

THE MEADE BASIN RODENT PROJECT: A PROGRESS REPORT

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ABSTRACT

Current knowledge regarding the stratigraphy and mammalian paleontology of the Meade County area of southwestern Kansas is provided. Stratigraphic nomenclature of the Rexroad, Ballard, Crooked Creek Formations and late Pleistocene basin-fill deposits is reviewed. A list of mammal species from many localities in the later Cenozoic of southwestern Kansas is presented, and the families are evaluated for their potential contribution to biochronologic and evolutionary investigations. New Blancan localities, some in superposition, have been recovered from the Rexroad Formation in the area of Keefe Canyon. Excavations from sediments directly above the source of the Deer Park local fauna have produced a diverse rodent assemblage. Another newly discovered series of sites in the Borchers Badlands, between the lower Huckleberry Ridge ash (2.10 Ma) and the higher Cerro Toledo B ash (1.23-1.47 Ma), spans the Pliocene-Pleistocene and Blancan-Irvingtonian boundaries. New basin-fill Rancholabrean localities in Clark County have spurred us to consider the problem of extrapolating the Vanhem and Kingsdown Formation nomenclature of Clark County to similar age beds in Meade County. Although many thorny stratigraphic and systematic puzzles remain, preliminary results are encouraging, and suggest that the later Cenozoic faunas of southwestern Kansas offer an unparalleled opportunity to examine the evolution of rodent community structure through at least the last five million years.

INTRODUCTION

The purpose of this paper is to briefly describe new paleontologic and stratigraphic studies being conducted by the authors in southwestern Kansas in the Meade County and surrounding area. These studies are part of a project designed to test hypotheses of rodent community structure and evolution in a geographically constrained area through several million years. The Meade County area became well known through the research of Claude W. Hibbard, who over a period of 37 years, from 1936 until 1973, studied the paleontology and stratigraphy there and developed a succession of land mammal faunas spanning the mid-Pliocene through late Pleistocene. Most of these faunas contain abundant rodents, thus making the Meade County area ideal for studying rodent community evolution through at least four million years (Martin and Fairbanks, 1999). There are, however, temporal gaps of varying lengths in this faunal succession, and

the authors are endeavoring to find new small mammal localities in these gaps to provide more complete biochronologic coverage. The stratigraphy in and around Meade County is locally complex and often only partly exposed, making physical correlations between different stratigraphic sections and their contained fossil sites quite difficult at times. The authors are thus also conducting stratigraphic studies in selected areas to provide a more complete framework upon which correlations between different localities can be made and to resolve some long-standing, albeit not always clearly recognized, stratigraphic and biostratigraphic questions. The work to date has involved collection of fossils from the Pliocene Rexroad and Ballard Formations, the Plio-Pleistocene Crooked Creek Formation, and overlying middle to upper Pleistocene units generally placed in the Kingsdown and Vanhem Formations (Figure 1). The majority of the localities in this research project are located in the Meade Basin, but a few localities

from Clark County (e.g. Keiger Creek, Beckerdite) that are not strictly in the basin are nevertheless considered because of their faunal components and close geographic proximity to the basin.

In subsequent sections of this paper we will endeavor to provide a "state-of-the-art" summary of our field and analytical work, and point out promising new avenues of inquiry. We begin with a review of our stratigraphic investigations. This is followed by an examination of mammals present in late Cenozoic faunas of southwestern Kansas, with an evaluation of the potential each group holds for further correlational and evolutionary studies. We end with a justification for the new chronology offered for Meade Basin faunas. A list of mammal species recovered to this point from many southwestern Kansas localities is also provided.

STRATIGRAPHIC SUMMARY

Figure 1 shows the stratigraphic nomenclature used by some workers in the Meade County area, and the approximate stratigraphic position of example fossil localities in southwestern Kansas (Meade, Seward, and Clark Counties). The column under Hibbard and Taylor, 1960, represents stratigraphic concepts at a time when only one volcanic ash, called the Pearlette ash, was thought to be present in the area. By the early 1970's (column under Zakrzewski, 1975) two (types B and O) and later three separate ash falls, widely separated in age, were recognized. The Huckleberry Ridge and Lava Creek B ash beds have source areas in Yellowstone National Park, Wyoming, and the Cerro Toledo B ash bed has a source area in the Jemez Mountains, New Mexico. Geologic mapping was done in the Irish Flats NE 7.5 minute quadrangle by the USGS in the late 1970's (Izett and Honey, 1995). On that map, all deposits from the base of the Stump Arroyo Member to those containing the Lava Creek B ash bed were included in the Crooked Creek Formation. The names Kingsdown Formation and Vanhem Formation were not used in the Irish Flats NE quadrangle because 1) outside the type areas in Clark County, Kansas, deposits are commonly assigned to these two formations primarily by age and topographic position, and 2) in Meade County, rocks assigned to these two formations include diverse and overlapping lithologies that are not always similar to lithologies in the type areas. Rather, a more descriptive terminology was employed by the USGS, and is used here with modifications.

In Table 1 we provide a tentative chronological list of classic and new collecting localities from southwestern Kansas, including the identification numbers Hibbard and Taylor used for their Meade

Basin faunal sources (sources of the species lists in Appendix 1 and 2). Preliminary faunal lists from a few of our recently discovered localities are included in Appendix 1 and 2, along with revised lists from previously published studies. In the case of our recent work, all individual quarries carry a name, and if collections were made from superposed quarries in a single outcrop they are usually individually identified by a letter, with the first alphabetical letter representing the lowest quarry in the sequence (e.g., Wiens A, Wiens B). Because the Aries locality (and local fauna) was named before a second fossiliferous level was discovered directly above it, the original Aries quarry (Izett and Honey, 1995) should be considered as the lowest unit (Aries A) in a superposed succession that also includes Aries B, the latter which is found in sediments above Aries A and directly beneath the Cerro Toledo B ash. Quarries in the same canyon that are not vertically related in the same outcrop are sometimes referred to by the same name, but given different numbers. Thus Raptor 1-4 are four localities (or sequences, as Raptor 1 has three levels, A-C) found in Keefe Canyon, but are not vertically superposed. Raptor 2 is high in the same geological outcrop as Raptor 1, but separated to the south by a covered interval. Rather than designate Raptor 2 as a higher and therefore younger level of the Raptor 1 succession (e.g., Raptor 1D), we chose the more conservative Raptor 2 designation. Deer Park was the first locality Hibbard collected in the Meade Basin (Hibbard, 1938). In 1997 and 1999 we recovered a diverse fauna from a level just above Hibbard's excavations, which is currently under study. We have designated our material as Deer Park B, and his original material as the Deer Park A local fauna. A preliminary species list for the rodents from Deer Park B is presented in Appendix 2.

The overall development of stratigraphic and paleontologic studies in the Meade County area up to Hibbard's death was concisely reviewed by Zakrzewski (1975), and will not be repeated here. Instead, we will examine some of the older and also the more recent work that has been done as it relates to our ongoing studies in the Meade County area, focusing on studies in the Rexroad, Ballard, and Crooked Creek Formations, and the overlying upper Pleistocene units.

Rexroad Formation

We have begun detailed stratigraphic work in the Rexroad Formation, particularly in deeper canyons along the Cimarron River, and have found several new micromammal localities, both north and south of the river. These new localities and their chronologic

TABLE 1. Collecting localities in Meade, Seward and Clark Counties. Some recently discovered localities may appear here but not in Figures 1 and 2 or in Appendix 1 and 2. If no locality number is listed, the fauna was taken from a single, apparently unnumbered, quarry. A question mark indicates the stratigraphic assignment is tentative. Localities in bold type are new. The localities are arranged chronologically.

<u>Locality Designation</u>	<u>Local Fauna</u>	<u>Rock Unit</u>
-	Robert	Basin - fill deposits (11,000 yrs. B.P).
MSU-3-97	?Keiger Creek	Basin - fill deposits
MSU-1-96	? Bob Dole	Basin - fill deposits
Jones (Upper))	Jones (<i>Ambystoma</i> faunule)	Basin - fill deposits (26,700 \pm 1500 - 29,000 \pm 300 yrs B.P.)
Jones (Lower)	Jones (Classen faunule)	Basin - fill deposits
MSU-22-97	? Taylor	Fluvial deposits
UM-K2-47	Jinglebob	Fluvial deposits
UM-K2-59	Mt. Scott	Fluvial deposits
Cragin Quarry Loc. 1 (KU Loc. 6 and USGS Cenozoic Loc. 21274)	Cragin Quarry	Basin - fill deposits
UM-K3-61	Butler Spring	Fluvial deposits
Butler Spring Loc. 1 (USGS Cenozoic Loc. 21042)	Adams	Fluvial deposits
KU Loc. 17 (Sunbrite Mine), KU Loc. 10 (Cudahy Mine), Arkalon 1	Cudahy	Crooked Creek Fm (Atwater Member) (directly underlies Lava Creek B ash, 0.67 \pm 0.01 Ma)
MSU-12-99	Aries B	Crooked Creek Fm (Atwater Member) (directly underlies Cerro Toledo B ash, 1.23 - 1.47 Ma)
MSU-14-97	Rick Forester	Crooked Creek Fm (Atwater Member)
MSU-6-98	Aries NE	Crooked Creek Fm (Atwater Member)
USGS 78G22	Aries A	Crooked Creek Fm (Atwater Member)
MSU-10-97	Short Haul	Crooked Creek Fm (Atwater Member)
UM-K1-72, UM-K1-71	Nash 72, Nash 71	Crooked Creek Fm (Atwater Member)
KU-Mea-009 (KU Loc. 9)	Borchers	Crooked Creek Fm (Atwater Member) (directly overlies Huckleberry Ridge Ash, 2.10 Ma)
MSU-5-97, MSU-6-97	NBAW, NBAE	Crooked Creek Fm (Atwater Member)
MSU-9-97	Margaret 1	Crooked Creek Fm (Atwater Member)
UM-K2-53	Sanders	Ballard Fm (Missler Member)
-	Hart Draw	Ballard Fm (Missler Member)
MSU-16-97	? White Hill	Ballard Fm (Missler Member)
MSU-20-99	Deer Park B	Ballard Fm (Missler Member)
Rexroad Loc. 1 (KU Loc. 25)	Deer Park A	Ballard Fm (Missler Member)
Bender Loc. 1b, c	Bender	Rexroad Fm
-	Rexroad Loc. 3	Rexroad Fm
UM-K3-53	?Wendell Fox Pasture	Rexroad Fm
-	?Rexroad Loc. 2a	Rexroad Fm
-	?Rexroad Loc. 2	Rexroad Fm
UM-K1-59	Hornet	Rexroad Fm
MSU-1-98, MSU-8-98, MSU-9-98	Wiens; Alien 1, 2	Rexroad Fm
MSU-19-99, MSU-6-99	Vasquez, Newt	Rexroad Fm

MSU-11-98, MSU-12-98, MSU-15-98	Raptor 2, 3, 4	Rexroad Fm
UK Loc. 22, MSU-2-99, MSU-10-98	Keefe Canyon, KC Turtle, Raptor 1	Rexroad Fm
MSU-7-99	Ripley	Rexroad Fm
UM-K1-47 (Rexroad Loc. 4)	Fox Canyon	Rexroad Fm
MSU-16-99	? XIT 2	Rexroad Fm
MSU-4-98	? XIT 1	Rexroad Fm
MSU-16-00	Red Fox	Rexroad Fm.
MSU-4-99	Bishop	Rexroad Fm
MSU-18-97	Fallen Angel	Rexroad Fm
MSU-11-00	? Argonaut	Rexroad Fm
Rexroad Loc. No. 6	Saw Rock Canyon	Rexroad Fm

placement relative to Hibbard's localities, as currently understood, are presented in Figure 1 and Table 1. As indicated in Figure 1, we employ Hibbard's stratigraphic nomenclature for the Rexroad Formation.

