

**GEOLOGY AND PALEONTOLOGY OF THE  
EARLY PLEISTOCENE (LATE BLANCAN) WHITE ROCK FAUNA  
FROM NORTH-CENTRAL KANSAS**

**Ralph E. Eshelman**

**1975**

*Claude W. Hibbard Memorial Volume 4*

CLAUDE W. HIBBARD MEMORIAL VOLUMES (1-5)

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and

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Peter G. Kimmel

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J. T. Wilson

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PAPERS ON PALEONTOLOGY NO. 13

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The Museum of Paleontology  
University of Michigan  
Ann Arbor, Michigan 48104  
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Edited by J.A. Dorr, Jr., and N.E. Friedland

APPRECIATION AND ACKNOWLEDGMENT IS EXPRESSED TO THE 1962 CLASS OF THE UNIVERSITY OF MICHIGAN FOR ESTABLISHING AN INSTITUTE OF SCIENCE AND TECHNOLOGY PUBLISHING FUND. THIS FUND AND A CONTRIBUTION BY DWIGHT W. TAYLOR HAVE AIDED IN THE PUBLICATION OF THIS WORK.

December 1, 1975



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## ABSTRACT

The late pre-Nebraskan (late Blancan) White Rock fauna was recovered from the ancestral Republican River paleovalley deposit (Belleville Formation) of north-central Kansas. Based on faunal content and delineation of this paleovalley, the Belleville Formation is in part a correlative of the Red Cloud sands and gravels of Nebraska to the northwest and the Holdrege, Fullerton, and Grand Island (in the sense of Lugin, 1935) formations of Nebraska to the northeast.

The diverse White Rock fauna consists of at least three mollusks, four ostracodes, one beetle, ten fish, six amphibians, 11 reptiles (*Sceloporus holmani*, new species), three birds, and 43 mammals [*Cynomys (Cynomys) hibbardi*, new species]. Based on morphological grade of evolution, the mammals of the White Rock fauna are post-Sand Draw local fauna (earliest Pleistocene) and pre-Borchers local fauna (Aftonian).

Comparison of probable environmental habitats and food habits between the White Rock fossil mammalian fauna and the modern mammalian fauna of the area shows that the White Rock fauna was more diverse than the modern fauna. The mammalian components of the White Rock paleoecosystem appear to be a good representation of the actual mammalian fauna of that time.

Collectively, the fauna suggests a climate with less extreme temperature and moisture fluctuations than now occur in north-central Kansas. Initial pre-Nebraskan glacial cooling could have allowed climatically incompatible elements of the White Rock fauna to live contemporaneously. Climatic deterioration was not sufficient to force southward taxa characteristic of more southern, warmer, and milder seasons.

THE WHITE ROCK fauna was discovered by R.L. Wilson of the Museum of Paleontology, University of Michigan, in the summer of 1966 in exposures resulting from the 1959 construction of the White Rock Canal in Republic County, Kansas (Figs. 1, 2). All of the material collected by Wilson was obtained from the early Pleistocene Belleville Formation, locality UM-K1-66. Claude W. Hibbard and Robert Carr returned to Wilson's locality in the summer of 1969 but were unable to locate Wilson's exact collecting site due to massive slumping of the canal walls after unusually heavy rains that spring. Apparently the original locality was buried during either the slumping or redredging of the canal. Hibbard and Carr did, however, process material from two additional localities in the Belleville Formation, UM-K3-69 and UM-K4-72. A volcanic ash was also discovered stratigraphically above the Belleville Formation in a ravine approximately 0.3 km to the W. This locality was designated the ash locality, UM-K4-69.

Extensive collecting and washing of bone-bearing horizons in the Belleville Formation in Republic County during the summers of 1972 and 1973 resulted in six additional University of Michigan collecting localities, UM-K5-72-UM-K9-72. Material was also recovered from three University of Kansas collecting localities, KU-Rep. Co. Locs. 1, 3, and 4. From these localities a diverse late Blancan fauna, which includes mollusks, ostracodes, fish, amphibians, reptiles, birds, and mammals, was recovered.

The main objectives of this study are: (1) to describe the White Rock fauna, (2) to interpret its paleoenvironment, (3) to correlate the White Rock fauna with faunas from chronologically equivalent deposits of the Great Plains, (4) to review the Pleistocene stratigraphy of the area, (5) to establish more precisely the age of the Belleville Formation, (6) to interpret the sedimentological history of the ancestral Republican River paleovalley, and (7) to attempt a reconstruction of the mammalian paleoecosystem of the White Rock fauna and compare it with the ecosystem now present in Republic County.

Except for a few specimens at the University of Kansas, all fossil vertebrates reported in this study are housed in the Museum of Paleontology, University of Michigan. The fossil mollusks are retained in the Museum of Zoology, University of Michigan mollusk collections. The ostracodes are kept by E.D. Gutentag of the U.S. Geological Survey. The pollen samples are retained by Steven A. Hall.

Abbreviations used in this report to designate institutional collections and localities are:

AMNH - American Museum of Natural History  
BEG - Bureau of Economic Geology, the University of Texas, Austin  
F:AM - Frick Collections, American Museum of Natural History  
KU - Kansas University  
KUMNH - Kansas University Museum of Natural History  
LACM (CIT) - California Institute of Technology, Pasadena, now housed in the Natural History Museum of Los Angeles County  
UA - University of Alaska  
UM-K - University of Michigan locality in Kansas  
UMMP V - University of Michigan Museum of Paleontology, Vertebrates  
UMMZ - University of Michigan Museum of Zoology  
UNSM - University of Nebraska State Museum  
USNM - United States National Museum (National Museum of Natural History, Smithsonian Institution)  
V - Short for UMMP V

## METHODS

Microfossils were wet washed, dried, and hand picked from the matrix residue using basically the techniques set forth by Hibbard (1949) and McKenna (1962). Ostracodes were recovered by wet washing fine-grained matrix samples with a screen of carburetor cloth. After drying, the ostracodes were picked from the matrix with a wet-haired brush under a microscope.

Thicknesses of stratigraphic sections were determined by Locke Level measurements, starting at lowest point and proceeding to highest elevation. Elevation determinations were obtained from engineering blueprints of the 1959 White Rock Extension Canal. Elevations established by this method usually matched within one contour interval with United States Geological Survey Kansas Quadrangles, 7.5 minute series (topographic).

Measurements of Recent and fossil specimens were made with a standard binocular microscope equipped with a calibrated 10X ocular micrometer. Measurements were estimated to the nearest 0.01 mm and rounded to the nearest 0.1 mm. A few specimens were measured to the nearest 0.01 mm using a Gaertner Measuring Microscope to facilitate better comparison with other specimens measured in the same manner.

All tooth measurements are girth measurements, which attempt to show the greatest tooth length and width regardless of tooth-wear stage (Semken, 1966). Girth measurements are not occlusal measurements and caution must therefore be exercised in comparing faunas measured

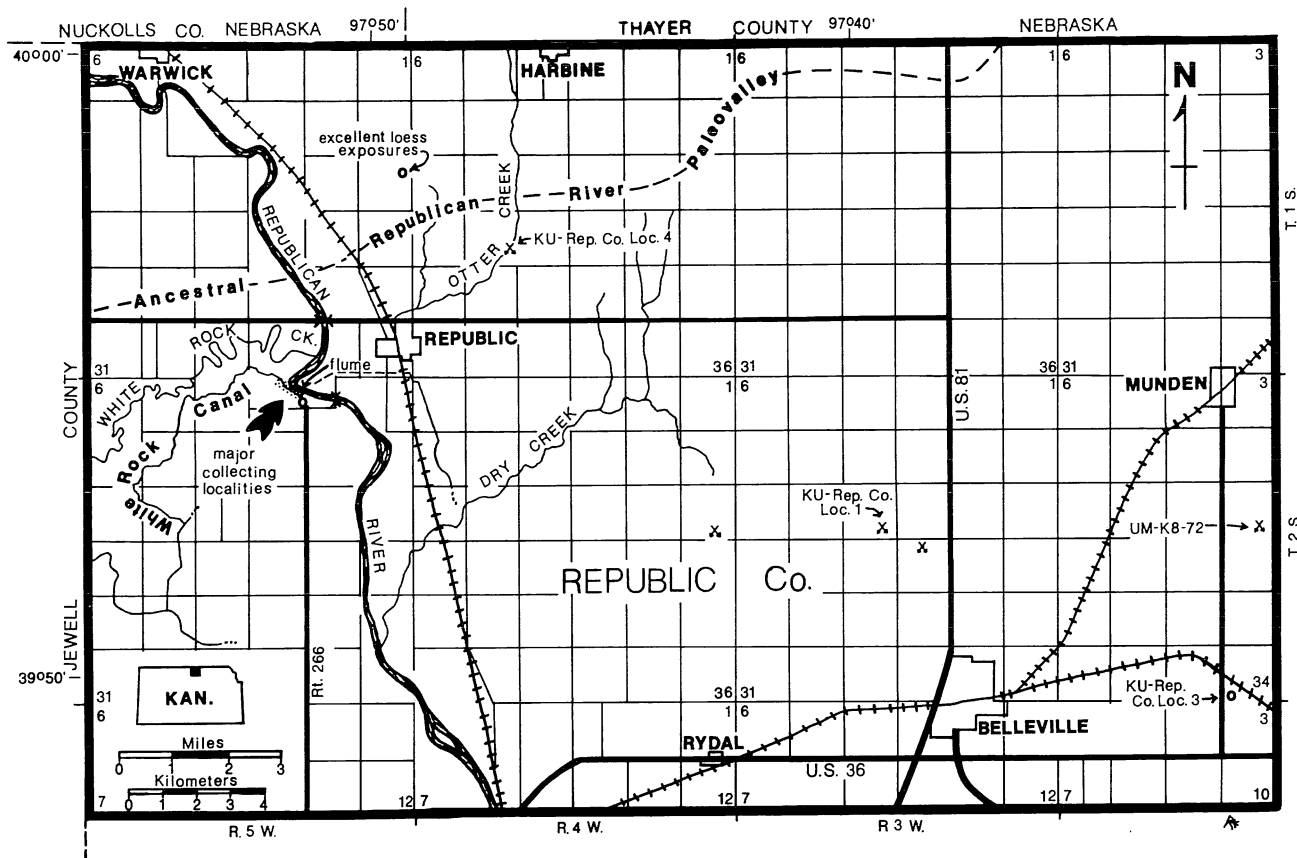


Figure 1. White Rock fauna collecting localities and approximate axis of ancestral Republican River paleovalley.

by different methods. Small samples of the same taxa from different faunas measured by occlusal measurements are not likely to have the same mean values because the mean stage of tooth wear may vary. This would be especially true of attritionally versus catastrophically accumulated samples (see Deevey, 1947; Kurten, 1953 for discussion).

In microtine molars the girth measurement is best obtained by measuring the length of the tooth from the side and the width of the tooth from the posterior end on lower and the anterior end on upper molars.

To conserve space, the length and width girth measurements of teeth are presented as follows: right  $M^1$ , 1.4 by 1.0 mm means length 1.4, width 1.0 mm.

#### CLIMATE AND BIOGEOGRAPHY

When interpreting a fossil fauna for paleoenvironmental reconstructions, an understanding of the present-day conditions is necessary to provide a basis for comparison. This task is complicated by the fact that since the advent of Europeans in the area, the natural biotic community has been altered by the stripping of natural vegetation

for agriculture, draining of marshes and damming of streams and rivers, and the introduction of foreign plants and animals.

#### Climate

Republic County, Kansas, lies near the geographical center of the coterminous United States, exhibiting a typical continental climate of cold winters and relatively warm summers. Wide seasonal changes in temperature, sometimes sudden, are common during any season due to the lack of effective wind barriers both to the N and S (Robb, 1967:57). The normal monthly temperature means range from a low of about 25 degrees F in January to a high of 78 degrees F in July. The mean annual temperature for Belleville, Kansas, is 53.1 degrees F.

The mean annual precipitation at Belleville is 27.8 inches. The months of April, May, and June are relatively wet and December, January, and February are relatively dry. About 78 percent of the precipitation falls during the six-month period from April 1 through September 30.

Using the Thornthwaite (1948) system of classification,

the present climate of Republic County is dry subhumid, second mesothermal, with little or no water surplus in any season, and a thermal temperature-efficiency regime normal to second mesothermal (C, B'2db'2).

#### Biogeography

Republic County lies within the Illinoian biotic province of Dice (1943) and the grama grass-antelope (grassland) biome of Shelford (1945). According to Shelford (1964:334), bison, pronghorn, badger, jack rabbit, prairie dog, and thirteen-lined ground squirrel are typical mammals of the grama grass-antelope biome, with the greater prairie chicken, rough-legged hawk, garter snake, and bullsnake typical of the other orders of vertebrates. Grasshoppers and ants are outstanding groups among the grassland insects.

Using Kuchler's (1964) potential natural vegetation map, which attempts to eliminate the effect of future climatic fluctuation and permits the effects of man's earlier activities to stand, Republic County falls within his bluestem-grama prairie floral province. It is dominated by the little bluestem, side-oats grama, and blue grama.

#### PHYSIOGRAPHY

Republic County lies within the Great Plains physiographic province of Loomis (1937). The topography of Republic County can be divided into three principal types (Fishel, 1948:15): (1) the loess-covered, gently sloping plain in the north-central part of the county, (2) numerous alluvial valleys, and (3) the deeply dissected uplands, which are typical of the eastern, southeastern, and southwestern parts of the county.

The county is drained principally by the Republican River and its tributaries, the more prominent being the White Rock, Otter, and Dry creeks. The Republican River has entrenched a valley nearly 60 m below the loess plain. It is a broad valley in an early mature stage with rather steep valley walls. The floodplain on which the Republican River meanders has an average width of about 1-1.3 km. The county's maximum topographic relief is about 96 m. The highest elevation lies along the Nebraska line at an altitude of about 492 m.

#### GEOLOGY

Studies on the geology of Republic County and the surrounding area have been done by Wing (1930), Fishel (1948), Fishel and Leonard (1955), and Miller et al. (1964). The reader is referred to these papers for more detailed geological accounts. Only the stratigraphic units exposed in outcrops where the White Rock fauna was collected are discussed below.

#### Cretaceous System

##### Carlile Shale

The Carlile Shale consists of a lower calcareous phase termed the Fairport Member and an upper noncalcareous phase called the Blue Hills Member. Numerous bentonite and limestone beds are present in both members. Because of its argillaceous nature, the Carlile is easily weathered and eroded. As a consequence the bedrock topography of the formation is very irregular and exhibits a relief of over 60 m. The shale weathers to a bright yellow to orange clay, which mantles much of the formation in the county. Because of the undulating, irregular surface of the Carlile, the overlying Quaternary deposits, mostly the Belleville Formation, are of varying thicknesses.

#### Quaternary System

##### Pleistocene Series

##### Previous Investigations

Because of the complex history of the early Pleistocene deposits of north-central Kansas and southeast-central Nebraska, a stratigraphic summary of these deposits, with emphasis on the history of the Belleville Formation, is presented. The first detailed report on the geology of Republic County, Kansas, was by Wing in 1930, who formally designated the sands and gravels that fill the ancestral Republican River paleovalley in the northern half of the county the Belleville Formation. In accordance with the Code of Stratigraphic Nomenclature (CSN, Article 13, Remark i), only a type area was designated. Based on proboscidean fossils, a middle Pliocene age was proposed.

Lugn (1934, 1935), studying the basal Pleistocene sand and gravel deposits of the Platte Valley and surrounding areas of Nebraska, found in many wells and test holes a zone of fine-grained material at the approximate midpoint of these deposits. Believing the three units were continuous (violation of CSN, Article 4, Remark c - Independence from inferred geologic history), Lugn proposed the formational terms Holdrege for the lower sands and gravels, Fullerton for the middle, fine-grained unit, and Grand Island for the upper sands and gravels. Lugn (1934:355, 1935:196) stated that the Belleville Formation of Wing was merely a southeastward extension of the Grand Island Formation in Nebraska (violation of CSN, Article 11 - Rule of priority). Because the Grand Island was thought to be early Pleistocene in age (CSN, Article 4, Remark d - formation as a rock-stratigraphic unit is independent from time concept) and because the Republic County deposits were not as typically developed as were those in Nebraska (violation of CSN, Article 13, Remark h - type section never

changed), Lugn recommended the acceptance of the term Grand Island for at least the upper sands and gravels of the Belleville Formation. Lugn thought that the lower part of the Belleville Formation of the Republic area could be physically equivalent to the Fullerton and Holdrege formations, but because well logs did not substantiate this, he restricted Wing's (1930) deposits as correlative with the Grand Island Formation. Moore, Frye, and Jewett (1944:146) and Frye (1945:84) agreed with Lugn in his assignment of the Belleville deposits to the Pleistocene.

In 1947 Condra, Reed, and Gorden stated that the Holdrege and Fullerton formations were equivalent in age to the Broadwater Formation of western Nebraska, the latter containing the Blancan age Broadwater local fauna (Schultz and Stout, 1945), similar to the Blancan age Blanco fauna of Rita Blanca Canyon, Texas (Evans and Meade, 1945; Meade, 1945).

Lohman (in Fishel, 1948:89) agreed with the age interpretation of Lugn for the "Belleville Formation" but retained the usage of the term "Belleville" for the following reasons. Even though Wing had misinterpreted the age of these deposits, Belleville still has priority over Lugn's terms. Also, as pointed out by Fishel (1948:90) and Cady (1949) the ancestral Republican River paleovalley sands and gravels of north-central Kansas and southeast-central Nebraska have no distinct zone of fine-grained material; it is therefore impossible to determine if one, two, or all three of Lugn's formations are represented. Lohman (in Fishel, 1948) further stated that occasional lenses of fine-grained material are encountered that separate larger bodies of sand and gravel (Fishel, 1948: Pl. 5, cross section E-E'), but as they are not persistent, these lenses should not be regarded as formations. Because Lugn's terminology was not useful in Republic County and because of priority, Lohman retained the term "Belleville Formation" in his study area. Lohman (1948: 92) did agree that the Belleville was physically correlative with at least a part of the Holdrege, Fullerton, and Grand Island sequence of Nebraska.

Condra and Reed (1950) differentiated the Grand Island Formation into the "Upper" and "Lower" Grand Island in an attempt to clarify new-found correlations; the lower part at Lugn's Grand Island type locality could be traced westward into early Kansan sands and gravels by test drilling and the upper part could be traced eastward into the glacial deposits where it rested stratigraphically on Kansan till. In this same paper Condra and Reed (1950:17, 21) also temporally correlated the lower member of the Broadwater Formation with the Holdrege (Nebraskan) and the upper unit of the Broadwater with the Grand Island Formation (Kansan). The middle unit, or Lisco Member, containing the Broadwater local fauna was considered Aftonian in age. Schultz, Reed, and

Lugn (1951) believed the splitting of the Grand Island Formation into the "Upper" and "Lower" Grand Island was inappropriate and proposed the name Grand Island be restricted to the "Upper" unit as Frye et al. (1948) had done in Kansas; they named the "Lower" unit the Red Cloud sands and gravels. Splitting the Grand Island Formation into two formations based on temporal correlations noted by Condra and Reed (1950) and not based on clear lithologic differences is in violation of the Code (CSN, Article 4, Remarks c and d). Schultz et al. (1951: 548) stated that based on fossil vertebrates, the Red Cloud Formation was temporally more closely related to the Broadwater and Fullerton deposits than to the Grand Island Formation (restricted).

Fishel and Leonard (1955:33, 109) stated that the sands and gravels of northeastern Jewell County are continuous with the Belleville Formation of Republic County. Following Frye and Leonard (1952) and ignoring priority and the correlation of the Belleville Formation to deposits of southeast-central Nebraska, they assigned the Jewell County paleovalley deposits to the Grand Island Member of the Meade Formation (violation of CSN, Article 11 - Rule of Priority). Fishel and Leonard (1955:109) stated that in at least their upper part these deposits are "clearly of Kansan and Yarmouthian age." They further stated that "sand and gravel deposits in the deeper part of the filled channel may, as Lohman suggested, be equivalent to older deposits," but because no surface outcrops of these lower sands and gravels were observed and no persistent fine-grained bed separates them from the upper part of the paleochannel fill (apparently referring to Lugn's three-formational sequence), they assigned the entire channel fill in Jewell County to the Meade Formation of Kansan age.

Miller et al. (1964:17), working on the geology of the Nebraska counties immediately N of Republic County (Franklin, Webster, and Nuckolls), did not formally recognize the division of the Grand Island Formation of Schultz et al. (1951:548) but referred all the coarse fluvial sands and gravels to the Red Cloud sands and gravels and the Grand Island Formation. They did, however, recognize that more than one age was indicated from the fossils recovered from coarse sands that they mapped as Grand Island Formation or its equivalent (Schultz et al., 1951:Table 1; Hibbard, 1958a:Table 1); some of the fossils indicated an earlier age than Kansan. As stated in the Code of Stratigraphic Nomenclature, Article 4, Remark d, a rock-stratigraphic unit may span time horizons and is delineated by lithologic, not biologic, characters. Thus all the fossils recovered by Schultz et al. (1951) could have been recovered from the same formation.

Fader (1968:Table 1) summarized the geology of Cloud, Jewell, and Republic counties and followed Fishel

and Leonard's (1955) violations of the Code by dropping the usage of the "Belleville Formation." He included all the basal sands and gravels of the ancestral Republican River paleovalley in the Grand Island Formation of Kansan age.

Bayne and O'Conner (in Zeller, 1968:66) stated that: (1) the Grand Island Formation deposits range in age from early Kansan to late Kansan; and (2) the "McPherson Formation" in McPherson (Sandahl local fauna, Semken, 1966), Harvey, and Sedgwick counties and the "Belleville Formation" in Republic County (White Rock fauna, this report) are in part temporally equivalent to the Grand Island Formation. It is not apparent whether Bayne and O'Conner were referring to the "upper" or "lower" units of the McPherson Formation or whether they were aware of Semken's (1966) work in which he redefined the McPherson Formation and assigned these deposits, based on fossil vertebrates, to an Illinoian age.

More recently Stanley and Wayne (1972:3677), in studying the early Pleistocene fluvial sediments of Nebraska, considered all pre-Loveland Formation Nebraskan and Kansan sediments as early Pleistocene in age. No further division was attempted because of the uncertainty of presently accepted stratigraphic correlations and classifications of these sediments.

It therefore appears possible that all or part of the Holdrege, Fullerton, Grand Island, and Red Cloud formations are in violation of the Code of Stratigraphic Nomenclature (the Code does, however, recognize the preservation of well-established names, Article 11, Remark b).

Many of the earlier above cited workers apparently failed to recognize that: (1) two deposits that do correlate in age may not be part of the same formation, (2) two areas of deposits that were once or are still continuous are not necessarily of the same age, and (3) a continuous deposit can change lithologically from one area to another. As a result, when correlations were attempted, workers often failed to distinguish whether the correlations were temporal, lithological, physically originally continuous, or some combination of the above correlation types. Until geologists and especially vertebrate paleontologists understand the differences between rock and time stratigraphic units and faithfully follow the Code of Stratigraphic Nomenclature, the cluttered and confused status of early Pleistocene stratigraphy of the High Plains will continue.

#### Ancestral Republican River Paleovalley

The ancestral Republican River paleovalley in which the Belleville Formation was deposited was first delineated by Wing (1930:19); its known extent subsequently was enlarged upon by Lohman (1948:29), Cady (1949), and

Fishel and Leonard (1955). The geomorphology of the valley has been established by test drilling and by contouring the bedrock surface (Waite et al., 1946; Fishel, 1948:Pls. 2, 5; Miller et al., 1964:Pl. 4) into which the paleovalley was entrenched.

The axis of the paleovalley is entrenched near the center of the western border of Franklin County, Nebraska, passes just S of Macon, and extends E about 8 km N of Riverton before it enters Webster County. From this point the paleovalley can be followed ESE, passing about 6.4 km N of Red Cloud and 6.4 km S of Cowles. The type locality for the Red Cloud Formation is approximately 4.8 km S of the paleovalley axis. The paleovalley continues ESE to a point just N of Guide Rock and enters Nuckolls County about 9.6 km N of its SW corner. From here the paleovalley turns SE and passes beneath Bostwick and Superior before it enters Jewell County, Kansas, about 9.6 km W of the NW corner of the county. Continuing SE, it passes into Republic County about 8 km S of the Nebraska line. There the paleovalley turns slightly N and crosses under the present Republican River channel about 1.6 km NW of Republic and continues E about 4.8 km S of Harbine. The valley then turns NE and reenters Nebraska about 1.6 km E of Chester, where it continues in a NE direction through Thayer County (see Fig. 1). Numerous tributaries along the paleovalley are suggested by the configuration of the bedrock surface (Fishel and Leonard, 1955:33).

The paleovalley was approximately 60 m deep and up to 16 km wide. The floor of the old valley is entrenched deeper into the bedrock than the modern Republican River valley.

Because of the braided nature of the ancestral Republican River, numerous cut and fill relationships, and temporary cessations of valley fill deposition associated with periods of degradation (Cady, 1949), the paleovalley fill is stratigraphically complex.

#### Belleville Formation

The term Belleville Formation is used in this study as defined by Wing (1930) and Lohman (1948:89) as the sands, gravels, and clays that filled the ancestral Republican River valley, except that two lithosomes, a silty clay and a sand lithosome, compose the formation. I have informally labeled these lithostratigraphic units lithosomes, following Wheeler and Mallory (1956), because: (1) these lithosomes are believed to have an intertonguing relationship, (2) they are extensively blanketed by overlying younger sediments (Sappa, Loveland, Peoria formations), (3) there is a lack of adequate subsurface data, and (4) I do not wish to clutter the literature with new terms in an already confused and complex stratigraphy.

### Silty Clay Lithosome

*Character.*— The silty clay lithosome is characterized by poorly sorted, massive silty clays containing some sandy silt. Near the base of the unit laminated, fine, limestone-gravel lenses are common. Caliche nodules ranging from 2-10 cm in diameter are numerous. Most nodules are spherical in form but a few are suggestive of burrow fillings. At least two layers of caliche nodules are present at locality UM-K9-72, 1.5 and 2.4 m below the sand lithosome-silty clay lithosome contact.

The silty clay matrix is believed to be derived mainly from the easily weathered argillaceous Carlile Shale. Weathering and erosion of the shale during the valley cutting by the ancestral Republican River, with overbank deposition and colluvial deposition from the valley sides, are suggested as the means by which this material was added to the paleovalley fill. An aggrading braided river switching its course and producing multiple channel fills would have produced an intertonguing relationship between the coarse sediments of the sand lithosome (braided channel fill deposits) and the fine sediments of the silty clay lithosome (overbank and colluvial sediments).

The silty clay lithosome-sand lithosome contact is characterized by an eroded surface exhibiting small undulations from 2-7 cm in relief. Pebbles are often encountered along the contact. A thin, manganese-stained layer about 1 cm thick usually forms in the coarse sand of the sand lithosome just above the contact with the underlying impermeable silty clay lithosome.

*Distribution.*— The silty clay lithosome outcrops stratigraphically below the sand lithosome 4 km SW of Republic in exposures along the White Rock Canal approximately 0.8 km from the point where the irrigation canal crosses the Republican River (Pl. 1A). This unit can be followed by continuous outcrop approximately 2.4 km to the west and then followed in subsurface by test holes taken for the canal construction (Earthwork and structures, White Rock extension canal station 307+90.4AH to end:1959) to the Jewell County line. These deposits are apparently lithologically equivalent to the Grand Island Member of the Meade Formation of Fishel and Leonard (1955:Table 6, physical characters).

*Age Determination.*— Fossils are scarce, but the type specimen of *Cynomys (Cynomys) hibbardi* (UMMP V616-48), fragments of mastodont teeth (V61678), and one jaw of *Geomys* sp. small (V61645) were recovered. Unfortunately, *C. hibbardi* is known only from this locality. It is morphologically intermediate between *Spermophilus* and *Cynomys*, which are believed to have evolved in late Pliocene time (Bryant, 1945:381), and therefore is suggestive of an early Pleistocene age. *Geomys* is common throughout the Pleistocene of the High Plains and is not helpful without a specific identification. The

mastodont tooth fragments are not suitable for identification.

The stratigraphic position of the silty clay lithosome beneath the sand lithosome, which contains an early Pleistocene late Blancan fauna, indicates that the unit from which the fossils were recovered is older, although probably not significantly older, than the White Rock faunal material recovered from the sand lithosome.

### Sand Lithosome

*Character.*— The sand lithosome consists mainly of horizontal and cross-stratified coarse sands with some gravel and green gritty clay lenses; occasionally clay balls and mottled clay and sand occur near the base. The sediments become coarser toward the top. Where this unit can be observed resting unconformably on the Carlile Shale (UM-K1-66, UM-K4-72), a basal sandy silt is typically present. These silts produced the best-preserved White Rock faunal material.

Quartz and orthoclase feldspar make up the major portion of the sand-size sediments, with pink granite pebbles common in the coarser fraction. A few anorthosite clasts and anorthosite granite pebbles were also identified from major White Rock faunal collecting sites (UM-K1-66, UM-K3-69). Anorthosite clasts from south-east-central Nebraska were interpreted by Stanley and Wayne (1972:3678) to have been transported E from the Laramie Range (Stanley and Wayne, 1972:Fig. 2, points 24, type area of Red Cloud Formation, Webster County; 25, Thompson sandpit, Cowles, Webster County; 26, near Guiderock, Nuckolls County; and 29, Thayer County). This supports a western source area for the Belleville sediments rather than the continentally glaciated region to the N or E.

The cross-stratified and horizontally bedded sandy gravels and gravelly sands, often associated with thick, gravel-rich lenses, are similar to those in longitudinal and transverse bars reported by Smith (1970) in the modern Platte River system of Nebraska. Using Smith's work as a modern analogue, Stanley and Wayne (1972:3682) stated that the similar sedimentary features exhibited in the lower Pleistocene channel deposits of Nebraska are the result of aggradation by braided rivers similar to the modern Platte.

*Distribution.*— Deposits of the sand lithosome make up most of the formation and essentially conform to the deposits mapped as Belleville Formation by Wing (1930:Pl. 2) and Fishel and Lohman (1948:Pl. 1). For the most part these deposits are restricted to the paleovalley, but they also occur as thin blanketing deposits on the uplands of the surrounding area. Some sands of this unit are present on the Johnson farm along the W valley slope of the present Republican River in NW¼, NE¼, Sec. 11, T. 2



S, R. 5 W; this interpretation requires a 0.4 km SE extension of the formation as mapped by Wing and Fishel.

Hibbard's (1972) usage of the Belleville Formation for deposits containing the Dixon local fauna in Kingman County, Kansas, is in clear violation of CSN, Article 4, Remarks a, c, and d - nature of rock-stratigraphic units. However, this unnamed deposit may be equivalent in age to the Belleville Formation.

*Age Determination.*— The White Rock fauna recovered from this lithosome contains mammals representative of the Blancan land-mammal age. These fossils are more primitive in evolutionary grade than those known from the Borchers local fauna of Aftonian age and are more advanced than the Sand Draw local fauna of pre-Nebraskan age. The White Rock fauna appears to be most similar in age and ecology to the poorly known Dixon local fauna of Kingman County, Kansas. The Dixon is considered by Hibbard (1972:134) to show slight climatic cooling and therefore was deposited just prior to Nebraskan glaciation.

#### Stratigraphic and Age Interpretation

It is clear why the early Pleistocene stratigraphy of this region has become so confused and its terminology so complex. Stratigraphic correlations are often influenced by political boundaries such as state lines. Some formation type localities (e.g., Fullerton, Holdrege, and Red Cloud) have been substituted on the basis of incorrect age determination or doubtful correlation (Reed and Dreeszen, 1965:18). As pointed out by Stanley and Wayne (1972:3677), sands and gravels that fill paleochannels in pre-Pleistocene rocks of Nebraska and Kansas are correlated and classified as formations, both from drill holes (e.g., Holdrege and Grand Island) and from surface exposures (e.g., Red Cloud and Sappa). Fine-grained units are generally believed to be correlatives of interglacial deposits and coarse-grained units of glacials (Lugn, 1935; Schultz and Martin, 1970).

In spite of these problems, sediments, regardless of their presumed lithologic correlation and classification, that contain late Blancan (as defined by Flint, 1971, who regards Nebraskan as uppermost or latest Blancan) fossils can be considered pre-Aftonian in age. This assumes that vertebrate fossils can define approximate time stratigraphic boundaries and that reworking of the fossils did not take place.

Late Blancan land-mammal age faunas or vertebrate fossils representative of late Blancan, such as *Nannippus phlegon*, *Equus (Dolichohippus) simplicidens*, and *Borophagus*, have been recovered from the following deposits: Grand Island (in the sense of Lugn, 1934, 1935) by Schultz (1934), Schultz et al. (1951); Fullerton by Schultz (1971, pers. comm. to Stanley and Wayne, 1972:

3676); Red Cloud by Schultz et al. (1951:548, who stated that the fossil vertebrates from the type locality have affinities more closely related to the Broadwater or Fullerton formations fossil vertebrates than to the Grand Island as redefined in 1951); and the Belleville, this report.

It is therefore conceivable that the Red Cloud, Holdrege, Fullerton, and Belleville formations are at least in part equivalent in age and that they were deposited at least in part during Nebraskan or pre-Nebraskan time. These conclusions are essentially in agreement with those of Stanley and Wayne (1972:Fig. 1).

