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14. Magnetostratigraphy and Biostratigraphy of the Eocene-Oligocene Transition, Southwestern Montana

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ABSTRACT

Detailed magnetostratigraphic and biostratigraphic studies of Eocene-Oligocene deposits in southwestern Montana have greatly refined the dating of the fossil mammal assemblages known from the region. In the Jefferson Basin, the middle Chadronian Pipestone Springs l.f. correlates with Chrons C15r to C16r1 (35.0-35.5 Ma). The assemblages known from the middle to late(?) Chadronian Little Pipestone Creek localities correlate at least in part with Chrons C15r to C16n1 (35.0-35.4 Ma). The late Chadronian West Easter Lily l.f. and the succeeding early Orellan Easter Lily l.f. span much of Chron C13r (33.5-34.3 Ma). In the Beaverhead Basin, the early Chadronian McCarty's Mountain fauna correlates with Chrons C16r1 to C17n1 (35.5-36.7 Ma). The late Duchesnean Diamond O Ranch l.f. may correlate with part of the long episode of normal polarity during Chron C17n. In the Sage Creek Basin, the late Uintan Dell beds have produced the stratigraphically successive Douglass Draw and Hough Draw local faunas, both of which appear to fall in Chron C18r (40.2-41.0 Ma). The Matador Ranch and Cook Ranch local faunas from the stratigraphically higher Cook Ranch Formation are correlated with the Orellan part of Chron C12r (32.0-33.0 Ma).

The mammalian local faunas of southwestern Montana strongly reflect the significant faunal provincialism that characterized western North America during the Eocene-Oligocene transition. A varying percentage (generally 20–40%) of the mammalian species known from the late Uintan through late Orellan local faunas of the region appear to have been endemic to southwestern Montana. Severeal taxa, including talpids, *Ocajila*, *Megalagus*, *Palaeolagus*, *Palaeogale*, and *Leptomeryx sensu stricto*, appear to occur significantly earlier in southwestern Montana than they do in the Great Plains region, while others, including apternodontids and cylindrodontids, persist later.

Sedimentation was highly episodic and locally very rapid throughout the Eocene-Oligocene interval in southwestern Montana. The timing of sedimentation in each basin or group of closely related basins appears to have been largely dependent on local basin tectonics. Significant, but not regionally synchronous, gaps occur in the sedimentary sequence preserved in each of the basins. Most of the exposed sequences, some of which are very thick, span less than one million years.

INTRODUCTION

Eocene and Oligocene sediments and associated volcanics are sporadically but locally well exposed in the small intermontane basins of southwestern Montana. Moderately extensive remnants of these deposits are also present at high elevation in some of the adjacent mountain ranges. Although exposures are generally limited and discontinuous, some of the sediments are richly fossiliferous and a temporally extensive suite of mammalian local faunas has been developed within the region. These preserve one of the most extensive and important records of the Eocene-Oligocene transition in continental rocks of western North America outside the Great Plains region (Fig. 1).

The Cenozoic geologic history of southwestern Montana is complex, characterized by episodic sedimentation and multiple episodes of faulting (Fields et al., 1985; Hanneman and Wideman, 1991). Tertiary basins initially developed and were locally receiving sediments by early middle Eocene (Bridgerian) time. By late Eocene (Chadronian) time all of the basins, with the possible exception of some of the small peripheral basins, were the site of significant sediment accumulation.

Although the largest of the intermontane basins of southwestern Montana is only about 60 miles long by 30 miles wide, the basins locally contain very thick sequences of Cenozoic continental deposits—approximately 16,000 feet in the relatively undissected Big Hole Basin and more than 10,000 feet in the Deer Lodge Basin (Fields et al., 1985). The present basins of southwestern Montana were largely outlined during an interval of intense Basin-and-Range style faulting in the middle and late Miocene and have been further fragmented by latest Tertiary and Quaternary faulting. The presence of Eocene and Oligocene sediments in some of the adjacent mountain ranges indicates that at least some of the Paleogene basins were more extensive than the present small basins of the region. Vertebrate paleontological field work in southwestern Montana was largely pioneered by Earl Douglass. Between 1894 and 1905, Douglass conducted extensive field investigations in the region, working in most of the intermontane basins of southwestern Montana and amassing a large collection of Eocene, Oligocene, and Miocene vertebrates. During this period Douglass discovered many of the most significant Tertiary localities known from the region, including the Pipestone Springs, Little Pipestone Creek, and McCarty's Mountain localities discussed below.

Figure 1. Index map showing location of sites mentioned in text. Localities: CR, Cook Ranch; DO, Diamond O Ranch; EL, Easter Lily; LP, Little Pipestone; MM, McCarty's Mountain; PS, Pipestone Springs; SC, Sage Creek.

Douglass described some of the Paleogene vertebrates he had collected in a series of papers published between 1901 and 1908 (Douglass, 1901, 1903, 1905, 1907, 1908a,b).

Douglass was hired by the Carnegie Museum in 1902, and his large collection of fossil vertebrates from southwestern Montana became one of the first key acquisitions made by the museum. Douglass'ss field notes were not, however, acquired at the time and for many years were unavailable and presumed lost (see Wood et al., 1941, p. 25). In 1976 Gawin Douglass donated his father's extensive surviving papers to the Marriott Library of the University of Utah; these contain a wealth of useful information, including much more precise locality data for many of the specimens Douglass collected than had been retained in the Carnegie Museum records.