North of the Cimarron River in the Keefe Canyon area, several stratigraphic sections have been measured that place some of the new fossil localities relative to the Keefe Canyon quarry, and to the overlying Ballard Formation. The geology in the Keefe Canyon area is quite complex due to the presence of laterally discontinuous units and at least one basin collapse which has disrupted the stratigraphy locally. A very productive new microvertebrate locality, Wiens, appears to project in stratigraphically about one meter above the Keefe Canyon quarry, while another fossiliferous locality, Raptor 1C, appears to lie at the same level as the quarry. Both of these new sites also contain large mammals; peccaries are relatively common at Wiens, whereas horses and camels appear to be more common at Raptor 1C.

Wiens, which is found on a ridge just to the east of Keefe Canyon, is stratigraphically related to a series of fossiliferous localities in two canyons to the east of Keefe Canyon. Unnamed on topographic maps, we have named these Alien Canyon and East of Alien (EOA) Canyon, respectively (the cap caliche remnant at the head of Alien Canyon bears a strong resemblance to the head of one of the monsters in the movie by the same name). Alien 1 and 2, discovered in 1998 in Alien Canyon, have so far produced only large mammal bones. In the summer of 1999 we discovered a series of localities in EOA Canyon that tie in stratigraphically both with Wiens, Alien 1 and 2 and the various Keefe Canyon quarries. Bishop is the lowest site, lying almost directly on a cemented gravel at the base of the canyon. It seems to be an ancient spring, with much large and no small mammal material. Ripley, Newt and Vasquez are very rich sites with both rodents and large mammals. In 2000 we also recovered rodent material from new localities in Fox Canyon (e.g., Red Fox,

Table 1) that may be older than Hibbard's original Fox Canyon quarry (Hibbard, 1950).

South of the Cimarron River, several new fossiliferous zones have been found ranging in age from late Hemphillian to early Blancan (e.g., Argonaut, Fallen Angel, XIT 1 and 2). Their stratigraphic positions relative to Hibbard's original Saw Rock Canyon quarry (Seward County; also south of the Cimarron River) are currently being determined.

Ballard and Crooked Creek Formations

The Crooked Creek Formation was named by Hibbard (1949b) for exposures in the S1/2 Sec. 16, W1/2 Sec. 15, and N1/2 Sec. 21, T. 33 S., R. 28 W., in the "Borchers Badlands" of Zakrzewski (1988). Frye and Hibbard (1941) had earlier designated these same exposures as the type section of the redefined Meade Formation of Cragin (1896). After the 1941 paper however, Hibbard concluded that these exposures of so-called Meade Formation in the Borchers Badlands were actually deposited in a younger cycle of deposition than that represented by Cragin's original "Meade gravels". Accordingly, Hibbard (1949a) moved the type locality of the Meade Formation about 13.4 km north to exposures along Hart Draw in Secs. 6 and 7, T. 32 S., R. 28 W., and made the exposures in the Borchers Badlands the type locality of the newly named Crooked Creek Formation. In 1958 Hibbard changed the name of the Meade Formation to "Ballard Formation", and designated a set of exposures, mainly in NW1/4 Sec. 18, T. 32 S., R. 28 W., as the type locality of the Ballard Formation.

As originally defined, the Crooked Creek Formation included a lower sand and gravel unit called the Stump Arroyo Member, and an upper, fine-grained unit which was later named the Atwater Member (Hibbard, 1958). The concept of a bipartite Crooked Creek Formation was utilized by Hibbard in his later publications and was used, with slight modification, by

the USGS during geologic mapping of the Irish Flats NE 7 1/2-minute quadrangle after Hibbard's death (Izett and Honey, 1995). In this geologic map the name "Stump Arroyo" was retained for the lower, sand and gravel member of the Crooked Creek Formation, but the overlying, finer-grained part of the Crooked Creek was informally called the "upper unnamed member"; the designation "Atwater Member" was not used because Hibbard's (1958) type section of the Atwater was incomplete, having included only the lowest post-Stump Arroyo rocks. However, reference sections could be measured in the surrounding area to supplement Hibbard's type section and to document more fully the vertical succession of lithologies in the Atwater Member; in this paper we utilize "Atwater Member" instead of "upper unnamed member", considering Hibbard's name still valid, although its referent is not completely characterized.

Some workers have suggested a more complex stratigraphy in the area of the Borchers Badlands than reported by Hibbard in his various publications, or shown on the geologic map of the Irish Flats NE quadrangle. Kovach (1979) and Zakrzewski (1988) have reported the occurrence of nine meters of Rexroad Formation, probably representing the lower part of the formation, just west of the Irish Flats NE quadrangle, in rocks previously thought to be part of the Ogallala (or Laverne) Formation. These Rexroad rocks are said to be unfossiliferous in the Borchers Badlands. Our field studies confirm the presence of these Rexroad sediments.

Overlying the Rexroad in the badlands is a sand and gravel unit which has been correlated with the Ballard Formation (Bayne, 1976; Kovach, 1979; Zakrzewski, 1988), the type section of which is 11.75 km to the north on Hart Draw. This sand and gravel unit originally formed the basis for the recognition of the Stump Arroyo Member of the Crooked Creek Formation. A published stratigraphic section of these rocks (Bayne, 1976), measured by Hibbard in 1972, is the same section as that measured by Hibbard (1949a, p. 71) in the type section of the Crooked Creek Formation and the Stump Arroyo Member, differing from the 1949 measured section only in nomenclatural changes and in some changes in thickness and lithologic descriptions. Apparently, by 1972 Hibbard had concluded that the type Stump Arroyo should be reassigned to the Ballard Formation (Kovach, 1979). The reasons for discontinuing use of "Stump Arroyo Member" and reassigning these same rocks to the Ballard Formation have not been discussed in detail. At the type locality of the Ballard Formation are two sand and gravel units, a lower and an upper sand and gravel unit, each of which is overlain by buff-colored silts (Hibbard, 1958). The lower sand and gravel unit

at the type and nearby sections is partly cemented, and was termed the Angell Member of the Ballard Formation, while the overlying silts constituted the Missler Member of the Ballard Formation. The upper, less consolidated sand and gravel unit was correlated with the unconsolidated gravels at the type section of the Stump Arroyo Member of the Crooked Creek Formation (Hibbard, 1949a), and the overlying silts were correlated with the Atwater Member of the Crooked Creek Formation. The basis for recorrelating the type Stump Arroyo Member rocks in the Borchers Badlands with the lower sands, gravels, and overlying silts (Angell and Missler Members) in the type area of the Ballard Formation, and not with the overlying gravels and silts as has been traditionally done, is not clear to us. Furthermore, Bayne (1976, p. 33) reprinted the measured section at the type locality of the Ballard Formation, and dropped usage of the terms Stump Arroyo, Atwater, and Crooked Creek; instead, he placed the gravels, sands, and silts which overlie the Ballard Formation into a so-called "unnamed formation".

It is not known if the type Stump Arroyo Member and the Ballard Formation are the same age. In its type area the Ballard Formation is normally magnetized and is considered to be deposited during the Gauss Chron (Lindsay et al., 1975). Rocks in the Borchers Badlands that underlie the silts immediately beneath the Huckleberry Ridge ash are shown by Lindsay et al. (1975, fig. 6) to also be normally magnetized, based on two samples. Although the Huckleberry Ridge ash was deposited in the Matuyama Reversed Chron, the normal polarity zone below the Huckleberry Ridge ash in the Borchers Badlands does not necessarily represent the Gauss Normal Chron; it is equally probable that the normal polarity represents one of the Reunion Subchrons in the Matuyama Reversed Chron. If so, this would imply a much shorter time interval between cessation of deposition of the normally magnetized sediments in the Borchers Badlands and beginning of deposition of the reversely magnetized sediments; while the top of the Gauss Normal Chron is dated at 2.58 Ma, the top of the uppermost Reunion Subchron is dated at 2.14 Ma (Berggren et al., 1995a), very close in time to the Huckleberry Ridge Tuff, dated at 2.10 ± 0.02 Ma (Obradovich and Izett, 1992; Honey et al., 1998).

On the geologic map of the Irish Flats NE quadrangle (Izett and Honey, 1995), the unnamed upper member (= Atwater Member) of the Crooked Creek Formation included rocks from the top of the Stump Arroyo Member upwards to include the Huckleberry Ridge, Cerro Toledo B, and Lava Creek B ash beds. Other workers have subdivided this succession, keeping the Huckleberry Ridge ash in the

Crooked Creek Formation, but placing the Cerro Toledo B ash (and presumably also the Lava Creek B ash) in a higher unit, which is either left unnamed (Bayne, 1976), or referred to the undifferentiated Sanborn Group (Kovach, 1979; Zakrzewski, 1988). The Crooked Creek Formation and undifferentiated Sanborn Group are apparently distinguished mainly by a change in color.

To date, very few new localities have been found that are certainly located in the Ballard Formation, partly because we have been fortunate to discover a number of new localities in Rexroad sediments and have spent much of our time working out stratigraphic relationships among these. The most promising new locality in the Ballard appears to be White Hill, but so far it has yielded relatively few fossils. As noted above, sampling of sediments in the proximity of Hibbard's original Deer Park locality has resulted in a diverse late Blancan assemblage (Appendix 2).

Our work in the Borchers Badlands has resulted in the discovery of a number of new fossil localities in the Atwater Member of the Crooked Creek Formation, spanning a stratigraphic interval from below the Huckleberry Ridge ash to just below the Cerro Toledo B ash. The relative stratigraphic positions of these localities are shown in Figure 2. Section A (Borchers area) is a composite section measured immediately north and south of Kansas State Highway 23, which forms the south boundary of section 16 and the north boundary of section 21, T. 33 S., R. 28 W. Composite section B (Aries) was measured about 404 m (0.25 miles) north of Highway 23. The Huckleberry ash bed thins and pinches out into greenish-gray sandstone and white clayey sandstone before reaching the Aries section. Between the Stump Arroyo Member gravels and the Huckleberry Ridge ash in section A, there is 2.4 m (7.9 ft) of yellowish-gray clayey sandstone which grades upward into 0.9 m (3.1 ft) of light greenish-gray silty sandstone. These units below the Huckleberry Ridge ash were traced northward to the Aries section where the stratigraphically lowest site, Margaret 1, was found to occur in the yellowish-gray sandstone. The occurrence in section A of the Huckleberry Ridge ash and a greater thickness of sediments suggests the presence of a paleotopographic low in which the Huckleberry Ridge ash was deposited and in which the Borchers local fauna accumulated. At the same time, the area around section B was probably higher topographically and the Huckleberry Ridge ash bed was not preserved.