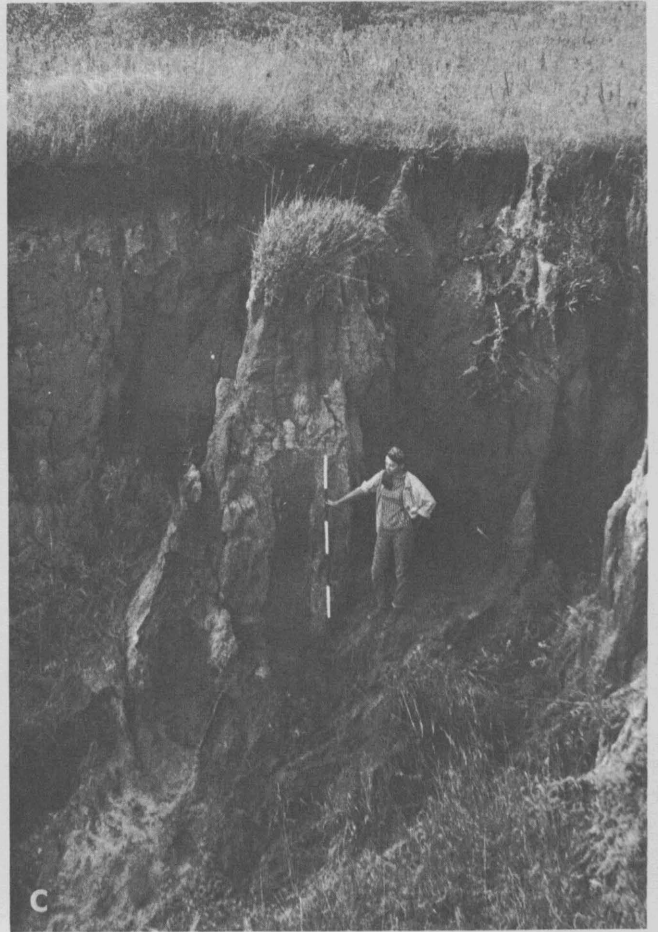
In most cases faunas from these formations are presently too poorly known to determine either their exact stratigraphic position or their chronological order, but some certainly represent earlier Pleistocene time than others.

Hibbard (1972:131) considers the late Blancan warm faunas such as the Sand Draw (Keim Formation), Broadwater (Lisco Member, Broadwater Formation), Cita Canyon and Blanco (Blanco Formation), and Deer Park and Sanders (Missler Member, Ballard Formation) to be representative of pre-Nebraskan Pleistocene deposits. The Dixon local fauna from Kingman County, Kansas, containing forms suggestive of cooler climate, was thought by Hibbard (1972) to be representative of the beginning of deteriorating climate just before glaciation. This poorly known fauna is similar to the White Rock fauna. If Hibbard's conclusions are correct, it is probable that the Belleville Formation, as well as the Holdrege, Fullerton, and Red Cloud formations, is at least in part equal to or post-Dixon (pre-Nebraskan or Nebraskan) in age.

Stanley and Wayne (1972:3684) believe that the lower Pleistocene sands and gravels of Nebraska and Kansas show glacial influence. Their belief is based on the relatively large clast sizes in these deposits and on the fact that the weak clasts, such as those of limestone and anorthosite, are transported farther than those in either the underlying Pliocene or overlying Recent fluvial deposits of the same area. It is therefore interpreted that the rivers that deposited these lower Pleistocene sands and gravels had a larger bed load and greater competency (Schumm, 1965). According to their interpretation, cooler climates caused greater mechanical weathering due to freeze and thaw in the source areas to the west and also caused greater river discharge and carrying capacity. They believe that this is suggestive of a glacial environment. However, climatic cooling prior to continental glaciation could have caused alpine glaciation (first suggested by Taylor, 1966) in the western mountain source areas and the affect on sedimentation would have been similar.

I propose a pre-Nebraskan age for the White Rock fauna because my paleoecological interpretation of it requires a more equable climate than is now present in Republic

PLATE I



County. The White Rock fauna is more advanced and therefore later in age than the Sand Draw local fauna (pre-Nebraskan) but less advanced and therefore earlier in age than the Borchers local fauna (Aftonian).

In summary, I believe the White Rock fauna accumulated under the influence of alpine glaciation in the mountains to the west and the early phases of climatic deterioration, which ultimately resulted in the Nebraskan continental glaciation. Therefore, at least the portion of the Belleville Formation that contains the White Rock fauna was deposited during latest pre-Nebraskan time.

#### Sappa Formation

Deposits recognized as Sappa Formation are known only from the ash locality, UM-K4-69 (Pl. 1B). At this outcrop the Sappa consists of sandy silts and intermixed ash totaling 234 cm in thickness. The beds range from 2-5 cm thick near the top and up to 15 cm in thickness near the base. Some pockets of relatively clean ash are present.

A three-gram sample of 120+ micron mesh shards was analyzed by Dr. John Boellstorf, University of Nebraska Conservation and Survey Division, who determined a spontaneous fission-track density of about  $2078 \pm 400$  tracks/cm<sup>2</sup>. This density is similar to that of the Pearlette ash (restricted, type O) ( $1971 \pm 218$  tracks/cm<sup>2</sup>), the Hartford ash ( $2227 \pm 292$  tracks/cm<sup>2</sup>), and the Bishop ash ( $2278 \pm 492$  tracks/cm<sup>2</sup>). Boellstorf (pers. corr., March 30, 1973) states:

The possibility of your ash sample being the Bishop ash is highly unlikely. The Bishop ash is light brownish-white in color and is rich in honey-colored biotite. None of this biotite was seen in the ash sample you sent — nor in the heavies. Also, your ash is silver-gray in color — unlike the Bishop ash. Therefore, two likely alternatives remain — either your sample is from the Pearlette ash (restricted) which has been dated at about  $0.61 \pm 0.04$  m.y. or from the Hartford ash which has been dated about  $0.74 \pm 0.04$  m.y. A possible third alternative is that your ash sample represents a new, yet undated ash. This possibility is unlikely.

The Sappa Formation lies unconformably above the Belleville Formation sand lithosome and is capped by the Loveland Formation. The presence of the ash (Pearlette ash, restricted, or Hartford ash) indicates a late Kansan age for these deposits. No fossils were recovered.

#### Loveland Formation

The Loveland Formation, the Sangamon soil, and the Peoria Formation can be seen in most of the upland outcrops in the county. All are well exposed at the loess locality (stratigraphic section 8, Pl. 1C). Especially good loess exposures are present in a stream cut at NE $\frac{1}{4}$ , SE $\frac{1}{4}$ , NE $\frac{1}{4}$ , Sec. 13, T. 1 S, R. 5 W and are pictured in Fishel (1948:Pl. 6B).

The Loveland Formation consists of sand and gravel in a reddish-brown silty clay matrix. Sand and fine gravel are disseminated throughout, with some sand and fine gravel lenses usually found near the bottom of the unit. Columnar jointing and calcareous nodules are common.

Fossil remains of *Cynomys ludovicianus* (Ord) (KU-7313-7322) from the NW corner, Sec. 18, T. 3 S, R. 4 W were identified by Hibbard from this formation (Fishel, 1948:95). The Loveland Formation is considered Illinoian in age.

#### Sangamon Soil

A paleosol developed in the top of the Loveland Formation has been named the Sangamon soil. The soil is dark brown in color and forms a gradational contact with the Loveland. No fossils are reported from this unit in Republic County.

#### Peoria Formation

The light yellowish-gray silt of this formation forms a blanket over most of the upland topography of the county. Terrestrial snails are reportedly common in it in Jewell County (Fishel and Leonard, 1955:122); however, none were recovered from Republic County. The formation is considered early Wisconsinan in age.

### MEASURED SECTIONS

Because the thickness and character of individual units vary greatly over short lateral distances, the sections given below are intended to be representative of the entire outcrop. Locality data from collecting points is not repeated. Sections made at other sites include locality data. The sections are arranged from east to west.

Plate I. (A) Belleville Formation showing sand lithosome (above) - silty clay lithosome (below) contact (at base of Jacob staff) on south side of canal at UM-K9-72 locality. (B) Sappa Formation overlying the sand lithosome of the Belleville Formation (contact exposed just to left of shovel) at the ash locality. (C) Upper stratigraphic sequence at the loess locality showing sand lithosome of Belleville Formation and overlying Loveland Formation (contact at tip of shovel handle), Sangamon soil (dark band at waist level of figure), and Peoria Formation (light colored loess above Sangamon soil).

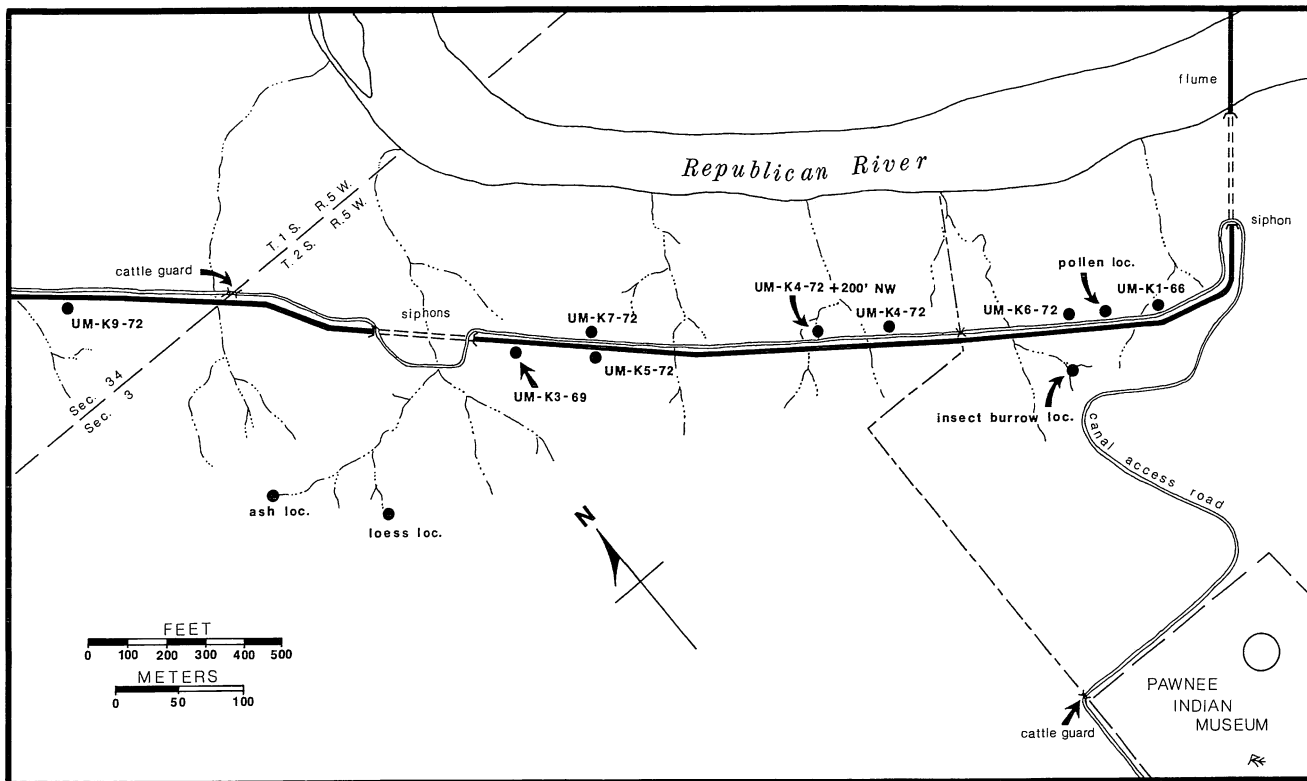


Figure 2. Major collecting localities and measured section locations on the White Rock Canal.

Section 1 – Pollen Sample Locality

Section taken approximately 91 m NW of UM-K1-66 at SW¼, NE¼, NE¼, Sec. 3, T. 2 S, R. 5 W, Republic County, on N side of canal.

Thickness (cm)

Pre-Nebraskan

Belleville Formation

- 3c. Soil: developed in formation. . . . . 48
- 3b. Sand: dirty toward top, gravel lens 60 cm above base of unit, some clay clasts in lower 60 cm. . . 163
- 3a. Sand: dirty, manganese rich, limonitic (marks erosional contact between sands and clay). . . . . 1
- 2b. Clay: blocky fracture, pale yellow (2.5Y 7/4 dry), contact with underlying unit sharp. . . . . 5
- 2a. Clay: silty, grayish-brown (2.5Y 5/2 moist) unweathered, white (5Y 8/2 dry) weathered, contact with unit 1 sharp with erosional surface, pollen samples taken here. . . . . 46

Cretaceous

Carlile Shale

- 1. Shale: bottom of unit not exposed, thickness to bottom grade of canal. . . . . 376+

Section 2 – Insect Burrow Locality

Section taken in ravine just W of large spoils pile at N½, SE¼, NE¼, Sec. 3, T. 2 S, R. 5 W, Republic County, on S side of canal.

Thickness (cm)

- 4. Spoil, predominantly Carlile Shale from canal construction. . . . . 112
- Pre-Nebraskan
- Belleville Formation
- 3d. Soil: developed in formation. . . . . 61
  - 3c. Sand: low-angle crossbedding, some gravel and silty clay lenses, fossils rare. . . . . 267
  - 3b. Sand: very limonitic, some load casting, numerous insect burrows. . . . . 122
  - 3a. Sand: crossbedding, some gravel, sharp contact with underlying unit. . . . . 160
  - 2. Clay: silty, sandy, light brownish-gray (2.5Y 6/2 wet), contact with underlying Carlile Shale distinct. . . . . 53

Cretaceous

Carlile Shale

- 1. Shale: bottom of unit not exposed, thickness to bottom grade of canal. . . . . 168+

## Section 3 – UM-K6-72 East Locality

Thickness (cm)

## Pre-Nebraskan

## Belleville Formation

- 2d. Soil: developed in formation . . . . . 42  
 2c. Sand: dirty, limonitic, with gravel lens and semi-consolidated manganese sand chunks up to 10 cm in diameter in upper 90 cm, sands become mottled with clay balls up to 10 cm in diameter in lower 90 cm, contact with underlying unit gradational, pockets of fossil bones in lower portion. . . . . 188  
 2b. Clay: silty, becomes more silty toward base of unit, pinches out westward, thickens eastward, light gray (2.5Y 7/2 dry) weathered, pale brown (10YR 5.5/3 moist) unweathered, fossil bones present. . . . . 25  
 2a. Sand: coarse, clay balls near base of unit, pinches out westward. . . . . 30

## Cretaceous

## Carlile Shale

1. Shale: bottom of unit not exposed, thickness to bottom grade of canal. . . . . 376+

## Section 4 – UM-K4-72 Middle Locality

Thickness (cm)

## Pre-Nebraskan

## Belleville Formation

- 2b. Soil: developed in formation. . . . . 46  
 2a. Sand: coarse, dirty toward top, interbedded with silty clay toward bottom, pale brown (10 YR 5.5/3 wet) unweathered, beds 0.5-2.5 cm in thickness, some small-scale crossbedding, becoming silty clay at base with *Inoceramus* and Carlile Shale fragments, sharp contact with unit 1, fossil shells rare, fossil bone pockets present. . . . . 109

## Cretaceous

## Carlile Shale

1. Shale: bottom of unit not exposed, thickness to bottom grade of canal. . . . . 313+

Note: 366 cm W the clayey silts thicken to 90 cm, interbedded with some sand, some crossbedding in upper portion.

## Section 5 – UM-K5-72 South Locality

Thickness (cm)

5. Spoil: mostly Carlile Shale from canal construction, thickens to S and E . . . . . 104

## Pre-Nebraskan

## Belleville Formation

- 4b. Soil: developed in formation . . . . . 61  
 4a. Sand: fine, clean, with some gravel and coarse sand lenses near base of unit. . . . . 238  
 3. Gravel: fine with coarse sand. . . . . 13  
 2. Sand: coarse with gravel and clay lenses, some clay balls near bottom of unit, contact with unit 1 sharp, fossil bone pockets. . . . . 160

## Cretaceous

## Carlile Shale

1. Shale: bottom of unit not exposed, thickness to bottom grade of canal. . . . . 280+

## Section 6 – UM-K7-72 Sandpit Locality

Thickness (cm)

## Pre-Nebraskan

## Belleville Formation

- 2d. Soil: developed in formation. . . . . 41  
 2c. Sand: with clay mottling, silty toward top. . . . 16  
 2b. Sand: fine, well-sorted, thin-bedded toward bottom, some crossbedding and some clay lenses. . . . 374  
 2a. Sand: with some gravel, thin-bedded, bottom 30 cm mottled with clay, dirty, contact with unit 1 sharp, fossil bones rare. . . . . 81

## Cretaceous

## Carlile Shale

1. Shale: bottom of unit not exposed, thickness to bottom grade of canal. . . . . 285+

## Section 7 – UM-K3-69 Hibbard Locality

Thickness (cm)

## Pre-Nebraskan

## Belleville Formation

- 3b. Soil: developed in formation. . . . . 48  
 3a. Sand: dirty with clay mottling in lower 90 cm of unit, some clay and gravel lenses throughout, bottom 90 cm contains fossil bone, contact with unit 2 sharp. . . . . 299

## Cretaceous

## Carlile Shale

2. Clay: highly weathered Carlile Shale, brownish-yellow (10YR 6/6 dry) weathered, numerous *Inoceramus* fragments. . . . .87
1. Shale: gray (5Y 5/1 dry), bluish to unaided eye, bottom of unit not exposed, thickness to bottom grade of canal. . . . .175+

## Section 8 – Loess Locality

A composite section taken from bottom grade of canal to head of left or S fork of ravine at S½, NW¼, NW¼, Sec. 3, T. 2 S, R. 5 W, Republic County, on the S side of canal.

Thickness (cm)

## Early Wisconsinan

## Peoria Formation

- 8b. Soil: developed in loess. . . . .56
- 8a. Loess: very pale brown (10YR 7/3.5 dry) weathered, yellowish-brown (10YR 5/4 moist) unweathered, some calcareous root casts, gradational contact with unit 7. . . . .252

## Sangamonian

## Sangamon Soil

7. Paleosol: developed into unit 6, brown (10YR 5/3 dry) weathered, dark brown (10YR 3/3 moist) unweathered, contact with underlying unit gradational. . . . .51

## Illinoian

## Loveland Formation

6. Silty clay matrix: with disseminated sand and fine gravel, light yellowish-brown (10YR 6/4 dry) weathered, brown (7.5 YR 4/4 moist) unweathered, appears orange-red to unaided eye, some sand and fine gravel lenses, columnar jointing, calcareous nodules, contact with underlying unit sharp. . . . .94

## Pre-Nebraskan

## Belleville Formation (sand lithosome)

5. Sand: with some fine gravel, clay and gravel lenses, contact with unit 4 sharp, erosional surface, often a thin approximately 6 mm manganese stained lamination, pebbles at base. . . . .330

## Belleville Formation (silty clay lithosome)

4. Clay: silty, carbon streaks. . . . .8
3. Sand: fine, clayey, silty, limonitic. . . . .15
- 2b. Clay: silty, plastic, yellowish-brown (10YR 5/4 moist) unweathered, compact, few calcareous nodules, gradational contact with unit 2a. . . . .132
- 2a. Clay: silty, plastic, yellowish-brown (10YR 5/4 moist) unweathered, numerous calcareous nodules, fine, calcareous, poorly sorted gravel lenses, contact with unit 1 sharp. . . . .381

## Cretaceous

## Carlile Shale

1. Shale: bottom of unit not exposed. . . . .672+

## Section 9 – UM-K4-69 Ash Locality

A composite section taken from bottom grade of canal to head of right or E fork of ravine at ash locality (UM-K4-69).

Thickness (cm)

## Illinoian

## Loveland Formation

7. Silty clay matrix: with disseminated sand and fine gravel, brown (7.5YR 5/4 moist) unweathered, sandier toward bottom of unit with some sand and fine gravel lenses, some calcareous nodules, contact with unit 6 gradational. . . . .36

## Kansan

## Sappa Formation

6. Silt: clayey, intermixed with either Pearlette restricted or Bishop ash, beds are 3-6 cm in thickness, pockets of relatively clean ash, beds thicken to 15 cm near bottom of unit, contact with unit 5b sharp. . . . .234

## Pre-Nebraskan

## Belleville Formation (sand lithosome)

- 5b. Sand: coarse, poorly sorted, with some disseminated fine gravel and clay lenses, contact with unit 5a sharp, erosional surface. . . . .71
- 5a. Sand: fine, clean, thin-bedded, sands coarser toward bottom with some fine gravel and clay lenses, contact with unit 4 sharp, erosional surface. . . . .221

Note: Units 1 to 4 (silty clay lithosome) are same as units 1 to 4 of Section 8 – Loess Locality.

Section 10 – UM-K9-72 *Cynomys* Locality

Thickness (cm)

## Pre-Nebraskan

## Belleville Formation (sand lithosome)

- 2c. Soil: developed in formation. . . . . 56
- 2b. Sand: limonitic, dirty and with small lenses of gravel, contact with underlying unit gradational. . . . . 71
- 2a. Sand: disseminated gravel, clean, very pale brown (10YR 7/3 moist), light gray (2.5Y 7/2 dry), becomes silty and clayey with mottled limonitic staining near bottom of unit, contact with unit 1b sharp, a thin lamination of manganese staining 2.5 cm thick marks contact between sand lithosome and underlying silty clay lithosome. . . . . 190

## Belleville Formation (silty clay lithosome)

- 1b. Clay: silty, few calcareous nodules, plastic, contact with underlying unit gradational. . . . . 61
- 1a. Clay: silty, numerous calcareous nodules (many appear to be burrow fillings, others irregular in form), plastic, brown (10YR 5/3 moist) unweathered, pale brown (10YR 6/3 dry) weathered, some lenses of poorly sorted, fine, calcareous gravel, *Cynomys* fossils rare, bottom of unit not exposed, thickness to bottom grade of canal plus 214 cm hand augered. . . . . 610+

## COLLECTING LOCALITIES

Locations of University of Michigan Collecting Sites  
Republic County, Kansas

## UM-K1-66 (Wilson Locality)

NW¼, SE¼, NE¼, Sec. 3, T. 2 S, R. 5 W. At tree level along N side of canal, approximately 91.5 m W of Republican River irrigation flume crossing, Snyder farm. Data from U.S.G.S. Republic Quadrangle, 1969, 7.5 minute series, Republic County. Belleville Formation, sand lithosome, at contact with underlying Carlile Shale; 472 m (1550 ft) elevation.

## UM-K3-69 (Hibbard Locality)

Center of NW¼, NE¼, Sec. 3, T. 2 S, R. 5 W. On S side of canal approximately 33 m SE of siphon, Warren farm. Data from U.S.G.S. Republic Quadrangle, 1967, 7.5 minute series, Republic County, Belleville Formation, sand lithosome, at contact and 30-60 cm above Carlile Shale; 471 m (1545 ft) elevation.

## UM-K4-69 (Ash Locality)

East border of E½, NW¼, Sec. 3, T. 2 S, R. 5 W. South bank of right branch of ravine heading from siphon, Warren farm. Data from U.S.G.S. Republic Quadrangle, 1969, 7.5 minute series, Republic County. Sappa Formation, consisting of silts and ash resting above the sand lithosome of Belleville Formation; 477 m (1565 ft) elevation.

## UM-K4-72 (Middle Locality)

Center of W line of W½, SW¼, NE¼, NE¼, Sec. 3, T. 2 S, R. 5 W. North side of canal, 324 m NW of Republican River irrigation canal flume crossing, Warren farm. Data from U.S.G.S. Republic Quadrangle, 1969, 7.5 minute series, Republic County. Belleville Formation, sand lithosome, at contact and 30-92 cm above Carlile Shale; 472 m (1550 ft) elevation.

## UM-K5-72 (South Locality)

Center of NW¼, NE¼, Sec. 3, T. 2 S, R. 5 W. South side of canal approximately 55 m S of E end of siphon, Warren farm. Data from U.S.G.S. Republic Quadrangle, 1969, 7.5 minute series, Republic County. Belleville Formation, sand lithosome, 120-180 cm above Carlile Shale contact; 472 m (1550 ft) elevation.

## UM-K6-72 (East Locality)

NW¼, SE¼, NE¼, Sec. 3, T. 2 S, R. 5 W. North side of canal, 76 m NW of UM-K1-66, Snyder farm. Data from U.S.G.S. Republic Quadrangle, 1969, 7.5 minute series, Republic County. Belleville Formation, sand lithosome, at contact with underlying Carlile Shale; 472 m (1550 ft) elevation.

## UM-K7-72 (Sandpit Locality)

Approximate center of NW¼, NE¼, Sec. 3, T. 2 S, R. 5 W. North side of canal, Warren farm. Data from U.S.G.S. Republic Quadrangle, 1969, 7.5 minute series, Republic County. Belleville Formation, sand lithosome, along contact and up to 153 cm above Carlile Shale; 472 m (1550 ft) elevation.

## UM-K8-72 (Hanel Sandpit Locality)

W½, NE¼, Sec. 15, T. 2 S, R. 2 W. In abandoned sandpits on the Hanel farm. Data from U.S.G.S. Munden Quadrangle, 1968, 7.5 minute series, Republic County. Belleville Formation, sand lithosome; 472 m (1550 ft) elevation.

UM-K9-72 (*Cynomys* Locality)

SE¼, SE¼, SW¼, Sec. 34, T. 1 S, R. 5 W. South side of canal, Erkenbrack farm. Data from U.S.G.S. Republic Quadrangle, 1969, 7.5 minute series, Republic County. Belleville Formation, silty clay lithosome, about 213 cm below sand lithosome to bottom of exposure; 471 m (1545 ft) elevation.



Locations of University of Kansas Collecting Sites  
Republic County, Kansas

- KU-Republic Co. Loc. 1 (McCullough Sandpit Locality)  
SW $\frac{1}{4}$ , SE $\frac{1}{4}$ , Sec. 16, T. 2 S, R. 3 W. In abandoned  
McCullough sandpit. Data from U.S.G.S. Belleville  
Quadrangle, 1966, 7.5 minute series, Republic County.  
Belleville Formation, sand lithosome; 482 m (1580 ft)  
elevation.
- KU-Republic Co. Loc. 3 (Railroad Locality)  
SW $\frac{1}{4}$ , NW $\frac{1}{4}$ , Sec. 34, T. 2 S, R. 2 W. On both sides of  
roadcut just S of and along railroad crossing. Data  
from U.S.G.S. Belleville SE Quadrangle, 1966, 7.5  
minute series, Republic County. Belleville Formation,  
sand lithosome, at contact with underlying Carlile  
Shale; 457 m (1500 ft) elevation.
- KU-Republic Co. Loc. 4 (Millen Sandpit Locality)  
Center of W $\frac{1}{2}$ , SW $\frac{1}{4}$ , SE $\frac{1}{4}$ , Sec. 20, T. 1 S, R. 4 W. In  
abandoned sandpit on Millen farm. Data from U.S.G.S.  
Republic Quadrangle, 1969, 7.5 minute series, Republic  
County. Belleville Formation, sand lithosome; 466 m  
(1530 ft) elevation.

SYSTEMATICS

Pollen

During the summer of 1973 the author and Stephen A. Hall collected eight samples from sediments containing the White Rock fauna for pollen analysis. These samples were processed for fossil pollen by Hall who reported the following results (pers. corr., Feb. 18, 1974):

One sample (UM-K6-72; SAH-91) contained a few broken, corroded grains of conifer and chenopod-type pollen. Several hystrichospheres, probably recycled from the underlying Cretaceous shale, were observed in the sample. The other samples (SAH-92, 217, 218, 219, 220, 297, 298) yielded neither pollen nor recycled palynomorphs.

The general absence and corroded condition of pollen in the samples examined likely resulted during the postdepositional history of the deposits. Oxidation of the pollen may have occurred with the movement of groundwater through the unconsolidated silts and sands. A Pleistocene pollen record is unknown for pre-Illinoian vertebrate localities in the North American plains (Kapp, 1970), although a single pollen assemblage with high frequencies of grass and sage pollen was obtained from matrix taken from a *Stegomastodon* skull that had been collected at the early Pleistocene Sand Draw local fauna in northern Nebraska (Skinner, Hibbard et al., 1972:36).

A biostratigraphic or paleoecologic interpretation of the pollen recovered from the White Rock fauna cannot be attempted owing to the low concentration and corroded condition of the grains.

Phylum MOLLUSCA

Class PELECYPODA

*Sphaerium* cf. *simile* (Lamarck)

*Material*.— UM-K4-72: UMMZ 232492, one complete and one fragmented valve.

*Remarks*.— *Sphaerium simile* and *S. striatinum* (Lamarck) are found to be morphologically similar in north-central Kansas today. However, the White Rock shells do not have striae of uniform size and spacing, characteristic of *S. striatinum* (Herrington, 1962:28). Taylor (1960:46) and Herrington (1962) state *S. simile* prefers a soft bottom in fairly still waters such as creeks, river eddies, and along lake shores. This species has also been recovered from the Sand Draw, Berends, and Jinglebob local faunas.

Class GASTROPODA

*Helisoma trivolvis* (Say)

*Material*.— UM-K4-72: UMMZ 232493, fragment of spire consisting of first whorl.

*Remarks*.— Inhabits quiet waters usually less than one foot in depth, preferring ooze-covered bottoms of rivers, small streams, lakes, and ponds. Occasionally found transient between pools and streams (Leonard, 1959:58).

*Deroceas aenigma* Leonard

*Material*.— UM-K4-72: UMMZ 232494, two internal shells.

*Remarks*.— These slug remains are thicker than most Recent *D. laeve* (Muller) internal shells. Each shell measures 4.4 and 3.7 mm in length, 2.3 and 2.1 mm in width and 0.6 and 0.5 mm in thickness, respectively. These measurements compare best with Taylor's (1954:6) 'b' group, which he regards as immature *D. aenigma*.

Taylor (1960:80) states that *D. aenigma*, like the living slugs, probably favored damp riparian habitats. *D. laeve* prefers moist habitats under leaves, bark, stones, and sticks in woodlands; it can remain submerged for periods of an hour or more (Leonard, 1959:127).

Phylum ARTHROPODA

Class CRUSTACEA

Subclass OSTRACODA

The White Rock ostracode fauna was identified by E. D. Gutentag. The fauna, listed by locality in Table 1, is sparse (both in species and individuals) but interesting. Together the forms recovered represent an assemblage of bottom dwellers found in shallow, or near shore, quiet waters, such as ponds or sluggish rivers. *Herpetocypris reptans* Baird, recovered from all three ostracode sampled



localities, is considered a part of the south temperate fauna (Benson, 1967, and Gutentag, in Skinner, Hibbard et al., 1972:39). This is the northernmost fossil occurrence for this taxon. This species has also been recovered from the Cottrell Pasture (late Pliocene) and Borchers (Aftonian) local faunas of SW Kansas. These fossil occurrences indicate that this species ranged north at least to Kansas during warmer periods of the late Pliocene, pre-glacial Pleistocene, and inter-glacials (Gutentag, pers. corr., Nov. 7, 1972).

Recent occurrences of *H. reptans* are reported by Delorme (1970) to be extant only rarely in the south-central part of the interior plains of Canada. Gutentag (pers. corr., May 24, 1973) has found *H. reptans* living in Meade County, Kansas. He states, however, that "*H. reptans* is typical of the ostracodes now found living in the warmer parts of the Gulf Coast. They are abundant in Mexico and areas south of the United States." Ecologically, the ostracode fauna suggests a shallow, slackwater habitat, probably with warmer conditions than exist in north-central Kansas today. Use of fossil ostracodes as ecological indicators is discussed by Gutentag and Benson (1962:14), and Delorme (1969).

#### Class INSECTA

##### Order COLEOPTERA (Beetles)

Numerous burrows (Pl. 2A, B), probably beetle, were discovered while clearing the section 2 outcrop surface for stratigraphic measurement. The burrows are developed in a crossbedded fine to coarse sand, measure from 8 to 16 cm in length, range from 0.7 to 1.0 cm in diameter, are vertical or nearly so with several becoming horizontal at the base, non-branching, smooth walled, and internally massive. These burrows are similar to insect burrows reported by Stanley and Fagerstrom (1973:515) from the Miocene Monroe Creek Formation of Nebraska, which they interpreted as tiger beetle burrows (Fagerstrom, pers. corr., Jan. 11, 1974).

Smith and Heim (1971:598) report that living staphylinid beetles (*Bledius pallipennis* and *B. bellicosus*) construct vertical and oblique tunnels along exposed sandy areas of the Platte and Loup rivers of Nebraska. The average lengths of these beetles, 10 and 6 mm respectively, make them ideal insect neoanalogues. Smith and Heim also indicate that such tunneling usually occurs on sandy riverbed areas, such as exposed bars shortly after emergence by receding waters. This is the same ecological interpretation suggested by Stanley and Fagerstrom, who use the Platte River as their modern analogue and infer a similar braided-river environment for the Monroe Creek Formation. This interpretation is extended to the Belleville Formation.

Table 1. White Rock Ostracode Faunal List

Species	UM-K3-69	UM-K5-72	UM-K4-72
<i>Herpetocypris reptans</i> Baird	+	+	+
<i>Candona</i> cf. <i>C. simpsoni</i> Sharpe	+	+	-
<i>Candona lactea</i> Baird	+	+	-
? <i>Eucypris</i> cf. <i>E. crassa</i> (Muller)	+	-	-

#### Phylum VERTEBRATA

##### Class OSTEICHTHYES

##### Order SEMIONOTIFORMES

##### Family Lepisosteidae

##### *Lepisosteus* sp.

*Material.*— UM-K5-72: V61304, five scales; UM-K3-69: V61305, eight scales (four broken); UM-K4-72: V61306, three scales (one broken), and one fragment of pterygoid element.

*Remarks.*— The scales are not sculptured and may represent any of the smooth-scaled gars, *L. osseus* (Linnaeus), *L. oculatus* Winchell, *L. platostomus* Rafinesque or immature alligator gar, *L. spatula* Lacepede. Gars are notorious fish eaters and indicate a large fish population was probably present (Rostlund, 1952:13). Gars are characteristic of clear, low-gradient large streams or rivers.

##### Order CYPRINIFORMES

##### Family Catostomidae

##### ?*Minytrema melanops* (Rafinesque)

*Material.*— UM-K1-66: V61307, right proximal end of maxillary.

