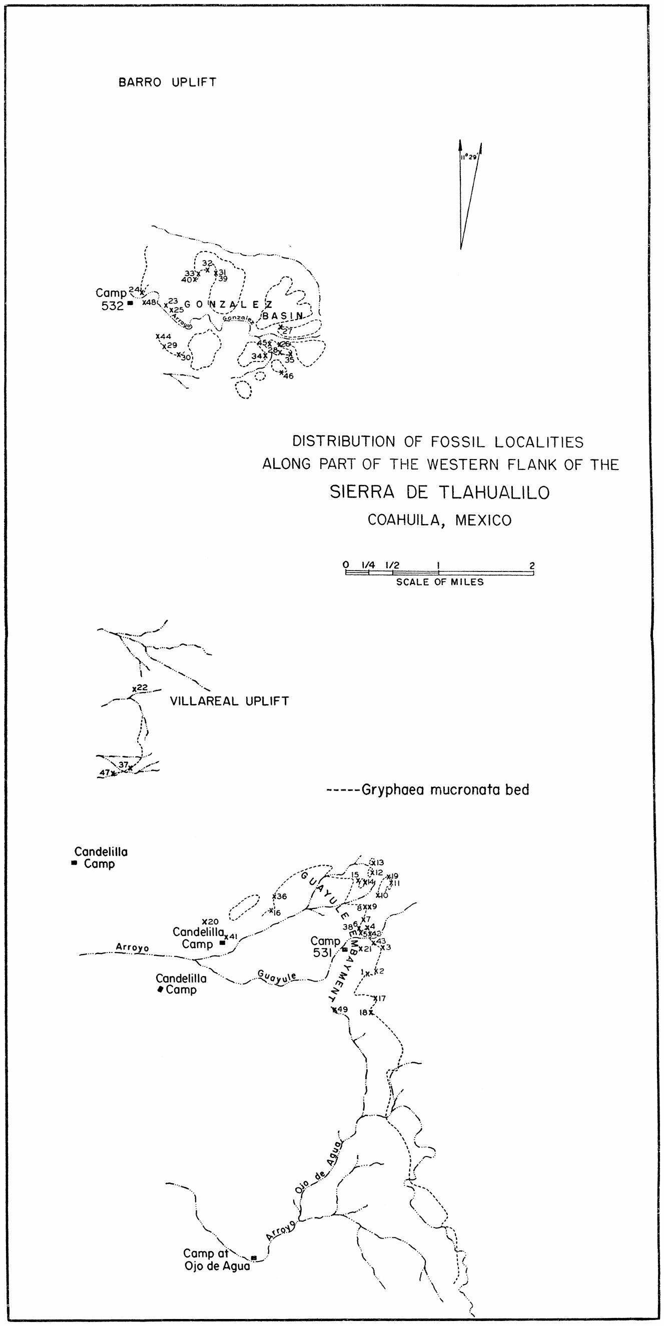

FIG. 1

THE FAUNA

The fauna of the Aurora limestone (see Table I) studied during the present investigation comprises sixty-nine species belonging to four phyla. The Mollusca constitute more than 75 per cent. The dominant element is the Pelecypoda, consisting of twenty-nine species. Gastropoda have the next largest representation, with nineteen species. Brachiopoda are abundant in number of individuals, but only one species is recognized. Echinoidea are represented by only a few individuals, but fifteen species have been identified. The remaining biologic groups, Cephalopoda and Anthozoa, are poorly represented, both in individuals and in species. The number of species in the fauna, their distribution in biologic groups, and the extent to which they have been identified are summarized in Table II.

TABLE I

DISTRIBUTION OF FAUNA OF THE AURORA LIMESTONE

Fossils	Localities																																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
COELENTERATA																																																	
Coral ?																	?												?																				
BRACHIOPODA																																																	
Kingena wacoensis (Roemer)	×	×	×	×	×		×	×	×	×	×	×	×		×	×	×	×	×	×		×	×	×	×	×			×		×	×		×	×		×	×				×			×		×		
PELECYPODA																																																	
Alectryonia carinata (Lamarck)	×																																								×								
Alectryonia (?) sp. cf. A. diluviana Linnaeus																																	×																
Gryphaea mucronata Gabb	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×				×	×	×	×	×	×	×	×	×	×	×	×	×		×	×		×		×	×	×	×	×			
Pteria pedernalis (Böse)													×																		×																		
Trigonia sp. cf. T. guadalupae Böse					×	×				×				×			×		×								×	×																					
Trigonia spp.																																								×		×				×			
Pecten indiduraensis Jones																				×																													
Pecten texanus Roemer	×	×	×	×	×	×	×	×		×	×	×	×		×	×	×	×	×		×	×	×	×	×	×			×		×	×			×	×	×	×		×		×			×	×			
Pecten spp.		×		×							×	×		×	×		×	×		×	×																								×				
Lima sp. cf. L. elpasensis Stanton																					×																												
Lima wacoensis quadrangularis Stanton																					×																												
Lima sp. aff. L. semilaevis Cragin																																																	×
Lima spp.																							×																						×				×
Pholadomya spp.			×			×															×																												
Pholadomya ? spp.					×																																												
Homomya sp. cf. H. alta Roemer																																													×				
Homomya sp.																					×																												
Cypricardia ? sp. aff. C. texanum Roemer	×																				×																												
Veniella coahuilaensis Jones				×																																													
Veniella sp. A																																											×						
Veniella sp. B				×													×																																
Eoradiolites sp. aff. E. davidsoni Hill																					×																												
Phacoides acute-lineolatus (Roemer)									×																																								
Cardium sp. A	×	×		×						×	×		×				×					×	×		×						×														×				
Cardium sp. B				×								×		×																	×			×															
Cardium sp. C																																×																	
Protocardia texana (Conrad)	×	×		×	×	×				×	×	×		×	×		×	×	×			×				×					×	×				×									×				
Protocardia sp. aff. P. multistriata Conrad																																																	
Cyprimeria texana (Roemer) ?		?																					?		?	?		?				?			?										?				
GASTROPODA																																																	
Pleurotomaria austinensis Shumard																					×																												
Pleurotomaria sp. A																	×																																
Pleurotomaria sp. B		×																				×																											
Turbo ? sp.																					×																												
Pseudomelania ? spp.									×								×																																
Natica sp.										×																																							
Amauropsis sp. cf. A. bulbiformis Sowerby				×																																													
Lunatia ? sp.			×																																														
Tylostoma kentense Stanton				×							×	×																							×							×			×	×	?		
Tylostoma ? sp.									×																																								
Turritella sp. aff. leonensis Conrad																					×																												
Turritella spp.																					×		×																										?
Nerinea ? sp.																				×																													
Anchura ? spp.				×								×																×																					
Aporrhais ? sp. aff. subfusiformis Stanton			×						×																														×										
Aporrhais sp.														×																																			
Aporrhais ? spp.				×	×					×							×				×																												
CEPHALOPODA																																																	
Cymatoceras hilli (Shattuck)			×	×							×			×									×		×	×				×	×		×		×	×		×							×	×			
Turrilites brazoensis Roemer																							×										×		×														
Turrilites spp.																						×			×										×														
Budaiceras mexicanum Böse																					×																												
ECHINOIDEA																																																	
Holectypus sp. A			×										×						×										×																				
Holectypus sp. B					×												×									×																	×				×		
Holectypus sp. C																																		×						×									
Holectypus sp. D				×												×																																	
Holectypus sp. E																																															×		
Holectypus spp.		×	×	×		×		×			×	×					×	×	×									×						×	×		×	×				×		×	×	×	×		
Enallaster sp.																																													×				
Hemiaster calvani Clark			×	?					?		?						×	×		?	?		×		×				×						?										?				
Hemiaster whitei (Clark)																				?			?			×														×									
Hemiaster sp.				×																																													
Enallaster texanus (Roemer)				×	×					?					?		?		?	?	?										×	×																?	
Holaster ? spp.				×			×									×	×																		×														