To our knowledge, NBA and Margaret 1 are the first reported fossil sites located between the stratigraphic level of the Huckleberry Ridge ash bed and the underlying Stump Arroyo Member gravels. These two localities are late Blancan based on the

occurrence in both of *Sigmodon minor*. The fauna from the original Aries quarry (= Aries A) is diverse, represented by both large and small mammals, and is early Irvingtonian in age (Izett and Honey, 1995), based on (1) the occurrence of common Irvingtonian taxa such as the vole *Microtus pliocaenicus*, the hare *Lepus*, and the horse *Equus* cf. *E. scotti*, and (2) the presence of "holdover", typically Blancan taxa such as *Stegomastodon* and *Equus* cf. *E. (Dolichohippus)*. The Short Haul locality, stratigraphically intermediate between Aries A and Margaret 1, is also considered Irvingtonian, as it has produced remains of *Microtus pliocaenicus* and *Sigmodon* cf. *S. curtisi*. Overlying the Aries quarry are the Rick Forester and Aries B sites, also Irvingtonian in age; the fossils from Rick Forester, Aries NE and Aries B (from just below the Cerro Toledo B ash bed) are the first fossils in southwest Kansas found in the interval between the Aries A and Cudahy faunas.

Recently, Cassiliano (1999) published a summary of the mammalian biostratigraphy of the Fish Creek-Vallecito section of the Anza Borrego Desert in southern California. He commented on the Blancan-Irvingtonian boundary and lamented the fact that there were so few sections anywhere in the country that were amenable to defining these North American Land Mammal Ages (NALMAs). He specifically rejected the Meade County area as a potential contributing region (Cassiliano, 1999; p. 183), apparently unaware of our current fieldwork. As noted above, counting the Borchers locality, we now have a series of eight superposed fossiliferous sites from the Borchers Badlands that span the Blancan-Irvingtonian boundary (from just below the Huckleberry Ridge ash to just below the Cerro Toledo B ash; see Figs. 1, 2). Large as well as small mammals have been recovered from Borchers and Aries A; the remaining sites have produced only microvertebrates. Throughout this treatment we note various taxa that may be pivotal in defining this boundary, at least on a regional basis, but a detailed analysis must await further collecting and study.

Kingsdown and Vanhem Formations

The Kingsdown and Vanhem Formations were named for exposures in Clark County, Kansas. The name "Kingsdown marls" was proposed by Cragin (1896) for exposures occurring in ravines between Kingsdown railway station and the upper part of Bluff Creek in Clark County. Cragin did not specify an exact type locality for his "Kingsdown marls", but he described them, along with subjacent gravels, sands and volcanic ash referred to the "Meade gravels" and

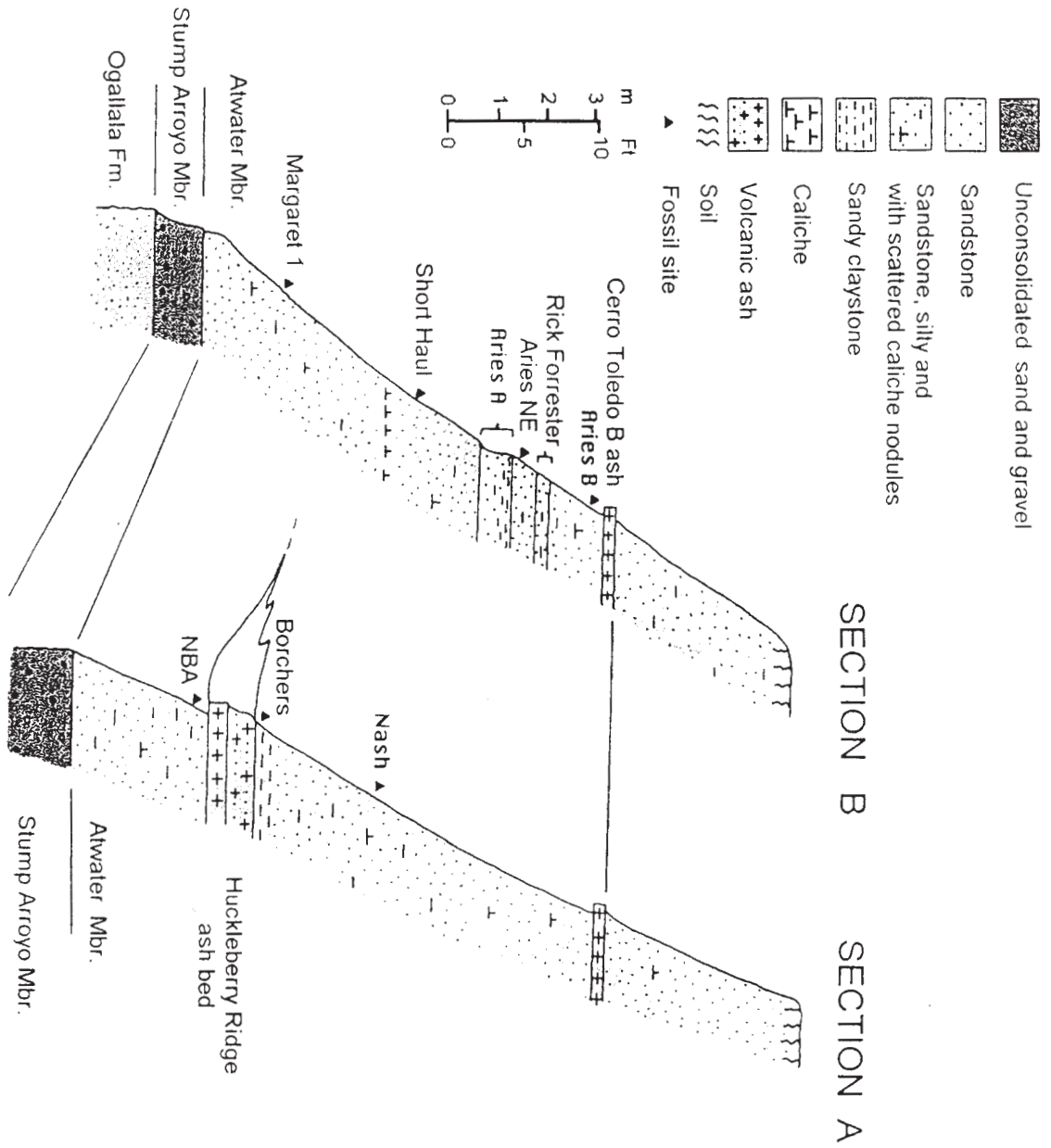


FIGURE 2. Stratigraphy of the Borchers Badlands area, showing the positions of collecting localities spanning the Pliocene-Pleistocene boundary. Section A (Borchers area) is a composite section measured immediately north and south of Kansas State Highway 23. Composite section B (Aries area) was measured approximately 404 m (0.25 miles) north of Highway 23.

"Pearlette ash", as occurring on Bluff Creek near to the location of the old Vanhem post office, in N1/2 sec. 13, T. 30 S., R. 23 W. (Hibbard, 1955, p. 184). According to Hibbard (1955), Cragin considered this area along Bluff Creek as the type area for the Kingsdown marls. Indeed, Smith (1940, p. 112) stated that the best exposures of Kingsdown Formation were found along Bluff Creek, and described a "typical section" of the Kingsdown Formation from the same area in section 13. Cragin (1896, p. 54), also stated that the Meade gravels, Pearlette ash, and Kingsdown marls were "unconformably overlaid with local beds of marl, sand, diatomaceous earth, etc., of supposed Quaternary age" although he did not say if this occurred along Bluff Creek near the Vanhem post office. In his examination of the exposures along Bluff Creek, Hibbard (1944a; 1949) concluded that Cragin's Kingsdown marls and subjacent units were indeed disconformably overlain by this younger unit, which, according to Hibbard, Smith (1940) had mistaken as Kingsdown Formation in his measured section in section 13. Hibbard (1944a) initially called this younger unit the Upper Kingsdown Silt (referring to Cragin's Kingsdown marls as the Lower Kingsdown Silt) and later (Hibbard, 1949a) renamed it the Vanhem Formation, with the type section of the Vanhem being Smith's (1940) measured section in section 13, T. 30 S., R. 23 W. Even though the Kingsdown Formation and overlying Vanhem Formation are exposed in section 13, Hibbard (1949a) reassigned the type section of the Kingsdown Formation to an area of better exposures in sections 8 and 17, T. 30 S., R. 23 W., where, according to him, the Vanhem Formation (=Upper Kingsdown Silt) overlies the Kingsdown Formation (=Lower Kingsdown Silt).

The names Kingsdown and Vanhem have, over the years, been extended away from their type areas in Clark County to include rocks of Pleistocene age in Meade County. The early nomenclatural history of the Pleistocene rocks in Meade County is complex and fraught with controversy, and is summarized by Hibbard (1955). However, after formalization of the names Kingsdown and Vanhem (Hibbard, 1949a), and the inclusion of these formations in the Sanborn Group (Hibbard, 1958), workers in this area have generally applied this terminology (Kingsdown and Vanhem Formations or undifferentiated Sanborn Group) to all post-Crooked Creek Formation rocks of Pleistocene age in Meade and adjacent counties in southwest Kansas (Zakrzewski, 1975; 1988; Bayne, 1976; Davis, 1975, 1987). One exception to this generalization is provided by Schultz (1969); while using the name "Kingsdown" for Illinoian and Sangamon sediments in the Butler Springs area, he referred to the superjacent sediments of Wisconsinan age as "Post-Kingsdown

beds". The Kingsdown/Vanhem terminology is also used in the correlation chart for the Quaternary geologic map of the Wichita 4° x 6° quadrangle (Denne et al., 1993). The Kansas Geological Survey however, does not recognize Kingsdown Formation, Vanhem Formation, and Sanborn Group as valid geological nomenclature and has abandoned usage of these terms as formal names (Baars and Maples, 1998).

The basis for recognition of the Sanborn Group (and the included Kingsdown and Vanhem Formations) in Meade County is "primarily...age and topographic position, only secondarily by...physical characteristics" (Hibbard and Taylor, 1960, p. 19). Thus these names were applied to sediments, considered to be of Illinoian through Wisconsinan age (Rancholabrean), which were deposited as alluvial fill in valleys cut in the Crooked Creek and older formations, or as fill in isolated collapse basins (Hibbard and Taylor, 1960). Other rocks that have been referred to the Kingsdown Formation include terrace deposits (Hibbard, 1955) and gravels and overlying fine-grained sediments, considered to be deposited by the ancestral Cimarron River (Schultz, 1969). The name Vanhem has commonly been applied to young (surficial) deposits on the upland surface in Meade County (Hibbard and Taylor, 1960), and to late Pleistocene (Wisconsinan) sinkhole deposits (Davis, 1975; 1987). Some of these deposits, which were referred to the Kingsdown and Vanhem Formations in Meade County, do not resemble these formations in their type areas in Clark County, where they are composed of gravels and overlying sands and silts of presumed alluvial valley-fill origin (Hibbard and Taylor, 1960). Davis (1975) commented specifically on the lack of lithologic resemblance between the type Vanhem Formation and some sinkhole deposits referred to the Vanhem Formation in Meade County.