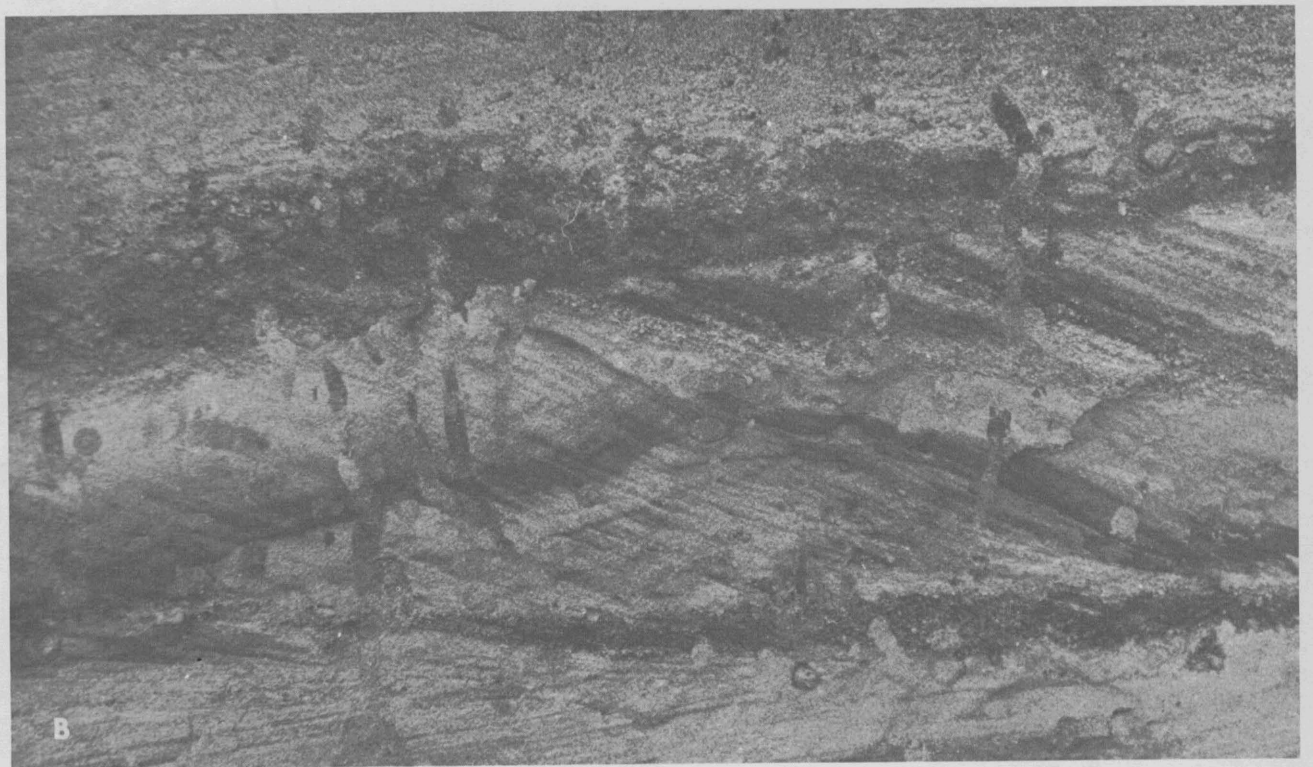
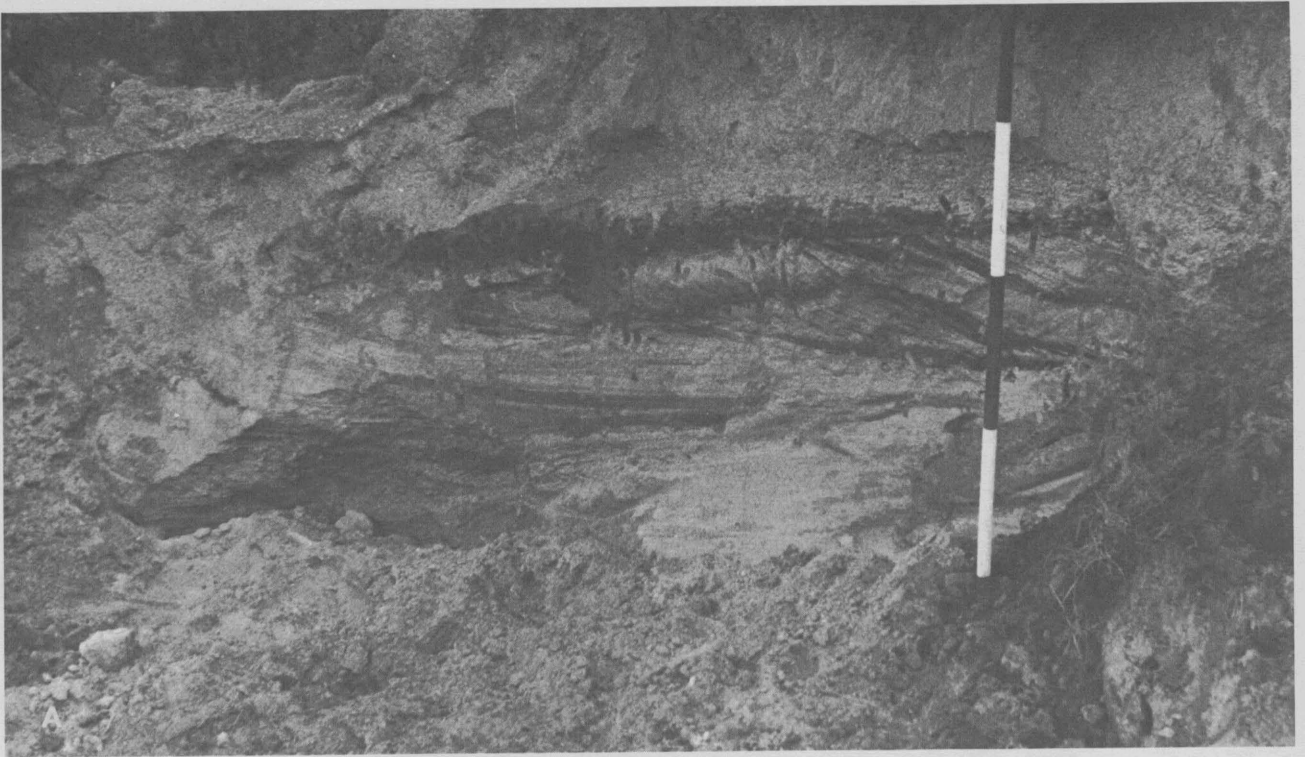
*Remarks.*— This specimen is most similar to *Minytrema melanops*, but without better comparative material showing the full range of variation within this form, no positive identification can be made. This is the first fossil occurrence for this form. The spotted sucker is scarce in Kansas and generally is found in small pools such as oxbow lakes (Cross, 1967:182).

##### Family Cyprinidae

##### *Nocomis biguttata* Kirtland

*Material.*— UM-K1-66: V61308, fragment of right pharyngeal arch; V61309, basioccipital. *Nocomis?*— UM-K1-66: V61310, three isolated pharyngeal teeth, one pharyngeal arch fragment; UM-K5-72: V61311, one left pharyngeal arch fragment, one isolated pharyngeal tooth.

PLATE II



*Remarks.*— Recovery of this taxon from the fauna is surprising in that generally *H. biguttata* inhabits clear gravelly streams. White Rock Creek may represent a similarly existing tributary once present along the ancestral Republican River paleochannel.

*Notropis* sp.

*Material.*— UM-K1-66: V61312, two left and one right pharyngeal arch. *Notropis*? — UM-K1-66: V61313, two pharyngeal arch fragments, six isolated pharyngeal teeth; UM-K3-69: V61314, two isolated pharyngeal teeth; UM-K5-72: V61315, one isolated pharyngeal tooth; UM-K5-72: V61316, two isolated pharyngeal teeth.

*Remarks.*— The unusually large number of species (about 100) in this genus, the great intraspecific variation in the osteology and dentition, and the scanty fossil material recovered limits the identification to *Notropis* sp. Species of this genus are the main source of food for the centrarchids, which are also represented in the fauna.

Order SILURIFORMES

Family Ictaluridae

*Noturus (Rabida) furiosus* Group

Fig. 3 D

*Material.*— UM-K1-66: V61317, medial fragment of right pectoral spine. *Noturus*? — UM-K4-72: V61318, one left dentary.

*Description.*— The subgenus *Rabida* is a very distinct group, containing the *Noturus* species with serrae on both the anterior and posterior edges of the pectoral spine (Taylor, 1969:128). The specimen has numerous, fine, not distinctly curved anterior dentations. Those on the posterior edge are large and distinctly recurved.

*Remarks.*— The *furiosus* group consists of four widely allopatric stocks, *N. furiosus*, *N. stignosus*, *N. munitus*, and *N. placidus*. The systematic level of these stocks to species or subspecies is still in question (Taylor, 1969: 168). The group is characterized by a long, strong, relatively well-serrated pectoral spine. Of the four stocks, *N. placidus*, of southeast Kansas, is geographically closest. However, the anterior edge of the pectoral spine of *N. placidus* is typically weakly dentated. The White Rock specimen has numerous fine anterior dentations with no distinct indication of curving. These characters are more characteristic of the *N. stignosus* stock.

The *furiosus* group appears to have been a once wide-ranging group that may have occurred in most pre-glacial rivers of eastern (east of Continental Divide)

North America (Taylor, 1969:129). Other known fossil occurrences for this group are from the Ree Hills of South Dakota (C. Ossian, in press) and the Java local fauna of South Dakota (D. Bennett, in prep.). *N. placidus* appears to be confined to riffles in the main channels of larger rivers.

*Ictalurus punctatus* (Rafinesque)

*Material.*— UM-K3-69: V61319, one left angular; UM-K1-66: V61320, fragment of pectoral spine. *Ictalurus* cf. *punctatus* — UM-K3-69: V61321, right maxillary spine fragment.

*Remarks.*— The fragmentary nature of the spine fragment (V61321) allows only a tentative assignment for this specimen. Comparison of this spine with Recent specimens from the University of Michigan, Museum of Zoology, Fish Division collections indicates the White Rock specimen was larger than 53 cm in length. The species is common in most streams of Kansas today.

*Ictalurus (Amiurus) cf. sawrockensis* Smith

*Material.*— UM-K1-66: V61324, left cleithrum; UM-K3-69: V61323, left angular, right and left pectoral spine fragments with distal ends missing; UM-K4-72: V61322, right angular and left cleithrum.

*Diagnosis.*— See expanded diagnosis and redescription by Smith and Lundberg (in Skinner, Hibbard, et al., 1972: 43).

*Description.*— The cleithrum shows little to no development of tubercles. The pectoral spines are poorly preserved but show weakly developed anterior serrae and moderately well-developed posterior dentations, which are generally regularly spaced along the shaft. The above characters distinguish *I. sawrockensis* from the other members of the subgenus *Amiurus*.

*Remarks.*— Smith and Lundberg (in Skinner, Hibbard et al., 1972) concluded that *I. sawrockensis* is an extinct species of *Amiurus* close to or even on a phylogenetic line leading to *I. melas* (Rafinesque). Bullhead remains from the Sand Draw, Dixon, and Wathena local faunas are referable to *I. sawrockensis* (Lundberg, 1975). The earliest fossil record for *I. melas* is the late Kansan Cudahy local fauna (Lundberg, 1975). Because the Wathena local fauna is considered more advanced than the White Rock and the White Rock material compares well with elements assigned to *I. sawrockensis*, this material is referred to this species. Ideally identification should be based upon a combination of several features from many elements. Such a sample is presently not available from the White Rock fauna, and due to the

scanty and fragmentary nature of the material, this assignment is tentative.

*Ictalurus cf. natalis* (Le Sueur)

*Material.*— UM-K1-66: V61325, right angular; UM-K3-69: V61326, left cleithrum; UM-K5-72: V61327, right cleithrum.

*Remarks.*— Remains of this taxon are too fragmentary for positive identification.

*Ictalurus* sp.

*Material.*— UM-K1-66: V61331, basisphenoid, dentary, and four pectoral spine fragments; UM-K3-69: V61328, fragments of dorsal and pectoral spines; UM-K4-72: V61330, three basisphenoids and pectoral spine fragments; UM-K5-72: V61329, fragments of pectoral spines.

*Remarks.*— The material is too fragmentary for specific identification.

Order PERCIFORMES

Family Centrarchidae

*Lepomis cyanellus* Rafinesque

*Material.*— UM-K1-66: V61332, right dentary and prevomer. *Lepomis cyanellus?* — UM-K1-66: V61333, left articular, three premaxilla fragments, one pharyngeal fragment.

*Remarks.*— This species is also reported from the Berends local fauna (Smith, 1954), Oklahoma and from the Rexroad local fauna (Smith, 1962), Kansas. The green sunfish is nearly ubiquitous in its habitats, but is characteristic of slow-moving parts of creeks or lakes.

Centrarchidae gen. et sp. indet.

*Material.*— UM-K1-66: V61335, various bones; UM-K3-69: V61334, isolated dorsal spine.

*Remarks.*— The material is too fragmentary for generic identification.

Class AMPHIBIA

Order URODELA

Family Ambystomatidae

*Ambystoma tigrinum* (Green)

*Material.*— UM-K1-66: V60603, one humerus, 21 vertebrae (four with open notochordal canals); UM-K3-69: V61362, one vertebra; UM-K4-72: V61361, two dentary fragments, five vertebrae (one with open notochordal canal); UM-K5-72: V61363, four vertebrae.

*Remarks.*— The vertebrae of *Ambystoma tigrinum* are easily separable from other species based on characters given by Tihen (1958) and Holman (1969). Based on criteria given by Tihen (1942), there is no evidence of neoteny. Neotonic forms are usually associated with cooler climates and metamorphosed forms with warmer climates. The tiger salamander is found today throughout Kansas and Nebraska. Breeding adults inhabit ponds and temporary pools while nonbreeding adults are typically found hidden under debris near pools of water.

Order ANURA

Family Bufonidae

*Bufo* aff. *cognatus* Say

*Material.*— UM-K1-66: V60606, right ilium; UM-K4-72: V61364, left ilium.

*Remarks.*— Holman (1971a) discusses the ilial characters that distinguish *Bufo cognatus* and *B. speciosus* Girard from the remaining Recent *Bufo* species. Holman further states that he requires sacral vertebrae to separate these two forms. No sacral vertebrae of *Bufo* were recovered. *Bufo cognatus* ranges into the western three-fourths of the state of Kansas and most of Nebraska. *B. speciosus* is presently found far to the south in western Oklahoma. The plains toad is most common in long-grass and mixed-grass prairies and less common in short-grass situations where it is usually restricted to the vicinity of streams.

*Bufo woodhousei woodhousei* Girard

*Material.*— UM-K1-66: V60604, four right ilia, eight left ilia; UM-K3-69: V61365, three right ilia, one left ilium; UM-K4-72: V61366, one right ilium; UM-K4-72+200 ft NW: V61367, two right ilia.

*Remarks.*— This species can be separated from other *Bufo* species on the height of the ilial prominence (Holman, 1971a). Tihen (1962) previously had separated the subspecies of *B. w. woodhousei* and *B. w. fowleri* Hinckley on the height of the ilial prominence. Holman (1971a) reported the earliest occurrence of *B. w. woodhousei* as Illinoian. The White Rock record extends this range into the early Pleistocene. This subspecies of the garden toad is presently found in Nebraska and Kansas except in the southeast corner where *B. w. fowleri* ranges. They are characteristic of long-grass and mixed-grass prairie, but may enter the periphery of wooded areas, especially in the eastern part of their range.

## Family Hylidae

*Acris* aff. *crepitans* Baird

*Material*.— UM-K1-66: V61369, one left ilium.

*Remarks*.— Based on characters discussed by Lynch (1966:Table 1) and Chantell (1968) the ilium is assigned to the genus *Acris*. As pointed out by Holman (in Skinner, Hibbard et al., 1972), the living species *A. crepitans* and *A. gryllus* (Le Conte) are extremely difficult to separate on ilial characters. *Acris crepitans*, the northern cricket frog, is found throughout Kansas and Nebraska today. *Acris gryllus*, the southern cricket frog, ranges in the southeastern United States along the Coastal Plain. Both frogs are characteristically found in low vegetation near the banks of streams.

## Family Ranidae

*Rana* cf. *catesbeiana* Shaw

*Material*.— UM-K1-66: V61370, two sacral vertebrae; UM-K4-72: V61371, one left ilium, three sacral vertebrae.

*Remarks*.— The ilium was distinguished from *Rana pipiens* Schreber and *R. areolata* Baird and Girard in having a more precipitous slope of the dorsal ilial blade into the dorsal acetabular expansion (Holman, 1971a). Using Tihen's (1954:219) sacral ratio plot, five sacral vertebrae were separated from *R. pipiens*. The sacral ratios fell within the *R. catesbeiana*, *R. gryllus* Stejneger, and *R. heckscheri* Wright plot. The sacral measurements (length of centra/width of centra through condyles - ratio) are: V61370, (3.3/3.8 - .8), (3.5/4.0 - .9); V61371, (3.8/4.2 - .9), (2.4/3.6 - .7), (3.5/4.0 - .9). Many of the sacral vertebrae are heavily worn, especially on the anterior facets of the centrum. Tihen (1954:219) points out that the fossil sacrum may be slightly shorter than those of Recent sacrum due to partial erosion.

*Rana gryllus* and *R. heckscheri* are confined to the Coastal Plain of the southeastern United States and were tenuously excluded by their present zoogeographical ranges. *Rana catesbeiana* is found throughout Kansas and Nebraska today. The bullfrog is restricted to permanent bodies of water such as lakes and rivers.

*Rana pipiens* Schreber

*Material*.— UM-K1-66: V61372, 21 right ilia, 19 left ilia, 11 sacral vertebrae; UM-K3-69: V61373, five right ilia, three left ilia, one sacral vertebra; UM-K4-72: V61374, 14 right ilia, ten left ilia, one sacral vertebra; UM-K4-72+200 ft NW: V61375, one right and left ilium, one sacral vertebra; UM-K5-72: V61376, three right ilia, one left ilium, one sacral vertebra.

*Remarks*.— The ilia were separated from *Rana catesbeiana* on the presence of a much less precipitous slope of the posterodorsal border of the ilial crest into the dorsal

acetabular expansion. The ilia were distinguished from *R. areolata* on characters discussed by Holman (1971a:351). All of the sacral vertebrae fall within the *R. pipiens* side of Tihen's (1954) sacral ratio plot. The following sacral measurements are given as under *R. catesbeiana*: V61372, (3.7/3.7 - 1.0), (2.9/3.2 - .9), (2.5/2.9 - .9), (3.9/3.9 - 1.0), (3.7/3.7 - 1.0), (3.5/3.4 - 1.0), (2.3/2.5 - .9), (2.6/2.8 - .9), (3.8/4.0 - 1.1), (2.0/2.4 - .8), (1.1/1.1 - 1.0); V61373, (2.9/3.4 - .9); V61374, (3.9/3.9 - 1.0), (1.9/2.5 - .8), (2.6/2.8 - .9); V61375, (3.4/3.9 - 1.1); V61376, (3.0/3.3 - .9). Specimen V61376 falls on the line between the two groups, but because of its great stage of wear it is placed with the *R. pipiens* group.

The leopard frog is found throughout Kansas and Nebraska today. It is generally ubiquitous, but is always found near water during the breeding season.

## Class REPTILIA

## Order CHELONIA

## Family Chelydridae

*Chelydra serpentina* (Linnaeus)

*Material*.— KU-Rep. Co. Loc. No. 3: V60643, right fourth and fifth peripheral; UM-K6-72: V61378, nuchal.

*Remarks*.— These elements best compare with Recent *Chelydra serpentina* specimens. Based on comparison with Recent specimens of approximately the same size, one specimen (V60643) had a carapace length in excess of 35 cm. A neck vertebra (V60644) from locality UM-K3-69 compares closely with *C. serpentina* vertebrae, but is too worn for positive identification. Today the common snapping turtle ranges throughout Kansas and Nebraska and can be found in most permanent waters.

## Family Emydidae

*Chrysemys picta* (Schneider)

*Material*.— UM-K3-69: V61379, right xiphylastron.

*Remarks*.— *Chrysemys picta* is identified by distinct serrations internally following the principal notch on the anterior edge just internal to the lateral impression of the first marginal shield (Holman, in Skinner, Hibbard et al., 1972). The specimen is identical to Recent specimens and can be separated from *Pseudemys scripta* (Schoeppf) which has a more distinct principal notch followed internally by weak serrations. The following material appears to be *C. picta*, but because of its fragmentary nature is unassigned: UM-K3-69: V60653, right anterior fragment of hyoplastron, left fragment of hyoplastron, costal fragment; and KU-Rep. Co. Loc. No. 1: V61386, one costal fragment.

The painted turtle is found throughout Kansas and Nebraska today. It frequents shallow, warm waters with some plant growth, such as ponds, streams, lakes, and still pools in rivers.

#### Family Testudinidae

##### *Geochelone* spp.

*Material*.— UM-K3-69: V60631, one distal phalange; UM-K6-72: V61380, one large carapace fragment; KU-Rep. Co. Loc. No. 1: V61381, one shell fragment; KU-Rep. Co. Loc. No. 3: V61382, one costal fragment, V61388, one pygal bone.

*Remarks*.— At least two species are represented, one large (V61380) and one small (V61382), but due to the fragmentary nature of the material specific determination was not attempted. The pygal bone (V61388) is abnormal in being extremely asymmetrical, possibly due to an early injury. The burrowing habits of the extinct small *Geochelone* are unknown, but as Preston (1971) points out, the small species of *Geochelone* often occurs in association with the large, nonburrowing species (see also Holman, in Skinner, Hibbard et al., 1972:65). Apparently this is true of the White Rock fauna. Living members of the genus *Geochelone* are confined to open sub-tropical or tropical regions where they feed on succulent plants (Brattstrom, 1961). Thus there probably were milder winters than exist in north-central Kansas today (Hibbard, 1960).

#### Family Trionychidae

##### *Trionyx* sp.

*Material*.— UM-K4-72: V61383, carapace fragment; UM-K4-72+200 ft NW: V63364, carapace fragment; UM-K5-72: V61384, two carapace fragments; UM-K6-72: V61385, one carapace fragment.

*Remarks*.— All of the specimens are too fragmentary for specific identification. Both smooth, *Trionyx mutica* Lesueur, and spiny, *T. ferox* Schneider, soft-shelled turtles occur in the area today. These turtles prefer rivers and streams with mud bottoms and aquatic vegetation.

### Order SQUAMATA

#### Family Iguanidae

##### *Sceloporus holmani* sp. nov.

(Fig. 3 A, B)

*Holotype*.— UM-K1-66: UMMP V61389, right dentary.

*Paratype*.— UM-K4-72: UMMP V61390, right dentary.

*Horizon and Type Locality*.— Type collected by R.L. Wilson, summer of 1966, at UM-K1-66 in gray, sandy silts at contact of the underlying Carlile Shale with the sand lithosome of the Belleville Formation, NW¼, SE¼, NE¼, Sec. 3, T. 2 S, R. 5 W, Republic County, Kansas.

*Distribution*.— Known only from UM-K1-66 and UM-K4-72 localities of the White Rock fauna, early Pleistocene in age.

*Etymology*.— This species is named in recognition of the extensive paleoherpetological studies done by Dr. J. Alan Holman in the High Plains region of North America.

*Diagnosis*.— A *Sceloporus*, approximately the size of adult *S. olivaceous* Smith. The meckelian groove is deeper than in living forms and the upper and lower borders of this groove are not fused or in contact with one another. A lingual shelf near the base of the teeth is heavy and broadened mesially. Depth of the dentary below the meckelian groove is greater than in living species of the genus. The teeth are weakly cusped, stout, and bluntly peg-like, exhibiting anteroposterior compression.

*Description of Holotype*.— The holotype consists of a nearly complete dentary, 10.7 mm in length. The deep and well-developed condition of the meckelian groove and the presence of a prominent mesially broadened lingual shelf at the base of the teeth is similar to the condition exhibited in the extinct sceloporine, *S. robustus* Twente, described by Twente (1952) from the upper Pliocene Rexroad fauna. However, *S. holmani* is 25 % larger than *S. robustus*. The tooth row length for the type *S. robustus* (UMMP V27665) is 6.5 mm and for *S. holmani* (UMMP V61389) it is 8.9 mm. Depth of the dentary below the meckelian groove is 1½ times greater proportionately in *S. holmani* than in other *Sceloporus* dentaries of the same size. Greatest depth of dentary below meckelian groove in living *S. olivaceous* (UMMZ R1668) is 0.3 mm, in *Crotaphytus collaris* (Say) (UMMZ S2676) 0.4 mm, and in *S. holmani* (UMMP V61389) 0.6 mm.

The dentary has ten teeth, two of which are broken, and nine alveoli. The posterior teeth are worn but exhibit very weak tricuspidation. The teeth are stout and compressed anteroposteriorly near the base, tapering to a peg-like bluntly tipped top. In transverse view, the teeth are approximately twice as wide at the base as at the top. The crown line is more or less even, the posterior teeth being more robust and slightly shorter than the anterior ones. On the ventrolabial border of the dentary there are present six prominent and two smaller foramina.

*Description of Paratype*.— The paratype (UMMP V613-90) consists of a nearly complete dentary, lacking only the extreme posterior end and measuring 10.4 mm in length and 0.5 mm in depth below the meckelian groove. There are fifteen teeth and the alveolus for another. A replacement tooth is present at the eleventh tooth position

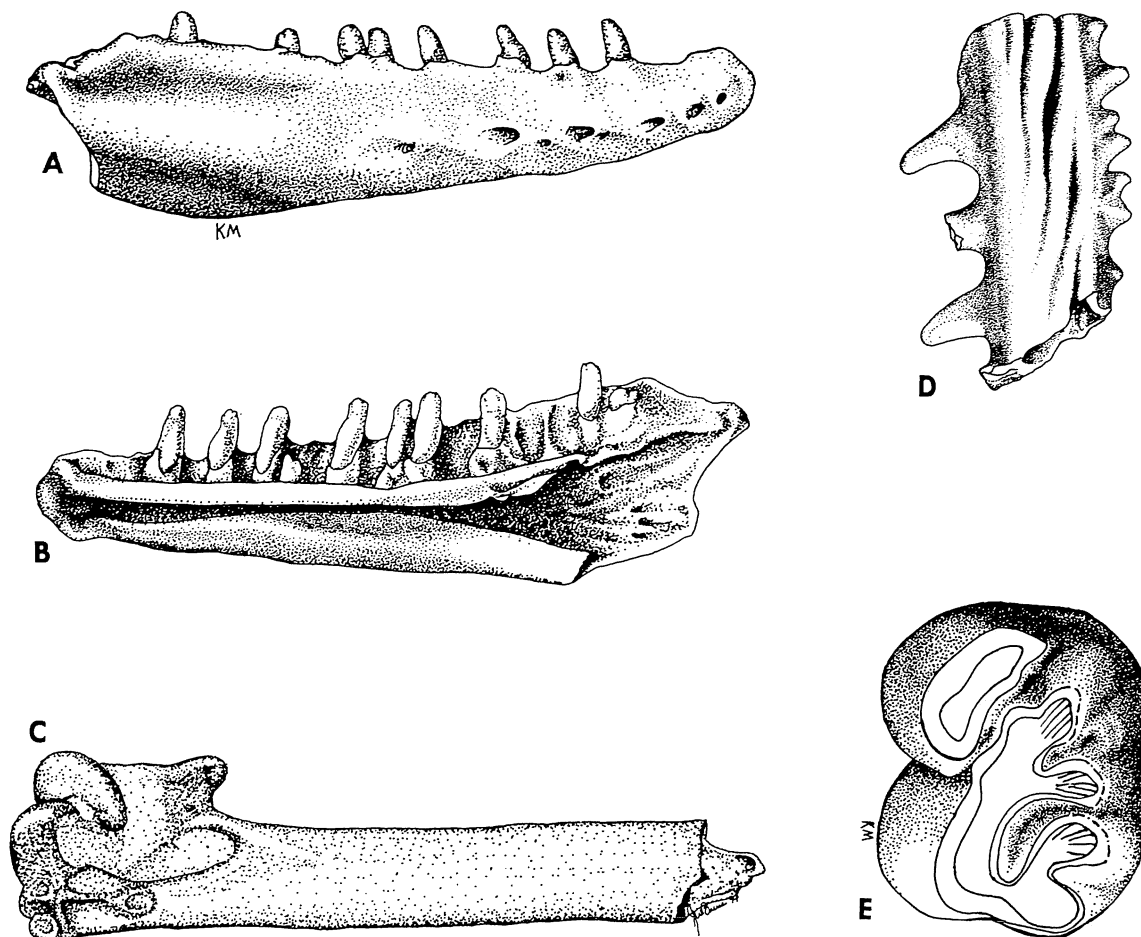


Figure 3. (A, B) *Sceloporus holmani*, holotype, right dentary, V61389, labial and lingual views, x 10. (C) *Pluvialis squatarola*, right humerus, V61287, palmar view of distal end, x 3. (D) *Noturus (Rabida) furiosus* Group, medial fragment of right pectoral spine, V61317, x 10. (E) Zaponinae, ?left M<sup>2</sup>, V60592, occlusal view, approximately x 40.

from the anterior end. The paratype is not as worn as the holotype and weakly tricusate posterior teeth are better illustrated.

Labially a distinct ridge extends from near the posterior end of the tooth row obliquely downward toward the anterior end of the jaw. This ridge forms the boundary of an excavation which runs to the middle part of the dentary causing the specimen to be concave at this position. A similar excavation is present on the type dentary but it is shallower and without a prominent ridge. The same character is given by Twente (1952) for *S. robustus* and is interpreted by him as the place of insertion for the adductor mandibularis muscle. This character, although variable in Recent sceloporines, is never as well developed when present. Labially, only four prominent foramina are present on the dentary.

*Remarks.*— Etheridge (1964:626) states that, "*Sceloporus*, by far the most abundant sceloporine genus, is osteologically the most variable." In spite of this variation, *S. holmani* possesses characters which are distinct from all living and extinct species of the genus. Morphologically the dentaries best compare with *S. robustus* in their similarly developed open meckelian groove, prominent and heavy lingual shelf, and labial excavation of the dentary. *S. holmani*, however, is distinct from other sceloporines by this combination of characters and from *S. robustus* by its larger size and relatively greater depth of dentary below the meckelian groove. These characteristic differences are summarized in Table 2.

Smith (1939:Fig. 3) has segregated the numerous *Sceloporus* species into morphological groups, the interrelation of which he formed into a phylogenetic tree. *S.*



Table 2. Dentary parameters of some sceloporines in comparison with *Sceloporus holmani* sp. nov.

Genus, species	Meckelian Groove <sup>1</sup>	Lingual Shelf <sup>2</sup>	Dentary Depth <sup>3</sup>	Cuspation <sup>4</sup>	Tooth Type <sup>5</sup>
<i>Sceloporus holmani</i>	O	D	G	W	N
<i>S. undulatus</i>	C	M	L	C	N or C
<i>S. variabilis</i>	C	M	L	C	N or C
<i>S. graciosus</i>	C	L	L	C	C
<i>S. olivaceous</i>	C	L	M	C	N or C
<i>S. magister</i>	C	L	M	W	N
<i>S. robustus</i>	O	D	M	W	N
<i>Phrynosoma cornutum</i>	O	L	G	O	N
<i>Crotaphytus collaris</i>	C	L	M	W	C
<i>Ctenosaura similis</i>	F	L	—	S	B

<sup>1</sup>Upper and lower border of meckelian groove, O – open, C – in contact, F – fused.

<sup>2</sup>Development of lingual shelf, L – least developed, M – medium developed, D – most developed.

<sup>3</sup>Depth of dentary below meckelian groove, L – least depth, M – medium depth, G – greatest depth.

<sup>4</sup>Cuspation, O – none, W – weakly, C – cuspsate, S – strongly cuspsate

<sup>5</sup>Tooth type (after Hotten, 1955), B – blade-like, N – blunt, non-cuspsate, C – conical, sharp, cuspsate.

*holmani* appears to belong to Smith's "Spinous Group."

Hotten (1955) has demonstrated a relationship between dentition form and diet in North American Iguanidae. The teeth of *S. holmani* fall between his groups B and C. Hotten (1955:107) added that the three *Sceloporus* species he studied (*S. magister* Hallowell, *S. undulatus* (Bosc, in Latreille), and *S. graciosus* Baird and Girard) formed a graded series between groups B and C. Of these three species, the teeth of *S. holmani* perhaps best compare with *S. magister*, which Hotten places in group B and whose diet consists mainly of ants supplemented by caterpillars (Knowlton, 1934, 1938). The reader is referred to Hotten (1955) for a more detailed discussion of his tooth type groups and diet. The dentition of *S. holmani*, characteristic of Hotten's group B, is thus suggestive of dry, upland areas where ants are common. Ant hills are numerous along the undissected upland flats of the Republican River valley today. *Sceloporus undulatus* is the only member of this genus presently occurring in north-central Kansas. The rough-scaled lizard is typical of dry, open forested areas.

## Family Colubridae

### *Natrix sipedon* (Linnaeus)

*Material.*— UM-K1-66: V61395, 13 vertebrae; UM-K4-72: V61396, five vertebrae.

*Remarks.*— The specimens compare well with Recent *Natrix sipedon* and were differentiated from other *Natrix* species by their lower neural spines (Holman, 1971a). The common water snake is found in most of Kansas and Nebraska today. It is frequently found near streams, rivers, marshes, and permanent ponds and lakes.

### *Heterodon* cf. *platyrhinos* Latreille

*Material.*— UM-K1-66: V61392, two vertebrae; UM-K3-69: V61391, two vertebrae; UM-K4-72: V61393, four vertebrae; UM-K6-72: V61394, three vertebrae.

*Remarks.*— Vertebrae of *Heterodon* are easily identified by characters discussed by Holman (1962). Both the common hog-nosed snake, *H. platyrhinos*, and the western hog-nosed snake, *H. nasicus* Baird and Girard, occur in Kansas and Nebraska today. Based on the large size of the vertebrae the specimens are tentatively referred to *H. platyrhinos*. Both snakes prefer dry areas with ample sunshine, such as on sandy river shores, sand dunes, or in dry woods.

### *Elaphe* cf. *vulpina* (Baird and Girard)

*Material.*— UM-K1-66: V61398, one vertebra; UM-K4-71: V61399, two vertebrae; UM-K7-72: V61400, one vertebra; UM-K9-72: V61401, one vertebra.