The fauna belongs to three distinct zones and to one locality, the stratigraphic position of which with reference to the others is not known. For convenience, the zones are designated by the name of the dominant fossil present. In descending order, stratigraphically, they are: (1) the *Lima wacoensis quadrangularis* zone; (2) the *Gryphaea mucronata* zone; and (3) the miliolid zone. The zones are of local significance only, but the fauna of each is distinct, and they are analyzed separately here.

LIMA WACOENSIS QUADRANGULARIS ZONE

The *Lima wacoensis quadrangularis* zone is in the upper part of the Aurora limestone, about four hundred feet above the *Gryphaea mucronata* zone. It was found only at localities 21 and 49 in the Guayule embayment. Eighteen species are recognized, ten of which are either identical with or similar to known species. Table III shows the geologic range of these related species as reported elsewhere in Mexico and Texas. Five of them are confined to the Washita group and two to the Fredericksburg group. The other three are long-ranging forms occurring in both the Washita and the Fredericksburg and, in one instance, extending downward into the Trinity group. The predominance of the five allied species confined to the Washita group indicates rather strongly that the *Lima wacoensis quadrangularis* zone is to be correlated with some part of the Washita group of the Comanchean series.

TABLE II

NUMBER OF FOSSIL SPECIES IDENTIFIED IN THE AURORA LIMESTONE AND DEGREE OF IDENTIFICATION

Degree of identification	Number of species identified						
	Anthozoa	Brachiopoda	Pelecypoda	Gastropoda	Cephalopoda	Echinoidea	Total
Identified with known species	..	1	9	2	3	3	18
Questionably identified with known species	..	..	1	1	..	3	5
Related to known species	..	..	4	2	..	..	6
Compared with known species	..	..	4	1	..	..	5
Generic identification only	..	..	11	13	1	9	34
Class identification only	1	..	..	..	..	..	1
Total	1	1	29	19	4	15	69

The distinctive character of the *Lima wacoensis quadrangularis* assemblage is shown by the fact that only four of its eighteen species occur also in the *Gryphaea mucronata* zone. *Lima wacoensis quadrangularis* itself (Pl. I, Fig. 3) is found only in the higher zone and is fairly common there. In Texas it is limited to the Washita group. The large gastropod *Pleurotomaria austinensis* Shumard (Pl. II), so common and widespread in the Washita of Texas, appears only in the *Lima wacoensis quadrangularis* zone in the small area of Coahuila covered by this investigation. A genus that appears to be of some stratigraphic value is *Pholadomya* (Pl. III, Fig. 5). *Pholadomya* and the closely related genus *Homomya* comprise an important element of the fauna at the top of the Aurora limestone. Although some species of these genera occur below, in the *Gryphaea mucronata* zone, they form a minor element there. Perhaps the most diagnostic fossil in this zone, so far as correlation goes, is *Budaiceras mexicanum* Böse (Pl. III, Figs. 1-2), whose known occurrence is in the Buda limestone. A single specimen of *Eoradiolites* sp. aff. *E. davidsoni* Hill (Pl. IV, Fig. 1), collected at Locality 21 in the Guayule embayment, although related to a form that occurs in the Edwards limestone of Texas, serves locally to tie this fauna to an assemblage found at the top of the Aurora limestone a few miles to the south, in the Ojo de Agua embayment. The fauna of this embayment is being studied in connection with stratigraphic investigations in that area.

TABLE III

GEOLOGIC RANGE OF FOSSILS RELATED TO SPECIES IN THE LIMA WACOENSIS QUADRANGULARIS ZONE OF THE AURORA LIMESTONE

Species	*Nearest allied species*	*Occurrence of allied species in Texas and Mexico*
Pecten texanus Roemer	P. texanus Roemer	Washita, Fredericksburg
Lima sp. cf. L. elpasensis Stanton	L. elpasensis Stanton	Duck Creek, Comanche Peak
Lima wacoensis quadrangularis Stanton	L. wacoensis quadrangularis Stanton	Washita
Cypricardia ? sp. aff. C. texanum Roemer	C. texanum Roemer	Fredericksburg
Eoradiolites sp. aff. E. davidsoni Hill	E. davidsoni Hill	Edwards
Pleurotomaria austinensis Shumard	P. austinensis Shumard	Georgetown, Duck Creek, Fort Worth
Turritella sp. aff. leonensis Conrad	T. leonensis Conrad	Washita
Budaiceras mexicanum Böse	B. mexicanum Böse	Buda
Hemiaster calvani Clark ?	H. calvani Clark	Washita
Enallaster texanus (Roemer) ?	E. texanus (Roemer)	Washita, Fredericksburg, Trinity

GRYPHAEA MUCRONATA ZONE

The *Gryphaea mucronata* zone is the most dependable stratigraphic marker in the Sierra de Tlahualilo. Its distribution is shown in Figure 1. It was traced for more than fifteen miles along the western side of the range, being associated with a characteristic lithologic sequence that facilitated its recognition along the canyons and flanks of the mountains. This sequence is illustrated in Plate V.