Numerous faunas attributed to the Kingsdown and Vanhem Formations are known from Meade County, and have been studied by Hibbard and his students. Faunas of Illinoian and Sangamon age in Meade County are usually placed in the Kingsdown Formation, while Wisconsinan faunas are placed in the Vanhem Formation (Hibbard and Taylor, 1960). However, very little has been published about the faunas in the type areas of these formations in Clark County, and what is published does not allow for precise determination of the ages of the two formations. For example, Hibbard (1944a) reported the sloth *Paramylodon* ("*Mylodon*") *harlani*, an indeterminate antilocaprid, and the horse *Equus* from the Kingsdown Formation ("Lower Kingsdown Silt") in Clark County; this faunal association could be either Irvingtonian or Rancholabrean in age. From the Vanhem Formation, Hibbard (1944a) reported the prairie dog *Cynomys*

ludovicianus, a peccary (probably *Platygonus*), the camel *Camelops kansanus*, and a bison, while Davis (1975) reported the occurrence of *Mammuthus* at the type section. The bison would appear to restrict the Vanhem to the Rancholabrean; however, whether the Vanhem is Illinoian, Sangamon, or Wisconsinan in age is not apparent from this list. In his study of the Jones local fauna from referred Vanhem sediments in Meade County, Davis (1975) pointed out that the fauna from the type Vanhem was too meager to demonstrate correlation with the Jones fauna, which is dated in part at $26,700 \pm 1500$ and $29,000 \pm 1300$ years BP. Thus while the Vanhem Formation is considered to be younger than the Kingsdown Formation based on reported superpositional relationships in Clark County, nothing really has been established in their type areas concerning the time difference between the two formations.

Because widely disparate lithologies, some of which do not resemble the two formations in their type areas, have been included in the Kingsdown and Vanhem Formations in Meade County, and because roughly 45 kilometers of largely covered interval occurs between the type exposures in Clark County and Jones Ranch, the most easterly major locality in Meade County, we do not use the Kingsdown/Vanhem terminology in our work in Meade and Seward Counties. Rather, we employ a more descriptive terminology, modified from Izett and Honey (1995), for post-Crooked Creek Formation rocks: valley-fill and alluvial deposits, basin-fill deposits, and upland deposits. This classification avoids the problem of placing diverse lithologies into formations based on the ages of the included faunas, and the assumed temporal correlation of these faunas with the sparse faunas collected in the type areas.

Two fossil localities have been discovered in recent years in upper Pleistocene rocks in Clark County, the Kingsdown Quarry and Taylor sites. They are very close to the type section of the Kingsdown Formation; Kingsdown Quarry occurs in the Kingsdown Formation and Taylor occurs at the base of the immediately overlying rocks which channel into the Kingsdown Formation, and which were considered by Hibbard (1944a) to be Vanhem Formation ("upper Kingsdown silt"). Fossil rodent teeth are present at both localities; further collecting and study should help refine the ages of these two units near their type areas. The Kingsdown quarry is dominated by the muskrat *Ondatra*, while a more diverse assemblage is present at Taylor (Appendix 2).

PALEONTOLOGIC SUMMARY

Specimens collected by the late C. W. Hibbard and his students are housed primarily at the University of Kansas, University of Michigan, and Fort Hays State University. Through the many years he was active in southwestern Kansas, Hibbard and others modified the taxonomy of Meade Basin mammals many times, and it is not our purpose here to extensively review this large body of work, some of which was considered by Zakrzewski (1975, 1988) and Martin and Fairbanks (1999). Since Hibbard's death, little organized paleontologic reconnaissance has occurred in southwestern Kansas, and only modest attempts have been made either to revise the late Cenozoic mammals of Kansas in existing collections or to try and fill gaps in our knowledge of various lineages and clades recovered from the state. Some papers that deal with Kansas mammals include Carleton and Eshelman (1979) on grasshopper mice, Martin (1975, 1979) on arvicolines and cotton rats, Goodwin (1993, 1995a, b; Goodwin and Hayes, 1994) on ground squirrels and prairie dogs and Zakrzewski (1993) on wood rats. Repenning (1987) also provided his perspectives on some of the Kansas arvicolines, as part of a larger presentation on continental biochronology. A few of the larger Kansas mammals have also been considered in various treatments (e.g., *Canis* - Nowak, 1979; horses - Winans, 1989; procyonids - Baskin, 1982, 1998a; mustelids - Baskin, 1998b; camelids - Honey et al., 1998; Proboscidea - Saunders, 1996).

As indicated in the Introduction, in 1997 the authors began a long-term field project designed to examine the evolution of rodent community structure in southwestern Kansas. Many new fossiliferous localities were subsequently discovered, some representing new temporal horizons. In a preliminary analysis of rodent community dynamics, Martin and Fairbanks (1999) presented a database of terrestrial rodent groups from some of the Kansas localities based on previously published information (geomyids and muskrats were excluded). Faunas from a number of Hibbard's localities were excluded from that database because of low species diversity or because specimens from the localities could not be located in existing collections. Although they collapsed known or suspected phyletic series in their preliminary community analyses, Martin and Fairbanks (1999) attempted no formal systematic revisions and their database includes the most recent taxonomic assumptions of Hibbard and other workers. In the present treatment we provide a listing of most recognized mammal species reported from southwestern Kansas (Appendix 1 and 2), and also comment, for select clades and lineages, on the current state of taxonomy of a given group and its potential for

both biostratigraphic and evolutionary information. A few species (e.g., *Pliophenacomys primaevus*) are not on the list because either 1) the faunas of which they are a part are limited in species numbers, or 2) the stratigraphic position of the locality is highly tentative, or 3) much of the material has not been studied by the authors. A few new localities for which we have some preliminary identifications are also included in the tables, but it must be understood that most of the fossiliferous concentrate from these localities has yet to be processed and the species identifications are tentative. Alroy (1999) presents an Internet database that includes species lists for most of the published, classic Meade Basin localities.

SYSTEMATIC EVALUATIONS

Orders Insectivora, Chiroptera, Xenarthra, Lagomorpha

The first three groups are insufficiently represented and inadequately studied to be of much value in biostratigraphic sequencing. Blancan faunas have species such as *Sorex rexroadensis*, *S. taylori*, *S. sandersi*, *Paracryptotis rex*, and *Cryptotis adamsi*, while the Irvingtonian Cudahy fauna has the modern *Sorex cinereus*, associated with the extinct *S. scottensis*, *S. cudahyensis*, *S. megapalustris*, *S. lacustris* and *Microsorex pratensis*. *Sorex scottensis* has also been reported from the younger Butler Spring local fauna (l.f.). The problem is that the extinct taxa have not been evaluated for possible phyletic ties, either with each other or with modern species, and without a modern phylogenetic scenario and an adequate understanding of character variation, it is not possible at this time to securely associate any of these species with particular intervals.

An extinct mole, *Scalopus (Hesperoscalops) sewardensis*, is found in the Saw Rock Canyon l.f. (Hibbard, 1964), and it is likely ancestral, by phyletic evolution, through *S. rexroadi* (Hibbard and Riggs, 1949) to the modern *Scalopus aquaticus* (Hibbard, 1953; Hutchison, 1968). We have recovered additional remains of *Scalopus (Hesperoscalops)* from a number of Blancan localities.

Three records of *Lasiurus*, representing three species (two extinct), are the only bats so far reported from the Meade Basin. From preliminary lab sorting, we now have bats from other localities ranging in age from early Blancan to latest Pleistocene.

Remains of *Megalonyx leptostomus* have been tentatively identified from the Keefe Canyon and Rexroad 3 localities. *Megalonyx* of indeterminate species have been reported from the Cudahy and Adams sites (Paulson, 1961; Schultz, 1967).

Megalonyx is apparently replaced in the Meade Basin during the early Rancholabrean by *Paramylodon harlani* (subsequent to Butler Spring time).

The most recent review of leporids from the Meade sequence was that of White (1991). Although the earliest site with rodents, Saw Rock Canyon, has leporid material, it has not yet been determined to even the generic level. *Hypolagus ringoldensis* is recorded only from the Fox Canyon l.f., and later Blancan faunas may have *H. regalis*, *H. voorhiesi*, *Notolagus lepusculus*, *Pratilepus kansasensis*, or *Nekrolagus progressus*. Rabbits and hares from the newly discovered Blancan and Irvingtonian localities have yet to be studied in detail.

The earliest record of *Sylvilagus* from the literature is in the late Irvingtonian Cudahy l.f., as *S. floridanus*, whereas *Lepus* cf. *L. californicus* is reported from the late Blancan at Borchers, although White (1991) also notes the resemblance of some p3s from Borchers to those of modern *L. townsendii*. There are additional records of *Lepus* from the Rancholabrean of Kansas, not identified to species.

Order Carnivora

Family Mustelidae

At least sixteen species of mustelids, including weasels, ferret, ermine, mink, badger, otter, and skunks are recognized as fossils in southwestern Kansas. In addition to the species of *Mustela* listed, another species, *M. meltoni*, is known from the Wendell Fox Pasture locality in the Rexroad Formation. Once again, the relationship of most of the extinct species to the modern ones has not been evaluated (e.g. *Mustela rexroadensis*, *M. meltoni*). *Buisnictis* is known from the latest Hemphillian and early Blancan in southwest Kansas (Baskin, 1998b), although it is found in later Blancan sites elsewhere. *Trigonictis* and *Satherium* are also known from sites ranging in age from latest Hemphillian through the late Blancan (Baskin, 1998b), although these mustelids have so far been found in only a few early Blancan sites in Meade County. *Brachyopsigale* is known from the early Blancan and questionably from the latest Hemphillian (Baskin, 1998b). The earliest specimens assigned to *Spilogale* are found in early Blancan faunas such as Rexroad 3, and have been suggested to be ancestral to later species (Kurtén and Anderson, 1980); the generic assignment of *rexroadensis* to *Spilogale* has been questioned however, based on the morphology of referred upper molars, and Dalquest (1978) suggested that *rexroadensis* may belong in a new genus. The larger striped skunk, *Mephitis mephitis*, has not yet been found in pre-Rancholabrean sites in southwestern Kansas, although it is known from the late Blancan and

Irvingtonian elsewhere. The generic reference of *Mephitis? rexroadensis* has always been questioned; *M.? rexroadensis* is known only from upper teeth, and it has been noted that they are large enough to belong to *Brachyopsigale dubius*, which is only known from lower teeth (Dalquest, 1978; Baskin, 1998b).