*Remarks.*— A discussion is given by Auffenberg (1963) and Holman (1965) concerning characters which may distinguish between vertebrae of *Elaphe*, *Pituophis*, and *Lampropeltis*. *Elaphe vulpina* may be separated from the other species of *Elaphe* (*E. guttata* (Linnaeus) and *E. obsoluta* (Say) – both presently ranging in Kansas) by its lower neural spine. The fox snake, *E. vulpina*, is known throughout eastern Nebraska. This snake may occur in northeastern Kansas, but actual records do not exist (Smith, 1956:323). Based on fossil herpetological evidence, the fox snake apparently ranged farther southward and westward during the Pleistocene (Holman, pers. comm., Oct. 15, 1973).

### ?*Pituophis* sp.

*Material.*— UM-K1-66: V61402, two vertebrae; UM-K4-72: V61403, six vertebrae; UM-K4-72+200 ft NW: V614-04, one vertebra.

*Remarks.*— Auffenberg (1963:180) states that vertebrae of *Elaphe* and *Pituophis* can be separated by the shape of the zygosphenes, which is concave in dorsal view in *Pituophis* and flat in *Elaphe*. This character did not divide the sample in the manner discussed by Holman



(1965). This, combined with poorly preserved specimens, made identification tenuous.

*Pituophis melanoleucus* (Davidin) is the only species of this genus recorded living in Kansas today. The bullsnake is found in open meadows, fields, and grasslands.

#### Family Crotalidae

gen. et sp. indet.

*Material.*— UM-K3-69: V61406, one vertebra; UM-K4-72: V61407, two vertebrae.

*Remarks.*— The vertebrae were identified to family by their elongate hypapophyses. The material is too fragmentary and worn for generic designation. No anterior body vertebrae are represented to allow separation based on characters discussed by Holman (1972:95). The copperhead, *Agkistrodon contortrix* (Linnaeus); massasauga, *Sistrurus catenatus* (Rafinesque); and the prairie rattlesnake, *Crotalus viridis* (Rafinesque), occur in the area today.

### DISCUSSION

All of the fossils are extant today except the large species of *Geochelone*. *Geochelone* is important environmentally because its presence suggests milder winters with temperatures rarely if ever below freezing (Hibbard, 1960; Holman, 1971b).

The herpetofauna did not produce any unexpected results other than a new species of lizard. This is at least in part due to the poor preservation of the material, especially in localities UM-K3-69 and UM-K5-72, where nearly one thousand indeterminate vertebrae are assigned to V60642 or V60602. Perhaps most surprising is the absence of easily identifiable *Coluber* or *Masticophis* (racer or coachwhip snake) vertebrae, usually plentiful in Pleistocene faunas of the High Plains.

#### Class AVES

#### Order ANSERIFORMES

#### Family Anatidae

*Anas* sp.

*Material.*— UM-K1-66: V61285, proximal end of left coracoid.

*Remarks.*— Owing to the difficulty in separating the species of this genus on the basis of a single postcranial element, the size overlap with coracoids of several teal species (Feduccia, in Skinner, Hibbard et al., 1972:74), and the fragmentary nature of the specimen, no specific assignment is attempted. The specimen best compares with *Anas carolinensis* Linnaeus and *A. discors* Linnaeus.

A fragmentary clavical (V61286) from the same locality (UM-K1-66) closely resembles that of *A. discors* in form, but is slightly smaller. No assignment other than subfamily Anatinae is made.

#### Order CHARADRIIFORMES

#### Family Charadiidae

*Pluvialis squatarola* Linnaeus

(Fig. 3 C)

*Material.*— UM-K1-66: V61287, distal end of right humerus.

*Remarks.*— The specimen is morphologically similar to humeri of *Pluvialis squatarola* and *P. dominica* (Muller), but because the specimen is larger than *P. dominica* and within the size range of *P. squatarola*, it is referred to the latter. The humerus has a maximum distal width of 7.8 mm and a minimum shaft width of 3.0 mm. This species is also reported as a fossil by Howard (1936:35) from the Rancho La Brea deposits. This occurrence extends the geological presence of this extant taxon back to the early Pleistocene.

#### Order PASSERIFORMES

gen. et sp. indet.

*Remarks.*— The remaining elements all appear to be passerines, but have not been identified beyond order. Passerines were recovered from the following localities: UM-K1-66: V60608, V60639; UM-K4-72: V61288; UM-K5-72: V61289; UM-K3-69: V61290.

#### Class MAMMALIA

#### Order INSECTIVORA

#### Family Soricidae

*Sorex* aff. *sandersi* Hibbard

*Material.*— UM-K1-66: V60595, left maxillary fragment with P<sup>4</sup>-M<sup>2</sup>; UM-K3-69: V61626, left jaw fragment with M<sub>1</sub>, right jaw fragment with M<sub>1</sub>; UM-K4-72: V61627, left maxillary fragment with P<sup>4</sup>-M<sup>1</sup>, right maxillary fragment with P<sup>4</sup>, right maxillary fragment with M<sup>1</sup>; UM-K5-72: V61628, right jaw fragment with M<sub>1</sub>.

*Measurements (mm).*— V60595, left P<sup>4</sup> 1.4 by 1.7, left M<sup>1</sup> 1.5 by 1.5, left M<sup>2</sup> 1.1 by 1.4; V61626, left M<sub>1</sub> 1.5 by .9, right M<sub>1</sub> 1.6 by 1.0; V61627, left P<sup>4</sup> 1.4 by 1.7, left M<sup>1</sup> 1.4 by 1.6, right P<sup>4</sup> 1.4 by 1.6, right M<sup>1</sup> 1.3 by 1.5; V61628, right M<sub>1</sub> 1.6 by 1.0.

*Description.*— The lower molar measurements are slightly larger than *Sorex leahyi* Hibbard and best compare with *S. sandersi* from the Sanders local fauna. The M<sub>1</sub> from the Sand Draw local fauna is slightly larger than the one from Sanders. The Sand Draw *S. sandersi* jaws have a horizontal ramus width intermediate between *S. taylora* Hibbard (Wendel Fox local fauna) and *S. sandersi* (Sanders local fauna). The Sand Draw material was collected from UM-K1-68, which is low in the stratigraphic section.

The mental foramen in *S. taylori* and *S. sandersi* is just anterior to the anterolabial root of  $M_1$  or just below it (Hibbard, in Skinner, Hibbard et al., 1972:77). In *S. leahyi* the mental foramen is immediately posterior to this root in the Dixon local fauna paratype (V31972). In the other paratype (V31970) from the same locality the foramen also is just posterior to the root but with a second very small anterior foramen located in the same depression. Repenning (1967:6) notes that in a very few individuals of living shrews a double mental foramen is present. A third very small foramen also was observed medially and more dorsally between the labial roots of  $M_1$ . The character was not observed in any other specimens. The type of *S. leahyi* is broken posterior to the mental foramen position. All mental foramina in specimens from the White Rock fauna have the foramen situated just posterior to the  $M_1$  anterolabial root as in *S. leahyi*. The White Rock specimens possess only the anterior mandibular foramen (see Paulson, 1961:130 and Hibbard and Bjork, 1971:174 for discussion of presence and position; both the anterior and posterior mandibular foramen are figured by Stephens, 1960:1688; Paulson, 1961:Fig. 2; and Hibbard and Jammot, 1971:Fig. 2).

Only one *Sorex* jaw from the White Rock fauna possesses the ascending ramus. The supracondylar notch (for terminology see Gaughran, 1954:Pl. 2) between the posterior border of the ascending ramus and condyle is broader and flatter as in *S. leahyi* (see Hibbard, 1956:161, Fig. 3). However, the posterointernal ramal fossa is not as narrow and elongate as in *S. leahyi*, but is more similar to *S. sandersi*.

Upper molars of *Sorex* are known from the Sanders and Dixon local faunas but cannot be definitely assigned to *S. sandersi* or *S. leahyi* because at least two *Sorex* species are represented by rami in both faunas. However, a maxillary with teeth representing *S. taylori* (V57066) from the Wendell Fox local fauna is known. Assuming the maxillaries from the Sand Draw (V57209), Sanders (V50257), and White Rock (V60595) represent specimens of *S. sandersi* which evolved from *S. taylori* as proposed by Hibbard (in Skinner, Hibbard et al., 1972:77) an interesting development of the anterior cingulum and protocone on  $M^1$  and  $M^2$  is exhibited.

In *S. taylori* a small cingulum anterior to the protocone in  $M^1$  is present. A similar cingulum is absent on the  $M^2$ . On the Sand Draw *S. sandersi* specimen this cingulum is much better developed and extends around the lingual side of the tooth to the hypocone; a similar lingual and anterior cingulum is present on the  $M^2$  but less well developed. In the Sanders local fauna an anterior cingulum is present on the  $M^1$  and  $M^2$  but it is not connected to the poorly developed lingual cingulum. Also an inflection in the enamel forming a concave, obtuse angle in the anterior side of the protocone is present in the  $M^1$

and  $M^2$  of the Sanders specimen. This enamel inflection is not present in the previously mentioned specimens. The White Rock maxillary compares closely with the Sanders specimen in the above characters (with wear the enamel inflection will become more accentuated as in the Sanders). A maxillary from the Dixon (V31971), although heavily worn, shows no enamel inflection of the protocone or anterior cingulum of the  $M^1$  or  $M^2$ . Assuming the maxillaries are correctly assigned, the above characters suggest an increase in the development of the anterior cingulum and enamel inflection in the protocone through time from *S. taylori* to *S. sandersi*. The Dixon maxillary does not appear to belong to this hypothetical line and may represent *S. leahyi*. No uppers of *S. taylori* are known from the Borchers local fauna.

*Remarks.*—Based on the above description, the White Rock sample best compares with *S. sandersi* from the Sanders local fauna. Position of the mental foramen and shape of the supracondylar notch, which is similar to *S. leahyi*, and the uncertainty in specific assignment of maxillaries do not allow positive specific identification at this time. The Sand Draw *S. sandersi* specimen probably represents a new species because its jaw is narrower,  $M_1$  larger, and the tentatively assigned maxillary possesses molars with broader and better developed lingual cingula than in the type *S. sandersi* from the Sanders local fauna. Size is probably a less reliable character than the others because many extant shrews exhibit variation in overall size with latitude (see McNab, 1971: Table 1).

#### *Sorex* near *cinereus* Kerr

*Material.*—UM-K3-69: V61629, left jaw fragment with  $M_2$ .

*Description and Remarks.*—Hibbard reported a fragmentary jaw with  $M_2$ – $M_3$  (V31973) from the Dixon local fauna (1956) and a jaw possessing  $M_1$ – $M_2$  (V57718) from the Sand Draw local fauna (Skinner, Hibbard et al., 1972:Fig. 27) as representing a small but slightly more robust *Sorex* than living or Kansan age *S. cinereus* specimens (Cudahy local fauna, Paulson, 1961). The White Rock specimen compares well with the Sand Draw and Dixon material in that the anterior cingulum of the  $M_2$  is broader and better developed than in the living *S. cinereus*. In this character the specimen is similar to *S. c. meadensis* (Jammot, 1972:456) from the Cudahy local fauna. All the fossil  $M_2$ s (V61629 White Rock fauna, V57718 Sand Draw local fauna, V31973 Dixon local fauna) measure 1.1 by 1.7 mm. These specimens appear to be closely related to and possibly ancestral to *S. cinereus meadensis*.

The White Rock molar is a relatively unworn  $M_2$ , which lacks normal pigmentation observed in other specimens. One mottled albinistic specimen of *Sorex cinereus lesueurii* (UMMZ 101235) from Washtenaw County, Michigan, has a pale yellowish color similar to the fossil in question. Whether the White Rock tooth is that of an albinistic individual or a result of post-mortal processes cannot be determined. The tooth, however, does not appear to have been darkened by fossilization. Repenning (1967:5) states that, "pigmentation in soricid teeth seems to be remarkably stable insofar as fossilization is concerned and is usually preserved even in Oligocene specimens."

*Blarina* aff. *carolinensis* (Bachman)

*Material*.— UM-K1-66: V60594, right jaw fragment with  $M_1$ .

*Remarks*.— The jaw and molar are about the size of living *Blarina carolinensis* from southeast Kansas; however, the ascending ramus is stubbier and the posteroexternal fossa is larger and better developed. See Hibbard (1970:423) and Genoways and Choate (1972) for a discussion on *Blarina* speciation. The molar measures 2.5 by 1.5 mm. The diagastric tubercle (Gaughran, 1954) is reduced as in *B. carolinensis* and is not as well developed as in *B. brevicauda* (Say). Repenning (1967:42) states that in the material he studied, *Blarina* showed the most intra-specific variation.

Family **Talpidae**

*Scalopus aquaticus* (Linnaeus)

*Material*.— UM-K3-69: V61409, lower molar fragment consisting of the metaconid, protoconid, and paraconid with small anterior accessory cuspid; UM-K5-72: V61410, left  $M^2$  and right  $P_4$ .

*Remarks*.— The  $M^2$  (V61410) measures 2.8 by 2.7 mm. It compares in size with *S. aquaticus machrinoides*, which occurs in the area today. An accessory anterior cuspid on specimen V61409 is not as well developed as in *Hesperoscalops* (Hibbard, 1941c).

Order LACOMORPHA

Family **Leporidae**

*Hypolagus* cf. *furlongi* Gazin

*Material*.— UM-K1-66: V60597, deciduous tooth, right lower jaw fragment, right  $P_3$ , right maxillary with  $P_4-M_2$ , right maxillary fragment and four upper molars; UM-K3-69: V60633, three deciduous teeth, three right  $P_3$ s, three left  $P_3$ s, six lower molars, three upper incisors, two  $P^2$ s, and eight upper molars; UM-K4-72: V60626, right  $P_3$ , left  $P_3$ , two upper incisors, eight upper molar fragments; UM-K4-72+12 ft SE: V61419, upper molar;

UM-K5-72: V61420, fused left and right premaxillary, two upper incisors, two right  $P_3$ s (one a fragment), two lower molars, small upper incisor, and three upper molars; UM-K6-72: V61421, lower deciduous tooth, two lower molars, and one upper molar; UM-K7-72: V61422, one lower molar.

*Measurements*.— See Table 3.

*Description*.— Most of the material represents young individuals. It is similar in size and morphology to *Hypolagus arizonensis* Downey and *H. limnetus* Gazin but can be differentiated from these species by the triangular shape of the  $P_3$  characteristic of *H. furlongi*. Also, the anteroexternal reentrant of the  $P_3$  is similar to *H. furlongi* in being shallower than that of *H. arizonensis* and *H. limnetus* (Gazin, 1934:118; Downey, 1962:1112).

The White Rock material is slightly smaller than the above species and slightly larger than *H. browni* (Hay). However, McNab (1971:Table 1) points out that Recent rabbits exhibit overall body size variations with latitude. Therefore slight differences in size over geographical areas are probably not taxonomically significant.

The anteroexternal reentrant on the  $P_3$  of *H. browni* forms an acute angle lingually that is not present in the White Rock sample. Hibbard's (1969:Fig. 3a) (UMMP V49414) and Gazin's (1934:Fig. 4b) (LACM [CIT] 1325) figures of  $P_3$ s of *H. furlongi* illustrate a small, sharp reentrant within a shallow open fold. However, of all other  $P_3$ s from the Grandview locality (UMMP 49699, V49610) and the White Rock locality (eight), none possess this small, sharp reentrant. This may be a result of wear or even individual variation. No plications were observed on the posteroexternal fold as is exhibited in *H. browni*, except in one specimen (V49699) from the Grandview local fauna. Enamel lakes opposite the posteroexternal reentrant, characteristic of *H. browni*, were not seen in any specimens of *H. furlongi* (see Dice, 1932:381; Gazin, 1934:117; and Dawson, 1958:62 for taxonomic discussion and occlusal pattern variation in  $P_3$ s of *H. browni*). However, a small lingual reentrant was observed in one specimen (V49699) from the Grandview local fauna. No anterior fold is exhibited in any of the White Rock specimens.

Two  $P^2$ s (V60633) were recovered from the White Rock locality. Both have a deep reentrant fold on the anterior surface and a shallow anteroexternal groove. The groove is deeper than in *H. limnetus*. One has a slight crenulation as in *H. furlongi* and the other has none as in *H. limnetus*. No upper dentitions are known for *H. arizonensis*. It may be that the presence or absence of crenulation in the  $P^2$  is variable, but too few specimens are known to determine its specific value. Downey (1962:1114) reported a *Hypolagus* sp.  $P^2$  with no crenulation associated with  $P_3$ s morphologically similar to *H. furlongi*. He notes that this may be an environmental difference.

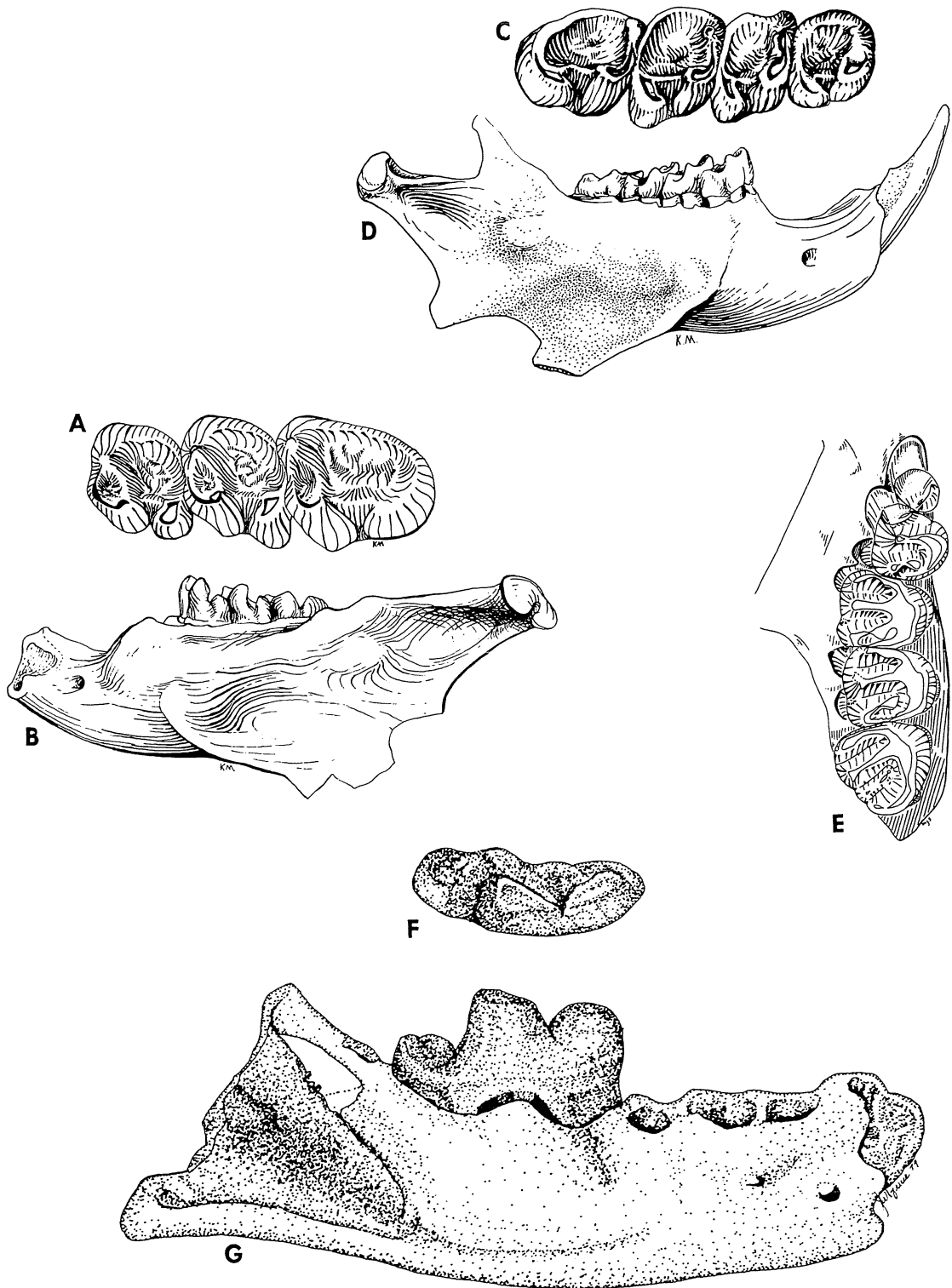


Table 3. *Hypolagus* P<sub>3</sub> Parameters (mm)\*

P <sub>3</sub> Sample	Anterior-Posterior Diameter			Transverse Diameter		
	N	X	OR	N	X	OR
Borchers	14	2.6	2.2-2.6	14	2.1	2.0-2.3
White Rock	8	2.4	2.2-2.7	7	2.1	1.9-2.5
Grandview	3	2.5	2.5-2.6	3	2.3	2.2-2.4
Deer Park	1	2.7	-	1	2.5	-

\*Measurements made at base of tooth to reduce variation with wear (tapering of the P<sub>3</sub> is especially evident in young individuals).

N=number, X=mean, OR=observed range

In all other aspects the White Rock material best compares with *H. furlongi*, but until additional material is recovered to clear up the P<sup>2</sup> and P<sub>3</sub> variation discussed above, I have made this assignment tentative.

**Remarks.**— This is the first occurrence for *H. furlongi* in the High Plains region. The White Rock material was compared to the small *Hypolagus* sp. from the Borchers and the Deer Park local faunas. The White Rock specimens are smaller in each case but compare well morphologically with the Deer Park material. The younger Borchers *Hypolagus* P<sub>3</sub> pattern is more advanced in that the posteroexternal reentrant penetrates more lingually across the tooth, curves anteriorly at its deepest penetration, and the enamel possesses crenulations. A few recovered elements (two P<sub>3</sub>s, V60633a, for example) are slightly larger than the majority of the White Rock rabbit material. These elements are still smaller than *H. vetus* (Kellogg) and probably represent adult specimens of *H. furlongi*.

#### Order RODENTIA

##### Family Sciuridae

##### *Cynomys (Cynomys) hibbaridi* sp. nov.

(Fig. 4 A, B)

**Holotype.**— UM-K9-72: UMMP V61648, left jaw with M<sub>1</sub>–M<sub>3</sub>.

**Horizon and Type Locality.**— Collected by Ralph Eshelman, summer of 1973, at UM-K9-72 in the silty clay lithosome, approximately 2.2 m below the contact with the sand lithosome, Belleville Formation, SE¼, SE¼, SW¼, Sec. 34, T. 1 S, R. 5 W, Republic County, Kansas.

**Distribution.**— Known only from the type specimen, White Rock fauna, of early Pleistocene age.

**Etymology.**— This species is named in recognition of the outstanding vertebrate paleontological contributions made by Dr. Claude W. Hibbard in the High Plains region of North America.

**Diagnosis.**— A small prairie dog about the size of *Spermophilus undulatus* (Pallas). Teeth mesohypsodont, the protolophid of the M<sub>1</sub>–M<sub>3</sub> curving prominently anterolabially giving the anterior portion of the teeth a relatively long anteroposterior length. Metalophid of M<sub>3</sub> is not as well developed as in Recent *Cynomys* and extends only from the protolophid to the protoconulid, and not to the parametaconid as in living forms.

**Measurements (mm).**— Greatest length of jaw 36.9 and least depth of jaw below diastema 5.8. Tooth measurements are given in Table 4.

**Description.**— The P<sub>4</sub> is missing, but its alveolus indicates the P<sub>4</sub> was about the size of the M<sub>1</sub>, possibly more elongate and with a fused birooted anterior root. The metalophid of the M<sub>1</sub> and M<sub>2</sub> are less hypsodont than the protolophid. The protoconid and parametaconid are proportionately closer together than in specimens of Recent prairie dogs in the same stage of tooth wear. This condition causes the trigonid basin formed between them by the protolophid and metalophid to be less elongate. This character plus the prominent anterolabial curving of the protolophid become less accentuated with wear. The M<sub>3</sub> is larger than the M<sub>2</sub>. The metalophid of the M<sub>3</sub> is weakly developed and extends lingually only to the protoconulid. In the subgenus *Spermophilus* no M<sub>3</sub> metalophid is present, but in living prairie dogs the metalophid on the M<sub>1</sub>–M<sub>3</sub> extends lingually to the parametaconid. The ectolophids are positioned lingually as in Recent *Cynomys*. An anteroposterior sulcus separates the ectolophid from the talonid basin.

Semken (1966:142) was able to separate ninety percent of a Recent prairie dog sample into their respective subgenera based on the presence (*Leucocrossuromys*) or absence (*Cynomys*) of a styloid on the talonid basin joining the ectolophid and thus separating the talonid basin into two parts. The White Rock specimen does not possess this styloid. Assuming this character separates these forms in early Pleistocene time, this species has been assigned to the subgenus *Cynomys*. The talonid basins of M<sub>1</sub>–M<sub>3</sub> possess complicated enamel folds.

The jaw has a proportionately short diastema and greater depth in this region as (*Cynomys*). The incisor

Figure 4. (A, B) *Cynomys (Cynomys) hibbaridi*, holotype, left jaw with M<sub>1</sub>–M<sub>3</sub>, V61648, occlusal view of molars and labial view of jaw, approximately x 2½. (C, D) *Cynomys (Cynomys?) cf. vetus*, right jaw with incisor and P<sub>4</sub>–M<sub>3</sub>, V61647, occlusal view of teeth and labial view of jaw, approximately x 2½. (E) *Spermophilus (Otospermophilus) boothi*, right maxillary with P<sup>3</sup>–M<sup>3</sup>, V59798, occlusal view, approximately x 4. (F, G) *Mustela cf. gazini*, right jaw with M<sub>1</sub>, V61669, occlusal view of molar and labial view of jaw, approximately x 5.

Table 4. Tooth measurements (mm) of *Cynomys (Cynomys) hibbardii*, new species and *Cynomys* sp. from the White Rock fauna

Tooth	UMMP V61648 (type)		UMMP V61649 (sp.)	
	length	width	length	width
I	—	—	3.13	2.09
P <sub>4</sub>	—	—	2.98	3.11
M <sub>1</sub>	2.96	3.36	2.42	3.28
M <sub>2</sub>	3.15	3.51	2.51	3.57
M <sub>3</sub>	4.45	3.70	4.22	3.82
P <sub>4</sub> -M <sub>3</sub>	—	—	12.41	—
M <sub>1</sub> -M <sub>3</sub>	10.18	—	9.58	—

alveolus suggests robust proportions. These characters are more similar to the subgenus (*Cynomys*). The masseteric ridge is well developed ventrally. The capsular process is slightly more pronounced than in living prairie dogs. The temporal fossa is deeper and better developed than in *Cynomys* and more like the condition seen in the subgenus *Spermophilus*. The coronid process and angular process are missing from the specimen.

A second jaw (V61649) with incisor and P<sub>4</sub>-M<sub>3</sub>, from the same stratigraphic horizon, was recovered directly across the canal from the type. The teeth are worn so that occlusal characters cannot be interpreted. It agrees in general with the type except the masseteric ridge is better developed anteriorly (possibly a function of age) and the molars are narrower anteroposteriorly. This may be a result of greater wear. Without intermediate wear stages this jaw cannot be assigned to species. The narrowest depth below the diastema is 5.2 mm. The teeth measurements are given along with the type in Table 4. The posterior portion of the jaw is broken behind the temporal fossa.

*Remarks.*— Bryant (1945:381, Fig. 48) suggests that the subgenera *Spermophilus* and *Cynomys* are closely related, probably separating in late Pliocene time. *Cynomys hibbardii*, early Pleistocene, exhibits some intermediate characters between these forms and thus supports Bryant's hypothesis. This intermediate condition is best illustrated by the development of the metalophid in the M<sub>3</sub>.

*Cynomys (Cynomys?) cf. vetus* Hibbard

(Fig. 4 C, D)

*Material.*— KU-Rep. Co. Loc. 1, taken 20 cm above sands in a reddish, sandy clay: V61647, right jaw with incisor and P<sub>4</sub>-M<sub>3</sub>, left jaw with P<sub>4</sub>-M<sub>3</sub>, and proximal

end of a left humerus. Both jaws and humerus of same individual.

*Measurements (mm).*— Greatest length of right jaw 35.1, left jaw 35.6; least depth of jaw below diastema of right jaw 6.0. Tooth measurements are given in Table 5.

*Diagnosis.*— See Hibbard, 1942:268.

*Description.*— The jaws are well preserved and complete except for the angular processes and the dorsal tip of the left coronid process. The P<sub>4</sub>s are molariform, but slightly narrower and more elongate than the M<sub>1</sub>s. The protolophid on the P<sub>4</sub> joins the protoconid and parametaconid as in *Cynomys*. The metalophids are complete in the P<sub>4</sub>s and nearly so in the M<sub>1</sub>s and are not developed on the M<sub>2</sub>s and M<sub>3</sub>s. In this character and in the enamel folding in the talonid basins of M<sub>1</sub>-M<sub>3</sub> the White Rock *C. cf. vetus* jaws are similar to the subgenus *Spermophilus*. The M<sub>3</sub> in comparison to the M<sub>2</sub> is not proportionately as large as in *Cynomys*. The temporal fossa is relatively deep and more like the condition in *Spermophilus*.

The jaw best compares to *Cynomys* in that the diastemal region of the horizontal ramus is shorter and stubbier with greater depth of jaw below the diastema. The hypsodont condition of the teeth is intermediate between *Cynomys* and the subgenus *Spermophilus*.

*Remarks.*— Hibbard (1942:268) assigned the maxillaries with P<sup>3</sup>-M<sup>3</sup> (KUMNH 6187) to *Cynomys* based on the following characters: posteriorly the tooth row converges; the P<sup>4</sup> and masseteric tubercles are large as in *Cynomys*. The occlusal enamel pattern is badly worn; however, an additional transverse ridge on the M<sup>3</sup>, characteristic of *Cynomys*, is not present. The M<sup>3</sup> in relation to the M<sup>2</sup> is not proportionally as large as in *Cynomys*.

The White Rock jaws were compared with the type maxillaries of *C. vetus* (no lower dentitions are known) and in spite of differences in state of wear, the occlusal surfaces match very well. Hibbard and I have compared Semken's (1966) Illinoian specimens of *C. cf. gunnisoni* (Baird) from the Sandahl local fauna and question Dalquest's (1967) assignment of these forms to *C. vetus*. Hopefully, associated upper and lower dentitions will be recovered to confirm this tenuous White Rock assignment.

The material in question has characteristics of both *Cynomys* and *Spermophilus*. I have chosen to retain the generic assignment made by Hibbard for the following reasons: (1) If *Cynomys* did evolve from *Spermophilus* in late Pliocene time as Bryant (1945) proposes, then early prairie dog forms should carry many spermophilous characters. They do today (Bryant, 1945:376) and this must have been more prevalent in the past. (2) Bryant (1945:367-8) places greater phylogenetic significance on zygomasseteric structure and corresponding mandibular configuration than on the characters of the teeth. Thus,

while many dental characters are more similar to the subgenus *Spermophilus*, the jaw structure is closer to *Cynomys*. Following Bryant (1945) emphasis is placed here.

Although Hibbard (1942) placed *C. vetus* in the subgenus *Cynomys*, Gromov et al. (1965) assign *vetus* to the subgenus *Leucocrossuromys*. *Cynomys vetus* can be distinguished from other early Pleistocene prairie dogs (*C. niobrarius* Hay, *spispiza* Green, and *meadensis* Hibbard) by its smaller size.

*Spermophilus (Otospermophilus) boothi* Hibbard

(Fig. 4 E)

*Material*.— UM-K1-66: V59798, right maxillary with P<sup>3</sup>—M<sup>3</sup>.

*Diagnosis*.— Hibbard, in Skinner, Hibbard et al., 1972: 82.

*Measurements*.— Table 6 compares the measurements of the White Rock maxillary with the upper dentition of the type Sand Draw specimen. The Sand Draw measurements are slightly larger than those given by Hibbard, as girth rather than occlusal measurements were used. The greater length of the type right maxillary is the result of its having been broken and cemented.

*Description*.— The White Rock maxillary is almost identical to the Sand Draw type (V57273) except that the White Rock mesostyles (terminology after Bryant, 1945) of the P<sup>4</sup>—M<sup>2</sup> are much less developed and are difficult to see by eye without proper lighting. In scanning 55 Recent skulls of *Spermophilus (Otospermophilus) variegatus grammurus* (Say), four of 110 P<sup>4</sup>s (less than four percent), 37 of 110 M<sup>1</sup>s (34 percent), and 31 of 110 M<sup>2</sup>s (28 percent) possessed well-developed mesostyles as seen in the type *S. boothi*. In 28 Recent skulls of *S. (O.) beecheyi* (Richardson), a greater percentage of mesostyles were observed; 15 of 56 P<sup>4</sup>s (27 percent), 35 of 56 M<sup>1</sup>s (63 percent), and 36 of 56 M<sup>2</sup>s (64 percent). Variation ranged from absent to well-developed mesostyles on the same maxillary.

The parastyle of the White Rock P<sup>4</sup> is better developed, more anteriorly protruded, heavier, and more hypsodont than in the Sand Draw specimen. The anterior cingulum is better developed and forms a platform between the parastyle and protocone. The parastyle of the type right maxillary is apparently abnormal in being situated more anteromedially than anterolabially as in the left type maxillary, the White Rock maxillary, and all observed Recent squirrels of the subgenus *Otospermophilus*. The P<sup>3</sup> on the White Rock specimen is larger than the type. Hibbard (in Skinner, Hibbard et al., 1972:82) states the P<sup>3</sup> is about one-fourth the size of the P<sup>4</sup>. Measurements from Hibbard's Table 8 and Table 6, this paper, indicate he meant the P<sup>3</sup> is about one-half the size of the P<sup>4</sup>.

Table 5. Tooth measurements (mm) of *Cynomys (Cynomys?) cf. vetus* from the White Rock fauna

Tooth	UMMP V61647 right jaw length	UMMP V61647 right jaw width	UMMP V61647 left jaw length	UMMP V61647 left jaw width
I	2.91	2.18	—	—
P <sub>4</sub>	2.91	3.23	2.91	3.13
M <sub>1</sub>	2.75	3.32	2.68	3.26
M <sub>2</sub>	3.03	3.61	3.06	3.56
M <sub>3</sub>	4.63	3.70	4.58	3.77
P <sub>4</sub> —M <sub>3</sub>	12.30	—	12.43	—

The infraorbital foramen is broken dorsally as in the type, but enough is present to indicate it was slightly larger than in the Sand Draw specimen. Metalophs are present on the M<sup>3</sup>s from both localities but are indistinct. Howell (1938:54) indicates great variability in this character among *Spermophilus*, but that the subgenus *Otospermophilus* lacks this character (Howell, 1938:43).