The *Gryphaea mucronata* zone is the most fossiferous horizon in the Sierra de Tlahualilo, both in number of megascopic specimens and in number of species. Along its outcrop there is usually a coquina one or two feet thick made up almost entirely of *Gryphaea mucronata*. Beneath it is a bench of yellowish-gray, granular limestone about four feet thick that is underlain by from three to five feet of rubbly, nodular limestone. Below this is a unit six or eight feet thick of thin, platy beds of limestone that characteristically weather into brownish slabs on the surface. This distinctive sequence is about fifty feet above a cliff-forming unit of thick benches of limestone that we mapped as the top of the middle Aurora limestone. Identification of the contact between the middle and the upper Aurora was everywhere confirmed by the presence of the coquina above the contact. The coquina appears to mark the base of the fossiliferous zone. In most places no fossils were found above or below the coquina, but occasionally the limestones above were sparsely fossiliferous through an interval of from ten to fifty feet. Specimens of *Cymatoceras hilli* (Shattuck) were present in a number of localities five to ten feet above the coquina, and specimens of *Turrilites brazoensis* were found at one place in the coquina and at several spots in the limestone above it.

Fifty-seven species have been recognized in the *Gryphaea mucronata* zone. Twenty-six of these were identified as identical with or similar to known species. These are shown in Table IV, together with the stratigraphic range of allied species in Texas or elsewhere in Mexico. Two are compared with species from the Upper Cretaceous (Eagle Ford or Austin Chalk). One is reported to occur in both the Eagle Ford formation and in the Washita group. Nine are allied to Washita species, six to Fredericksburg species, and five to species that are known to range through both the Washita and the Fredericksburg groups. Two are allied to species extending from the Eagle Ford to the Fredericksburg group and one to a species extending from the Washita to the Trinity group. The fact that more species of the *Gryphaea mucronata* zone are allied to those of the Washita group than to those of the Fredericksburg, that more allied species are known from strata higher than from strata lower than the Washita, and, finally, that the number that occur in both the Washita and the Fredericksburg groups is greater than the number restricted to the Fredericksburg but less than the number restricted to the Washita indicates a

somewhat greater affinity with the Washita group than with the Fredericksburg group.

TABLE IV

GEOLOGIC RANGE OF FOSSILS RELATED TO SPECIES IN THE GRYPHAEA MUCRONATA ZONE OF THE AURORA LIMESTONE

Species	*Nearest allied species*	*Occurrence of allied species in Texas and Mexico*
Kingena wacoensis (Roemer)	K. wacoensis (Roemer)	Washita, Fredericksburg, Trinity
Alectryonia carinata (Lamarck)	A. carinata (Lamarck)	Washita, Fredericksburg
Alectryonia (?) sp. cf. A. diluviana Linnaeus	A. diluviana Linnaeus	Austin Chalk
Gryphaea mucronata Gabb	G. mucronata Gabb	Fredericksburg
Pteria pedernalis (Böse)	P. pedernalis (Böse)	Fredericksburg, Indidura (members 2 and 3)
Trigonia sp. cf. T. guadalupae Böse	T. guadalupae (Böse)	Fredericksburg, Waco
Pecten indiduraensis Jones	P. indiduraensis Jones	Indidura (members 1, 2, and 3)
Pecten texanus Roemer	P. texanus Roemer	Washita, Fredericksburg
Lima sp. aff. L. semilaevis Cragin	L. semilaevis Cragin	Denton, Fort Worth
Homomya sp. cf. H. alta Roemer	H. alta Roemer	Fredericksburg
Cypricardia ? sp. aff. C. texanum Roemer	C. texanum Roemer	Fredericksburg
Veniella coahuilaensis Jones	V. coahuilaensis Jones	Indidura (members 2 and 3)
Phacoides acute-lineolatus (Roemer)	P. acute-lineolatus (Roemer)	Edwards
Protocardia texana (Conrad)	P. texana (Conrad)	Washita, Fredericksburg
Protocardia sp. aff. P. multistriata Conrad	P. multistriata Conrad	Weno, Pawpaw
Cyprimeria texana (Roemer) ?	C. texana (Roemer)	Fredericksburg
Amauropsis sp. cf. A. bulbiformis Sowerby	A. bulbiformis Sowerby	Benton
Tylostoma kentense Stanton	T. kentense Stanton	Washita
Aporrhais ? sp. aff. subfusiformis (Shumard)	A. subfusiformis (Shumard)	Washita, Comanche Peak
Cymatoceras hilli (Shattuck)	C. hilli (Shattuck)	Washita
Turrilites brazoensis Roemer	T. brazoensis Roemer	Main Street, Grayson
Holectypus sp. A	H. castilloi Cotteau	Washita
Holectypus sp. B	H. transpecosensis Cragin	Washita
Hemiaster calvani Clark	H. calvani Clark	Washita
Hemiaster whitei (Clark)	H. whitei (Clark)	Fredericksburg
Enallaster texanus (Roemer)	E. texanus (Roemer)	Washita, Fredericksburg, Trinity

The type locality of *Gryphaea mucronata* Gabb (Pl. VI, Figs. 1-3) is near Arivechi, Sonora, Mexico, where the species is associated with fossils definitely of Fredericksburg age. Stanton (1947, p. 28) evidently considered *G. mucronata* to be restricted to the Fredericksburg. Correlation Chart 10a prepared by Imlay (1944b) under the auspices of the Committee on Stratigraphy of the National Research Council indicates the range of *G. mucronata* to be middle Fredericksburg and upper Trinity. It is a widely variable species, which has often been confused with *G. graysonana* Stanton, from the upper Washita. Our species shows the same range of variation as specimens of *G. mucronata* from Arivechi and from the Goodland limestone of Tarrant County, Texas. It is a smaller, thinner, and narrower form than the figured specimens of *G. graysonana*.