Families *Canidae*, *Procyonidae*, *Ursidae*, *Felidae*, *Hyaenidae*

Borophagines are found in the latest Hemphillian Saw Rock Canyon local fauna and in the early Blancan Fox Canyon, Keefe Canyon, and Rexroad 3 local faunas. Hibbard (1944b) named *Osteoborus progressus* from Saw Rock Canyon; Kurtén and Anderson (1980) listed *O. progressus* as a junior synonym of *Borophagus direptor*. According to Kurtén and Anderson (1980), *B. direptor* survived until Fox Canyon time, but was replaced in the Keefe Canyon and Rexroad 3 faunas by *B. diversidens*. Munthe (1998) shows a different taxonomy: she lists *O. hilli* from Saw Rock Canyon (*O. progressus* being a junior synonym), and lists *B. diversidens* only from Fox Canyon, Keefe Canyon, and Rexroad 3. *Canis lepophagus*, a likely ancestor to *C. latrans* (Nowak, 1979), was present from Keefe Canyon through Borchers time (Nowak reports *C. latrans* but not *C. leptophagus* from Borchers), and it will be very useful to compare these species and identify the tempo of character change in this lineage. *Canis edwardii*, considered a junior synonym of *C. priscولاتrans* by Kurtén (1974), was reported from Cudahy faunal equivalents at the Big Springs Ranch in Meade County and the Arkalon gravel pit in Seward County (Kurtén, 1974; Nowak, 1979); in the U.S. it is found in Irvingtonian faunas, but it has also been reported from the Blancan Minaca Mesa in Mexico. *Canis dirus* is a good Rancholabrean index species. *Urocyon progressus*, the probable ancestor to the modern gray fox, is recorded from Rexroad Loc. 3, and *U. atwaterensis* from the Borchers fauna has been tentatively referred to *U. cinereoargenteus* (Kurtén and Anderson, 1980); additional records of the gray fox genus are too sparse for this lineage to be of much interpretative value. The swift fox, *Vulpes velox*, enters the Meade Basin during the Rancholabrean.

A lower jaw, compared to *Paranasua*, is known from Jack Swayze Quarry (early Hemphillian) in Clark County (Baskin, 1982). An early raccoon, *Procyon* sp., is questionably known from the Fox Canyon locality (Baskin, 1998a): this procyonid was originally called *Bassariscus rexroadensis* by Hibbard (1950), and was apparently referred to *Procyon rexroadensis* by Anderson (1984). *Procyon rexroadensis* and *Bassariscus casei* are recorded from Rexroad locality 3

and the Wendell Fox Pasture locality; both genera are then absent from the fossil record of southwestern Kansas, though the raccoon *P. lotor* is commonly encountered there today. The absence of raccoon fossils from most localities suggests that this may be more than a taphonomic artifact, but we will reserve judgement until recently collected fossils have been sorted and evaluated.

Ursids are rare in the Meade Basin; the only record is of *Arctodus simus*, from the presumably Wisconsinan Jinglebob locality. Richards et al. (1996) reported *A. simus* and *A. cf. A. pristinus* from two localities at Arkalon in Seward County; the latter identification, if correct, would represent a range extension for *A. pristinus* in the U.S. into the western Great Plains, previous records (excluding that from the Cedazo local fauna in Mexico (Dalquest and Mooser, 1980)) being from the eastern U.S. Felids are better represented, with *Homotherium*, *Megantereon hesperus*, *Lynx rexroadensis* and possibly *Puma lacustris* at Rexroad 3, and *Panthera atrox*, *Panthera onca*, *Puma concolor*, and *Smilodon* sp. at the Rancholabrean Cragin Quarry site (Bjork, 1973; Kurtén and Anderson, 1980; Berta and Galiano, 1983; Izett and Honey, 1995; L. Martin, 1998). There has been some uncertainty concerning whether or not *P. lacustris* is present at Rexroad (Werdelin, 1985; L. Martin, 1998). *Megantereon hesperus* and *Lynx rexroadensis* are found in faunas of late Hemphillian through Blancan age, *Puma lacustris* is found in Blancan and early Irvingtonian faunas, and *Homotherium* ranges from the Blancan through the Rancholabrean in the U.S. *Panthera* arrived in North America in the early Irvingtonian (L. Martin, 1998); *P. onca* ranged from the early Irvingtonian through the Rancholabrean, while *P. atrox* is known certainly only from the Rancholabrean. *Puma concolor* is also found in Rancholabrean faunas, but *Smilodon* ranges from the Irvingtonian through the Rancholabrean. *Nimravides catacopis* has been reported from the Beckerdite l.f. (Liggett, 1997). However, Baskin (1981) considered *N. catacopis* a nomen vanum and suggested that *N. thinobates* be used for described specimens of the Nimravidae from the Great Plains. The hyaenid *Chasmaporthetes ossifragus* (Blancan to early Irvingtonian) is reported from one of the Rexroad quarries (apparently Rexroad 2) and questionably from Fox Canyon (Bjork, 1973; Berta, 1998).

Order Perissodactyla

Families *Equidae* and *Rhinocerotidae*

No equids have been reported from the Saw Rock Canyon and Fox Canyon local faunas, but *Nannippus peninsulatus*, *Equus simplicidens*, and *E. cumminsi* are

found in other Blancan faunas of the Meade Basin. Horse material is very fragmentary at the classic Borchers site, considered as latest Blancan. Blancan horses are replaced by *Equus calobatus* and *E. scotti* in the Meade Basin during the Irvingtonian. Dental remains of three kinds of horses are abundant at the early Irvingtonian Aries A Quarry (Izett and Honey, 1995): most common are fossils belonging to a caballine horse probably conspecific with the common Irvingtonian and Rancholabrean *E. scotti*, less abundant are probable remains of the stilt-legged horse *E. calobatus*, and relatively rare are teeth of a zebrine referred to as *E. cf. E. (dolichohippus)*. The Aries A zebrine represents a late, but not unique Irvingtonian occurrence of these common Blancan horses. The taxonomy of North American Pleistocene horses is currently somewhat controversial from the genus to species levels (compare Dalquest, 1988; Winans, 1989; Repenning et al., 1995). Repenning et al. (1995) raised important nomenclatural issues regarding North American zebrines, and the Aries zebrine perhaps is more logically referred to as *Equus cf. E. (Plesippus)*. *Equus calobatus*, *E. conversidens*, and *E. scotti* have been identified in the Rancholabrean of southwestern Kansas. Prothero and Manning (1987) and Prothero (1998) reported the occurrence of *Teleoceras* at Saw Rock Canyon.

Order Artiodactyla

Family Tayassuidae

The most common early Blancan peccary in the Meade Basin appears to be *Platygonus bicalcaratus*. In addition to previous records, we have unearthed a partial skull and isolated teeth from a new Blancan locality, Wiens. The Rancholabrean peccary *Platygonus compressus* has been reported from the Cragin Quarry and Jones sites.

Family Camelidae

Procamelus and *Megatylopus* have been reported from the early Hemphillian Beckerdite locality in Clark County (Liggett, 1997). Only a single locality, Keefe Canyon, has produced an abundance of well-preserved camel material, described by Hibbard and Riggs (1949). This Blancan material is referable to three species: *Gigantocamelus spatulus*, *Megatylopus* (?) *cochrani* and *Hemiauchenia blancoensis*. *Gigantocamelus spatulus* and *M. (?) cochrani* are known only from Blancan localities, whereas *H. blancoensis* is known both from the Blancan and Irvingtonian. *Gigantocamelus spatulus* is the most abundant camelid,

represented by the remains of at least 21 individuals, according to Hibbard and Riggs (1949). Keefe Canyon is the type locality for *Pliauchenia cochrani*. This species was reassigned to *Megatylopus* by Webb (1965); recently, it was studied by Voorhies and Corner (1986), who, noting that the species was inadequately known, questionably retained it in *Megatylopus* pending revision of that genus. The species nomenclature for *Hemiauchenia* is currently somewhat controversial, with *H. blancoensis* either considered valid (Webb, 1974; Breyer, 1977; Webb and Stehli, 1995) or a junior synonym of *H. macrocephala* (Dalquest, 1992). Although not common, we have recovered additional Blancan camelid material from several quarries, including Rexroad Loc. 3 and localities in Keefe Canyon. An early record of *Camelops* from the Blancan Deer Park A l.f. represents the first appearance of this genus in the Meade area, and it was subsequently reported from a number of localities. *Camelops* sp. was also reported by Hibbard (1944) from the Vanhem Formation ("upper Kingsdown silt") in Clark County.

Families Cervidae, Antilocapridae and Bovidae

These families are only marginally useful for biostratigraphic purposes. A cervid, *Odocoileus brachyodontus*, is known from the early Blancan Fox Canyon (type) and Rexroad 2a and 3 localities, but its relationship to either mule or white-tail deer remains unexplored. This species is known mainly from teeth (the holotype is M1-2), and a referred single antler tip from Rexroad 2a; because of similarities between the dentitions of *Odocoileus* and *Bretzia*, Gustafson (1985) regarded as unproven, reference of this early Blancan cervid to *Odocoileus* rather than *Bretzia*. The only other cervid record is *Odocoileus virginianus* and *O. sp.* from Cragin Quarry.

We are aware of only four records of antilocaprids from Meade County; of these records, only *Capromeryx furcifer* from Cragin Quarry has been identified below the family level. An indeterminate antilocaprid was also reported from the type area of the Kingsdown Formation in Clark County (Hibbard, 1944a), and a questionable antilocaprid is present in the Hemphillian Beckerdite l. f. (Liggett, 1997).

The first appearance of bovids in the Meade Basin appears to be *Bison* cf. *B. latifrons* from the Rancholabrean Mt. Scott l.f. Remains of the same species are identified from the presumed Wisconsinan Jinglebob site. *Bison* sp. was reported from the Vanhem Formation in Clark County (Hibbard, 1944a).

Order Proboscidea

Families Gomphotheriidae and Mammutiidae

A variety of mammutids and gomphotheriids are found in Blancan localities in southwestern Kansas, including *Mammut*, *Stegomastodon*, and *Rhynchotherium*; in addition, indeterminate gomphotheriids have been reported from the late Blancan Seger gravel pit in Meade County, and from the early Hemphillian Beckerdite locality in Clark County (Liggett, 1997; Lambert and Shoshani, 1998). *Mammut adamsi* at Keefe Canyon is possibly an early occurrence of *M. americanum* (Saunders, 1996). Although *Mammuthus* may have arrived in North America as early as the late Blancan (Lambert et al., 1995; Lambert and Shoshani, 1998), the oldest *Mammuthus* in the Meade Basin is from the Cudahy fauna in the later Irvingtonian. The absence of Irvingtonian and Rancholabrean mastodonts in the Meade Basin may be of ecological significance; in northwest Texas just southwest of Meade County, mastodonts are reported to be rare in the Pleistocene (Dalquest and Schultz, 1992), a fact attributed to the presence of widespread prairie and grassland, considered unsuitable habitat for the mastodon.

Order Rodentia

By far, the most commonly encountered mammals throughout the Meade Basin localities are the rodents, and this group has been studied in enough detail to determine that certain lineages have considerable biostratigraphic utility.