*Remarks*.— Based on characters used by Bryant (1945: 286, Table 1), I agree with Hibbard that *S. boothi* best fits the subgenus *Otospermophilus*. Except for the relatively large P<sup>3</sup> parastyle in the White Rock specimen and the presence of an indistinct mesoloph on the M<sup>3</sup>, all discussed characters fall within the variation of living *Otospermophilus*. Only individual differences are recognized between the Sand Draw and White Rock specimens; thus the latter is assigned to *S. boothi*. This occurrence extends the known geographical range of this ground squirrel from north-central Nebraska to north-central Kansas.

Isolated cheek teeth from three localities (UM-K3-69, UM-K4-72, and UM-K5-72) compare closely with the type and White Rock maxillary teeth described above. They have been assigned to *S. boothi* and are catalogued under UMMP V61651.

*Spermophilus* sp. small

*Material*.— V61650, numerous isolated teeth were recovered from the following localities and catalogued by locality under this number: UM-K3-69, UM-K4-72, UM-K4-72+200 ft NW, UM-K5-72, UM-K6-72, KU-Rep. Co. Loc. No. 3.

*Remarks*.— The isolated sciurid teeth are about the size of *S. franklini* (Sabine). These teeth may belong to either *S. johnsoni* or *S. meltoni* from the Sand Draw local fauna; however, no specific identification is attempted due to the fragmentary nature of the material.

Table 6. Measurements (mm) of the upper dentition of *Spermophilus (Otospermophilus) boothi* from the White Rock and Sand Draw local faunas.

Tooth	Sand Draw UMMP V57273				White Rock UMMP V59798	
	Right Maxillary length	Left Maxillary width	Right Maxillary length	Left Maxillary width	Right Maxillary length	Left Maxillary width
P <sup>3</sup>	1.59	1.72	1.42	1.53	1.63	1.78
P <sup>4</sup>	2.85	3.25	2.63	3.00	2.94	3.23
M <sup>1</sup>	3.09	3.82	3.06	3.70	3.12	3.63
M <sup>2</sup>	3.09	3.98	3.04	4.04	3.16	3.83
M <sup>3</sup>	3.78	3.70	3.81	3.73	3.69	3.69
P <sup>3</sup> -M <sup>3</sup>	13.56 (broken)	12.93	—	—	13.06	—

### Family Geomyidae

#### *Geomys* spp.

*Material.*— Large species? UM-K1-66: V61630, five upper incisor fragments, four lower incisor fragments; UM-K3-69: V61631, 20 upper incisor fragments, DP<sup>4</sup>, nine P<sup>4</sup>s, 11 M<sup>3</sup>s, nine lower incisor fragments, ten P<sup>4</sup>s, 28 molars, right jaw with incisor, two left jaws (one with incisor); UM-K4-72: V61632, seven upper incisor fragments, three P<sup>4</sup>s, M<sup>3</sup>, 11 lower incisor fragments, five P<sup>4</sup>s, six molars; UM-K4-72+12 ft SE: V61633, four P<sup>4</sup>s, two M<sup>3</sup>s, two P<sup>4</sup>s, three molars; UM-K4-72+200 ft NW: V61634, P<sup>4</sup>; UM-K5-72: V61635, nine upper incisor fragments, three P<sup>4</sup>s, four M<sup>3</sup>s, three lower incisor fragments, three P<sup>4</sup>s; UM-K6-72: V61636, P<sup>4</sup>, three lower incisor fragments, one molar; KU-Rep. Co. Loc. No. 3: V60627, upper incisor. Total number of isolated teeth is 168.

Small species? UM-K1-66: V61637, 16 upper incisor fragments, five right jaw fragments (one with incisor fragment), two left jaw fragments; UM-K3-69: V61638, 73 upper incisor fragments, two DP<sup>4</sup>s, 91 P<sup>4</sup>s, 53 M<sup>3</sup>s, seven lower incisor fragments, 78 P<sup>4</sup>s, five DP<sup>4</sup>s, 285 molars, two right jaw fragments; UM-K4-72: V61639, 33 upper incisor fragments, 21 P<sup>4</sup>s, 12 M<sup>3</sup>s, five lower incisor fragments, 17 P<sup>4</sup>s, two DP<sup>4</sup>s, 60 molars, five right jaw fragments (two with incisor fragments), left jaw fragment with incisor, two fused maxillary fragments; UM-K4-72+12 ft SE: V61640, DP<sup>4</sup>, 14 P<sup>4</sup>s, six M<sup>3</sup>s, 14 P<sup>4</sup>s, 39 molars; UM-K4-72+200 ft NW: V61641, nine upper incisor fragments, three P<sup>4</sup>s, M<sup>3</sup>, 18 molars; UM-K5-72: V61642, 42 upper incisor fragments, 13 M<sup>3</sup>s, seven lower incisor fragments, 57 P<sup>4</sup>s, 124 molars; UM-K6-72: V61643, seven upper incisor fragments, three P<sup>4</sup>s, five M<sup>3</sup>s, DP<sup>4</sup>, seven molars, fused maxillary fragment; UM-K7-72: V61644, seven upper incisor fragments, three P<sup>4</sup>s, three M<sup>3</sup>s, six lower incisor fragments, P<sup>4</sup>, nine molars; UM-K9-

72: V61645, right jaw with incisor, P<sup>4</sup>-M<sup>2</sup>, right jaw fragment with incisor fragment. Only the larger and better preserved material was counted. Total number of isolated teeth is 1,164.

*Measurements (mm).*— V61645: length of mandible 28.4, depth of jaw at diastema 5.5, diastemal length 9.2, greatest width of jaw at masseteric ridge 5.5.

*Description.*— The White Rock specimens compare closely with the genus *Geomys* in the following characters: the upper incisors are strongly bisulcate to the unaided eye (see Akerston, 1973a for variation in this character), anterior and posterior enamel plates on M<sup>1</sup> and M<sup>2</sup>, P<sup>4</sup> with four enamel plates, only posterior enamel plate on M<sup>1</sup>-M<sup>3</sup>, and P<sup>4</sup> decidedly longer than P<sup>4</sup>. The mental foramen of the lower jaw is anterior and slightly ventral to the anterior extremity of the masseteric ridge. In two other jaws (V61637a,b) the mental foramen is just slightly anterior to the anterior border extremity of the masseteric ridge. The remaining jaws were more similar to *G. bursarius* (Shaw) in this anterior foraminal position. There is some variation in this character, as two jaws of *G. quinni* McGrew (V25609, V25606) from the Sand Draw local fauna have the mental foramen positioned farther posterior than normal. In Recent *Geomys* only one of 112 jaws examined (*G. p. pinetis* Rafinesque, UMMZ 96910, Camden Co., Georgia) exhibited a similar posteriorly placed mental foramen. Russell (1968a:527) states that, "the mental foramen relative to the anterior part of masseteric ridge varies with individuals and according to species." None of the White Rock specimens possessed a heteromyid projection (see Akerston, 1973b) with mental foramen directly underneath as in *Nerterogeomys*.

Only one specimen (V61643) is complete with a basitemporal fossa of the lower jaw (between the lingual side of the ascending ramus and M<sup>3</sup>) and it differs from *G. bursarius* in that the fossa is not as deep. Depth appears to increase with age, but the depth of the fossa is more similar to *G. quinni* (see Hibbard, in Skinner, Hibbard et al., 1972:88).

*Remarks.*— The pocket gopher is the most common rodent in the White Rock fauna, as in many Pleistocene faunas of the High Plains. Gophers are unusual rodents in that the jaw and dentition increase considerably in size with age (indeterminate growth). Merriam (1895:20) and Russell (1968a:497, 499; 1968b:Fig. 1) also note that the degree of sexual variation is great. Based on greatest width of the upper incisor, the White Rock sample has a size range from 1.7 to 4.2 mm. These measurements fall within the observed range of living *G. b. bursarius* (Shaw) from Iowa and Kansas. However, one large P<sup>4</sup> (V61639a) from UM-K3-69 is that of a young individual indicated by its uninterrupted dentine tracks (Russell, 1968a:479, 526). This tooth is larger than P<sup>4</sup>s with interrupted enamel patterns. This character



plus the variance in the mental foramenal position argue for two species, one large and one small. Two species of *Geomys* appear to be common in the earlier Pleistocene faunas of the High Plains. For this reason the White Rock material has been divided into two questionable populations. Without complete skulls and lower jaws with complete dental series, specific identification is impossible.

### Family Heteromyidae

#### *Perognathus pearlettensis* Hibbard

*Material*.— UM-K3-69: V61682, left P<sub>4</sub>; UM-K4-72+12 ft SE: V61683, right jaw fragment with P<sub>4</sub>.

*Diagnosis*.— See Hibbard, 1941a:207.

*Description*.— The partial jaw (V61683) is lacking the ramus posterior to the M<sub>1</sub> alveolus. The mental foramen is almost directly below the anterior edge of the masseteric crest, typical of *Perognathus pearlettensis*, and not slightly anterior as usual in *P. rexroadensis* Hibbard. The P<sub>4</sub> measures 0.7 by 0.7 mm. The cusps form an X-pattern as the anterior groove separating the two cusps of the anterior loph and the labial and lingual reentrant grooves between the anterior and posterior lophs are well developed. A second P<sub>4</sub> (V61682) exhibits the same characters and identical measurements.

Size as well as shape of the enamel pattern of the P<sub>4</sub> allows separation of *P. pearlettensis* from the other species of this genus. *Perognathus pearlettensis* has also been reported from the Borchers (Hibbard, 1941a:207), Fox Canyon (Hibbard, 1950:139), and Sanders (Hibbard, 1956:181) local faunas.

#### *Perognathus* sp. large

*Material*.— UM-K3-69: V61684, right M<sub>1</sub>?; UM-K5-72: V61685, right M<sub>2</sub>?

*Description*.— The right M<sub>1</sub>? (V61684) measures 1.1 by 1.3 mm and the right M<sub>2</sub>? (V61685) 1.0 by 1.4 mm. Both the anterior and posterior lophs of these molars consist of three cusps, exhibiting an H-pattern with wear. These molars are one-third larger than those of *Perognathus pearlettensis* and compare more favorably in size with *P. magnas* Zakrzewski from the Hagerman local fauna. It is impossible to make a species determination on these two isolated molars. The occurrence of two species of *Perognathus* from one fauna is common, as two (one large and one small) forms are recognized from the Fox Canyon (Hibbard, 1950), Hagerman (Zakrzewski, 1969), and Borchers (Hibbard, 1941a, 1942) local faunas.

#### *Prodipodomys* sp.

*Material*.— UM-K3-69: V61686, right P<sub>4</sub> and isolated molar; UM-K5-72: V61687, right P<sub>4</sub>.

*Description*.— Both P<sub>4</sub>s are two rooted and possess poorly developed incipient dentine tracts; each measures 1.3 by 1.5 mm and is in early stage of wear. The White Rock material can be distinguished from *Prodipodomys idahoensis* Hibbard by the lack of well-developed wedge-shaped dentine tracts, and from *P. centralis* (Hibbard) and *P. rexroadensis* Hibbard by its larger size. This material is similar to two isolated P<sub>4</sub>s (V32035, V32034) from the Sanders local fauna (*Prodipodomys* sp., Hibbard, 1956:181) and to *Etadonomys tiheni* Hibbard (1943:185) from the Borchers local fauna. All three forms are alike in size, development of dentine tracts, and well-developed nearly equal enfolding of the lingual and labial P<sub>4</sub> reentrants. The grooves between the lophids of one P<sub>4</sub> (V61687) do not extend to the base of the crown, whereas in the other P<sub>4</sub> (V61686) they do. This suggests there is intraspecific variation in this character and it does not reflect a specific difference (Zakrzewski, 1970:475).

One isolated molar (V61686a) with roots not yet developed measures 1.1 by 1.6 mm. Both the anterior and posterior lophs (ids) consist of three cusps, which wear into a usual H-pattern.

*Remarks*.— I find no characters based on isolated teeth that substantiate a generic separation of *Etadonomys tiheni* from *Prodipodomys*. Before a formal synonymy can be made, complete jaws will be necessary to establish the position of the temporal fossa in relation to the mandibular foramen as well as the shape of the M<sub>3</sub> root (Hibbard, 1943:186; 1962:Fig. 1).

### Family Castoridae

#### *Castor* sp.

*Material*.— UM-K1-66: V60635, two molar fragments; UM-K3-69: V61416, right lower incisor fragment; UM-K4-72: V61417, left proximal end of humerus; UM-K5-72: V61418, two molar fragments.

*Remarks*.— The humerus is that of an adult slightly larger than average Recent *Castor canadensis* Kuhl humeri and slightly smaller than the Hagerman *Castor* humeri material. The humerus can be distinguished from *Procastoroides*, *Dipoides*, and *Castoroides* by the placement of the third trochanter, which is nearly opposite the second trochanter in all the above genera except *Castor*, where it is well down the shaft (Shotwell, 1970:45). Also, the third trochanter of *Castor* is more tubercular and not blade-like as in all the other above genera (Erickson, 1962; Martin, 1969; Shotwell, 1970). Greatest width is 52.3 mm.

A left molar fragment (V61418a) from UM-K5-72

may be a deciduous P<sub>4</sub>. Its greatest width is 6.8 mm; no other measurements are possible due to the fragmentary nature of the material. The tooth is too fragmentary for specific identification.

The White Rock occurrence is the earliest report of *Castor* from the High Plains area. *Castor* has also been reported from the Butler Spring, Doby Springs, Berends, and Sandahl local faunas (Hibbard, 1970), regarded as Illinoian in age. The Kentuck local fauna, questionably of Aftonian age, also contains *Castor*. East of the High Plains *Castor canadensis* is reported from Port Kennedy Cave and Conard Fissure, considered Kansan in age. Earliest records for this genus are from the late Pliocene west of the High Plains. The Plesio-type of *Castor accessor* Hay is from the Grandview local fauna of Idaho. The presence of *Castor* indicates the proximity of trees, possibly in a marsh-meadow community.

*Procastoroides* sp.

*Material*.— KU-Rep. Co. Loc. No. 3: KUMNH 6637, molar fragment.

*Remarks*.— The generic assignment is based on tooth morphology and size. Due to the fragmentary nature of this tooth and the tremendous amount of variation in *Procastoroides* teeth (Woodburne, 1961), no specific assignment is attempted. The tooth has a maximum width of 10.5 mm.

Family Muridae

Subfamily CRICETINAE

*Reithrodontomys pratincola* Hibbard

*Material*.— UM-K3-69: V61688, right M<sub>2</sub>, right maxillary fragment with M<sup>1</sup> and M<sup>2</sup>; V61691, left and right maxillary fragment with M<sup>1</sup>; UM-K4-72: V61689, right M<sub>2</sub>; UM-K4-72+12 ft SE: V61690, left jaw with M<sub>1</sub> and M<sub>2</sub>.

*Diagnosis*.— See Hibbard, 1941a:209; 1941b:266.

*Description*.— The jaw with M<sub>1</sub> and M<sub>2</sub> (V61690) compares favorably with *Reithrodontomys pratincola* from the Borchers local fauna. The diastemal distance between the M<sub>1</sub> and incisor is less than that of *R. rexroadensis* Hibbard or *R. wetmorei* Hibbard. The mental foramen, located dorsolabially 0.3 mm anterior to the anterior root of the M<sub>1</sub>, is larger than in living forms of the genus and more similar in size to *R. wetmorei*. The diastemal region is proportionately broader than in the genus *Baiomys*. The M<sub>1</sub> measures 1.3 by 0.8 mm; M<sub>2</sub>, 1.0 by 0.9 mm.

The M<sub>1</sub> is broader anteriorly than in *R. moorei* (Hibbard) (Cudahy local fauna) and *R. rexroadensis* (Fox Canyon local fauna). A cingulum of the posteroexternal valley just posterior to the protoconid (for terminology

see Hibbard, 1952:Fig. 1) is weakly developed and not as prominent as in *R. wetmorei*. The M<sub>2</sub> is not as elongate and thus proportionately broader than that observed for *R. rexroadensis* or *R. moorei*; the M<sub>2</sub> is smaller than that of *R. wetmorei*. *Reithrodontomys pratincola* is much smaller than *R. simplicidens* Brown (Hibbard, 1941a:210). The remaining lower molars, both right M<sub>2</sub>s, each measure 1.1 by 0.9 mm.

Based on the position, shape, and degree of development of the masseteric tubercle, the maxillary fragment with M<sup>1</sup> and M<sup>2</sup> (V61688) best compares with Recent *Reithrodontomys* maxillaries and to one left maxillary (V28891) from the Fox Canyon local fauna also identified as *Reithrodontomys* (Hibbard, 1952:200). The M<sup>1</sup> measures 1.5 by 0.8 mm; the M<sup>2</sup>, 1.1 by 0.8 mm. One left and one right maxillary, each possessing M<sup>1</sup>s (V61691), were also recovered from the same locality (UM-K3-69). The right M<sup>1</sup> measures 1.6 by 0.9 mm; the left M<sup>1</sup>, 1.5 by 0.9 mm. All three are essentially alike in size and in morphology. Two of the three M<sup>1</sup>s (right M<sup>1</sup> V61688 and left M<sup>1</sup> V61691) possess a weak anterior enfolding on the face of the anterocone. It is not as well developed as in *Bensonomys*.

Upper dentitions of the fossil forms of *Reithrodontomys* from the High Plains region will not be known with certainty until associated upper and lower dentitions are recovered (Hibbard, 1952:201). However, because these White Rock M<sup>1</sup>s are smaller than *Peromyscus cragini* Hibbard (V39519, Cudahy local fauna), also known from this fauna, because no other smaller cricetids were recovered, because they match the expected dentitional size and morphology for upper molars of *R. pratincola*, and because the masseteric tubercle (V61688) possesses characters most similar to *Reithrodontomys*, the maxillaries are assigned to this form.

*Remarks*.— Following Hibbard's (1952:201) hypothetical niche assignment of fossil *Reithrodontomys* based on extant species found in Meade County, Kansas (Hill and Hibbard, 1943), *R. pratincola* probably inhabited moist lowland areas. This species of harvest mouse is also known from the Borchers local fauna and tentatively recorded from the Cudahy local fauna (Hibbard, 1944:724).

*Peromyscus cragini* Hibbard

*Material*.— UM-K3-69: V61692, right jaw with M<sub>1</sub>.

*Diagnosis*.— See Hibbard, 1944:724; 1954:234.

*Description*.— The jaw and M<sub>1</sub> are similar to *Peromyscus cragini* (Cudahy local fauna) and *P. baumgartneri* Hibbard (Rexroad local fauna). The mental foramen is slightly larger than in *P. cragini* (compare V38346, Cudahy local fauna). The diastemal width is proportionately greater in *P. baumgartneri* and more like the condition

found in *P. cragini*. This plus a small anterior groove on the face of the anteroconid of the  $M_1$ , characteristic of *P. cragini* (Hibbard, 1954:234), allows placement of this specimen within *P. cragini*. The  $M_1$  possesses a poorly developed cingulum connecting the protoconid and hypoconid. No accessory cusps are present. The  $M_1$  measures 1.5 by 1.0 mm. Two isolated left  $M_1$ s (V61693) from locality UM-K3-69 are the size of *P. cragini* and are tentatively assigned to this form. Neither molar shows evidence of accessory cusps or an anterior groove on the face of the anteroconid.

*Remarks.*— The presence of *P. cragini* in the White Rock fauna extends the geological range of this species from late Kansan to pre-Nebraskan time. The similarities exhibited by *P. baumgartneri* and *P. cragini* suggest a close relationship, possibly *P. cragini* evolving from *P. baumgartneri*. An isolated unidentified *Peromyscus* tooth (V32045) from the slightly older Dixon local fauna is larger and belongs to a different taxon.

An isolated cricetid  $M_1$  (V61749) from locality UM-K5-72 possesses a small labial and lingual anteroconulid. The cusps are much too hypsodont and are morphologically distinct from *Bensonmys*. A second species of *Peromyscus* may be present.

#### *Onychomys fossilis?* Hibbard

*Material.*— UM-K3-69: V61694, right  $M_1$ , left  $M_1$ , right  $M_2$ , left  $M_2$ .

*Diagnosis.*— See Hibbard, 1941a:208.

*Measurements (mm).*— right  $M_1$ , 2.1 by 1.3; left  $M_1$ , 2.1 by 1.3; right  $M_2$ , 1.6 by 1.3; left  $M_2$ , 1.5 by 1.2 (questionably placed within this taxon).

*Description.*— Isolated first and second molars agree in size with *Onychomys gidleyi* Hibbard (Rexroad fauna), *O. fossilis* (Borchers local fauna), and living *O. leucogaster* (Maximillian). They may be differentiated from each other by the size of the  $M_3$  and mandibular characters (Hibbard, 1941a, b). Unfortunately, no jaws or  $M_3$ s are presently known from the White Rock fauna. It is impossible to make a definite specific assignment at this time. However, because *O. fossilis* exhibits an intermediate development of the posterior cingulum (entostylids of Hibbard, 1941b) of the  $M_1$  and  $M_2$  between *O. gidleyi* and *O. leucogaster*, the White Rock material is questionably assigned to *O. fossilis*.

*Remarks.*— Hibbard (1964:125) suggests *O. gidleyi* may have been derived from *O. larrabeei*. In view of the close similarity displayed between *O. gidleyi*, *O. fossilis*, and *O. leucogaster*, I see no reason why these species cannot represent a single lineage over time, extending this phylogeny from Pliocene to Recent.

#### *Onychomys* sp. small

*Material.*— UM-K3-69: V61695, two right  $M_1$ s, left  $M_1$ , right  $M_1$ , right  $M_2$ ; UM-K4-72: V61696, two right  $M_1$ s; UM-K5-72: V61697, left  $M_1$ .

*Measurements (mm).*— V61695 right  $M_1$ , 1.9 by 1.3; right  $M_1$ , 1.8 by 1.2; left  $M_1$ , 1.9 by 1.2; right  $M_1$ , width 1.3; right  $M_2$ , 1.5 by 1.3; V61696 right  $M_1$ , 2.1 by 1.3; right  $M_1$ , 2.1 by 1.4; V61697 left  $M_1$ , 2.1 by 1.3.

*Description.*— The above material is smaller than *Onychomys fossilis* and best compares with the living southern grasshopper mouse, *O. torridus* (Coues). Of the four  $M_1$ s present, two (V61697 and V61696a) exhibit well-developed anterior enfolding on the face of the anterocone. This condition is infrequently observed in living *Onychomys* and is exhibited on isolated  $M_1$ s assigned to *O. fossilis* from the Borchers local fauna (e.g., V60079 and V60081).

*Remarks.*— Jaws with complete dental series are essential for specific assignment. Whether the  $M_1$ s with anterocone enfolding are actually teeth of *Onychomys* or represent another small cricetid cannot be determined by isolated teeth.

The presence of two sympatric species of grasshopper mice is not surprising; the northern grasshopper mouse (*O. leucogaster*) and the southern grasshopper mouse (*O. torridus*) are sympatric today (Van Cura and Hoffmeister, 1966, report nine instances of sympatry in Arizona). Careful examination of the Borchers *Onychomys* reveals that one large (*O. fossilis*) and one small species of *Onychomys* are present (compare V35763a and V28151 with V35763 and V28150). The small species of *Onychomys* from the White Rock and Borchers local faunas is similar to the living grasshopper mouse, *O. torridus*, and upon further examination may prove to be ancestral to *O. torridus*.

#### *Sigmodon minor* Gidley

*Material.*— UM-K1-66: V61292, two right  $M_1$ s; UM-K3-69: V61293, four right  $M_1$ s, three left  $M_1$ s, four right  $M_2$ s, three left  $M_2$ s, right  $M_3$ , two left  $M_3$ s, four right  $M_1$ s, three left  $M_1$ s, left maxillary fragment with  $M_1$ , two right  $M_2$ s, three left  $M_2$ s, right  $M_3$ , left  $M_3$ ; UM-K4-72: V61291, right  $M_1$ , left jaw fragment with  $M_2$ ; UM-K4-72+12 ft SE: V61295, right  $M_1$ , left jaw fragment with  $M_1$ , right  $M_1$ , right  $M_3$ ; UM-K5-72: V61294, three right  $M_1$ s, left  $M_1$ , two left  $M_2$ s, right  $M_1$ , three left  $M_1$ s, three left  $M_2$ s; UM-K7-72: V61681, left  $M_2$ . Total number of isolated teeth is 52.

*Description.*— I agree with Hall and Kelson (1959: 671) that the genus *Sigmodon* is in need of taxonomic revision. The fossil species of this genus are especially in need of reevaluation. Much of the confusion is the

Table 7. Length and width measurements of upper and lower molars of fossil *Sigmodon* (mm)

Tooth	Rexroad ( <i>S. medius</i> )			Benson <sup>1</sup> ( <i>S. medius</i> )			Sanders ( <i>S. medius</i> )			Tusker <sup>2</sup> ( <i>S. medius</i> )			White Rock ( <i>S. minor</i> )			Borchers ( <i>S. hilli</i> )			Curtis Ranch <sup>3</sup> ( <i>S. minor</i> )		
	N	X	OR	N	X	OR	N	X	OR	N	X	OR	N	X	OR	N	X	OR	N	X	OR
LM <sup>1</sup>	10	2.2	2.0-2.3	20	2.2	2.0-2.3	10	2.2	2.1-2.3	2	2.1	2.0-2.1	15	2.1	1.9-2.3	10	2.2	2.0-2.5	10	2.1	1.8-2.5
WM <sup>1</sup>	10	1.7	1.5-2.0	20	1.6	1.5-1.9	10	1.6	1.5-1.6	2	1.6	1.4-1.8	15	1.6	1.3-2.0	10	1.6	1.4-1.8	10	1.5	1.3-2.1
LM <sup>2</sup>	6	1.6	1.6-1.7	37	1.6	1.4-1.9	5	1.6	1.6-1.8	2	1.7	1.5-1.8	8	1.6	1.4-1.8	10	1.6	1.4-1.7	14	1.4	1.2-1.9
WM <sup>2</sup>	6	1.6	1.4-1.7	37	1.5	1.3-1.7	5	1.6	1.4-1.7	2	1.6	1.6-1.6	8	1.5	1.4-1.6	10	1.5	1.4-1.6	14	1.5	1.2-1.8
LM <sup>3</sup>	3	1.5	1.5-1.6	10	1.5	1.4-1.6				2	1.7	1.6-1.7	3	1.6	1.5-1.6	10	1.5	1.3-1.6	5	1.4	1.1-1.5
WM <sup>3</sup>	3	1.5	1.5-1.5	10	1.4	1.3-1.6				2	1.6	1.5-1.6	3	1.4	1.3-1.4	10	1.4	1.3-1.5	5	1.3	1.2-1.4
LM <sub>1</sub>	27	2.2	2.0-2.5	14	2.1	1.9-2.5	6	2.2	2.1-2.3	2	2.2	2.1-2.3	9	2.1	2.0-2.3	10	2.0	1.8-2.2	6	2.1	1.8-2.2
WM <sub>1</sub>	27	1.4	1.3-1.6	14	1.4	1.3-1.6	6	1.5	1.4-1.5	2	1.4	1.4-1.4	9	1.3	1.2-1.4	10	1.3	1.2-1.3	6	1.4	1.2-1.7
LM <sub>2</sub>	13	1.7	1.5-1.8	6	1.7	1.5-1.9	3	1.7	1.6-1.8	2	1.7	1.7-1.7	10	1.7	1.5-1.9	10	1.6	1.5-1.8	7	1.5	1.2-1.7
WM <sub>2</sub>	13	1.6	1.5-1.6	6	1.6	1.5-1.7	3	1.5	1.4-1.6	2	1.7	1.6-1.7	10	1.5	1.4-1.6	10	1.4	1.3-1.5	7	1.5	1.4-1.6
LM <sub>3</sub>	8	1.7	1.6-1.8	20	1.8	1.5-2.0	3	1.9	1.7-2.0	2	1.7	1.6-1.7	3	1.9	1.8-2.0	10	1.8	1.5-1.8	7	1.5	1.4-1.7
WM <sub>3</sub>	8	1.4	1.4-1.5	20	1.5	1.3-1.7	3	1.6	1.5-1.6	2	1.6	1.5-1.6	3	1.4	1.4-1.6	10	1.4	1.2-1.5	7	1.4	1.3-1.4

<sup>1</sup>Data from Lammers, 1970

<sup>2</sup>Loan from University of Arizona

<sup>3</sup>Data from Lammers, 1970; measurements made by author on loan material from University of Arizona fall within the observed ranges given by Lammers. It appears, however, Lammers did not use girth measurements — compare M<sub>3</sub> lengths for example.

result of the great variation in occlusal pattern of molars with wear and individual size variation within a single species (Cantwell, 1969).

Table 7 is a compilation of the length and width girth measurements of upper and lower molars for all fossil *Sigmodon* species except *S. curtisi* Gidley and *S. hudspehensis* Strain, which obviously are larger than the White Rock taxon. The data are arranged by locality, oldest first (Rexroad, *S. medius* Gidley) to youngest last (Curtis Ranch, *S. minor* Gidley). For each tooth type from each locality, a slight size decrease over time is suggested. The observed ranges for each, however, overlap considerably (see Table 7), and as in the case of the length of the M<sup>1</sup>, although the mean for *S. minor* is 2.1 mm, the most elongate specimens are found in this sample and not in the earlier samples of *S. medius*, which have a mean length of 2.2 mm. Figure 5 is a bar diagram showing the size variation in *Sigmodon* M<sub>1</sub>s.

Gidley (1922:126) states, "*S. minor* differs from *S. medius* only in its smaller size, having a relatively narrower anterior lower cheek tooth, in which the anterior lobe is relatively smaller with adjacent reentrant valleys nearly equal in length." He also states the teeth of *S. minor* are less hypsodont. As the ranges of variation shown in the larger fossil samples overlap these criteria, the above characters no longer provide discrete taxonomic units.

Recent *Sigmodon hispidus hispidus* measurements of condylobasal length, zygomatic breadth, and M<sup>1</sup>–M<sup>3</sup> alveolar length, when correlated with latitude (Table 8), show a positive Bergmann's response. Assuming such a response was exhibited by species of *Sigmodon* in the past, not only are there individual and temporal variations, but spatial ones as well.

Cantwell (1969:377) indicated that a significant percentage (not given) of isolated first lower molars from the Tusker locality have incipient mesiolabial rootlets, ranging from a minute projection to a small but well-developed third root. Gidley (1922) and Lammers (1970) give no data on the number or condition of roots in *S. minor* and *S. medius* from their respective type localities. Two specimens of each species from the University of Arizona were examined. Both M<sub>1</sub>s of *S. minor* from the Curtis Ranch had only two roots; both M<sub>1</sub>s of *S. medius* from the Tusker fauna had two good roots plus a small labial third rootlet. UMMP material shows that approximately 50 percent of the M<sub>1</sub>s have no third rootlet and the remaining have only a minute projection. These results are summarized below:

Borchers local fauna, *S. hilli* (*minor*) — 40, no third root; 53, a minute projection; one, a small, well-developed third root.

White Rock fauna, *S. minor* — six, no third root; two, a minute projection.

Sanders local fauna, *S. medius* — one, no third root; three, a minute projection.

Rexroad local fauna, *S. medius* — 13, no third root; ten, a minute projection.

Wendel Fox local fauna, *S. medius* — two, no third root; two, a minute projection.

From these same faunas, all M<sup>1</sup>s examined had three well-developed roots plus a small projection ranging from a slight protrusion to a rootlet up to 0.4 mm in length. All M<sup>2</sup>s were three rooted except for two (UA 3218, a right and left of the same individual from Curtis Ranch), which have small medial labial fourth roots. In the Florida Reddick fauna (late Pleistocene in age) less than nine percent of the M<sup>2</sup>s (12 of 136) possess a fourth rootlet. Presently available data do not indicate specific differences or obvious trends in root development.

*Remarks.*— If *S. minor* and *S. medius* are good species and *S. minor* evolved from *S. medius* as Martin (1970) contends, then populations with both or intermediate characters should be expected. The White Rock population fits this situation. However, without statistically significant additional samples from localities with good stratigraphic control, including *S. minor* and *S. medius* material from the type localities (Curtis Ranch and Benson), I find no specific differences based solely on isolated tooth characters. The size of the sample necessary to give a reliable approximation of the population depends largely upon the range of variation of the character being studied; the greater the variation of a character, the larger the sample necessary to approximate the population extremes (Klauber, 1941:33). Because tooth size and occlusal pattern in *Sigmodon* are extremely variable, very large samples are needed to show these variation extremes. I have compared and measured a sample of *Sigmodon* material from the University of Arizona's Tusker and Curtis Ranch collections and Gidley's type and paratype material from the National Museum of Natural History. Until specific characters for isolated molars are discovered or more complete material is recovered from the White Rock fauna, I have assigned the White Rock cotton rat material on priority to *S. minor* following Cantwell (1969).

#### *Neotoma (Paraneotoma) taylori* Hibbard

*Material.*— UM-K1-66: V60628, left M<sup>1</sup>; UM-K3-69: V61414, four left M<sup>1</sup>s, four right M<sup>2</sup>s, two left M<sup>2</sup>s, two right M<sup>3</sup>s, four left M<sup>1</sup>s, two right M<sup>2</sup>s, two right M<sup>3</sup>s, left M<sup>3</sup>; UM-K4-72: V61411, right M<sup>1</sup>, left M<sup>1</sup>, right M<sup>1</sup>; UM-K4-72+12 ft SE: V61412, right M<sup>1</sup>, right M<sup>2</sup>, left M<sup>2</sup>, left jaw fragment with M<sup>1</sup>, right M<sup>1</sup>, left M<sup>1</sup>, right M<sup>2</sup>, left M<sup>2</sup>; UM-K4-72+200 ft NW:

Table 8. Measurements (mm) of Recent *Sigmodon hispidus hispidus*\* and correlation of *S. hispidus* parameters to latitude.