The next most common species at this horizon is *Pecten texanus* Roemer. Although in Texas it ranges downward into the Fredericksburg, it is a characteristic Washita species. Stanton (1947, p. 46) states that it is "common at almost all exposures of the Washita throughout Texas. At Denison in Grayson County it is especially abundant in the Duck Creek limestone, Denton Clay, Fort Worth limestone and Grayson Marl. In the Austin section in Travis County it has a similar range, occurring in the Georgetown, Del Rio and Buda formations."

Cymatoceras hilli (Shattuck) (Pl. I, Fig. 4; Pl. III, Figs. 3-4; Pl. IV, Fig. 2; Pl. VI, Fig. 4) and *Turrilites brazoensis* Roemer (Pl. VII) are probably the best indicators of age because of their limited range elsewhere in Mexico and Texas. In regard to the distribution of *C. hilli*, Miller and Harris (1945, p. 6) say: ". . . insofar as we have been able to ascertain, this species is not known to occur outside of the Washita of central Texas; stratigraphically it ranges throughout all but the extremities of that group." They go on to mention its occurrence in the Buda, Fort Worth, Weno, and Main Street formations, and in the transition zone between the Main Street and Grayson formations.

Turrilites brazoensis is one of the most distinctive and widely distributed ammonites in the Washita group. Adkins (1928, p. 214) gives its range in Texas as Main Street and Grayson. Böse and Cavins (1927, p. 90) say: "A characteristic for the base of the Cenomanian is the occurrence of the large *Turrilites brazoensis* Roemer in the Main Street Beds."

Another group of invertebrates that is present nearly everywhere in the *Gryphaea mucronata* zone in the Sierra de Tlahualilo is the Echinoidea. Specimens of the large *Holectypus* (Pl. I, Figs. 1, 3) have been tentatively grouped by me into five species, based on the size, shape, and position of the periproct. These are almost certainly the forms that Böse (1910, p. 159) included in his *H. limites*. Cooke (1946) does not recognize *H. limites*, but places it in synonomy partly with *H. castilloi* Cotteau and partly with *H. transpecosensis* Cragin, both of which are confined to the Washita group. *Hemiaster calvani* Clark is another well-known Washita species that occurs at a number of localities in the *Gryphaea mucronata* zone.

One of the most abundant fossils associated with *Holectypus* and *Turrilites brazoensis* in this zone is the brachiopod *Kingena wacoensis* (Roemer). In Texas it is abundant in the Washita and rare in the Fredericksburg. With regard to the association of these forms Böse and Cavins (1927, p. 25) say: ". . . the base of the Cenomanian in Texas and northern Mexico is to be found in the uppermost Georgetown beds . . . . The limestones contain a great number of *Acanthoceras cunningtoni* Sharpe, a characteristic Cenomanian group, and *Turrilites brazoensis* Roemer. They are accompanied by a great number of *Holectypus limitis* Böse. A little lower there is a bed with numerous *Kingena wacoensis* Roemer. We consider these beds as the lower Cenomanian." At another place Böse (1927, p. 153) says: "In the Mexican region *Holectypus limitis* Böse, *Acanthoceras cunningtoni* Sharpe and *Turrilites brazoensis* Roemer occur in the same bed, and with them rather rare specimens of *Kingena wacoensis* Roemer, but the main layer of the latter species is below the bed with ammonites, which is not over three meters thick; the *Kingena* bed is a calcareous marl, and the ammonite bed above it is a blue gray soft shale. It may be well to include the *Kingena* bed in the Cenomanian but no characteristic ammonite so far has been found in it which would decide the question." Böse and Cavins (1927, p. 16) correlated the strata in northern Mexico containing this association of species with the Upper Georgetown beds of Texas and placed the Albian-Cenomanian boundary in the middle of the Georgetown formation.

MILIOLID ZONE

About one hundred feet stratigraphically below the *Gryphaea mucronata* zone is the top of a foraminiferal limestone unit that has a thickness of sixty-five feet along Cañon Guayule. This appears to be the miliolid limestone that is widely distributed over western Texas and Mexico. Although not every bed of the unit is composed of the tests of foraminifera, layers of miliolid limestone are well distributed through the entire thickness. This unit was observed elsewhere in the Sierra de Tlahualilo at several places on top of the range and on the west flank of the Villareal uplift.

In regard to the age and distribution of miliolid limestone, Imlay (1944a, p. 1095) says: "Miliolid-bearing limestone containing some rudistids and apparently of upper Albian to lower Cenomanian age occurs in the upper part of the El Abra limestone of the southern oil fields near Tuxpan, Veracruz and in the front ranges west of Tampico between Gomez Farias and Tamazunehale."

Adkins (1932, p. 347) has noted that miliolid limestone is a common Edwards fades in Texas. Concerning its stratigraphic position and distribution he says: "Miliolid limestone is practically confined to reefy Fredericksburg in southern Coahuila, southwards in the El Abra limestone of the Front Ranges, underground in the South Fields, along the mountain front west of Orizaba, to the Isthmus of Tehuantepec."

CONCLUSIONS

This survey of the fossils collected from the Aurora limestone in a small area along the western flank of the Sierra de Tlahualilo indicates that the upper part of the formation is correlated with part of the Washita and Fredericksburg groups. In the Ojo de Agua embayment to the south, in the Sierra de Tlahualilo, I have collected *Exogyra arietina* Roemer from strata resting on top of the Aurora limestone. Since *E. arietina* is characteristic of the Del Rio clay (upper Washita) in Texas, its presence supports a correlation of the top of the Aurora with the upper part of the Georgetown limestone. The zone of *Gryphaea mucronata*, which is also Washita, would likewise be correlated with part of the Georgetown limestone of Texas, since that is the lowest formation of the group in the western part of the state. The middle of the Aurora, which contains the miliolid member, is certainly to be correlated with the upper part of the Fredericksburg group.

ACKNOWLEDGMENTS

I am indebted to the Executive Board of the Horace H. Rackham School of Graduate Studies of the University of Michigan and to the Executive Committee of the Michigan Memorial-Phoenix Project for grants made in November and December 1952 in support of this investigation (Faculty Research Fund Project No. 874 and Michigan Memorial-Phoenix Project No. 62) and others. The present study is part of a larger research program which was supported by a grant from the Geological Society of America and a previous grant made by the Board of Governors of the Horace H. Rackham School of Graduate Studies (G.S.A. Project 386-41 and University of Michigan Research Project No. 115).