Family Sciuridae

A series of ground squirrels is known from southwestern Kansas, but only the presumed prairie dogs and ground squirrels from the Borchers l.f. have been studied recently (Goodwin and Hayes, 1994; Goodwin, 1993, 1995a). Relationships among the Blancan species *Spermophilus howelli*, *S. rexroadensis* and *S. meadensis* remain obscure.

According to Goodwin (1995b), prairie dogs first appear in the fossil record during the late Blancan. The earliest record is of ?*Cynomys vetus* Hibbard, from an unnamed locality in Jewell County, Kansas. *Cynomys hibbaridi* Eshelman (1975) is recorded from the late Blancan White Rock l.f., Republic County, from extreme north-central Kansas. The earliest prairie dog record from the Meade Basin is of *C. hibbaridi* from the Nash locality (Eshelman and Hibbard, 1981), of Irvingtonian age, between the Huckleberry Ridge ash (2.10 Ma) and the higher Cerro Toledo ash (1.23-1.47 Ma). Material of *Cynomys* from the late Blancan Deer

Park A locality appears to be intrusive (Goodwin, 1995b).

An extinct species *Cynomys* (*Cynomys*) *spenceri*, was named by Goodwin (1995a) from the early Rancholabrean Butler Spring l.f. This species was subsequently, although briefly, replaced in the Meade Basin by an unspecified member of the white-tailed group (*Leucocrossuromys*) in the stratigraphically higher Cragin Quarry l.f. *C. ludovicianus* was reported by Goodwin (1995a) from the late Pleistocene Keiger Creek l.f. of Clark County, slightly east of the Meade Basin. We have no radiocarbon dates yet for this site, but we tentatively correlate it with either the Jones or Robert local faunas of late Wisconsinan time.

Marmots are not common in the late Cenozoic of Kansas, but they have been reported from the Saw Rock Canyon, Fox Canyon and Keefe Canyon local faunas (Repenning, 1962; Hibbard, 1964). The Saw Rock Canyon record, originally described as *Marmota sawrockensis* (Hibbard, 1964) was transferred to *Paenemarmota* by Voorhies (1988). *Paenemarmota sawrockensis* was apparently directly ancestral to the slightly larger *P. barbouri* (Hibbard and Schultz, 1948). At this point, the genus is restricted to the latest Hemphillian and early Blancan in the Meade Basin.

Family Castoridae

Dipoides wilsoni is known from the Saw Rock Canyon l.f. (Hibbard, 1949b), and *D. rexroadensis* has been reported from Keefe Canyon (Hibbard's Rexroad Loc. 22), Rexroad Localities 2a and 3, and the Wendell Fox Pasture locality (Hibbard's UM-K3-53) (Woodburne, 1961). Saw Rock is of Hemphillian age; the others are Blancan. Another beaver, *Procastoroides sweeti*, is limited to Blancan time, and was sympatric with *D. rexroadensis* at most of the same localities from which the latter species was reported. *Procastoroides sweeti* most likely evolved into *Castoroides ohioensis* (Martin, 1969), of which there is a likely record from the Rancholabrean Adams site. Although the beaver *Castor canadensis* is a member of the modern fauna, it has been reported only from the late Pleistocene Cragin Quarry l. f. (Schultz, 1969).

Family Geomyidae

Pocket gophers are common in the Pliocene and Pleistocene quarries of southwestern Kansas, and as Wilkins (1984) showed for Florida fossil gophers, evolutionary sequences can be established based on certain dental criteria. One of us (RAM) recently examined the gopher material in the Museum of Paleontology collections at the University of Michigan,

and it is clear that there has been considerable turnover and some microevolution within this ubiquitous fossorial family. The following summary represents a distillation of these observations, and is therefore only a working hypothesis of relationships.

The terminal Hemphillian Saw Rock Canyon l.f. is the only southwestern Kansas locality with *Pliogeomys buisi*, a gopher with rooted cheek teeth. This genus and species was first described from the Buis Ranch l.f. (Hibbard, 1954), just southeast of Saw Rock Canyon in Oklahoma. An array of both large and small pocket gophers is found in Blancan and Irvingtonian deposits. *Geomys (Nerterogeomys) smithi* and the diminutive *G. adamsi* were recovered from Fox Canyon (Hibbard, 1967). Hibbard (1967) referred *G. adamsi* to the subgenus *Geomys*, but *G. adamsi* has unisulcate or faintly bisulcate upper incisors, and may be related to *Pappogeomys*. The larger *G. (Geomys) jacobii* is found at Rexroad Loc. 3 with a small member of the subgenus *Nerterogeomys*, *G. minor*. *Geomys quinni* is recorded with *G. minor* in the late Blancan Deer Park A and B local faunas. A larger, and probably new, member of the subgenus *Nerterogeomys*, about the size of modern *G. bursarius*, replaces the Deer Park geomyids in the late Blancan Sanders l.f. However, a population of giant gophers probably referable to *G. quinni* appears again with *Geomys tobinensis* in the late Blancan Borchers l.f. *Geomys tobinensis* seems to be the typical Irvingtonian gopher, as it is also tentatively reported from Rick Forester, Nash and Cudahy. The modern *Geomys bursarius* is first noted in the early Rancholabrean Butler Spring l.f. (Schultz, 1967) and *Thomomys*, not currently extant in Meade County, has been recovered from Cudahy and two late Rancholabrean localities, Robert and Jones.

Family Heteromyidae

Early washing techniques in the Meade area precluded an adequate investigation of the proportion of heteromyids represented in the various faunas. With 0.50 mm screens we have found a number of sites, in particular Blancan ones, with disproportionately high numbers of *Perognathus* molars. The relationship of the Hemphillian and Blancan *Perognathus mclaughlini*, *P. gidleyi*, *P. rexroadensis* and *P. pearlettensis* to the modern forms *P. flavescens*, *P. flavus* and *Chaetodipus hispidus* remains to be determined.

Prodipodomys, a genus with rooted cheek teeth, is common in Blancan localities. The named forms present in the Meade Basin likely represent a phyletic series of a single species that becomes locally extinct following Borchers time. We are hopeful that changes in the dentition of this lineage will provide indicator taxa. The earliest record of *Dipodomys* is also from the

Borchers l.f. The relationship of this species, *D. hibbardi*, to the common species in younger faunas, *D. ordii*, is unknown.

Family Cricetidae

Patterns of both evolution and temporal distribution in the cricetids provide useful biostratigraphic information. For instance, the genera *Calomys (Bensonmys)*, *Symmetrodontomys* and *Baiomys* are restricted in the Meade Basin to late Hemphillian and Blancan time (e.g., Baskin, 1978). Until recently, *Symmetrodontomys* was considered to be exclusively Blancan in temporal distribution. However, Martin (2000) showed that Hibbard's (1964) *Peromyscus sawrockensis* was instead referable to *Symmetrodontomys*, probably *S. simplicidens*. This extends the Kansas record of *Symmetrodontomys* back into the Hemphillian. Recent collecting has extended the record of *Baiomys* into the late Blancan at Deer Park B. Two lineages of grasshopper mice are represented in the Meade faunal sequence, one leading to *O. leucogaster* and the other to *O. torridus* (Carleton and Eshelman, 1979).

The taxonomic and evolutionary status of the many species of *Reithrodontomys* and *Peromyscus* from the Meade sequence is unknown; these taxa need to be reviewed. On the other hand, the relationships among the cotton rats is fairly well understood and provides useful information. In a series of papers Cantwell (1969) and Martin (1970, 1974, 1979, 1986) suggested that there were only two species of cotton rat in the Meade Basin through Pliocene and Pleistocene time, *Sigmodon minor* and *S. curtisi*. The earliest record of *Sigmodon minor* is from either Raptor 1C or Ripley B (Table 1, Appendix 2), depending on the stratigraphic relationships of these sites. The youngest published record of *S. minor* is from Borchers, and we now have remains of *S. minor* from other localities (e.g., Margaret 1) below this level in the Borchers Badlands. For reasons that will become clearer below under the discussion of the Arvicolidae, we tentatively conclude that *S. minor* is a good Blancan indicator, and that the Blancan/Irvingtonian boundary in this region may eventually be identified on the basis of the last record of *S. minor* in the former and the first record of *Microtus pliocaenicus* and perhaps *S. curtisi* in the latter. If the stratigraphy we are developing is correct, cotton rats have been variously present and absent during the early Blancan. This would not be surprising, as Kansas represents the northern limit to cotton rat distribution today, and it might be expected that their presence in the past would have been affected by regional environmental change or by the immigration of certain (perhaps arvicoline) competitors.

The woodrats, genus *Neotoma*, of southwestern Kansas were studied by Zakrzewski (1993) in a review of dental evolution in this genus. He noted that there were not enough specimens to adequately diagnose the Hemphillian *N. sawrockensis*, but *N. quadriplicata* appears to be a good Blancan indicator. *Neotoma quadriplicata* is either replaced by or evolves into *N. taylori* during Borchers time. Only modern woodrats, either *N. micropus* or *N. floridana*, have been recorded from younger deposits, though the woodrat record is essentially unknown for the Irvingtonian of this region.

Following Baskin (1978), *Bensonomys* is here considered a subgenus of the modern neotropical sigmodontine *Calomys*. Hibbard (e.g., 1956) named a number of *Calomys* (*Bensonomys*) species from the Meade Basin, and additionally referred the Fox Canyon *Calomys* to *C. arizonae*, a species named from the San Pedro valley of Arizona by Gidley (1922). Although this is certainly a possibility, we cannot find any significant differences between the Fox Canyon *Calomys* and the species from Rexroad Loc. 3 that Hibbard (1937) named *C. eliasi*. For consistency, and until a thorough review of the Meade Basin *Calomys* material is made, we prefer to synonymize the Fox Canyon *Calomys* under *C. eliasi*. *Calomys stirtoni* from the Saw Rock Canyon l.f. is distinct from *C. eliasi*, though it may be related to *Calomys* from the recently discovered XIT 1B locality. For now we accept the integrity of *C. meadensis* from the Sanders l.f., though it seems very likely that it evolved by phyletic change from the Rexroad Loc. 3 species. We have also recovered *Calomys* from the intermediate aged Deer Park B locality, which may eventually aid in this determination.

Family Arvicolidae: Archaic Taxa

The arvicolid record from the Meade Basin is exceptionally strong and helpful in biostratigraphic sequencing, although there still remains quite a bit of refinement in taxonomy to be accomplished. Currently, the only Hemphillian arvicoline in the Meade Basin is *Ogmodontomys sawrockensis*, from the Saw Rock Canyon l.f. Blancan time is characterized by a series of archaic arvicolines with rooted cheek teeth, including *Ogmodontomys*, *Nebraskomys*, *Pliophenacomys* and *Ondatra* (= *Pliopotamys*). Zakrzewski (1967) proposed a transition in characters from *O. sawrockensis* of the Saw Rock l.f. to *O. poaphagus* in various Blancan sites. He also named a new subspecies, *O. p. transitionalis*, for the sample from Fox Canyon, to separate it from *O. p. poaphagus* of later localities. This scenario may have to be modified somewhat, as a new archaic arvicoline has been recovered from a site, Fallen Angel, that lies above Saw Rock Canyon and

presumably below Fox Canyon. This taxon may be either an advanced population of *O. sawrockensis* or a new species, but whatever its relationships it is apparently not ancestral to *O. poaphagus* from later Meade Basin localities.