Latitude (degrees)	Condylbasal length			Zygomatic breadth			M <sup>1</sup> –M <sup>3</sup> length		
	N	X	OR	N	X	OR	N	X	OR
30-31 <sup>1</sup>	23	30.5	25.8-36.2	25	19.5	16.9-21.8	25	6.7	6.1-7.2
32-34 <sup>2</sup>	54	30.0	25.3-33.5	46	19.3	16.8-21.2	54	6.6	6.1-7.1
35-36 <sup>3</sup>	20	27.2	24.1-31.4	21	17.8	15.8-20.3	23	6.4	6.0-6.9

<sup>1</sup>Sample from Putman County, Florida; Clinch County, Thomas County, Georgia.

<sup>2</sup>Sample from Lee County, Alabama; Cobb County, DeKalb County, Georgia; Charleston County, Beaufort County, South Carolina.

<sup>3</sup>Sample from Wake County, Mecklenburg County, Burke County, North Carolina.

\*All specimens from the University of Michigan, Museum of Zoology, Division of Mammalogy collections.

V61415, two right M<sup>2</sup>s, right M<sup>1</sup>, right M<sup>2</sup>, right M<sup>3</sup>; UM-K5-72: V61413, left M<sup>3</sup>, right M<sup>2</sup>, left M<sup>2</sup>; UM-K7-72: V61680, left M<sup>1</sup> fragment. Total number of isolated teeth is 40.

*Measurements.*— See Table 9.

*Diagnosis.*— See Hibbard, 1967, for complete diagnosis of subgenus and species.

*Description.*— Of eight M<sup>1</sup>s recovered, all except one possess three roots, as in the Borchers local fauna *Neotoma taylori*. The exception (V61411a) from locality UM-K4-72 has a fourth small (0.5 mm) rootlet under the paracone, as is typical of the Rexroad *N. quadriplacatus* (Hibbard). Hibbard (1967:129) states that 21 of 23 right M<sup>1</sup>s of *N. quadriplacatus* possess a fourth rootlet ranging from a slight protuberance to 1.0 mm in length. Three of four White Rock M<sup>3</sup>s possess the typical three-loop pattern, as in Recent and Borchers species. The other (V61414a) retains a fourth posterior internal reentrant angle present in some specimens of *N. quadriplacatus* (see Hibbard, 1941c:Pl. 2, Figs. 4, 6, 8). All the M<sup>3</sup>s are distinctly three rooted as in *N. quadriplacatus* except one (V61415) from UM-K4-72+200 ft NW, where the anterior two roots have fused as in three of five M<sup>3</sup>s of *N. taylori* from the Borchers local fauna.

Two M<sup>2</sup>s from locality UM-K3-69 (V61414a, b) possess enamel lakes. V61414a has an enamel lake opposite the anterior labial reentrant angle and V61414b possesses one opposite the posterior lingual reentrant angle. Hibbard (1941c:360) discusses the wear pattern of these molars and illustrates similar enamel lakes in Pl. 1 and Figs. 9, 11, and 12. The M<sup>3</sup>s have the distinct S-pattern characteristic of the subgenera *Hodomys* and *Paraneotoma* but are like *Paraneotoma* in that the enamel is thicker and the reentrant angles broader and

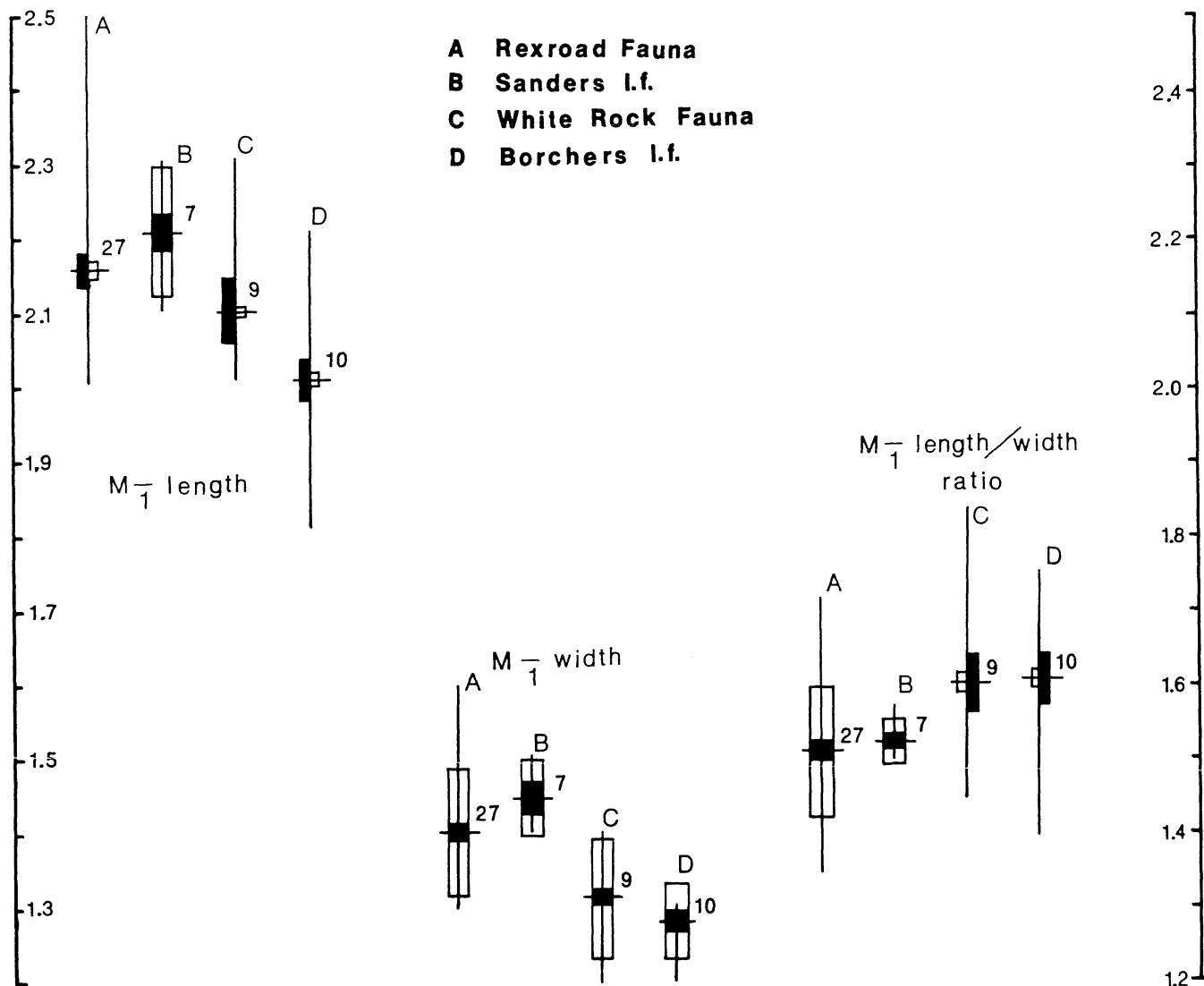


Figure 5. Bar diagram modified from Dice and Leraas (1936) showing variation in size parameter of *Sigmodon*  $M_1$ s from the Great Plains region. Horizontal line represents the sample mean, the darkened area two standard errors of mean, the white area a standard deviation on either side of mean, and the vertical line the observed range.

shallower (Hibbard, 1967).

*Remarks.*— The White Rock fauna provides the first sufficiently large sample of specimens from an intermediate age between Rexroad (*N. quadriplicatus*) and Borchers (*N. taylora*) local faunas (the Sand Draw and Deer Park *Neotoma* samples consist of only four isolated molars each). From the description above, no characters were found that alter a proposed phylogeny of *N. taylora* evolving from *N. quadriplicatus* (Hibbard, 1967:130). This sample supports a reduction in root number and  $M^3$  loop number for this phylogenetic line over time. The White Rock specimens are referred to *N. (Paraneotoma) taylora* because the molar characters discussed above

are more similar to this clade than to *N. (Paraneotoma) quadriplicatus*.

The White Rock specimens were compared with the type (USNM 10,524) and the paratype (USNM 10,526) material of *N. fossilis* Gidley and with Lammers' (1970) description and measurements. Unfortunately, no  $M_3$ s are represented for this form, but *N. fossilis* is a smaller pack rat than *N. taylora*.

*Neotoma (Hodomys) olseni* Lammers (1970, unpub.) is similar to *N. taylora* in that the  $M_3$  has a distinct S-pattern,  $M^1$  labial reentrants are generally oblique and lingual reentrants are perpendicular to the long axis of tooth, and  $M_1$  labial reentrants are generally perpendic-

ular and lingual reentrants oblique to long axis of tooth. However, *N. olseni* is approximately 25 percent smaller than *N. taylori*.

The type of *N. (Parahodomys) spelaeus* (Sinclair) (USNM 12,037) was also compared. Lingual and labial valleys are nearly perpendicular to the long axis of the molars (see Hibbard, 1967:125, for discussion of M<sub>3</sub> and other differences) and thus unlike the condition found in *N. taylori*.

#### Subfamily ARVICOLINAE

##### *Synaptomys (Synaptomys) cf. rinkerii* Hibbard

(Fig. 6 G, H)

*Material.*— UM-K1-66: V60589, left M<sub>1</sub>; UM-K3-69: V61303, three right M<sub>1</sub>s, two left M<sub>1</sub>s, right M<sub>3</sub>, two left M<sub>3</sub>s, two right M<sub>1</sub>s, two left M<sub>1</sub>s, right M<sub>2</sub>, two right M<sub>3</sub>s, three left M<sub>3</sub>s; UM-K4-72: V61302, right M<sub>1</sub>, left M<sub>1</sub>, right M<sub>2</sub>, left M<sub>2</sub>, right M<sub>3</sub>, left M<sub>3</sub>, left M<sub>1</sub>, left M<sub>2</sub>; UM-K4-72+200 ft SE: V61299, left M<sub>2</sub>; UM-K4-72+200 ft NW: V61300, right M<sub>3</sub>; UM-K5-72: V61301, two left M<sub>1</sub>s, right M<sub>2</sub>, right M<sub>3</sub>, two left M<sub>3</sub>s, right M<sub>3</sub>, left M<sub>3</sub>. Total number of isolated teeth is 38.

*Measurements.*— See Table 10.

*Diagnosis.*— See Hibbard (1956:156) for specific diagnosis; Zakrzewski (1972) for subgeneric characters.

*Description.*— Hibbard separates *Synaptomys rinkerii* from *S. cooperi* Baird primarily on the position of the mental foramen and shape of the diastemal region on the lower jaw. Unfortunately, the White Rock material consists only of isolated teeth. Of the ten M<sub>1</sub>s present in the sample, the anterior loop shows variation as expected. However, as indicated by Hibbard on the holotype of *S. rinkerii* (UMMP V32069) from the Dixon local fauna, the anterior loops are more pointed or elongate, as in *S. borealis* (Richardson) and unlike the more rounded or compressed anterior loops in *S. cooperi* and *S. australis* Simpson. The loop condition in *S. rinkerii* is somewhat intermediate between *S. borealis* and *S. cooperi*. This character was compared with four races of Recent *S. cooperi* in the UMMZ mammal collections (*S. c. stonei* Rhoads, *gossii* (Coues), *cooperi* Baird, and *paludis* Hibbard and Rinker; no specimens of *relictus* Jones, *kentucki* Barbour, or *helaletes* Merriam were available). No trend in elongation of the anterior loop was observed. Thus, the White Rock sample is more closely related to the *rinkerii* than to the *cooperi* condition.

The molar enamel bands forming the apices of the inner reentrant angles do thin in the White Rock sample, but generally less than in the Recent forms. The molars are smaller than those of the Dixon local fauna sample and range nearer to *S. cooperi paludis*, the largest of the Recent races. Until lower jaws are obtained for compari-

Table 9. Molar measurements (mm) of *Neotoma (Paraneotoma) taylori* from the White Rock fauna

Tooth	Length			Width		
	N	X	OR	N	X	OR
M <sub>1</sub>	8	4.2	3.9-4.5	8	2.5	2.4-2.8
M <sub>2</sub>	10	3.5	3.1-3.9	10	2.6	2.5-2.8
M <sub>3</sub>	3	3.1	3.1-3.1	3	2.2	2.0-2.4
M <sup>1</sup>	8	4.1	3.6-4.5	9	2.8	2.4-2.9
M <sup>2</sup>	7	3.3	2.8-3.8	7	2.6	2.5-2.8
M <sup>3</sup>	4	2.6	2.5-2.6	4	2.2	2.0-2.3

N=number, X=mean, OR=observed range

son, I have referred this material tentatively to *S. rinkerii*.

*Remarks.*— The small degree of variation in molars reinforces Hibbard's (1956:169) suggestion of a direct phylogenetic lineage of *S. cooperi* from *S. rinkerii*. Later Hibbard (1963:211) demonstrated a negative Bergmann's response for the subgenus *Synaptomys*. Data from the scanty sample presented in Table 10 also indicates a possible east-west size cline for the living members of the subgenus. In addition this same data shows that the M<sub>1</sub>s of *S. rinkerii* are proportionately narrower than those of *S. cooperi*. The response of fossil populations to the same or similar size clines may account for the smaller size of the White Rock sample compared to the Dixon sample over 240 km to the south.

Table 10. Fossil and Recent *Synaptomys (Synaptomys) M<sub>1</sub>* measurements (mm)

Species (Locality)	Length			Width		
	N	X	OR	N	X	OR
<i>S. (S.) rinkerii</i> (Dixon)	2	3.3	3.2-3.3	2	1.5	1.4-1.5
<i>S. (S.) cf. rinkerii</i> (White Rock)	10	3.1	2.8-3.1	10	1.3	1.3-1.5
<i>S. (S.) cooperi paludis</i> (Kansas*)	4	3.1	3.0-3.1	4	1.6	1.5-1.6
<i>S. (S.) cooperi</i> (Indiana and Missouri*)	8	2.8	2.6-3.0	8	1.3	1.2-1.5
<i>S. (S.) cooperi</i> (Ohio*)	10	2.5	2.3-2.6	10	1.2	1.1-1.3

\*Specimens from the University of Michigan, Museum of Zoology

Table 11. Molar measurements (mm) of *Ophiomys meadensis* from the White Rock fauna

Molar	N	Length		N	Width	
		X	OR		X	OR
M <sub>1</sub>	2	2.8	—	2	1.4	1.3-1.5
M <sub>2</sub>	1	1.8	—	2	1.3	1.2-1.3
M <sub>3</sub>	—	—	—	—	—	—
M <sup>1</sup>	4	2.2	2.1-2.3	4	1.4	1.3-1.5
M <sup>2</sup>	4	1.8	1.8-1.9	5	1.3	1.2-1.4
M <sup>3</sup>	1	1.6	—	1	1.0	—

*Nebraskomys mcgrewi* Hibbard

*Material and Measurement.*— UM-K1-66: V59817, right M<sub>2</sub>, 1.0 mm in width.

*Diagnosis.*— See Hibbard, 1957; Skinner, Hibbard et al., 1972.

*Description.*— The M<sub>2</sub> lacks the anterolabial border consisting of the second and fourth alternating triangles, but is complete enough to show that the first and second triangles are completely confluent and the salient angles of the two triangles are nearly opposite. This, plus lingual triangles nearly twice the size of the labial ones, allows assignment of this isolated tooth to *Nebraskomys mcgrewi*. This microtine is rare, known only from the Sand Draw, Dixon, and White Rock faunas. Two right M<sub>2</sub>s (V61656) from UM-K4-72 may belong to this taxon, but because these molars are slightly larger and the triangles not positioned as opposite as typical of *N. mcgrewi*, no assignment is made.

*Ophiomys meadensis* (Hibbard)

*Material.*— UM-K1-66: V60591, right M<sub>2</sub>, right M<sup>2</sup>, right M<sup>3</sup>; UM-K3-69: V61652, two left M<sup>1</sup>s; UM-K4-72: V61653, left M<sub>1</sub>, right M<sup>2</sup>, two left M<sup>2</sup>s; UM-K4-72+12 ft SE: V61654, left M<sub>1</sub>, left M<sub>2</sub>, right M<sup>1</sup>; UM-K5-72: V61655, right M<sup>1</sup>, right M<sup>3</sup>. Total number of isolated teeth is 14.

*Measurements.*— See Table 11.

*Diagnosis.*— See Hibbard, 1956; Hibbard and Zakrzewski, 1967.

*Description.*— The White Rock material compares well with the type *Ophiomys meadensis* material from the Sanders local fauna and with assigned specimens from the Dixon local fauna. The enamel of the M<sub>1</sub> is uniform in thickness except on the anterior edge of the anterior loop, where it thins. The enamel walls thicken with wear and are generally thicker than *O. parvus* (Wilson).

There is noticeable broadening of the molars with wear. The M<sub>1</sub> in young individuals consists of five triangles and a complicated anterior loop, which wears to five triangles and a simple anterior loop in adults. The fourth and fifth triangles are broadly confluent to the anterior loop. In a few extremely old individuals a pattern of three triangles and a simple anterior loop is formed as the fourth lingual and third labial reentrant angles become shallow and are finally lost with wear. No enamel pits are present.

All M<sup>1</sup>s with developed roots are three rooted. Two of three M<sup>2</sup>s are two rooted and the third (V60591) three rooted. A fourth M<sup>2</sup> (V61653a) shows evidence of once having had two anterior roots, which have since fused. Hibbard and Zakrzewski (1967) fully describe *Ophiomys* and compare *O. meadensis* with other species of the genus.

*Ogmodontomys* sp.

(Fig. 6 I, J)

*Material.*— UM-K1-66: V61657, left M<sub>1</sub>, left M<sup>3</sup>; UM-K3-69: V61658, right M<sub>1</sub>, left M<sub>1</sub>.

*Measurements (mm).*— V61657: left M<sub>1</sub>, 2.8 by 1.4; left M<sup>3</sup>, 2.0 by 1.2; V61658: right M<sub>1</sub>, width 1.4; left M<sub>1</sub>, 2.7 by 1.4.

*Description.*— All three M<sub>1</sub>s are about the size of *Ophiomys meadensis*. Each possesses a posterior loop, three alternating triangles, and a complicated anterior loop with a prism fold forming a trilobate condition of the loop (for terminology see Zakrzewski, 1967: 134). The posterior loop and first triangle are closed or slightly open, as are the first and second, second and third, and third and anterior loop. The enamel walls become thin on the anterior borders of the reentrant angles. In this character they are similar to *O. magilli* Hibbard except no pits are present on the anterior loop, the dentine tracts are better developed than *O. magilli*, and the anterior loops are more pointed and less broad.

An isolated, well-worn M<sup>3</sup> has two roots, the anterior of which indicates fusion of two smaller roots. Hibbard (in Skinner, Hibbard et al., 1972:97) reports three of four *Ogmodontomys* M<sup>3</sup>s from the Sand Draw local fauna possess two fused anterior roots. The only known M<sup>3</sup> of *Ophiomys magilli* is an isolated one (V57189) from the Sand Draw local fauna. It shows no evidence of anterior root fusion.

*Remarks.*— The scanty White Rock specimens, with better developed dentine tracts, anterior loop more complicated, and birooted condition of the M<sup>3</sup>, appear more advanced than *Ogmodontomys poaphagus*. For these reasons the White Rock specimens may represent a new, more advanced species of this genus. However,



without better material no designation is attempted.

Hibbard (in Skinner, Hibbard et al., 1972:97) suggested *Ogmodontomys* was replaced by *Pliopotomys* in more moist or aquatic habitats. The presence of *Ogmodontomys* and the absence of *Pliopotomys* from locality UM-K1-66 and the extreme predominance of *Pliopotomys* over *Ogmodontomys* from locality UM-K3-69 support this conclusion.

*Ondatra idahoensis* Wilson

*Material.*— UM-K3-69: V61358, seven right M<sub>1</sub>s, left M<sub>1</sub>, two right M<sub>2</sub>s, eight left M<sub>2</sub>s, three right M<sub>1</sub>s, five left M<sub>1</sub>s, right M<sub>2</sub>, left M<sub>2</sub>, right M<sub>3</sub>, three left M<sub>3</sub>s; UM-K4-72: V61356, left M<sub>1</sub>, right M<sub>2</sub>, left M<sub>2</sub>? broken, left M<sub>1</sub>, left M<sub>2</sub>; UM-K4-72+200 ft NW: V61354, right M<sub>2</sub>, right M<sub>2</sub>; UM-K4-72+12 ft SE: V61355, right M<sub>1</sub>, left M<sub>2</sub>, two right M<sub>3</sub>s; UM-K5-72: V61357, left M<sub>2</sub>, right M<sub>3</sub>; KU-Rep. Co. Loc. 3: V61359, left jaw fragment with M<sub>1</sub>–M<sub>2</sub> and incisor fragment. Total number of isolated teeth is 45.

*Measurements (mm).*— See Table 12. I follow Semken (1966) in using girth measurements to eliminate variation of tooth size with wear. This is especially true of M<sub>3</sub>s, which taper dorsally. In Table 12 after girth measurements the occlusal measurements are given in parentheses to illustrate these differences. As several methods have been employed, caution must be used in comparing dentine tract measurements.

*Diagnosis.*— See Wilson, 1933:132; Hibbard, 1959:29.

*Description.*— The only jaw recovered (V61359) consists of the anterior portion with M<sub>1</sub>–M<sub>2</sub> and a fragmentary incisor. The mental foramen is approximately 0.4 mm anterior to the M<sub>1</sub> root and on a horizontal line with the anterior edge of the masseteric crest. The foramen is positioned dorsolabially along the diastema and can be seen easily in dorsal view. This position compares with material from the Grandview local fauna.

The following variations of M<sub>1</sub> are noted: of eleven specimens, two (V61355, a young tooth with no roots yet developed and V61358-2, a young tooth with roots just budding) possess an enamel pit in the anterior loop; three have all triangles open (V61359, V61358-1, -2); three have the posterior loop closed to the first triangle (V61358-3, -4, -5); all eleven have the fifth triangle open to the anterior loop; and all the remaining triangles are slightly open except V61358-5 (old adult) where the fourth and fifth triangles are closed. Well-developed crenulation of the labial side of the anterior loop is present in V61358-1, -2 (young adults, roots budding).

Cement varies from specimen to specimen but is generally absent in young individuals. Thick, poorly intersticed cement is present in most old adults (best

Table 12. Molar measurements (mm) of *Ondatra idahoensis* from the White Rock fauna\*

	N	Length		N	Width	
		X	OR		X	OR
M <sub>1</sub>	7	5.0	4.4-5.4	11	2.3	2.1-2.5
	—	(4.8)	(4.2-5.3)	—	(2.1)	(1.8-2.4)
M <sub>2</sub>	7	3.1	2.8-3.7	11	2.3	2.1-2.5
	—	(2.9)	(2.6-3.5)	—	(2.0)	(1.7-2.4)
M <sub>3</sub>	—	—	—	1	2.4	—
	—	—	—	—	(1.9)	—
M <sub>1</sub> <sup>1</sup>	8	4.1	3.2-4.4	10	2.8	2.4-3.0
	—	(3.7)	(3.1-4.0)	—	(2.5)	(2.2-2.9)
M <sub>2</sub> <sup>2</sup>	4	3.5	3.1-3.9	4	2.4	2.3-2.7
	—	(3.0)	(2.8-3.1)	—	(2.1)	(2.0-2.1)
M <sub>3</sub> <sup>3</sup>	1	3.1	—	1	2.0	—
	—	(2.9)	—	—	(1.9)	—

\*Occlusal molar measurements in parentheses

seen in V61357 left M<sub>2</sub>, V61358 left M<sub>1</sub>, and V61354 right M<sub>2</sub>). Cementation, generally, is better developed in the Grandview sample. No cement is present in any examined *Pliopotamys minor* (Wilson) specimen; only very thin, poorly developed cement is found in a few molars of *P. meadensis* Hibbard (e.g., V32055 and V32056-3c from the Dixon local fauna).

Shotwell (1970:66) states, "the primary character difference between these genera (*Ondatra* and *Pliopotamys*) is in the presence of dentine tracts on the teeth of *Ondatra*, and their absence on those of *Pliopotamys*." Dentine tracts are present in some specimens assigned to *Pliopotamys*, but when present are less well developed than in *Ondatra*. Although the degree of dentine tract development is important, the presence or absence of cement is the primary generic character (Hibbard, 1938).

Dentine tract heights were measured on the lingual side of the M<sub>1</sub> on the fifth alternating triangle (first triangle from the anterior end), parallel and posterior to it (after Semken, 1966). I have followed Semken because he plots samples of most fossil species in his demonstration of a well-developed chronocline. Also, by measuring the dentine tract height posterior to the fifth alternating triangle one eliminates the variation present in the anterior loop discussed by Shotwell (1970:66). No teeth of very young individuals without roots or well-worn teeth were used. The tracts averaged 0.6 mm in height and compare well with the Grandview local fauna (see Table 13 for mean and observed ranges). Generally, the tracts in *Pliopotamys* are smaller in *P. meadensis* and often absent in *M. minor*. None of the tracts in *Pliopotamys* or *O. idahoensis* Wilson have the parallel sides characteristic of *O. zibethicus* (Linnaeus)

Table 13. *Ondatra* and *Pliopotamys* M<sub>1</sub> molar measurements and dentine tract heights (mm)

Taxa (Fauna)	Length			Width			Dentine Tract Ht		
	N	X	OR	N	X	OR	N	X	OR
<i>O. annectens</i> (Cudahy)	3	6.0	5.7-6.4	4	2.5	2.3-2.6	2	1.0	0.7-1.3
<i>O. idahoensis</i> (Borchers)	1	5.0	-	1	2.3	-	1	0.5	-
<i>O. idahoensis</i> (Grandview)	10	4.6	4.4-4.9	14	2.2	2.0-2.3	16	0.6	0.4-0.8
<i>O. idahoensis</i> (White Rock)	7	5.0	4.4-5.4	11	2.3	2.1-2.5	8	0.6	0.4-0.9
<i>P. meadensis</i> (Dixon)	7	4.8	4.4-5.2	9	2.3	2.2-2.4	7	0.5	0.3-0.8
<i>P. meadensis</i> (Deer Park)	1	4.8	-	1	2.3	-	1	0.4	-
<i>P. meadensis</i> (Sand Draw)	3	4.8	4.6-5.0	3	2.2	2.1-2.3	2	0.4	-
<i>P. minor</i> (Hagerman)	18	4.1	3.8-4.5	18	2.0	1.7-2.1	33	0.3	0.0-0.5

or *O. annectens*.

All M<sub>1</sub>s of *Ondatra idahoensis* are three rooted, while the M<sub>2</sub>s and M<sub>3</sub>s are two rooted. Hibbard (1959:28) reported all upper molars of *P. minor* from the Hagerman local fauna had three well-developed roots. Zakrzewski (1969:26), using additional *P. minor* material, observed two-rooted molars in 12 of 169 M<sub>2</sub>s and 15 of 100 M<sub>3</sub>s. Shotwell (1970:67) reported one of five M<sub>3</sub>s from his Hagerman sample had two roots, while the others had three. *Pliopotamys meadensis* material (Deer Park, Sand Draw, and Dixon) is rare (four M<sub>2</sub>s and four M<sub>3</sub>s) but all adult forms were three rooted. All upper second and third molars from the White Rock and the University of Michigan Grandview sample (*O. idahoensis*) are two rooted. Suggestion of fusion of two anterior roots is shown in three specimens (e.g., Grandview, V48958, M<sub>2</sub>; White Rock, V61356, M<sub>2</sub>, roots budding). Shotwell (1970:67), based on his Grandview sample, states that only five of six M<sub>2</sub>s and three of four M<sub>3</sub>s are two rooted, while the remainder are three rooted. When more material is collected, the frequency of a third root in M<sub>2</sub> and M<sub>3</sub> may prove helpful in specific separation of large samples. However, Stephens (1960) has been able to demonstrate that in the living muskrat (*O. zibethicus*) the frequency of two- versus three-rooted M<sub>1</sub>s varies with age. Therefore variation in upper molar root number is complicated by both phylogenetic reduction and ontogenetic variation.

All lower molars are two rooted with one exception. A lower M<sub>1</sub> (V61358) from UM-K3-69 has a small

third rootlet located on the lingual side, centrally situated between the two normal roots. The tip appears broken 0.3 mm below the base. A small nubbin or projection was observed on M<sub>1</sub>s from the following localities: Hagerman DWT Loc. 540, one of 27 (V50319); Hagerman UM-IDA la-65, four of 49 (V53597); Hagerman UM-IDA 2-65, one of nine (V53086-7); Sand Draw, one of three (V57086); Dixon, zero of nine; Grandview, one of 14 (V56324-A); Borchers, zero of one, and Cudahy (*O. annectens* Brown), zero of three. The best developed of these small projections are found in the Hagerman UM-IDA la-65 locality where they reach a maximum length of 0.1 mm. They are situated slightly posterior to the middle of the roots and on the labial side. They are not rootlike in appearance or homologous to the rootlet in the White Rock specimen. Two left M<sub>1</sub>s of *Pliophenacomys primaevus* (V56416a) from the Fox Canyon local fauna are the only other microtine three-rooted lower molars in North America known to the author.

*Remarks.*—Hibbard and Zakrzewski (1967:270) consider *Pliopotamys* ancestral to *Ondatra*. Subsequent work by Zakrzewski (1969) on *Pliopotamys* and Nelson and Semken (1970) on *Ondatra* showed no evidence contrary to this proposed phylogeny. Zakrzewski (1969:27) noted that a size chronocline of M<sub>1</sub> and dentine tract height established by Semken (1966) for *Ondatra* can be carried back through *Pliopotamys*. A summary of this data can be found in Nelson and Semken (1970: Figs. 1, 2). If such a phylogeny arose along a direct line, samples containing characters of both *Pliopotamys* and *Ondatra* should exist. The White Rock sample, which fits this situation, presents a difficult generic choice. I have relied heavily on three characters: (1) size chronocline established on M<sub>1</sub> length and width ratio (Semken, 1966), (2) dentine tract height cline (Semken, 1966), and (3) presence or absence of cement (Hibbard, 1938).

A resolution of the above characters and comparisons with related faunas suggests that the White Rock material is best assigned to *O. idahoensis* for the following reasons:

1) First molar length/width ratio.—The White Rock sample clusters into two groups on Nelson and Semken's (1970:Fig. 1) size chronocline. The lower cluster falls between or on the *O. idahoensis* and upper *P. meadensis* plots. The upper cluster lies just below the *O. annectens* group and above the Borchers (*O. idahoensis*) specimen. Overall the sample best compares with the Grandview and Borchers plots. Other apparently bimodal plots, perhaps sexual dimorphic or more probably an index to speciation, can also be seen in the Cudahy, Isle Royal, and possibly Grandview samples (see Fig. 1 of Nelson and Semken, 1970:3734). A comparison of M<sub>1</sub> measurements from other faunas is given in Table 13.

2) Dentine tract height.— The means and observed ranges for dentine tract heights are included in Table 13. The White Rock mean dentine tract height is 0.6 mm and compares favorably with the Grandview sample. This mean is higher than that obtained for *Pliopotamys* and fits Nelson and Semken's cline (1970:Fig. 2).

3) Cement.— Cement in various amounts is present in all White Rock adult molars. Usually cement is absent in adult *Pliopotamys* dentitions, with exceptions having very thin, poorly developed deposits. Good interstitial cement is rare in *O. idahoensis* but suggestive in a few specimens. Generally the cement is slightly better developed in the Grandview than in the White Rock fauna, but the high degree of variation is difficult to quantify. It is apparent that the development of cement was gradual during the phylogeny of this group.

Although the Dixon material has been identified as *P. meadensis*, small amounts of cement are found in some teeth. I feel that it is taxonomically close to the White Rock *Ondatra* clade of evolution and with further study and larger samples may be reassigned in the future. Based on the development of cement the Grandview local fauna is probably younger than the White Rock fauna.

Nelson and Semken (1970) were able to show that the length/width ratio of first lower molars can be used to distinguish between warm and cool faunas. This study was substantiated by corresponding differences in ratios between Recent northern and southern specimens, and fossil glacial and interglacial specimens (Nelson and Semken, 1970:Figs. 4, 7). McNab (1971:Table 1), working with Recent mammals, correlated body length to latitude. He found that individuals of *Ondatra zibethica* showed a positive correlation (larger) between 30 and 45 degrees N and a negative correlation (smaller) between 46 and 60 degrees N latitude. Thus both McNab's and Nelson and Semken's conclusions support each other. The mean M<sub>1</sub> length/width ratio for the White Rock fauna is 2.2 mm and corresponds with the warmer faunas on Nelson and Semken's (1970) graph.