Assistance in the field was provided by Robert M. Linsley, of Traverse City, Michigan, then a graduate student in geology at the University of Michigan. Pedro Ayala, of Cordova ejido, near Tlahualilo, Durango, served as guide. His knowledge of the mountains, his resourcefulness in the field, and his advice in hiring native personnel were of inestimable value. Cornelio Gomez, of Valencia ejido, acted as field assistant; Modesto Barboza and Camillo Ramirez, of Cordova, were the camp cooks and contributed much to the comfort and efficiency of the camps and of the field trips.

I wish also to express my appreciation for the help rendered by Mr. Walter Ohlendorf, of Lerdo, Durango, and his wife, Sheila Ohlendorf, who repeatedly made the facilities of their home available to me. To Mr. Celzo E. Gonzalez, of Torreon, I owe much for his cooperation, advice, and hospitality. Mrs. J. H. Vaughan, of Tlahualilo, elicited the gratitude and appreciation of the Michigan field party by her help in establishing their credit locally and by her welcome and entertainment whenever they were in town.

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EXPLANATION OF PLATE I

(All figures natural size.)

Holectypus sp.

FIG. 1. Aboral view, showing ambulacral and interambulacral plates. Specimen No. 32387, Locality No. 28 (*Gryphaea mucronata* zone)

FIG. 2. Side view of same specimen as in Figure 1, showing elevation of aboral surface

Lima wacoensis quadrangularis Stanton

FIG. 3. Right valve of cast, showing the characteristic ribbing, prominent beak, and nearly 90° angle between the dorsal and the anterior margins. Specimen No. 32388, Locality No. 21 (*Lima wacoensis quadrangularis* zone)

Cymatoceras hilli (Shattuck)

FIG. 4. Ventral view, showing rounded venter and sculpture of impressed lines. Specimen No. 32389, Locality No. 35 (*Gryphaea mucronata* zone)

EXPLANATION OF PLATE II

(All figures natural size.)

Pleurotomaria austinensis Shumard

FIG. 1. Umbilical view, showing sculpture of revolving lines. Specimen No. 32390 Locality No. 21 (*Lima wacoensis quadrangularis* zone)

FIG. 2. Apertural view of same specimen as in Figure 1, showing elevation and profile of oral surface

FIG. 3. Top view of same specimen as in Figure 1, showing coiling

EXPLANATION OF PLATE III

(All figures natural size.)

Budaiceras mexicanum Böse

FIG. 1. Ventral view, showing breadth of the test and profile of the venter. Specimen No. 32392, Locality No. 21 (*Lima wacoensis quadrangularis* zone)

FIG. 2. Umbilical view of same specimen as in Figure I, showing broad, low, curved ribs on the flank

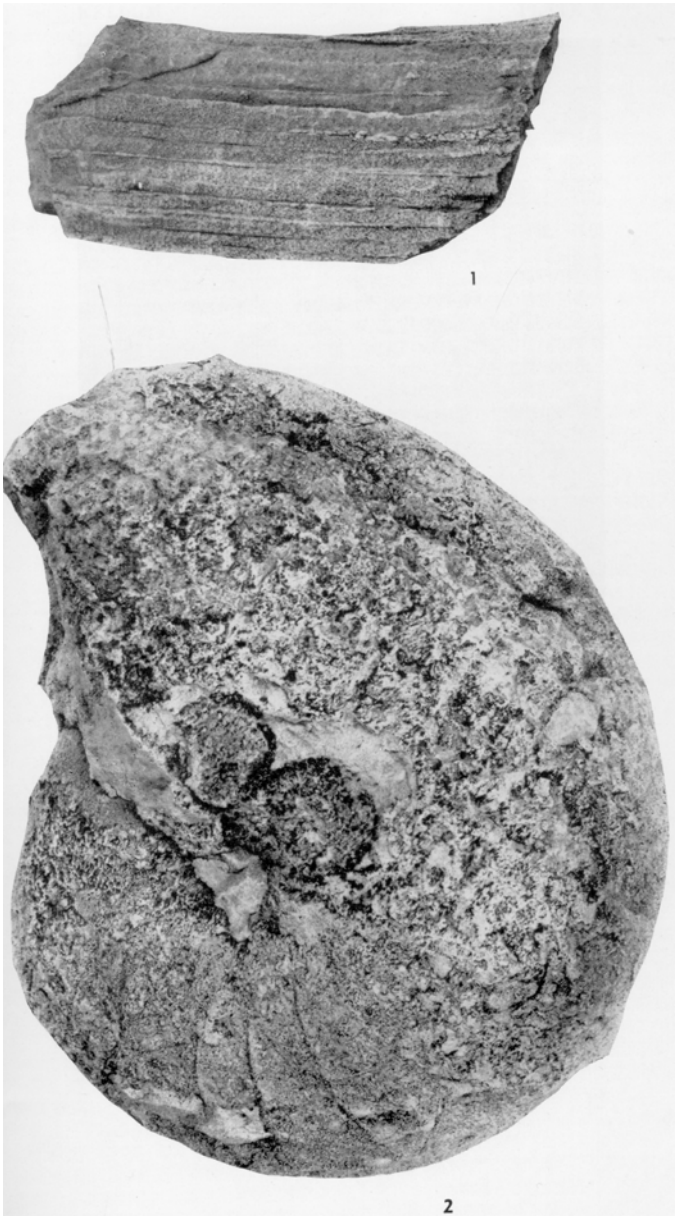
Cymatoceras hilli (Shattuck)

FIG. 3. Apertural view, showing breadth of the test and profile of the venter on inner and outer whorls. Specimen No. 32391, Locality No. 35 (*Gryphaea mucronata* zone)

FIG. 4. Ventral view of same specimen as in Figure 1, showing sutures crossing the venter

Pholadomya sp.