Pliophenacomys finneyi, known from thousands of molars and hundreds of jaws, is present at Fox Canyon, and a possibly derived species, *P. primaevus*, is known from Rexroad Loc. 2 (not Loc. 2a; these are different quarries, though located in the same pasture). These are the only records of *Pliophenacomys* in the Meade Basin, and may help characterize these earlier Blancan localities. Although there has been some confusion in the literature in this regard, *Pliophenacomys primaevus* has not been recovered from the rich Rexroad Loc. 3, which has only *Nebraskomys* and *Ogmodontomys*. Consequently, Rexroad Loc. 2, which is within 10 km of Loc. 3, is not likely the same age as Rexroad Loc. 3, and we intend to collect further at Loc. 2.

Nebraskomys rexroadensis appears initially in the Bender 1c l. f. and becomes locally extinct before Sanders time. We have now recovered it from the Deer Park B local fauna, presumably from the Ballard Formation. *Ophiomys meadensis* (= *Pliophenacomys meadensis* Hibbard, 1956, in part) has thusfar been recovered only from the Sanders l.f. in the Meade Basin, and may be a good indicator for late Blancan time and the upper part of the Ballard Formation. The Deer Park B l. f., considered to have been deposited in the lower part of the Missler Member of the Ballard Formation, has *Nebraskomys rexroadensis* and *Ogmodontomys poaphagus*, neither of which have been recovered from the Sanders locality. A morphologically advanced population of *O. poaphagus* is last seen in the Hart Draw l. f., which lies directly below Sanders (Zakrzewski, 1967; Lindsay et al., 1975). The Meade Basin record of *Pliolemmus antiquus* extends from Bender 1c, the highest fossiliferous level in the Rexroad Formation, through Deer Park A and Sanders in the Ballard Formation. It is not found in the intervening Hart Draw l.f., but this is likely due to sampling bias, as *Pliolemmus* is not common where it is found.

Semken's (1966) initial presentation of a chronocline in size of North American muskrat molars influenced a number of investigators through the years, including Zakrzewski (1969), L. Martin (1979, 1993), Viriot et al. (1993), and Martin (1993, 1996a). Originally represented by two genera and six species, this phyletic series was collapsed by Martin (1993, 1996) into a single species with five generally intermediate stages, called chronomorphs. Chronomorphs are informal populations defined on a set of characters, and consequently there can be overlap

in time of chronomorphs in lineages that display a mosaic pattern of evolution (see Martin and Barnosky, 1993 and Martin, 1996 for further discussion). The sequence in southwestern Kansas is represented by the following: *Ondatra zibethicus /meadensis* (late Blancan; Deer Park A only) - *O. z. /idahoensis* (late Blancan; Borchers only) - *O. z. /annectens* (mid Irvingtonian; Cudahy only) - *O. z. /zibethicus* (Rancholabran).

To this point neither the genus *Hibbardomys* nor advanced species of *Pliophenacomys* (e.g., *P. dixonensis* Zakrzewski 1984) have been recovered from southwestern Kansas, though they are known in Kansas just to the northeast, from the Dixon l.f. of Kingman County, and in northcentral Kansas, from the White Rock l.f. (Zakrzewski, 1984). At this point we do not know if this geographical distribution represents an ecological separation or the absence of similar aged localities in Meade County.

Family Arvicolidae: Bog Lemmings, Genera Mictomys and Synaptomys

The bog lemming record in North America was reviewed by von Koenigswald and Martin (1984), Repenning and Grady (1988) and Repenning and Fejfar (1999). For convenience, we recognize the genera *Pliotomys*, *Mictomys* and *Synaptomys*. Primitive bog lemmings with symmetrical and relatively underdeveloped dentitions referred to *Pliotomys* are known from the White Rock and Dixon local faunas, but not from the Meade Basin. Lemmings are unrecorded from the Meade Basin until the Borchers l.f., of latest Blancan time (*Mictomys landesi*). White Rock and Dixon are to the north and east of the Meade Basin, which suggests that these early bog lemmings were restricted to more northern habitats. Alternatively, perhaps localities of similar age are not represented or not yet sampled in the Meade Basin.

Mictomys landesi was referred to the subgenus *Mictomys (Metaxyomys)* by Zakrzewski (1972), related to *M. vetus* and *M. anzaensis* by virtue of its relatively underdeveloped anterior cap, which was somewhat vole-like, and moderate, rather than extreme, buccal shift of the m1 axis. For reasons that are too complex to explain here, *Mictomys landesi* was probably not ancestral to later species of *Mictomys*, but in one scenario could have been ancestral to the genus *Synaptomys*, based on a modified version of the hypothesis originally presented by Repenning and Grady (1988). If this is shown to be true, *M. landesi* would, by virtue of modern phylogenetic principles, be transferred to the genus *Synaptomys*.

Mictomys kansasensis is the common bog lemming between the Huckleberry Ridge and Cerro

Toledo B ashes (Nash, Short Haul, Rick Forester localities). As shown by von Koenigswald and Martin (1984), *M. kansasensis*, originally described from the Kentuck l.f. of McPherson Co., Kansas (Hibbard, 1952), is very specialized, with a schmelzmuster reduced to a single monolayer of radial enamel on the triangle trailing edges. *Mictomys meltoni*, described by Paulson (1961) from the Cudahy l.f. and directly underlying the Lava Creek B ash at 0.67 Ma, has thicker enamel than *M. kansasensis* and, though occurring later in time, is not likely descended from the latter species.

During the Rancholabrean we see a shift at various times from the bog lemming group that characterizes more northern latitudes (*Mictomys*) to the one found mostly in the north temperate and austroriparian eastern United States (*Synaptomys*). Mt. Scott and Jinglebob have the giant bog lemming *Synaptomys australis*, and this is followed by the return of *Mictomys* sp. in the newly discovered Taylor site (Appendix 2). McMullen (1978) reported *M. borealis* in the Duck Creek l.f. of Ellis County, Kansas which has been allocated to the "Illinoian," but the collective fauna at Duck Creek is very modern in appearance, and may date to the Wisconsinan. The modern *S. cooperi* first appears in the Robert l.f., radiocarbon dated at 11, 000 years B.P. (Schultz, 1969).

Family Arvicolidae: Derived Voles, Genus Microtus

There is a "*Microtus* event" in the Meade Basin, and it seems now like a good tentative regional marker for the beginning of the Pleistocene epoch and the Irvingtonian North American Land Mammal Age. Although we may eventually obtain enough faunas that cross the Pliocene-Pleistocene and Blancan-Irvingtonian boundaries in the Borchers Badlands to see a gradual change in faunas, at this time the localities we have discovered show somewhat distinct small mammal associations. We have no radiometric dates between the 2.10 Ma and 1.23-1.47 Ma ashes, so we cannot say for certain where the faunal break occurs. We do know, however, that sometime in that interval faunas with the diminutive cricetid *Sigmodon minor* give way to faunas with *Microtus plicocenicus*. Whether or not this is the same species as named from the type locality, Betfia 2 in Romania, cannot be determined for certain, but every comparison that has been made to date has shown almost complete consistency of characters and measurements (e.g., Martin, 1975, 1989a, 1998; Hir, 1998). The stratigraphically lowest zone with *Microtus* is the level from which the Nash l.f. was recovered (Eshelman and Hibbard, 1981; personal observation). We also have

three new localities with *M. pliocaenicus*, Short Haul, Aries and Rick Forester, that lie between the Borchers l.f. and the Cerro Toledo ash (Izett and Honey, 1995; Hurt and Martin, 1998; R. Hurt, unpublished M.S. thesis). As noted by Hurt and Martin (1998), the *Microtus* specimens from these sites are interestingly primitive in the simplicity of M3, and this may have later ramifications for understanding evolutionary trends in this taxon.

At 0.67 Ma, in the Cudahy l.f., we see the shift to a more advanced, distinct association of *Microtus* that includes *M. (Microtus) paroperarius*, *M. (Pedomys) ochrogaster* /*llanensis* and *M. meadensis*. The dentition of *Microtus paroperarius* shows some similarity to the *M. oeconomus* group of living species, but there are variants that are also similar to five triangle forms of *M. pennsylvanicus* (Bell and Repenning, 1999). Guthrie (1965) suggested that extant *M. pennsylvanicus* could be descended from *M. paroperarius*, but at this point intermediates have not been recovered. Martin (1987, 1993, 1995) developed a plausible scenario for the evolution of the prairie vole, *M. ochrogaster*, from Great Plains populations of *M. pliocaenicus*, and the Cudahy *Pedomys* is considered an intermediate in that phyletic series. The relationships of *M. meadensis* remain controversial. This species has been allied with *Pitymys* (Hibbard, 1944a; Paulson, 1961), *M. quasiater* in Mexico (Repenning, 1983), the ground voles (*Terricola*) of the Old World (Repenning and Grady, 1987; Martin, 1989a) and the subgenus *Microtus* (Martin, 1987, 1998). A detailed comparative analysis is lacking, but recent evidence indicates that confluency of triangles 4-5 (T 4-5; the "pitymyan rhombus") and closure of T5 from the anterior loop on m1 have evolved independently in a number of *Microtus* lineages, and consequently other characters will have to be found to determine relationships of this species. As Martin (1987) noted, the long and attenuated anteroconid and thin enamel suggests similarities with some European voles, such as *M. gregaloides* and *M. arvalidens*.

Finally, during the Rancholabrean, we see the prevalence of exclusively modern *Microtus* species: *M. ochrogaster*, *M. pennsylvanicus*, and possibly *M. xanthognathus*. The earliest record of *Microtus pennsylvanicus* is in the Butler Spring l.f., associated with *M. ochrogaster*.

Family Zapodidae

Zapodids have been present in the Meade Basin since Fox Canyon time (Klingener, 1963), and their absence from Saw Rock Canyon is likely an accident of sampling, as modern zapodids are surely derived from North American stocks (Martin, 1989b, 1994). Two

extinct species, *Z. rinkeri* (Fox Canyon) and *Z. burti* (Borchers) are known from Blancan localities, and *Z. sandersi* ranges from Blancan (Rexroad Loc. 3, Deer Park B, Sanders) through possibly the early Irvingtonian (Aries), but despite the identification of the Borchers *Zapus* as a unique species, these may form a phyletic series and ultimately give rise to *Z. hudsonius*, the common Rancholabrean jumping mouse.

NOTES ON PLIOCENE CHRONOLOGY

The chronology we currently accept for Pliocene Meade Basin localities differs somewhat from that previously published (e.g., Lundelius et al., 1987). The rationale for these changes, presented below, is based on preliminary investigations of the rodents, in concert with paleomagnetic and radiotope evidence from other faunal sequences. The Hemphillian/Blancan boundary is currently considered somewhat fuzzy, ranging from 4.5 - 5.0 Ma (Lundelius et al., 1987; Albright, 1999).