*Pliophenacomys? osborni* Martin

(Fig. 6 A-F)

*Material.*— UM-K1-66: V55523, left jaw fragment with M<sub>1</sub>–M<sub>2</sub>, V60590, right M<sup>1</sup>, V60593, four right M<sup>1</sup>s, left M<sup>1</sup>, four right M<sup>2</sup>s, left M<sup>2</sup>, right M<sup>3</sup>, five right M<sub>1</sub>s, left M<sub>1</sub>, five right M<sub>2</sub>s, three left M<sub>2</sub>s, left M<sub>3</sub>; UM-K3-69: V61736, 14 right M<sup>1</sup>s, 26 left M<sup>1</sup>s, ten right M<sup>2</sup>s, 13 left M<sup>2</sup>s, eight right M<sup>3</sup>s, three left M<sup>3</sup>s, 17 right M<sub>1</sub>s, 18 left M<sub>1</sub>s, 12 right M<sub>2</sub>s, 17 left M<sub>2</sub>s, three right M<sub>3</sub>s, five left M<sub>3</sub>s; UM-K4-72: V61737, five right M<sup>1</sup>s, three left M<sup>1</sup>s, four right M<sup>2</sup>s,

Table 14. Molar measurements (mm) of *Pliophenacomys? osborni* from the White Rock fauna

Tooth	N	Length		N	Width	
		X	OR		X	OR
M <sup>1</sup>	52	2.3	2.1-2.5	55	1.4	1.2-1.6
M <sup>2</sup>	36	2.0	1.7-2.1	34	1.3	1.1-1.4
M <sup>3</sup>	20	1.9	1.6-2.0	24	1.1	0.9-1.2
M <sub>1</sub>	22	2.9	2.6-3.2	43	1.2	1.0-1.4
M <sub>2</sub>	29	1.6	1.5-1.8	50	1.1	0.9-1.3
M <sub>3</sub>	10	1.5	1.3-1.6	16	0.9	0.8-1.0

two left M<sup>2</sup>s, right M<sup>3</sup>, left M<sup>3</sup>, three right M<sub>1</sub>s, three left M<sub>1</sub>s, right M<sub>2</sub>, left M<sub>2</sub>, right M<sub>3</sub>, left M<sub>3</sub>; UM-K4-72+12 ft SE: V61738, three right M<sup>1</sup>s, two left M<sup>2</sup>s, four right M<sub>1</sub>s, left M<sub>1</sub>, right M<sub>2</sub>, left M<sub>2</sub>; UM-K4-72+200 ft NW: V61739, right M<sup>1</sup>, left M<sup>1</sup>, right M<sub>1</sub>; UM-K5-72: V61740, ten right M<sup>1</sup>s, 11 left M<sup>1</sup>s, right M<sup>2</sup>, five left M<sup>2</sup>s, five right M<sup>3</sup>s, five left M<sup>3</sup>s, six right M<sub>1</sub>s, five left M<sub>1</sub>s, seven right M<sub>2</sub>s, five left M<sub>2</sub>s, three right M<sub>3</sub>s, four left M<sub>3</sub>s; UM-K6-72: V61741, left jaw fragment with M<sub>1</sub>–M<sub>2</sub>, left M<sup>1</sup>, right M<sup>3</sup>, left M<sup>3</sup>, two right M<sub>1</sub>s, left M<sub>1</sub>, right M<sub>2</sub>, left M<sub>2</sub>, right M<sub>3</sub>; UM-K7-72: V61742, left M<sup>1</sup>. The total number of isolated teeth is 291.

*Measurements.*— See Table 14.

*Diagnosis.*— See Martin, 1972:174.

*Description.*— The White Rock lower dentitions agree with Martin's (1972:174) description. Because the Mullen Assemblage sample did not contain assigned upper molars, the upper dentition of the taxon is worthy of description. The M<sup>1</sup>s consist of a posterior loop, four alternating closed or nearly closed triangles. Of 28 molars possessing roots, five are three rooted. The remaining 23 are two rooted, six of which exhibit evidence of fusion of the posterior roots. Dentine tracts are well developed on the anterior loop and the first alternating triangle on the lingual side. Tracts are absent or incipient on the others. The M<sup>1</sup> (UNSM 39592) figured by Martin (1972:Fig. 2) as possibly belonging to *P. osborni* compares well to the White Rock specimens and should be assigned to this form.

The M<sup>2</sup>s consist of an anterior loop and three closed or nearly closed alternating triangles. Dentine tracts interrupt the occlusal surface of the molar by early maturity on both sides of the anterior loop and the posterior end of the third triangle. A reentrant pit (see Zakrzewski, 1969:Fig. 7c) on the posterior lingual side of the M<sup>1</sup> and M<sup>2</sup> is present.

The M<sup>3</sup>s consist of an anterior loop, three alternating triangles, and a posterior loop. The posterior loop is

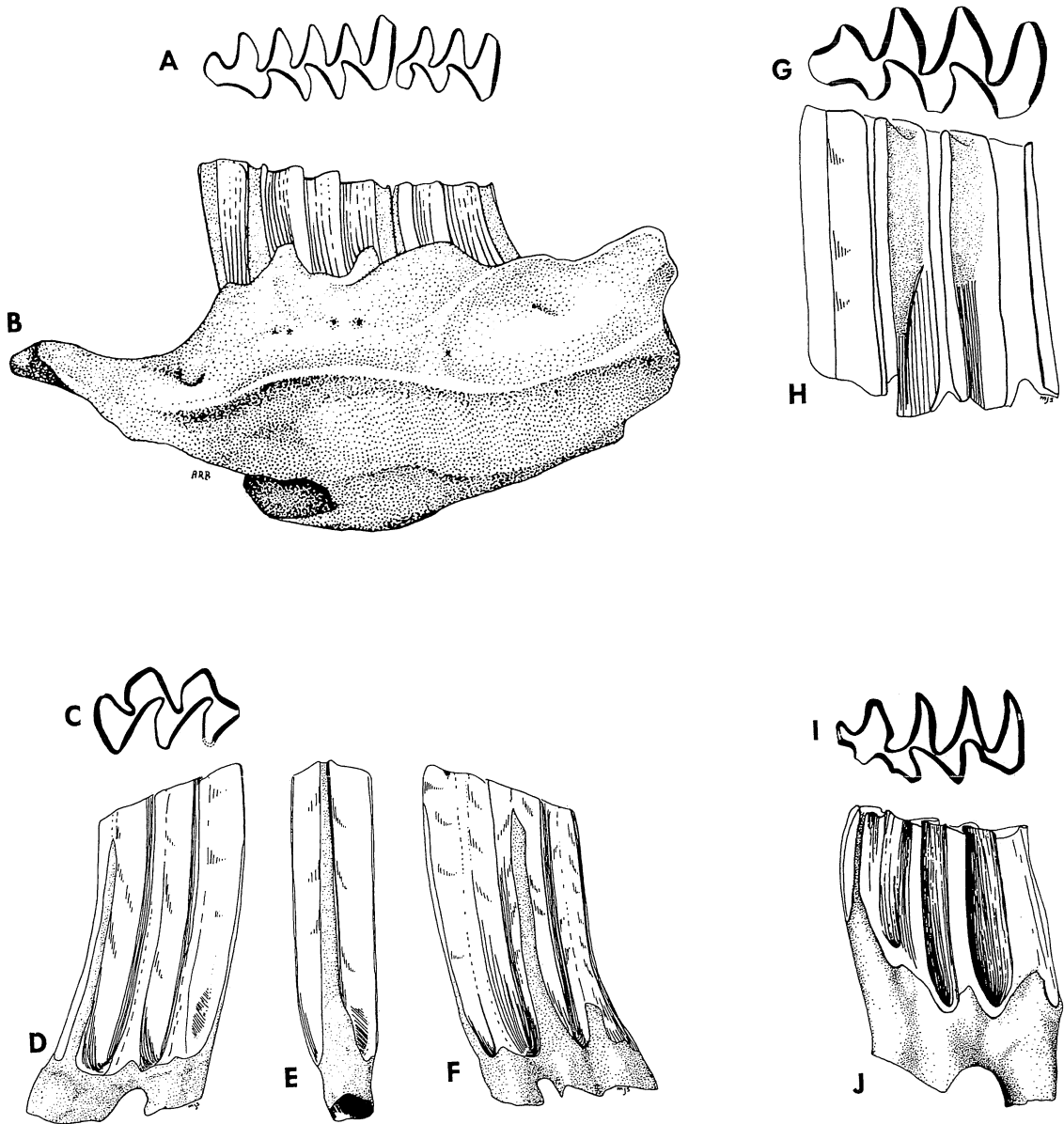


Figure 6. (A-F) *Pliophenacomys? osborni*. (A,B) left jaw with  $M_1$ - $M_2$ , V55523, occlusal view of molars and labial view of jaw. (C-F) right  $M_1$ , V60593, occlusal, labial, anterior, and lingual views, all approximately  $\times 10$ . (G, H) *Synaptomys (Synaptomys) cf. rinkeri*, left  $M_1$ , V60589, occlusal and labial views, approximately  $\times 10$ . (I, J) *Ogomodontomys* sp., left  $M_1$ , V61657, occlusal and labial views, approximately  $\times 9$ .

hook shaped in 16 of 23 specimens. Dentine tracts are present on both the labial and lingual sides of the anterior loop and occasionally on the posterior end of the posterior loop. Both the  $M_2$ s and  $M_3$ s are two rooted. The enamel on all upper molars is thinner on the anterior sides of the alternating triangles than on

the posterior sides.

*Remarks.*— *Pliophenacomys osborni* is the same microtine figured by Hibbard (1956:Fig. 6f) from the Dixon local fauna and mentioned by Hibbard and Zakrzewski (1967:262) as being undescribed. I have compared the White Rock sample and Nebraska type specimen of *P.*

*osborni* (UNSM 39216) with four specimens of *Pliomys deeringensis* Guthrie and Matthews (UA 770, 771, 773, 777) from the early Pleistocene Cape Deceit fauna of Arctic Alaska (Guthrie and Matthews, 1972) and with ten isolated teeth of *Pliomys episcopalis* Kormos from the Mindel deposits of Podumci, Dalmatia, Yugoslavia (V34901) and from Koneprusy, Central Bohemia, Western Czechoslovakia (V39773).

If Guthrie and Matthews (1972) are correct in their assignment of the Cape Deceit material to the genus *Pliomys*, then the presence of *Pliophenacomys* in the Mullen Assemblage should be questioned (Martin, 1972). In comparing the two supposed genera I find that the type for the genus, *Pliophenacomys primaevus* Hibbard from the Fox Canyon local fauna, has poorly developed dentine tracts, relatively uniform enamel thickness, confluent alternating triangles, and a more complex anterior loop on M<sub>1</sub>. Both *Pliophenacomys osborni* and *Pliomys deeringensis* have well-developed dentine tracts that interrupt the occlusal surface by the early adult stage of wear, different thicknesses of enamel on the anterior and posterior sides of triangles (most pronounced in *Pliophenacomys osborni*), closed or nearly closed alternating triangles, and a simple trefoil on the anterior loop of the M<sub>1</sub>. *Pliomys episcopalis* is similar to *Pliophenacomys osborni* and *Pliomys deeringensis*, except the teeth are slightly smaller and the overall enamel thickness thinner. The lingual posterior reentrant pit on M<sup>1</sup> and M<sup>2</sup>, a character used to distinguish *Pliophenacomys* from all other fossil microtine genera of North America (Hibbard, in Skinner, Hibbard et al., 1972: 102), is exhibited by *Pliomys deeringensis*, *P. episcopalis*, and *Pliophenacomys osborni*, as well as in *Pliophenacomys primaevus* (the degree of enfolding and development of pit is best developed in *Pliophenacomys primaevus*).

Guthrie and Matthews (1972:491) mention the similarities of *Pliomys* to *Pliophenacomys*, but cite Hibbard (1959:23) for his discussion of their distinct differences. Caution must be exercised since Hibbard's (1959) comparison was based on forms he and Zakrzewski (1967) subsequently described as being a different genus, *Ophiomys*. The similarities of these genera can be realized with the example of *O. parvus* (Wilson), which initially was placed in the genus *Pliophenacomys*, changed to *Pliomys*, returned to *Pliophenacomys*, and is presently retained in *Ophiomys* (Hibbard and Zakrzewski, 1967: 259).

The above discussion points out that the difference between *Pliophenacomys primaevus* and *Pliophenacomys osborni* is greater than that between *Pliophenacomys osborni* and *Pliomys deeringensis*. I therefore question the assignment of *Pliophenacomys osborni* to *Pliophenacomys*. I have not synonymized *Pliophenacomys osborni* with *Pliomys* at this time because: (a) the small European

samples of *Pliomys episcopalis* studied (10 isolated molars) are all slightly smaller and possess thinner enamel bands than the North American specimens, and (b) the small sample of *Pliomys deeringensis* studied (4 isolated molars) is larger and has thicker enamel bands than the European *Pliomys* and compares in these characters more favorably with *Pliophenacomys osborni*. It is therefore possible that *Pliophenacomys osborni* may represent either *Pliomys*, *Pliophenacomys*, or a distinct genus. Only a total review of the entire group, with samples much larger than those presently available to me, will resolve this problem. Until then the White Rock specimens should be retained in *Pliophenacomys*.

A review of the Dixon local fauna microtine material at the University of Michigan revealed many specimens (22 vials of isolated molars) that C.W. Hibbard had separated from *Ophiomys meadensis* (Hibbard) (formerly *Pliophenacomys*) and labeled as "new." Comparison allows these specimens to be referred to *Pliophenacomys osborni*.

Martin (1972:181) suggests an early Pleistocene age for at least a few of the forms from the Mullen Assemblage. The presence of *Pliophenacomys osborni* from the White Rock and Dixon local faunas tends to confirm this conclusion.

#### *Pliophenacomys* cf. *primaevus* Hibbard

*Material*.— UM-K4-72: V61743, right M<sup>1</sup>, two left M<sup>2</sup>s; UM-K5-72: V61744, three right M<sup>1</sup>s, two left M<sup>1</sup>s, two right M<sup>2</sup>s, two left M<sup>2</sup>s.

*Diagnosis*.— See Hibbard, 1938:248; Hibbard, in Skinner, Hibbard et al., 1972:102.

*Description*.— The 12 isolated molars compare favorably with the *Pliophenacomys primaevus* sample from the Sand Draw local fauna, except that enfolding of the lingual posterior reentrant pit is not as deep. The material is distinct from *P. osborni* by its less developed dentine tract height, which does not interrupt the occlusal surface by early maturity. All six M<sup>1</sup>s are three rooted. The M<sup>1</sup> length ranges from 2.3 to 2.5 mm, with a mean of 2.5 mm. Width ranges from 1.3 to 1.6 mm, with a mean of 1.5 mm. The M<sup>2</sup> length ranges from 1.9 to 2.2 mm, with a mean of 2.0 mm; width ranges from 1.1 to 1.5 mm, with a mean of 1.3 mm.

*Remarks*.— If *P. osborni* is a direct descendant of *P. primaevus*, then a sample as large as the White Rock *P. osborni* sample might exhibit a few specimens that are intermediate and possibly more characteristic of *P. primaevus* than *P. osborni*. If, however, *P. osborni* is an early offshoot of *P. primaevus* or even a separate, although closely related, genus, then species from each could be expected from the same fauna if geologic and geographic conditions are appropriate. If the latter is

true, then the Sand Draw *P. primaevus* material may represent a more northerly distributed species and the Dixon *P. osborni* material a more southerly distributed species. Both of these species may have ranged near the geographical intermediate White Rock fauna. By Mullen Assemblage time *P. primaevus* may have been displaced by *P. osborni*, which had moved northward. The age of the Mullen Assemblage is poorly understood so that a climatic framework that might have caused such a fluctuation cannot be attempted.

The greater degree of difference in enamel thickness of the alternating triangles and the lesser degree of confluence in the triangles allow one to distinguish the Sand Draw material from the earlier Fox Canyon local fauna material. The White Rock sample is definitely more closely related to the Sand Draw sample. Because of the small sample available and differences in the degree of development of the lingual posterior reentrant pit, only a tentative assignment is made.

#### Family Dipodidae

##### *Zapus sandersi sandersi* Hibbard

*Material*.— UM-K3-69: V61297, two right M<sub>1</sub>s; UM-K4-72: V61298, left M<sub>1</sub>.

*Measurements (mm)*.— V61297a, M<sub>1</sub>, 1.6 by 1.0; V61297b, M<sub>1</sub>, 1.7 by 1.1; V61298, M<sub>1</sub>, 1.7 by 1.1.

*Diagnosis*.— See Klingener, 1963:256.

*Description and Remarks*.— The left M<sub>1</sub> shows extensive crown wear (stage 4 of Klingener, 1963:249). Its dimensions and presence of the taxon from UM-K3-69 allow its placement within this form. Both right M<sub>1</sub>s (V61297a, b) have a stage 3 wear of Klingener. The anteroconids of the *Z. s. sandersi* M<sub>1</sub>s are wider at the base (posterior) than at the top (anterior). This, plus the narrowness of the tooth due to less broadening of the posterior cingulum, allows separation of *Z. s. sandersi* from *Z. s. rexroadensis* (Klingener, 1963). The White Rock specimens do not have a posterior anteroconid notch, which is present in some Cudahy M<sub>1</sub>s. The White Rock specimens do not possess a prehypococonid angle cingulum, which is present in the Sanders local fauna specimen (V31984). The measurements of the White Rock sample are slightly greater than those from the Sanders and Cudahy local faunas.

#### ? Subfamily ZAPODINAE

(Fig. 3 E)

*Material*.— UM-K1-66: V60592, ?left M<sup>2</sup> and maxillary fragment.

*Measurements (mm)*.— ?left M<sup>2</sup>, 1.1 by 1.0.

*Description*.— The tooth is a typical zapid M<sup>2</sup> with parallel sides resembling a rectangle. Penetration of the internal reentrant fold is deep and well developed as in *Megasmithus* and *Plesiosmithus* (a siscistid), where this reentrant remains open into late-wear stages. It is not cut off by a mure between the protocone and hypocone as in little-worn teeth of *Zapus*, *Napaeozapus*, and *Eozapus* (Klingener, 1966:5). The tooth is in stage 2 wear (Klingener, 1963:249) based on comparison with similarly worn Recent *Zapus*. The paracone and hypocone, connected by an open mure, form a continuous loph, which is proportionally broader than in *Zapus*. The molar has three well-developed roots. The maxillary fragment is too broken to determine definitely which molar is represented.

*Remarks*.— The White Rock specimen is smaller and the cusps are not as bulbous as in *Megasmithus*. The occlusal pattern is simpler and appears distinct from *Plesiosmithus*, *Macrognathomys*, *Megasmithus*, *Zapus*, *Napaeozapus*, *Eozapus*, and unidentified forms reported by Wilson (1968:118) from the Wakeeney local fauna of Trego County, Kansas. A positive taxonomic position is not possible without associated skull and dentitions.

#### *Incertae sedis*

*Material*.— UM-K7-72: V63347, rodent-gnawed bone fragment.

*Remarks*.— The tooth marks were compared to the Recent mammal cuttings collection of the University of Michigan, Museum of Zoology, Division of Mammalogy. They agree most closely to those of porcupine and tree squirrels. Similar bone gnawings are reported by Wood (1952) on mastodon bones from Ohio.

#### Order EDENTATA

##### Family Mylodontidae

##### *Megalonyx leptostomus* Cope

*Material*.— UM-K3-69: V61296, right M<sup>4</sup>?

*Measurements (mm)*.— Anteroposterior, 7.8; medio-lateral, 11.1. Measurements were taken just below the occlusal surface, following Hirschfeld and Webb (1968). The tooth is broken at the base and measures only 10.2 in length.

*Remarks*.— Based on size and shape of tooth, the specimen compares well with *M. leptostomus*. The tooth tapers from root to crown, indicating it is a very young individual. The occlusal surface is concave, characteristic of *Megalonyx*. The posterior side of the tooth is convex. Cope (1899:213), however, reports great variation in the shape of the last superior tooth. This specimen is the first known record of *M. leptostomus* from outside the Panhandle of Texas. All previously known material came from Blancan age deposits.

## Order CARNIVORA

## Family Canidae

gen. et sp. indet.

*Material.*— UM-K1-66: V61672, distal end of metapodial; UM-K7-72: V61671, left calcaneum.

*Remarks.*— The metapodial measures 12.9 mm in width and is approximately the size of *Canis dirus* Leidy. The calcaneum is 36.6 mm in length, 13.7 mm in width across the astragalar facets, 11.8 mm across the cuboid articulation, and 15.2 mm in depth. The specimen is larger than *Vulpes vulpes* Churcher, smaller than *Canis latrans* Say, and agrees best in size with *C. aureus* Linnaeus. It is slightly smaller than calcaneum of *C. lepophagus* Johnston (V50335) from the Hagerman local fauna. The White Rock specimen is too eroded for a detailed comparison based on characters discussed by Bjork (1970:14). However, the slope between the sustentaculum tali and cuboid facet is gently sloped as in *C. lepophagus* and not as deeply notched as in most *C. latrans*.

## Family Mustelidae

*Mustela cf. gazini*

(Fig. 4 F, G)

*Material.*— UM-K4-72+200 ft NW: V61669, right jaw fragment with M<sub>1</sub>.

*Description.*— The M<sub>1</sub> is 5.1 by 1.9 mm and the trigonid 3.4 mm in length. The carnassial notch is not as open and the paraconid blade not as low as in *Mustela rexroadensis* Hibbard (Rexroad fauna) but is similar to living *M. erminea* Linnaeus and *M. frenata* Lichtenstein. The width of the M<sub>1</sub> is greater than in these extant mustelids and in this character compares more favorably with *M. rexroadensis* from the Hagerman local fauna.

*Remarks.*— Hibbard (1958b) described *M. gazini* from the Hagerman local fauna as distinct from *M. rexroadensis*. Bjork (1970:18) considered the differences between the two to be merely individual and synonymized *M. gazini* under *M. rexroadensis*. Samples of significant number showing the variation within these specimens are presently unavailable. The White Rock tooth agrees most closely to the Hagerman specimen, but no definite assignment is attempted without better material. The specimen does not appear to belong to *M. reliquus* Hall based on the description given by Hall (1960:535), who states that the paraconid of the M<sub>1</sub> is wider than that of *M. gazini*. No lower teeth are known for *M. gracilis* Brown (1908:182) from the Conard Fissure. A left endentulous jaw fragment (V61670) from UM-K5-72 is tentatively assigned to this same form.

## Family Felidae

aff. *Smilodon* sp.

*Material.*— UM-K3-69: V60646, distal end of metatarsal?

*Remarks.*— The width of the distal end is 15.1 mm and the depth 16.9 mm. The specimen is larger than *Felis concolor* Linnaeus and smaller than *Panthera atrox* (Leidy) and *Smilodon californicus* Bovard (based on measurements given by Merriam and Stock, 1932). It may belong to either *F. palaeonca* Meade (1945:521) from the Blanco locality or *F. studeri* Savage (1960:318) from the Cita Canyon local fauna, but compares well with undescribed Florida *Smilodon* material in the Frick Collections, American Museum of Natural History.

*Incertae sedis*

*Material.*— UM-K1-66: V60607, fragmented coprolite.

*Remarks.*— The coprolite measures 27 mm by 15 mm and is cylindrically shaped, with one end tapering to a rounded, blunt point. It does not ideally conform to any of the coprolite shape groups figured by Hantzschel et al. (1968:Fig. 1), but best agrees with their cigar shape group. Identifiable elements within the coprolite include a rabbit (*Hypolagus*?) M<sub>3</sub>, proximal epiphysis of a humerus, distal humerus fragment, one phalanx, and one cervical vertebra. The molar shows evidence of etching, probably the result of digestive action. There are numerous thin, elongate impressions, which appear to have been made by hair.

The coprolite was compared with Recent mammal scats in the University of Michigan, Museum of Zoology, Division of Mammalogy collections. It best compares in size, shape, and composition with felid scats, agreeing most closely with those of the bobcat *Lynx rufus* (Schreber). It is also similar, especially in texture, to felid coprolites reported and figured by Kao (1962:Pl. 3) from the Nihowan Series of China.

## Order PROBOSCIDEA

## Family Gomphotheriidae

?*Stegomastodon* sp.

*Material.*— KU-Rep. Co. Loc. 1: KUMNH 395, right M<sub>3</sub>.

*Description.*— The molar is well worn and lacks the posterior end. The estimated length is at least 180 mm, the width 78 mm, and the length/width ratio is 43. There are 5½+ lophs and some cement present. Trefoiling is difficult to identify at this advanced wear stage, but a minimum of double trefoiling and well-developed ptychodonty are present.

*Remarks.*— The presence of cement, ptychodonty, and

large size are characteristic of the genus *Stegomastodon*, but without better diagnostic material this assignment is tentative.

Wing (1930:21) reported two trilophodont teeth were taken from the McCullough pit (KU-Rep. Co. Loc. 1), one of which was donated to and the other loaned to the State Geological Survey of Kansas. It is assumed that the tooth listed by Fishel (1948:92) as a *Stegomastodon* molar (KUMNH 395), recovered from the same sand pit, is the tooth Wing indicated was donated to the State Geological Survey of Kansas.

gen. et sp. indet.

*Material.*— UM-K8-72: V61043, palate with right M<sup>3</sup> and posterior half of left M<sup>3</sup>.

*Description.*— The molars are extremely worn with the pretrite cones completely lost in all lophs except the pentaloph of the right M<sup>3</sup>. The molars fall between Savage's (1955:51) old-age and mature tooth-wear groups. The right M<sup>3</sup> has a length of 159 mm and a width of 77 mm, with a length/width ratio of 48. There are 5½ lophs present with no apparent cement. The trefoil patterns are not clear due to the great degree of wear but appear double with compound ectotrefolding (terminology after Savage, 1955:Figs. 1, 5).

*Remarks.*— Tobien (1973:243) states that *Haplomastodon* and *Cuvieronius* molars are primitive in being structurally simpler, with secondary trefoils and no cement, while *Stegomastodon* and *Notiomastodon* are more advanced, with more complicated molar patterns and thick cement. This, plus the fact that the M<sup>3</sup> measurements given fall below the minimum range of measurements reported for *Stegomastodon* by Savage (1955) and Woodburne (1961:Table 4), suggests that the teeth are those of *Cuvieronius* or *Haplomastodon*.

Simpson and Paula Couto (1957:167) indicate that the pretrite and posttrite cones of the posterior lophs of the M<sup>3</sup> in *Haplomastodon* are oblique, with a stronger tendency towards alternation than in *Cuvieronius*. Because the pretrites and posttrites of the White Rock specimen are opposite each other and the molar is proportionately broad (based on length/width ratios given by Savage, 1955, and listed by Osborn, 1936:575 as characteristic of *Cuvieronius*), this specimen appears to best compare with the genus *Cuvieronius*. No generic determination is attempted, however, without associated tusks and complete dentitions (see Simpson and Paula Couto, 1957:179) because: (1) the molar structures of *Haplomastodon* and *Cuvieronius* are almost identical, so that isolated teeth may be difficult if not impossible to distinguish, (2) a revision of the genus *Cuvieronius* is needed for North America, and (3) it is possible that both *Haplomastodon* and *Cuvieronius* existed along with the true *Stegomasto-*

*don* in North America (Simpson and Paula Couto, 1957: 165, 168, 180).

Fishel (1948:Pl. 6A) pictures a palate with two M<sup>3</sup>s of "*Stegomastodon*" from the Hanel sand pit (UM-K8-72). No number was given by Fishel and the specimen was assumed lost until the summer of 1973, when Hibbard and I visited C.W. Hanel, who showed us the pictured specimen. Since it was illustrated by Fishel, the anterior half of the left M<sup>3</sup> has been broken and lost. The specimen (V61043) has been donated to the University of Michigan, Museum of Paleontology, by Mr. Hanel.

A tooth similar to the Hanel M<sup>3</sup>s (V61043) is pictured by Wing (1930:21, Pl. 11) from the McCullough sand pit (KU-Rep. Co. Loc. 1). The molar consists of 4½ lophs, no apparent cement, and simple enamel structure. The specimen was loaned to the Kansas State Geological Survey for identification and has since been lost.

Fragments of mastodont teeth have been recovered from the silty clay lithosome of the Belleville Formation from the UM-K9-72 locality (V61678) and from a sand pit just east of the McCullough pit at NE¼, NW¼, Sec. 22, T. 2 S, R. 3 W, Republic County (V61679).

## Order PERISSODACTYLA

### Family Equidae

*Equus (Dolichohippus) cf. simplicidens* (Cope)  
new combination  
Skinner, Hibbard et al., 1972

*Material.*— UM-K1-66: V61814, left metacarpal, V61815, two right P<sup>2</sup>s, V61816, right upper molariform tooth, V61817, right upper molariform teeth; UM-K3-69: V60647, left maxilla with P<sup>2</sup>–P<sup>4</sup>; UM-K7-72: V61811, left M<sub>3</sub>; UM-K8-72: V61823, right M<sub>3</sub>; KU-Rep. Co. Loc. 3: V60651, right P<sub>2</sub>, V60652, right M<sub>2</sub>; KU-Rep. Co. Loc. 4: KUMNH 6642, right M<sub>1</sub>, V61813, distal end of metapodial; sand lithosome in ravine just south of UM-K3-69: V61819, left lower premolar; sand lithosome on Johnson farm just south of Pawnee Bridge: V61835, upper molariform tooth fragment; spoil from canal dredging: V61824, right M<sub>3</sub>, V61827, right M<sub>1</sub>, V61828, right P<sub>2</sub>; sand lithosome in abandoned sandpit west of KU-Rep. Co. Loc. 1: V61826, left upper molariform tooth.

*Diagnosis.*— See Skinner, in Skinner, Hibbard et al., 1972:118.

*Description.*— All of the White Rock zebroid teeth compare well with the Sand Draw *Equus (Dolichohippus) simplicidens* material. Particular comparison was made to a skull and associated jaws (F:AM 87428) from this locality. As is diagnostic of lower molars of *Dolichohippus*, the protoconid is united to the metaconid by an anteroisthmus, the hypoconid to the metastylid



by a postisthmus and the metaconid united to the metastylid by a metaisthmus. To put it another way, the metastylid and metaconid of lower molars are separated by a V-shaped groove, the ectoflexid (terminology after Skinner, Hibbard et al., 1972:Fig. 57). All incisors are cupped.

A left metacarpal (V61814) compares well with metacarpals of modern wild zebra, *E. (D.) grevyi* Oustalet (AMNH 82038). The fossil specimen measures 251.0 mm in length, 48.2 mm in distal width, 34.2 mm middle shaft width, and 49.9 mm in proximal width.

*Remarks.*— The classification used in this report is that of Skinner (in Skinner, Hibbard et al., 1972). Because of the complex taxonomy of horses and the scanty material at hand, a tentative specific assignment is made.

*Equus (Hemionus) cf. calobatus* (Troxell)

*Material.*— KU-Rep. Co. Loc. 4: KUMNH 24950, right M<sub>3</sub>; V61825, metapodial.

*Diagnosis.*— See Skinner, Hibbard et al., 1972:123.

*Description.*— The M<sub>3</sub> possesses a single, distinct isthmus uniting the metaconid-metastylid column with the protoconid and hypoconid, characteristic of *Equus (Hemionus)* (Skinner, Hibbard et al., 1972:123).

The metapodial (V61825), that of a young colt, is missing the distal epiphysis. It is shorter and narrower than metapodials of *E. (D.) simplicidens* and *E. (D.) grevyi* and compares favorably with the Mongolian kiang, *E. hemionus*.

*Remarks.*— Two molars borrowed from the University of Kansas collections (KUMNH 6642, right M<sub>1</sub>; KUMNH 24950, right M<sub>3</sub>) and recovered from KU-Rep. Co. Loc. 4 were originally identified as *E. cf. excelsus* Leidy (Fishel, 1948:92). Following the taxonomy of Skinner (Skinner, Hibbard et al., 1972) the right M<sub>1</sub> is referred to *E. (D.) cf. simplicidens* and the right M<sub>3</sub> to *E. (H.) cf. calobatus*. Metapodials representative of these two forms were also recovered from KU-Rep. Co. Loc. 4. The association of *E. (D.) simplicidens* and *E. (H.) calobatus* from the same locality is also known from the Sand Draw and Donnelly Ranch (Hager, 1973) local faunas. Because of the scanty nature of this material, a definite specific assignment is not attempted.

Order ARTIODACTYLA

Family Tayassuidae

*Platygonus* sp.

*Material.*— UM-K5-72: V61349, fragment of left C<sub>1</sub>; UM-K1-66: V60596, unerupted right M<sup>2</sup>, silts above Carlisle Shale N of UM-K4-72: V61350, ?right M<sup>2</sup>; UM-K4-72: V61351, right lower labial molar fragment;

UM-K3-69: V60634, left lower labial premolar fragment and two molar fragments; UM-K7-72: V61352, left lower posterior premolar loph fragment; spoils E of UM-K1-66: V61353, one upper and lower unerupted third molar heel fragment.

*Measurements (mm).*— V61349, left C<sub>1</sub>, transverse width 13.6, anteroposterior length 18.2 (broken); V60596, right M<sup>2</sup>, length 18.4, greatest anterior width 15.9, greatest posterior width 16.5 (measured at cingulum); V61350, ?right M<sup>2</sup>, greatest anterior width 15.2; remaining material too fragmented for measurement.

*Remarks.*— Early Pleistocene species of *Platygonus* are poorly understood taxonomically. This is a result of numerous "species" being described on fragmentary material and the high degree of variability, both individual and sexual, observed in the genus (e.g., see Simpson, 1949; Guilday et al., 1971, on variation in *P. compressus* LeConte; Gidley, 1920:669, on *P. cumberlandensis* Gidley). Therefore, without complete dentitions, specific identification is not attempted.

The material does not appear to be *P. bicalcaratus* Cope because the third molars (V61353) possess a large and distinct heel. The oblique ridge on the posterior loph of M<sup>2</sup> (V60596) merges with the cingulum and does not form a distinct shelf around the loph as in *P. texanus* Gidley.

Based on size, the White Rock specimens best compare with *P. pearcei* Gazin and *P. cumberlandensis*, being smaller than measurements given for *P. bicalcaratus* and *P. texanus*. The material is larger than means given by Simpson (1949) for *P. compressus*, but falls within the upper observed ranges of this form.

Family Camelidae

*Gigantocamelus* sp.

*Material.*— UM-K7-72: V61805, proximal end of right ulna.

*Remarks.*— The specimen was compared with two radii and ulnae (F:AM 24906 and 87482) of *Gigantocamelus spatulus* (Cope) from the Sand Draw local fauna. Unfortunately, both specimens are lacking the proximal end of the ulna, but based on size, the White Rock specimen is referred to this genus. Both Webb (1965:35) and Hibbard (in Skinner, Hibbard et al., 1972:114) discuss the questionable taxonomic position of *Gigantocamelus*.