FIG. 5. Side view of outer surface of left valve of cast, showing low beaks, marginal contour, and sculpture of concentric elevated lines. Specimen No. 32393, Locality No. 21 (*Lima wacoensis quadrangularis* zone)



EXPLANATION OF PLATE IV

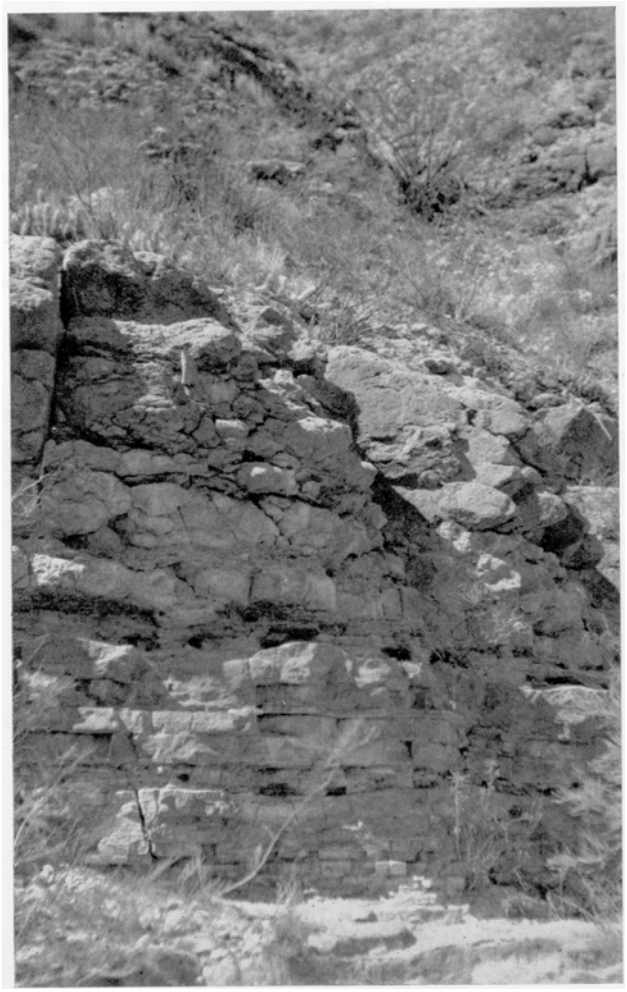
(All figures natural size.)

Eoradiolites sp. aff. *E. davidsoni* Hill

FIG. 1. Side view of fragment of right valve of cast, showing laminations. Specimen No. 32394, Locality No. 21 (*Lima wacoensis quadrangularis* zone)

Cymatoceras hilli (Shattuck)

FIG. 2. Umbilical view, showing sutures. Specimen No. 32391, Locality No. 35 (*Gryphaea mucronata* zone)



Outcrop of *Gryphaea mucronata* zone at Locality 23, showing characteristic lithologic succession below the coquina at the top of the bench

EXPLANATION OF PLATE VI

(All figures natural size.)

Gryphaea mucronata Gabb

FIG. 1. Anterior view of left valve, showing curvature of beak and depth of valve. Specimen No. 32395, Locality No. 25 (*Gryphaea mucronata* zone)

FIG. 2. Inner side view of left valve of same specimen as in Figure 1, showing curvature of beak

FIG. 3. Outer side view of left valve of same specimen as in Figure 1, showing radial groove and width of valve

Cymatoceras hilli (Shattuck)

FIG. 4. Umbilical view, showing sculpture of radiating impressed lines. Specimen No. 32389, Locality No. 35 (*Gryphaea mucronata* zone)

EXPLANATION OF PLATE VII

(Figure natural size.)

Turrilites brazoensis Roemer

Ventral view, showing spiral coiling and arrangement of nodes near the shoulders. Specimen No. 82396, Locality No. 35 (*Gryphaea mucronata* zone)

SOME UNUSUAL PRE-CAMBRIAN EXPOSURES IN ONTARIO

DEAN B. McLAUGHLIN

University of Michigan

THE exposures here described were noted during a reconnaissance of northern Ontario. They are placed on record at this time, in spite of the incompleteness of study, because they exhibit features of special interest and because it is unlikely that I shall have opportunity to study them further.

STRATIGRAPHY

The general stratigraphic sequence in northern Ontario can be summarized as follows:

Keweenawan:	Olivine diabase dikes
Cobalt:	Boulder conglomerate, graywacke, quartzite
Great unconformity	
Matachewan:	Quartz diabase dikes
Algoman:	Granitic intrusives
Haileyburian:	Basic intrusives; serpentine
Timiskaming:	Conglomerate, graywacke, arkose, quartzite, slate (volcanics in Kirkland Lake area)
Unconformity	
Keewatin:	Hoyle sediments: graywacke and slate Acid lavas and pyroclastics; quartz porphyry dikes and stocks Basic volcanics; iron formation
Pre-Keewatin (?):	Graywackes and slates in Lightning River belt

Perhaps more than one pre-Timiskaming sedimentary group has been included under the name “Hoyle.” Formerly these sediments were mapped as Timiskaming in the Porcupine area, but recognition of the Keewatin-Timiskaming unconformity required their inclusion in the Keewatin.

KEEWATIN-TIMISKAMING UNCONFORMITY AT PORCUPINE

Timiskaming sediments in the Porcupine area overlie Keewatin volcanics unconformably in the north limb of a syncline whose south limb is faulted out. Only gradually did the great magnitude of the unconformity gain recognition. The issue was confused by the Hoyle sediments, which so closely resemble the Timiskaming slates and graywackes that they were mapped as Timiskaming for a number of years. An unconformity between Timiskaming sediments and Keewatin lavas was suspected (Burrows 1915, p. 6) as early as 1915. In 1925, Burrows (1925, p. 26) described the angular unconformity between Timiskaming sediments and

Keewatin basic volcanics, but he still mapped the Hoyle sediments as Timiskaming. Finally, Hurst (1936, p. 452) recognized the thick Hoyle series and pointed out an angular unconformity between these beds and the overlying Timiskaming. Published references to this important exposure are very scant. No printed report was issued to accompany the most recent detailed map of the area (Ontario Department of Mines, 1938).

The contact is more spectacular than one might expect from Hurst's brief description. The exposure is on a broad knoll on the line between the sections 1 of concessions III and IV, Tisdale Township, one mile north of South Porcupine and about four miles east of Timmins. It is reached from the road along the eastern township line by walking west some three hundred yards on an obscure trail along the concession line.

The unconformity can be traced southwesterly for a few hundred yards. Keewatin graywackes lie to the northwest, Timiskaming conglomerate to the southeast. The Keewatin is well bedded, with strike N. 70° W., dip 65° NE. No cross-bedding was found, but excellent grain gradation shows that tops of beds are southward (overturned). The contact with the Timiskaming strikes N. 70° E., beveling a great thickness of Keewatin. The dip of the Timiskaming is almost vertical, but not precisely defined, since only rude bedding appears in the conglomerate. Before deposition of the Timiskaming, the Keewatin must have dipped about 45° SW.