There are no paleomagnetic data for the Saw Rock Canyon locality of Seward County, but the fauna from this locality is considered the earliest in the Rexroad Formation, with a rhinoceros (Prothero and Manning, 1987), the primitive arvicoline *Ogmodontomys sawrockensis* and a geomyid with rooted molars, *Pliogeomys buisi*. This locality was assigned an approximate age of 4.3 Ma by Lundelius et al. (1987), but this age is likely too young. Modifications in the Magnetic Polarity Time Scale (MPTS; Berggren et al. 1995b) and our current interpretation of North American rodent evolution suggest the Saw Rock locality is closer to 5.0 Ma. A molar of *O. sawrockensis* from Saw Rock Canyon recently examined displayed only radial enamel (R. Martin, unpublished data), a very primitive condition in arvicolines, and the occlusal pattern of *O. sawrockensis* indicates it is near basal for the genus (Repenning, 1987). An *Ogmodontomys* referred to *O. poaphagus*, a more derived species than *O. sawrockensis*, has been identified from the House Mountain Locality 319 of the Verde Formation of Arizona which, according to Czaplewski (1990), was deposited during the third reversed polarity interval of the Gilbert chron. Following the Magnetic Polarity Time Scale of Berggren et al. (1995), this places Loc. 319 between about 4.6 - 4.8 Ma. This information suggests that the Saw Rock Canyon l.f. should be considerably older, a conclusion supported by additional faunal evidence from Kansas. Because a relatively underderived population of *O. poaphagus* has been recovered from the Fox Canyon l.f. of Kansas (Zakrzewski, 1967), we consider the latter fauna an approximate contemporary of Verde. Lindsay et al.

(1975) showed that sediments at Fox Canyon were magnetically reversed. However, we have no way at this time of determining which reversed interval is represented at Fox Canyon, and for now we consider this locality to have been deposited between 4.3 - 4.8 Ma.

The latest Hemphillian *Yepomera* l. f. of Chihuahua, Mexico is considered to be about 4.8 - 4.9 million years old (Lindsay and Jacobs, 1985; Albright, 1999), primarily on the basis of a rhinoceros and other large mammals (e.g., *Pliohippus*). The *Prodipodomys* from *Yepomera*, *P. idahoensis*, is morphologically more advanced than that from Saw Rock Canyon (*P. griggsorum*; Zakrzewski, 1970), and the pygmy mouse from *Yepomera*, *Baiomys kolbi*, has also been identified from the younger Fox Canyon l. f. (Hibbard, 1950). *Pliogeomys carranzai* from *Yepomera* is of a considerably more advanced evolutionary grade than *P. buisi* of Saw Rock Canyon, and is probably best referred to the genus *Geomys* (e.g., the p4 of *P. carranzai* illustrated by Lindsay and Jacobs [1985] has U-shaped reentrants and cementum in the reentrant folds. *Pliogeomys* lacks cementum in the reentrants and has V-shaped reentrants; the latter represents the plesiomorphic condition. There is also no clear evidence of lack of roots in *P. carranzai*). Therefore, if *Yepomera* is correctly sequenced chronologically, Saw Rock Canyon should be older.

Since Zakrzewski (1975) reviewed the stratigraphy of southwestern Kansas following C. W. Hibbard's death, many new Blancan localities have been discovered in the Meade Basin that fit stratigraphically between Saw Rock Canyon and Rexroad Loc. 3. Some of these are listed in Table 1. Argonaut, Fallen Angel and Red Fox appear to be older than Fox Canyon, whereas Ripley, the Raptor sequence, Vasquez, Wiens and Hornet may be younger than Fox Canyon, but older than Rexroad Loc. 3. Although the faunas from the new early Blancan localities bear some resemblance to that of Fox Canyon (Appendix 1, 2), there are enough differences that it has become clear there is a significant temporal displacement among them. We also tentatively conclude that Rexroad Loc. 3 is faunistically and chronologically distinct from many of these early faunas. The sediments at Rexroad Loc. 3 are normally magnetized (Lindsay et al. 1975), and based on the MPTS of Berggren et al. (1995b), it seems possible that Rexroad Loc. 3 was deposited during subchron C2An.3n of the Gauss chron between 3.3 - 3.5 Ma. The Bender l.f., which faunistically shows similarities to both the lower Rexroad Loc. 3 and the higher Deer Park assemblages, lies directly below the Angell Gravel, is normally magnetized (Lindsay et al. 1975) and may have been deposited about 3.2 Ma.

Deer Park, Hart Draw and Sanders apparently lie above the Angell Gravel, which forms the base of the Ballard Formation (Zakrzewski, 1975; this study). Sanders is superposed above Hart Draw on the Big Springs Ranch, about 3 km north of Deer Park. The *Ogmodontomys poaphagus* sample from Hart Draw is the most morphologically advanced in the Meade Basin (Zakrzewski, 1967; R. Martin, personal observation), and therefore both Hart Draw and Sanders must be younger than Deer Park. This is confirmed by the presence of an advanced arvicoline, *Ophiomys meadensis*, at Sanders (Hibbard and Zakrzewski, 1967). Both Hart Draw and Sanders are normally magnetized (Lindsay et al., 1975). These faunas are assigned to the C2An.1n subchron of the Gauss interval, perhaps deposited between 2.6 - 3.0 Ma.

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	Bk	SR	FC	KC	R3	DP	Sa	Bo	Ar	Cud	Ad	BS	MS	CQ	Ji	Jo	Ro	Mo	
<i>Urocyon progressus</i>					x														
<i>Urocyon cinereoargenteus</i>								x										K	
<i>Vulpes velox</i>														x		cf			
<i>Vulpes vulpes</i>																		K	
<i>Vulpes</i> sp.														x					
Procyonidae																			
<i>Procyon rexroadensis</i>					x														
<i>Procyon lotor</i>																		x	
<i>Procyon</i> sp.					?														
<i>Bassariscus casei</i>					x														
Ursidae																			
<i>Arctodus simus</i>																x			
<i>Ursus americanus</i>																		x	
<i>Ursus horribilis</i>																		x	
Felidae																			
<i>Nimravides catacopis</i>	x																		
<i>Megantereon hesperus</i>					?														
<i>Smilodon</i> sp.																		x	
<i>Homotherium</i> sp.						x													
<i>Panthera leo atrox</i>																		x	
<i>Panthera onca</i>																		x	
<i>Puma concolor</i>																		x	
<i>Puma lacustris</i>						?													
<i>Felis</i> or <i>Puma</i> sp.									x									x	
<i>Lynx rexroadensis</i>									x										
<i>Lynx rufus</i>																		x	
Hyaenidae																			
<i>Chasmaporthetes ossifragus</i>					?														
PERISSODACTYLA																			
Rhinocerotidae																			
<i>Teleoceras</i> sp.	x	x																	
<i>Aphelops</i> sp.	x																		
Equidae																			
<i>Pseudhipparion</i> sp.	x																		
<i>Nannippus peninsulatus</i>					x	x	x												
<i>Equus simplicidens</i>				x	x	x	x			cf									
<i>Equus calobatus</i>										cf								x	
<i>Equus giganteus</i>									cf										
<i>Equus conversidens</i>													cf					x	
<i>Equus scotti</i>									cf	x		x						cf	
<i>Equus niobrarensis</i>													cf						
<i>Equus cumminsii</i>							x												
<i>Equus</i> sp.										x	x	x						x	

	Bk	SR	FC	KC	R3	DP	Sa	Bo	Ar	Cud	Ad	BS	MS	CQ	Ji	Jo	Ro	Mo
ARTIODACTYLA																		
Tayassuidae																		
<i>Platygonus bicalcaratus</i>				x	x	x												
<i>Platygonus</i> sp.								x		x								
<i>Platygonus compressus</i>														cf		x		
Camelidae																		
<i>Procamelus</i> sp.	x																	
<i>Gigartocamelus spatula</i>		cf		x														
<i>Megatylopus? cochrani</i>				x														
<i>Megatylopus</i> sp.	x																	
<i>Camelops kansanus</i>												x		x				
<i>Camelops</i> sp.						x		x	x	x	x			x		x		
<i>Hemiauchenia blancoensis</i>				x	x													
<i>Hemiauchenia macrocephala</i>														x				
<i>Hemiauchenia</i> sp.								?	cf									
Cervidae																		
<i>Odocoileus brachyodontus</i>			x		x													
<i>Odocoileus virginianus</i>														x				x
<i>Odocoileus</i> sp.					x									x				
<i>Cervus elephas</i>																		x
Antilocapridae																		
<i>Capromeryx furcifer</i>														x				
<i>Antilocapra americana</i>																		x
Bovidae																		
<i>Bison latifrons</i>													cf		x			
<i>Bison bison</i>																		x
<i>Bison</i> sp.																x		
PROBOSCIDEA																		
Gomphotheriidae																		
<i>Rhynchotherium</i>	x					x												
<i>Stegomastodon primitivus</i>					x													
<i>Stegomastodon mirificus</i>						x												
<i>Stegomastodon elegans</i>								cf	cf									
Mammutidae																		
<i>Mammut adamsi</i>				x														
<i>Mammut</i> sp.					?													
Elephantidae																		
<i>Mammothus columbi</i>														x	x			
<i>Mammothus c. jeffersonii</i>																cf		
<i>Mammothus</i> sp.									x	x				x				

	SR	X1B	FC	RipB	KC	Wns B	Hor	R3	DP	Ss	Bor	Na	Ar	RF	Cud	Ad	BS	MS	CQ	Jln	Ta	Jon	Rob	Mod
<i>Pliolemmus antiquus</i>									xA	x														
<i>Nebraskomys rexroadensis</i>								x	x															
<i>Ondatra zibethicus /meadensis</i>									xA															
<i>Ondatra zibethicus /idahoensis</i>											x													
<i>Ondatra zibethicus /annectens</i>															x									
<i>Ondatra zibethicus /zibethicus</i>																	x							x
<i>Mictomys landesi</i>											x													
<i>Mictomys kansasensis</i>												x		x										
<i>Mictomys meltoni</i>															x									
<i>Mictomys sp.</i>																						x		
<i>Synaptomys australis</i>																		x		x				
<i>Synaptomys cooperi</i>																							x	x
<i>Microtus pliocaenicus</i>												x	x	x										
<i>Microtus paroperarius</i>															x									
<i>Microtus meadensis</i>															x									
<i>Microtus pennsylvanicus</i>																	x	x		x	x	x	x	
<i>Microtus ochrogaster/ llanensis</i>															x									
<i>Microtus ochrogaster/ ochrogaster</i>																	x	x	cf	x		x	x	x
<i>Microtus xanthognathus</i>																		x		cf				
<i>Microtus sp.</i>																						x		
Zapodidae																								
<i>Zapus rinker</i>			x																					
<i>Zapus sandersi</i>							cf	x	cf	x					cf									
<i>Zapus burti</i>											x													
<i>Zapus hudsonius</i>																		x		x	cf		x	K