<i>Onychomys</i> sp. small	-	+	+	-	+	-	-	-	-	-	-
<i>Sigmodon minor</i> Gidley <sup>a</sup>	+	+	+	-	+	-	+	-	-	-	-
<i>Neotoma (Paraneotoma) taylora</i> Hibbard <sup>a</sup>	+	+	+	+	+	-	+	-	-	-	-
<i>Synaptomys (Synaptomys)</i> cf. <i>rinkera</i> Hibbard <sup>a</sup>	+	+	+	+	+	-	-	-	-	-	-
<i>Ondatra idahoensis</i> Wilson <sup>a</sup>	-	+	+	+	+	-	-	-	-	+	-
<i>Pliophenacomys?</i> <i>osborni</i> Martin <sup>b</sup>	+	+	+	+	+	+	+	-	-	-	-
<i>Pliophenacomys</i> cf. <i>primaevus</i> Hibbard <sup>b</sup>	-	-	+	-	+	-	-	-	-	-	-
<i>Ophiomys meadensis</i> (Hibbard) <sup>b</sup>	+	+	+	+	-	-	-	-	-	-	-
<i>Ogmodontomys</i> sp. <sup>b</sup>	+	+	-	-	-	-	-	-	-	-	-
<i>Nebraskomys mcgrewi</i> Hibbard <sup>b</sup>	+	-	-	-	-	-	-	-	-	-	-
<i>Zapus s. sandersi</i> Hibbard <sup>a</sup>	-	+	+	-	-	-	-	-	-	-	-
Zapodidae gen. et sp. indet.	+	-	-	-	-	-	-	-	-	-	-
<i>Megalonyx leptostomus</i> Cope <sup>b</sup>	-	+	-	-	-	-	-	-	-	-	-
Canidae gen. et sp. indet.	+	-	-	-	-	-	+	-	-	-	-
<i>Mustela</i> cf. <i>gazini</i>	-	-	-	+	-	-	-	-	-	-	-
aff. <i>Smilodon</i> sp. <sup>b</sup>	-	+	-	-	-	-	-	-	-	-	-
? <i>Stegomastodon</i> sp. <sup>b</sup>	-	-	-	-	-	-	-	-	-	+	-
Gomphotheriidae gen. et sp. indet.	-	-	-	-	-	-	-	+	+	-	-
<i>Equus (Dolichohippus)</i> cf. <i>simplicidens</i> (Cope) <sup>a</sup>	+	+	-	-	-	-	+	-	-	+	+
<i>Equus (Hemionus)</i> cf. <i>calobatus</i> (Troxell) <sup>a</sup>	-	-	-	-	-	-	-	-	-	-	+
<i>Platygonus</i> sp. <sup>b</sup>	+	+	+	-	+	-	+	-	-	-	-
<i>Gigantocamelus</i> sp. <sup>b</sup>	-	-	-	-	-	-	+	-	-	-	-
<i>Tanupolama</i> cf. <i>blancoensis</i> Meade <sup>b</sup>	-	-	-	-	-	-	+	-	-	-	-
<i>Capromeryx</i> sp. <sup>b</sup>	-	-	+	-	-	-	+	-	-	-	-

<sup>a</sup>Extinct species<sup>b</sup>Extinct genus

+ - Occurrence in locality

H - Holotype

UM-K4-72+ = UM-K4-72+200 ft NW

*Tanupolama blancoensis?* Meade*Material.*— UM-K7-72: V61806, right M<sup>1</sup>.*Diagnosis.*— See Meade, 1945:535.

*Remarks.*— The tooth is well worn, having an anterior-posterior diameter of 28.0 mm and a transverse diameter of 21.8 mm. These measurements are larger than *Tanupolama americana* (Wortman) and best agree in size with the paratype of *T. blancoensis* (BEG 31176-5) from the Blanco fauna of Texas. The White Rock molar was compared with a cast of this paratype; differences in tooth wear made a positive identification impossible.

## Family Antilocapridae

*Capromeryx* sp.

*Material.*— UM-K4-72: V61675, proximal and medial phalanx; UM-K7-72: V61676, proximal phalanx.

*Remarks.*— The phalanges compare well morphologically with the small pronghorn *Capromeryx furcifer* Matthew from the Cragin Quarry local fauna. However, the White Rock phalanges are slightly larger and may belong to the larger and earlier form of *Capromeryx*, *C. furcifer* var. reported by Frick (1937; see also Stirten, 1938; Hibbard and Taylor, 1960) from the *Stegomastodon* Quarry of Nebraska. Measurements of the phalanges are as follows: V61675, proximal phalanx, 36.4 mm in length, 8.4 mm proximal width, medial phalanx, 20.2 mm in length, 7.5 mm proximal width; V61676, proximal phalanx, 38.5 mm in length, 10.1 mm proximal width.

## BIOSTRATINOMY

Because of the presumed braided stream deposition at the major White Rock faunal localities, opportunities for transportation and mixing of remains from different ecological environments were great (Voorhies, 1969:455). The predominance of abraded and isolated micromammal teeth with relatively few complete jaws or maxillaries, especially characteristic of localities UM-K3-69 and UM-K5-72, suggests transportation and sorting. Generally, larger vertebrate fossils such as peccary and horse teeth were recovered from coarser sediments such as gravel lenses, and micromammal remains were recovered from finer sediments such as sands and silts. No laterally continuous bone bed or layer is present (although some fossils occur scattered randomly throughout the sediment), but 0.5-2.0 m lenslike concentrations of bone are present. It was at these concentrations that the major collecting localities were established. Various taxa of presumed incompatible ecological habitat are found associated within one collecting locality (i.e., fish, frog, horse, and land tortoise remains). No articulated or semiarticulated skeletons are known from any locality.

The White Rock fauna, owing to the above characters, is regarded as a "transported fossil assemblage," which is defined by Fagerstrom (1964:1199) as a fossil assemblage "in which nearly all the specimens have been subject to preburial transportation and therefore may have been

derived from more than one contemporaneous community. Almost none of the fossils are found in their original habitats or living positions." In other words, the White Rock fauna is a "death assemblage," or thanatocoensis, representative of more than one environment or habitat zone. Such a mixed fossil assemblage, containing ecologically incompatible individuals from several widely different habitats, is not ideally suited for interpretations of population dynamics. However, such an assemblage is useful for general paleoclimatic interpretations if the assemblage does not span more than one climatic episode of time.

Unfortunately, no samples of taxa suitable for individual age assessment, such as ungulates, are available; thus an interpretation of catastrophic versus attritional accumulation of the fauna is not possible. The only large samples are those of rodents for which only a rough ontogenetic age estimate of tooth wear is possible. Using tooth wear, a 50-80 percent predominance of adult over immature microtine teeth was observed. This same proportion was found by Zakrzewski (1969:Figs. 9, 10) for *Cosomys primus* and *Pliopotamys meadensis* samples from the Hagerman, Sand Point, and Dixon local faunas. Owl predation and subsequent pelleting at the site of deposition would result in accumulations similar to these ratios if it is assumed that the weaker and slower old individuals were the usual prey; however, it is usually presumed that young individuals are the main prey of owls.

### PALEOECOLOGY

Several different environments or habitat zones are indicated by the taxa represented in the White Rock fauna: (1) permanent water habitat, (2) stream-river bank, (3) lowland meadow-savanna valley habitat, (4) valley slope habitat, and (5) upland prairie habitat. Because of the ubiquitous habits of many animals, several forms are to be expected in more than one of these environments. Below is a listing of animals identified from the White Rock fauna and thought to be most characteristic of one or another of these habitat zones. The validity of paleoecological interpretations based upon fossil remains and inferences from their ecological, physiological, and morphological Recent counterparts has been demonstrated by many authors, e.g., Semken (1966:167), Wilson (1968:81), and Konizeski (1957).

*Permanent water habitat.*— The presence of permanent water, probably a river, is implied by the presence of 10 forms of fish, one clam, one freshwater snail, four ostracode species, and the soft-shelled turtle, *Trionyx*. One specimen of channel catfish, *Ictalurus punctatus* (V61321), indicates a living size of over 54 cm. Fish of this size are typical of relatively large rivers such as the

present Republican River. A nearby small, clear, gravelly stream is suggested by the presence of the hornyhead chub, *Nocomis biguttata*, and the yellow bullhead, *I. natalis*.

*Stream-river bank habitat.*— Animals characteristic of this environment require a permanent water supply but are transitional between it and the land (semiaquatic). Such forms include the tiger salamander (*Ambystoma tigrinum*), leopard frog (*Rana pipiens*), bull frog (*R. catesbeiana*), common snapping turtle (*Chelydra serpentina*), painted turtle (*Chrysemys picta*), common water snake (*Natrix sipedon*), muskrat (*Ondatra idahoensis*), and two beavers (*Castor* and *Procastoroides*). Because *Castor* feeds on bark, twigs, and tree branches, a quantity of brush or standing timber (gallery forest) must have been present in the area. The black-bellied plover, *Pluvialis squatarola*, probably spent a major portion of its time along the river shore. Surface feeding ducks (*Anas*) as well as other water border animals may have inhabited small, temporary ponds on the river floodplain.

*Lowland meadow-savanna valley habitat.*— This environment extended from the water border to the valley slope. Animals that lived here included the northern cricket frog (*Acris crepitans*), Rocky Mountain toad (*Bufo w. woodhousei*), Great Plains toad (*B. cognatus*), hognose snake (*Heterodon platyrhinos*), rattle snakes (crotalids), land tortoise (*Geochelone* spp.), gopher (*Geomys*), mole (*Scalopus aquaticus*), shrews (*Blarina* and *Sorex*), rabbit (*Hypolagus*), jumping mouse (*Zapus s. sandersi*), harvest mouse (*Reithrodontomys*), and microtines (*Nebraskomys*, *Ophiomys*, *Pliophenacomys*, *Synaptomys*). Several large herbivores lived primarily on the floodplain savanna: gomphotheres (*Stegomastodon*), camels (*Gigantocamelus* and *Tanupolama*), and the ground sloth (*Megalonyx leptostomus*). The peccary (*Platygonus*) and several carnivores (*Mustela* cf. *gazini*) probably spent a major portion of their time here but frequented other habitats as well.

*Valley slope habitat.*— Living along the slopes of the valley between the uplands and the floodplain were the woodrat (*Neotoma taylori*), mice such as *Peromyscus*, and along the lower valley slopes the cotton rat (*Sigmodon minor*).

*Upland prairie habitat.*— Occupants of this relatively flat, dry grassland were ground squirrels (*Spermophilus bootheri*, *Cynomys vetus*, and *C. hibbardi*), heteromyids (*Perognathus* and *Prodipodomys*), grasshopper mouse (*Onychomys*), horses (*Equus* [*Hemionus*] and *E. [Dolichohippus]*), and the antilocaprid (*Capromeryx*). The rough-scaled lizard (*Sceloporus holmani*) may have lived here. Most of these larger upland forms frequented the river valley for water and possibly protection from fire and climatic extremes. Death of the larger forms during such visits and owl predation on the smaller forms

probably accounts for their occurrence in the fauna.

The ecological significance of the large terrestrial tortoise *Geochelone* has been discussed by Hibbard (1960), Brattstrom (1961), and Holman (1971b, 1972). Because these animals cannot tolerate the severe winters of Kansas today, and because there is no evidence that these fossil tortoises could burrow, it is concluded that the winters were warmer than Kansan winters are today, probably with frost-free nights. On the other hand, the abundance of microtines that are typical of moist and cool habitats suggests that, at least within the paleovalley, the summers did not produce the temperature extremes presently characteristic of the Great Plains and that the effective moisture level was higher, probably a result of greater rainfall associated with less evaporation. Such an interpretation is also supported by the presence of *Geochelone*, which is tropical and subtropical in distribution today and prefers succulent plants (Brattstrom, 1961:552).

It is necessary to postulate a more equable climate with less extreme temperature and moisture fluctuations in order to explain how closely associated members of the White Rock fauna could have lived contemporaneously. Significantly, both the sedimentological and biological data are compatible in this interpretation.

#### PALEOECOSYSTEM

The ecosystem, as defined by Alee et al. (1949:695), consists of the interacting physical and biotic systems. The following interpretation is restricted to an analysis of the mammalian components of the White Rock paleoecosystem with the modern mammalian ecosystem of the area serving as a standard for comparison. It is my intent to demonstrate that proper collecting may produce a representative fossil assemblage of the mammals once living in the paleoecosystem. It is hoped that such studies will result in recognition of paleointerbiotic relationships, as attempted by Konizeski (1957). Such studies must always be restricted because precise temporal and physical boundaries of the faunas are difficult to delineate, and fossil deposits are probably recovered from long-time accumulations from a large area (Hibbard, 1941d:94). The above certainly appears to be true of the White Rock fauna.

From localities where washing techniques were employed, small mammals (mice and shrews) comprise approximately 89 percent of the total number of individuals, medium-sized mammals (rabbits and ground squirrels) approximately 9 percent, and large mammals (peccaries and horses) one percent (tabulation procedure essentially that of Clark et al., 1967).

Data from Shelford (1964) on estimates of number of individuals of mammals from a ten-square-mile area of undisturbed prairie in Kansas showed that small mammals

(mice and shrews) comprise 74.7 percent of the total population, medium-sized mammals (ground squirrels) 24.7 percent, and large mammals (bison and pronghorn) 0.5 percent.

The larger percentage of small mammals from the White Rock fauna in comparison with Shelford's (1964) estimate is probably a result of the fast breeding behavior of rodents. Over a given span of time this faster breeding would provide a larger available proportion of skeletons for fossilization than the actual number of individuals living at any given time (Voorhies, 1969:459). Owl predation on small mammals in the diverse surrounding ecological environments, with subsequent regurgitation at owl roost sites in gallery forests along the paleovalley, could also cause overrepresentation of small mammals (Semken, 1966:169). In view of the above discussion it is perhaps surprising that the White Rock small mammal percentage is not greater.

The above percentages of mammals given by Shelford (1964) are somewhat misleading for the purposes of this study because Shelford's data included only prairie species. The White Rock fauna certainly includes forms that lived in a prairie area, but the deeply entrenched paleovalley provided several additional habitats. Cockrum (1952: Table 1, Fig. 4) presents data that indicates the mammalian distribution along the present wooded Republican River valley in Republic County consists of 43 taxa (species and subspecies). The upland prairie of the same area contains 39 taxa. Of these, 30 taxa from the river valley have close faunal relationships with the eastern deciduous forest while only seven from the upland prairie have similar affinities. On the other hand, seven kinds from the river valley have faunal relationships to the Great Plains while 23 forms from the upland prairie have western faunal affinities. Five species and subspecies from the drier upland prairie have southern affinities whereas only two from the more moist river valley have southern faunal relationships.

According to Cockrum (1952) there are 41 mammalian species representative of 34 genera (excluding bats) presently living in Republic County. This total includes taxa from all the ecological environments or habitat zones present in the county (i.e., stream-river bank, savanna valley, upland prairie, etc.). Thus far 31 mammalian genera, 23 identified to species, are known from the White Rock fauna. If forms that cannot be identified beyond family because of their poor preservation are counted, 43 different kinds are represented. A listing of the mammals now extant in Republic County and their probable ecological analogues from the White Rock fauna is given in Table 16. Table 16 attempts to group these mammals into their most characteristic habitat and probable food niche.

The most pronounced differences between the modern

Table 16. A comparison of the present Republic County and fossil White Rock mammalian faunas with inferred food habit and ecological habitats<sup>1</sup>

Early 19th Century Fauna	Food Habit	White Rock Fauna
<b>STREAM-RIVER BANK HABITAT</b>		
<i>Castor canadensis</i>	Semi-aquatic herbivore	<i>Castor</i> sp.
<i>Ondatra zibethicus</i>	Semi-aquatic herbivore	<i>Procastoroides</i> sp.
<i>Lutra canadensis</i>	Semi-aquatic herbivore	<i>Ondatra idahoensis</i>
<i>Lutra canadensis</i>	Semi-aquatic carnivore	
<b>LOWLAND MEADOW SAVANNA HABITAT</b>		
<i>Blarina brevicauda</i>	Insectivore	<i>Blarina</i> aff. <i>carolinensis</i>
<i>Cryptotis parva</i>	Insectivore	<i>Sorex</i> near <i>cinereus</i>
	Insectivore	<i>Sorex</i> aff. <i>sandersi</i>
<i>Scalopus aquaticus</i>	Fossorial carnivore	<i>Scalopus aquaticus</i>
<i>Sylvilagus floridanus</i>	Medium-sized grazer	
<i>Sciurus niger</i>	Arboreal granivore	
<i>Geomys bursarius</i>	Small fossorial herbivore	<i>Geomys</i> sp.
<i>Reithrodontomys megalotis</i>	Granivore	<i>Reithrodontomys pratincola</i>
<i>Peromyscus leucopus</i>	Omnivore	<i>Peromyscus cragini</i>
<i>Synaptomys cooperi</i>	Herbivore	<i>Synaptomys rinkeri</i>
<i>Microtus ochrogaster</i>	Omnivore	<i>Pliophenacomys</i> cf. <i>primaevus</i>
	Omnivore	<i>Pliophenacomys?</i> <i>osborni</i>
	Omnivore	<i>Ophiomys meadensis</i>
	Omnivore	<i>Ogmodontomys</i> sp.
	Omnivore	<i>Nebraskomys mcgrewi</i>
	Granivore	<i>Zapus s. sandersi</i>
	Granivore	Zapodinae
<i>Ursus americanus</i>	Large omnivore	
<i>Procyon lotor</i>	Medium-sized omnivore	
<i>Mustela vison</i>	Small carnivore	<i>Mustela</i> cf. <i>gazini</i>
<i>Mustela frenata</i>	Small carnivore	<i>Tanupolama</i> cf. <i>blancoensis</i>
<i>Odocoileus virginianus</i>	Large herbivore	<i>Gigantocamelus</i> sp.
	Large herbivore	<i>Stegomastodon</i> sp.
	Large herbivore	Gomphotheriidae

and fossil fauna are the low incidence of fossil carnivores and both the greater proportion and absolute number of fossil microtine rodents and medium to large herbivores. As pointed out by Konizeski (1957:149) and Shotwell (1955:328), carnivores are by necessity fewer in number than the rest of the fauna simply because of the nature of the food chain, or "Eltonian Pyramid." Thus, fewer of these generally wide-ranging predators were available for fossilization.

The greater diversity of medium to large sized herbivores (eight to four over the modern fauna) suggests a greater diversity of browsing and grazing habitats in the past, probably similar to the grazing hierarchy described by Vesey-Fitzgerald (1960) for parts of Tanganyika. After the extinction of many large Pleistocene herbivores in the Great Plains, the optimum refilling of their niches by surviving and subsequent herbivores has never taken place.

Fossil microtines outnumber the present microtines of Republic County seven to three. Cricetines are

represented equally by six forms from both faunas. In the Sand Draw local fauna, in which the rodent sample is well known, microtines outnumber the cricetines seven to five. A more equable climate with cooler summers and more effective moisture is postulated as necessary for the abundant fossil microtine faunas characteristic of the early Pleistocene in the Great Plains region.

It appears that in spite of the problems associated with biostratigraphy and fossil diagenesis, the White Rock fauna as listed in Table 16 is a good representation of the actual early Pleistocene mammalian fauna. Aside from the expected small number of carnivores, all habitat zones were occupied by an equal or greater number of forms of the same food habit as occupy these zones today. Therefore, like several other well-studied Pleistocene faunas, the early Pleistocene White Rock mammalian fauna was equally or more diverse than the modern fauna. The decreased size of the modern fauna is probably a result of both man's activity reducing the natural modern mammalian fauna and greater climatic

## VALLEY SLOPE HABITAT

*Peromyscus maniculatus*  
*Neotoma floridana*

Herbivore  
Herbivore

*Sigmodon minor*  
*Neotoma taylora*

## UPLAND PRAIRIE HABITAT

*Lepus californicus*  
*Cynomys ludovicianus*

Medium-sized grazer  
Small semi-fossorial herbivore  
Small semi-fossorial herbivore  
Small semi-fossorial herbivore

*Hypolagus cf. furlongi*  
*Cynomys cf. vetus*  
*Cynomys hibbardi*  
*Spermophilus boothi*  
*Spermophilus sp. small*  
*Perognathus pearlettensis*  
*Perognathus sp. large*  
*Prodipodomys sp.*  
*Onychomys fossilis?*

*Spermophilus tridecemlineatus*  
*Spermophilus franklini*  
*Perognathus hispidus*

Small semi-fossorial herbivore  
Granivore

*Onychomys leucogaster*  
*Reithrodontomys montanus*  
*Cervus canadensis*  
*Bison bison*  
*Antilocapra americana*

Granivore  
Granivore  
Omnivore  
Granivore  
Large herbivore  
Large herbivore  
Large herbivore

*Equus cf. simplicidens*  
*Equus cf. calobatus*  
*Capromeryx sp.*

## UBIQUITOUS

*Erethizon dorsatum*  
*Canis latrans*  
*Canis lupus*  
*Vulpes vulpes*  
*Taxidae taxus*  
*Mephitis mephitis*  
*Spilogale interrupta*  
*Felis concolor*  
*Lynx rufus*

Herbivore  
Medium-sized carnivore  
Medium-sized carnivore  
Medium-sized carnivore  
Medium-sized carnivore  
Medium-sized omnivore  
Medium-sized omnivore  
Medium-sized carnivore  
Medium-sized carnivore  
Large herbivore

Canidae

*Platygonus sp.*

aff. *Smilodon sp.*

*Megalonyx leptostomus*

<sup>1</sup>Ecological habitats primarily after Beed (1936); Landry (1970) points out that in reality most rodents are omnivores.

fluctuations during the Pleistocene, which increased the mammalian fauna density of the past. Such an increase could have been caused by alternate compressing and expanding of life zones southward and northward, causing greater niche competition and speciation during compression. Cooling summers prior to continental glacial advance is postulated to have allowed a southward advance of the microtine rodents and associated vertebrates into the more southern cricetine and heteromyid rodent-rich habitats. The cooling climate had not, however, deteriorated sufficiently to cause all the forms with more southern affinities to vacate the region.

Smith (1957:207) advanced a similar idea when he wrote on the Wisconsin glaciation and its affect on faunal distribution:

That the fauna of glaciated territory was forced southward or eliminated does not imply that the boreal fauna completely replaced a more southern faunal type or that the area south of the ice front was appreciably colder than at present. This view holds that an admixture of ecologically segregated boreal and austral elements existed, possibly almost side by side, near the ice front but within unglaciated territory.

## PALEOZOOGEOGRAPHY

Of the three Recent North American rodent units (boreal, sonoran, tropical) recognized by Merriam (1890), microtines are characteristic of the boreal unit. In all, 19 genera comprise this unit, ten shared in common with Eurasia and eight restricted to North America. The remaining genus, *Erethizon*, is probably a relatively new addition from Central or South America (Hooper, 1949: 24). Several sciurids are represented in the boreal unit. *Spermophilus*, *Castor*, *Synaptomys*, *Ondatra*, and *Zapus* are representative of this rodent unit and are also known from the White Rock fauna. *Pliophenacomys* is probably related to or even ancestral to *Phenacomys* and *Microtus*, both of the boreal rodent unit.

*Reithrodontomys*, *Peromyscus*, *Onychomys*, *Neotoma*, *Cynomys*, and some subgenera of *Spermophilus* are members of the arid western or sonoran rodent unit. This unit shares few species with and is unrelated to those of the boreal unit; they are indigenous forms with their closest relatives in Central and South America (Hooper, 1949: 25).

The third rodent unit of Merriam, the tropical unit, is represented only by *Sigmodon*. Judging from its complex penis structure, *Sigmodon* was derived from a South American stock; it was one of the earliest overwater migrants to North America (Herskovitz, 1966:736), known from the upper middle Pliocene Rexroad fauna (Hibbard, 1938).

Hoffmann and Jones (1970:Table 1) present a more detailed division for all the mammals of the northern Great Plains region. However, it is difficult to relate fossil faunas to their model. In addition, the rodents are the best represented portion of the White Rock fauna and in an attempt for clarity, a simplistic approach was employed.

#### Neogene Rodent Fluctuations on the Great Plains<sup>1</sup>

A summary of the known number of fossil species of cricetines, microtines, and heteromyids from the Great Plains of Kansas, Nebraska, and Oklahoma reveals an interesting relationship (Table 17). In the late Miocene (Norden Bridge local fauna) no cricetines or microtines are known, whereas six heteromyids are present. The Wakeeney local fauna, early Pliocene in age, is represented by four cricetines, no microtines, and only two heteromyids. By late middle Pliocene (Rexroad fauna) time, eight cricetines, three microtines, and three heteromyids were present. The pre-Nebraskan faunas of the Sand Draw and White Rock local faunas taken together contain six cricetines, seven microtines, and three heteromyids.

Table 17 suggests that cricetines migrated into the Great Plains area for the second time by early Pliocene time (Wakeeney local fauna). Microtines do not appear until middle Pliocene (Rexroad fauna) time. Therefore, Clark et al.'s (1964:42) suggestion that an Old World invasion of competing microtines reduced the heteromyids and allowed the native American cricetids to reenter the Plains does not appear to be the case for the portion of the Great Plains that is now Kansas. During the Kansan and Wisconsinan glacials, heteromyids decreased in number presumably because some were pushed southward by cooler, moist climates and because of competition with invading boreal unit rodents. Microtines achieved their greatest faunal diversity during the period that included the late pre-Nebraskan cooling, probably the Nebraskan glaciation (faunally unknown) and Kansan glaciation.

The Illinoian glacial faunas, consisting of nine known cricetines and only four microtines, are an exception to this trend. This inconsistency may be partly explained

<sup>1</sup>The recent trend in raising the Mio/Pliocene boundary to about 5.5 m.y. has changed the presumed ages of most of the Neogene faunas. No attempt is made to revise these ages here since the faunas are chronologically arranged, suggesting the same rodent fluctuations, albeit possibly earlier in time.

by noting that some of the faunas representing this time interval (Berends, Doby Springs) are relatively southern in their location and others may be interglacial in age (Semken, pers. comm., April 11, 1974).

Herskovitz (1966:729), speaking of the sonoran rodent unit, states that, "from Middle America, cricetines and other New World mammals spread into higher northern latitudes in the wake of retreating glaciers and as suitable habitats became available." Probably, this was also true of preglacial and interglacial times.

Several authors have shown that cricetines appear limited in their northern distribution by winter extremes (Cockrum, 1952; Jones, 1964). The Recent northward movement of the pygmy mouse (*Baiomys taylori*) and cotton rat (*Sigmodon hispidus*) is regarded by Jones (1964:31) to have been a result of gradual warming in North America over the last 100 years (Dorf, 1959). But, Jones states (1964:39) that, "in four of the last 14 winters at Lawrence, Kansas, prolonged periods of low temperature or a heavy ground-cover of ice or snow, or both, have drastically reduced the numbers of *S. hispidus* and are thought to be the principal factors limiting continued northward dispersal of the species." Cockrum (1948:306-312; 1952:22, 185) has shown similar evidence for *S. hispidus* in Kansas and Dunaway and Kaye (1961) reported similar cotton rat winter kills in Tennessee. *Sigmodon* is not presently known in Republic County but was recovered from the White Rock fauna.

Disjunct animal populations are believed to be relics of former geographical distributions that have shifted with climatic change. The occurrence of the rice rat (*Oryzomys palustris*) in archeological sites in Illinois, far north of its present range, is an example of such a shift. Smith (1957) explained this former more northern range extension by a warmer and wetter climate associated with the Hypsithermal episode; the rice rat's current absence is believed to be a result of more severe winters in Illinois today. Packard (1960:659) suggested that the evolution and speciation of the pygmy mouse (*Baiomys*) was directly affected by alpine glaciation and related cooling in the higher regions of the Valley of Mexico. It therefore appears that, in general, cricetines are limited in their northern distribution by winter extremes. When such extremes surpass the animals' physiological tolerances, they must leave the area or become extinct.

Finally, Hoffmann and Jones' (1970) study of the late-glacial and post-glacial effects on the distribution of the Recent mammals of the Great Plains is a good summary of the similar effects postulated for mammal distributions throughout the Pleistocene.

The above rodent unit interrelationships are to be expected if the physiologies of these animals have not significantly changed during the Pleistocene. In other words, many of the sonoran cricetines, generally charac-



teristic of warmer, mildly seasonal climate, could not adequately adapt to the cooler periods of the Pleistocene and were forced southward during glacials. Boreal microtines, characteristic of cooler, seasonal climate, were preadapted for glacial climates and migrated southward with the advancing ice. Because the physiologies of these rodents are believed to be basically unchanged, the paleoecological requirements stated above are necessary.

### CONCLUSIONS

1) During late Blancan time, in what is now Republic County, Kansas, a braided river filled the ancestral Republican River paleovalley 60 m deep and 16 km wide with deposits (Belleville Formation) containing a diverse fauna (White Rock fauna).

2) Delineation of this paleovalley indicates that the Belleville Formation is at least in part physically and temporally correlative with the Red Cloud sands and gravels of Nebraska to the northwest and with the Holdrege, Fullerton, and Grand Island (in the sense of Lugn, 1935) formations of Nebraska to the northeast.

3) Scanty vertebrate fossil remains of large biostratigraphic index fossils from these formations are all suggestive of a late Blancan land-mammal age and add further support to the above correlation.

4) The term Belleville Formation has been retained in this report for the deposits in Republic County based on priority and the inadequacy of Lugn's terminology for this area.

5) Based on stratigraphic correlation and faunal comparison with other early Pleistocene faunas of the High Plains, the portion of the Belleville Formation containing the White Rock fauna is regarded as late pre-Nebraskan in age (post-Sand Draw local fauna and pre-Borchers local fauna).

6) Study of the White Rock faunal material shows no ecologically significant intraspecific morphological change from one locality to another.

7) As a whole, the fauna suggests a large and diverse lowland meadow-savanna valley fauna with representative taxa of permanent water, stream-river bank, valley slope, and upland prairie forms. These taxa are compatible with the known geomorphology of the paleovalley.

8) The taxa of the White Rock fauna imply a more equable climate with less extreme temperature and moisture fluctuations than occur in north-central Kansas today. Only in such an environment could forms such as *Geochelone* and *Sigmodon*, characteristic of relatively warm, mildly seasonal climate, coexist contemporaneously with forms such as boreal microtines and *Zapus*, which are characteristic of cooler, seasonal climate. Pre-Nebraskan glacial cooling is postulated to have allowed typically

Table 17. Known species of cricetine, microtine, and heteromyid rodents from late Cenozoic faunas of Nebraska, Kansas, and Oklahoma<sup>1</sup>

Age	Cricetines	Microtines	Heteromyids
Recent	10	4	3
Wisconsinan	2	3	1
Sangamonian	9	4	3
Illinoian	9	4	3
Yarmouthian*	3	3	1
Kansan	3	7	1
Aftonian	4	2	3
Nebraskan*	0	1	0
pre-Nebraskan	6	7	3
upper middle Pliocene	8	3	3
lower Pliocene	4	0	2
late Miocene	0	0	6

<sup>1</sup>Data compiled in part from Hibbard (1970: Tables 1-8)

\*Faunas that are poorly known

cooler climate forms to move southward; however, the cooling had not progressed to the point that all forms with more southern affinities were forced out of the region.

9) A comparison of presumed environmental habitats and food habits between the mammalian fauna of Republic County today and the fossil White Rock fauna (Table 16) shows that the White Rock fauna was more diverse than the modern fauna. It is shown that the mammalian components of the paleoecosystem are probably a good representation of the mammalian fauna of that time.

10) For the early Pleistocene of the Great Plains, only the geographically more northern Sand Draw local fauna contains as many microtine rodent species (seven) and as diverse a vertebrate fauna as the White Rock fauna. The White Rock is presumed to have existed under a paleoclimate unlike any climate found in North America today.

11) Neogene rodent fluctuations on the Great Plains are shown to reflect climatic shifts through time. Higher proportions of cricetines and heteromyids over microtines are suggestive of warmer or interglacial episodes and higher proportions of microtines suggest cooler or glacial episodes, but proportions vary with latitude.

### ACKNOWLEDGMENTS

I am deeply indebted to Dr. Claude W. Hibbard, who suggested this study, advised and assisted me in all field aspects of this project, and served as my doctoral chairman until his death. I am indebted to Hibbard and his field crew, which included Robert Habetler, Terry McMullen, Robert Carr, Alan DeGood, and Samuel Awalt. They helped collect, wash, and pick a major portion of the processed matrix.

The following local residents of Republic County generously allowed me access to their property: Messrs. Kenneth Erkenbrack, Clarence Hanel, Gene Johnson, C.E. Larkins, James Kevendofsky, Howard Millen, Lola Snyder, and Rodney Warren. Mr. James B. Purcell of Bostwick Irrigation District No. 2 allowed access to and from the White Rock Canal. Mr. Arthur W. Ferguson of this same office was especially helpful in obtaining information and opening office files pertinent to this project. Dr. Coyt A. Noble allowed me to process matrix on his property. Mr. Glenn Hoff and Mr. Clarence Hanel graciously donated specimens for the study.

This research was supported by a grant (1581-72) from the Geological Society of America, a Grant-in-aid of Research from The Society of the Sigma Xi, and a University of Michigan Rackham Student Dissertation Grant that provided funds for field expenses during the summers of 1972 and 1973 and for artists, Ms. Keelin Murphy (KM) and Mr. James W. Bruce. A National Science Foundation Grant (project GB-5450) to Hibbard provided funds for artists, Mrs. Marvin J. Schmid (MJS) and Ms. Alice R. Ballard (ARB).

The author would like to thank the following specialists for their help in specimen identification or for critical reading of pertinent sections: Dr. S.A. Hall, pollen; Drs. H. van der Shalie and B.B. Miller, mollusks; Drs. C.K. Chamberlain and J.A. Fagerstron, insect burrows; Mr. E.D. Gutentag, ostracodes; Dr. G.R. Smith, fishes; Dr. J.A. Holman, amphibians and reptiles; Mr. R.E. Preston, turtles; Drs. R.W. Storer and J.A. Feduccia, birds; Mr. T. Galusha, felid; Dr. D. Klingener, Dr. A.J. Van der Meulen, and Mr. M.D. Carleton, rodents; Mr. M.F. Skinner, horses; Mr. Beryl E. Taylor, camels; Dr. D. Gillette, sloth; Dr. C.W. Hibbard, mammals; Dr. J. Boellstorff, volcanic ash fission-track dating.

The following loaned specimens under their care: Dr. R.D. Guthrie, University of Alaska; Dr. E.T. Hooper, University of Michigan, Museum of Zoology; Dr. L.D. Martin, University of Kansas, Museum of Natural History; Dr. C.E. Ray, National Museum of Natural History; and Dr. C.B. Schultz, University of Nebraska State Museum.

I would like to thank Drs. J.A. Dorr, Jr., D.F. Eschman, E.T. Hooper, H.A. Semken, and G.R. Smith for critical reading of the manuscript. Appreciation is extended to Mr. Karoly Kutasi for help in photographing the plates.

Finally, I would like to thank my wife, Evelyne, who served as my field assistant and typed a major portion of the manuscript.

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