The discordance is clearly visible at many places, even where the contact is covered. If no actual contact were visible, it would still hardly be possible to postulate a fault, for there are no indications of shearing or crumpling. Apparently the rocks behaved as a rigid mass and were tilted bodily to their present attitude. On the crest of the knoll, at and for several yards north of the concession line, the contact is perfectly exposed (PI. I). It is slightly irregular, some Keewatin rocks projecting southward into the conglomerate for possibly a foot beyond the straight line that most nearly defines the contact. An occasional hollow in the Keewatin is filled by conglomerate to a foot or so north of the average trace. Plate I displays the most irregular part of the exposed contact. On the whole, it is remarkably straight for many yards. The Keewatin rocks appear fresh and unweathered right up to the contact, and there is no regolith between them and the conglomerate.

The Timiskaming conglomerate here is about one hundred feet thick and contains closely packed cobbles and boulders up to about a foot in diameter. Many of these are of porphyry, but other Keewatin types occur, with basic volcanics minor, in spite of their strong development in the district. No granite cobbles were seen. The attitude of the Timiskaming is best shown by a large exposure of graywacke one-half mile east of the unconformity. There the strike is practically parallel to the unconformity, and the beds dip 80° NW., with tops south.

The exposure described by Burrows (1925, p. 26), where the Timiskaming truncates basic lavas, is about one mile northeast of the sedimentary contact. The lavas have tops south and strike nearly parallel to the graywacke at the unconformity. Here too the discordance is about 45°. Clearly the Keewatin rocks were strongly tilted and eroded before Timiskaming sedimentation began.

The Keewatin graywackes are noteworthy for their uniform bedding and lack of coarse elastics. They closely resemble certain rocks called Couchiching in Gorham Township, north of Port Arthur (Macdonald, 1941, p. 4), as well as the thick Seine series (formerly called Couchiching) along the Atikokan road in western Ontario (my personal observation). The weight of evidence in regard to the Seine series favors a post-Keewatin age (Merritt, 1934). Correlation on the basis of lithologic resemblance would be meaningless, but it is rather remarkable that, wherever a thick sedimentary series has been recognized or suspected within or below the Keewatin, it is characterized by very uniform, graded bedding, practically complete lack of cross-bedding, and almost entire absence of coarse elastics. Whatever their ages, these sediments are probably geosynclinal deposits. In striking contrast, the typical Timiskaming series, though it contains similar graywackes and slates, has extensive arkosites and great lenticular conglomerates strongly suggestive of alluvial fan deposits in a region of mountainous relief.

SERPENTINE PEBBLES IN TIMISKAMING CONGLOMERATE

In the southwest corner of German Township, eighteen miles east of Timmins, a large body of Timiskaming quartzite and arkosite, with numerous bands of conglomerate, is exposed beside Provincial Highway 67A. The locality is on the north limb of the Porcupine syncline. The beds stand vertically and strike nearly due east. No appreciable shearing or squeezing was noted; apparently the rock acted as a massive, competent unit. Superposition of sand beds on lag gravel shows that tops of beds are southward. Cross-bedding suggests that the depositing current flowed from south to north.

Detail of part of the exposure is shown in Plate II. Pebbles in the conglomerate range from very small to over four inches in diameter. They are densely packed in some beds, while a sparse sprinkling of pebbles up to one inch in diameter is found in many of the arkose beds. The rock appears to have been a stream gravel, possibly part of an alluvial fan. The most common pebbles are of rhyolite, acid tuff, and feldspar porphyry. There are numerous one-quarter-inch quartz pebbles, a few large ones of quartzite and quartz, and occasional ones of white or gray chert. No granite pebbles were found, though especially searched for, nor were any unaltered basic volcanic pebbles noted. Of greatest interest are a number of pebbles of dark-green serpentine. Unlike the others, some of these pebbles are flat and rather schistose.

Possible sources of serpentine pebbles are found only two to three miles south and southwest, on the peninsulas of Night Hawk Lake. In the report on that area (Hopkins, 1925), the serpentine was considered to be of Keewatin age, which is consistent with the presence of pebbles of serpentine in Timiskaming conglomerate. Sources in these locations are also consistent with the slight indication of direction of flow given by cross-bedding.

Burrows (1915, p. 26) had stated that some serpentines represent alteration from Keewatin volcanics and are much older than the large intrusive bodies. In the course of time, this distinction seems to have been lost sight of, and the tendency has been to call all serpentines Haileyburian (see, for example, the latest detailed map of the area, that issued by the Ontario Department of Mines, 1938). More recently, Dunbar (1948, p. 445) and Hogg (1950) have again indicated that the serpentines may be Keewatin, since they are not known to intrude the Timiskaming.

The pebbles in the conglomerate are proof that some of the serpentines are Keewatin. These particular pebbles are believed to represent altered basic volcanics, rather than original ultrabasic intrusives.

The literature on surrounding areas yielded little information on serpentine pebbles. Burrows (1925, p. 29) described Timiskaming conglomerate near the Pamour mine as containing fragments of "rusty-weathering lavas and serpentine." The only other mention was by Cooke (1919, p. 20), who noted some serpentine pebbles in Timiskaming (Kiask) conglomerate in Midlothian Township, about forty miles south of Porcupine. He showed that the conglomerate body resembled an alluvial fan and was apparently of very local derivation. Evidence was presented that the depositing stream flowed from south to north. Outcrops of serpentine were mapped by Cooke only two miles south of the Keewatin-Timiskaming contact. He assigned these to the Keewatin. In a more recent report on the same area (Marshall, 1947, p. 9), the peridotite and serpentine were called Haileyburian, and serpentine pebbles were not mentioned, though reference was made to pebbles of "altered greenstone."

In Beatty Township, in the Lightning River belt, some forty miles east of the Porcupine area, the ultrabasic rocks cut both volcanics and sediments. But in that area the sediments are older than the volcanics (Satterly and Armstrong, 1949, p. 10), hence the ultrabasic rocks could be pre-Timiskaming. Similar relations obtain farther east in the same district. However, Abraham (1951, p. 22) pointed out that in McElroy Township (seventy-five miles southeast of Porcupine) no serpentine pebbles occur in Timiskaming conglomerate, and serpentine does intrude Timiskaming sediments. In the entire region, this is the one clearly demonstrated example of Haileyburian serpentine.

Apparently the earlier workers were correct in assigning some serpentines to the Keewatin. Recent workers in the Porcupine area also recognize the possibility or probability of Keewatin serpentines. But, following the recognition of the Haileyburian intrusives (Miller and Knight, 1920), the tendency to fit the observations into an adopted classification has at times tended to obscure possible alternatives.

Contact of Gowganda Conglomerate on Algoman Granodiorite

On Provincial Highway 11, south of Latchford, excellent exposures of the Gowganda formation (Cobalt series) occur in road cuts. Some are the well-known boulder conglomerate that has been generally regarded as a probable tillite. Others are nearly level strata of finegrained, banded, dark-gray argillite. The banding suggests very thin varves. Topographic relations and the directions of gentle dips indicate that the argillite overlies the "tillite."

At 3.9 miles south of the Montreal River at Latchford, the "tillite" is in contact with underlying "Algoman" gray granodiorite. The rock was blasted when the highway was built or widened, and there are indications that the outcrop has caved or slid somewhat in the past few years. Since it is at the edge of the road, it may be in danger of destruction. Detail of part of the exposure is shown in Plate III.

The lowest exposed part of the granodiorite is massive and fresh. In the northern part of the exposure the granodiorite continues so right up to the contact with the overlying conglomerate. The top of the granodiorite here is approximately level and makes sharp contact with the conglomerate, which consists of subround cobbles and pebbles, mainly of pink granite, set rather thickly at random in a very dark graywacke matrix. The whole is thoroughly indurated, and there is no tendency to break around the pebbles. The contact is also tightly cemented, so that the rock breaks across it. One slab of the granodiorite, several inches long, is in the conglomerate a few inches above the contact.

Owing to the blasting and partial caving, perfectly continuous exposure of the contact is not visible, but a few yards farther south the character of the contact changes. The lowest granodiorite, as before, is fresh and massive. A few feet higher, it was evidently much fractured, either before or contemporaneously with the deposition of the conglomerate. The fragments of the breccia generally decrease in size upward. None shows any sign of weathering. The breaks are clean, and the original fit of the blocks is apparent throughout. The breccia has been shot through and thoroughly recemented with a dark graywacke-like material, identical with the matrix of the conglomerate. In a few places, an occasional small pebble of pink granite, like those in the conglomerate, is found in a crevice of the breccia. The whole is firmly indurated, so that there is no tendency to break along contacts.

In this part of the exposure the contact descends almost vertically for several feet; thus the conglomerate lies

south of brecciated granodiorite. Here, within a few inches of the vertical contact, a few fragments of the granodiorite were seen. They are thoroughly angular, with no sign of weathering, and probably have not moved more than a foot or so from their source. One of the most interesting features is a “dike” of conglomerate that passes through the granodiorite for several feet northward from this nearly vertical contact. It resembles the overlying conglomerate in every respect.

Miller (1913, p. 79) described contacts of the Gowganda with underlying rocks, but the general impression conveyed by his descriptions is that the basement complex was much weathered before deposition of the conglomerate. In the exposure here described, there is no suggestion whatever of pre-Cobalt weathering. It appears as if the fresh rock was shattered and immediately buried under the conglomerate, whose matrix seems to have behaved like a fluid, insinuating itself into the tiniest cracks of the broken granodiorite. The extreme induration of the contacts is possibly due to metamorphic action of neighboring diabase sills, which may have been eroded from directly above this exposure.

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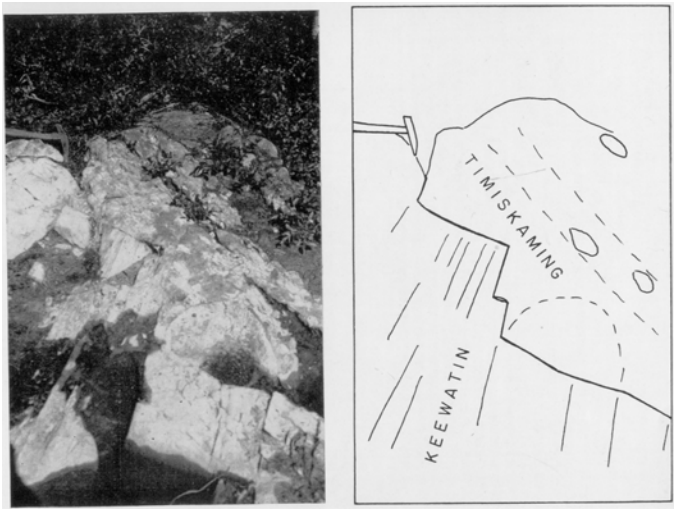
McLAUGHLIN PLATE I

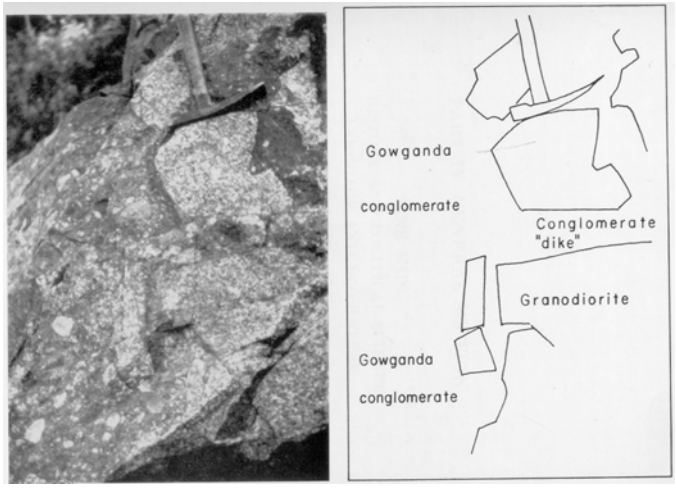


Keewatin-Timiskaming unconformity, four miles east of Timmins, Ontario. Photo taken looking a few degrees south of east. Bedding is visible in both formations. Tops of beds are southward (right) in both.

McLAUGHLIN PLATE II

Timiskaming quartzite and conglomerate, eighteen miles east of Timmins, Ontario. Photo taken looking west. Tops of beds are southward (left). The darkest pebbles are of serpentine.

McLAUGHLIN PLATE III



Contact of Gowganda conglomerate and Algoman granodiorite, four miles south of Latchford, Ontario.