In 1937 J. LeRoy Kay renewed collecting in southwestern Montana for the Carnegie Museum. Kay collected in the region for more than twenty years, discovering several important new localities and greatly increasing the sample available from many of the localities previously worked by Douglass. The collection amassed by Douglass and Kay and housed at the Carnegie Museum is both the largest and historically most important collection of fossil vertebrates known from southwestern Montana.

Major progress in unraveling the complicated Cenozoic history of southwestern Montana was made by Robert W. Fields and his students at the University of Montana. In the late 1950s, Fields initiated a long-term project to investigate the stratigraphy and vertebrate paleontology of the intermontane basins of the region. Theses by his students describing the Cenozoic geology and vertebrate paleontology of the Beaverhead (Riel, 1963; Hoffman, 1972; Petkewich, 1972), Flint Creek (Rasmussen, 1969), Jefferson (Kuenzi, 1966), Muddy Creek (Dunlap, 1982), North Boulder (Lofgren, 1985), Smith River (Runkel, 1986), and Upper Ruby River (Monroe, 1976) basins, combined with data collected from most of the other intermontane basins of southwestern Montana, have greatly clarified the stratigraphic and temporal relationships of the Cenozoic deposits known from the region. The information contained in these studies, as well as that from many other published and unpublished sources, was summarized in Fields et al. (1985). During the course of their work, Fields and his students greatly increased the available sample of fossil vertebrates known from southwestern Montana. In particular, the University of Montana collection retains the precise locality information that is often lacking in the older collections.

In their review paper, Fields et al. (1985, fig. 4 and Appendix A) attempted to assign relatively precise ages to many of the mammalian local faunas known from southwestern Montana. These were based in large part on the then unpublished, but widely circulated, bichronological studies of Emry et al. (1987) and Tedford et al. (1987), combined with the preliminary results of some of Prothero's magnetostratigraphic studies in the region. While we generally endorse the placement of the southwestern Montana local faunas within the North American Land Mammal "Ages" advocated by Fields et al. (1985), significant advances in calibration of the late Paleogene global time scale (Berggren et al., 1992, 1995) coupled with refinements in both the dating and correlation of the North American Land Mammal "Ages" (Woodburne, 1987; Prothero and Swisher, 1992) have necessarily modified some of the numerical age estimates they provided. For example, Fields et al. (1985, fig. 2) placed the Eocene/Oligocene boundary at 36.6 Ma, within the Chadronian Land Mammal "Age" which they illustrated as spanning the interval from 32.4-38.7 Ma; more recent estimates, however, place the Eocene/Oligocene boundary at about 34 Ma (Berggren et al., 1992, 1995) and the age range for the Chadronian as approximately 33.7-37.0 Ma (Prothero and Swisher, 1992).

The late Uintan through late Orellan mammalian local faunas from southwestern Montana, discussed below, differ significantly from contemporaneous assemblages known from other areas of North America. The moderate to high level of provincialism exhibited by these local faunas has tended to inhibit precise correlation with assemblages known from other parts of the continent. High-resolution chronostratigraphy, combining detailed biostratigraphic and magnetostratigraphic analysis, is, however, now available for several of the key sections in the region and allows us to correlate many of the local faunas from southwestern Montana with a degree of precision hitherto unattainable. In the following pages we report the results of our analyses of key localities in the Beaverhead, Jefferson, and Sage Creek basins. These span much of the Eocene-Oligocene interval in southwestern Montana and include many of the most fossiliferous and historically most important localities known from the region. We should, however, add the cautionary caveats that some of our faunal analyses are preliminary and that much work remains to be done in the region.

MAGNETIC METHODS

Magnetic sampling in southwestern Montana was conducted over several field seasons. In 1980, the Easter Lily section, and the Cook Ranch Formation were sampled; both were briefly summarized in Prothero (1982). The main section at Pipestone Springs was sampled in 1983, and described the following year (Prothero, 1984). The McCarty's Mountain section was sampled in 1986, and the Dell beds, Little Pipestone Creek, and Diamond O Ranch were sampled in 1987. A minimum of three oriented block samples was taken at each site with simple hand tools. In most sections, sites were spaced 1.5-3 m (5.5-11 feet) stratigraphically, depending upon exposures. Samples were then trimmed on a band saw with a tungsten carbide blade; crumbly samples were hardened with sodium silicate solution.

The 1980 samples were run at the paleomagnetics laboratory at Woods Hole Oceanographic Institute, and the 1983 samples were analyzed at the South Dakota School of Mines and Technology. All other samples were analyzed at the paleomagnetics laboratory of the California Institute of Technology. After measurement of NRM (natural remanent magnetization), a suite of samples was subjected to stepwise demagnetization to determine the origin of magnetization. AF (alternating field) demagnetization (Fig. 2A) showed a steady and rapid decline in intensity, suggesting that the primary carrier of the remanence is a low-coercivity mineral such as magnetite. Under thermal demagnetiza-tion (Fig. 2B-D), almost all remanence had vanished by temperatures of 600°C (above the Curie point of magnetite), indicating that very little remanence is carried by hematite.

This interpretation was corroborated by IRM (isothermal remanent magnetization) studies of representative lithologies, as described by Pluhar et al. (1991). Most samples (Fig. 3) reached saturation IRM values between 100 and 300 mT (millitesla) and did not gain any further magnetization even at fields of 1300 mT. This suggests that fine-grained magnetite is the primary carrier of the remanence. The same IRM samples were also subjected to a modified Lowrie-Fuller ARM test (Johnson et al., 1975; Pluhar et al., 1991). This test compares the resistance to AF demagnetization of both the IRM produced in a 100-mT peak field, and the ARM (anhysteretic remanent magnetization) gained in a 100 mT oscillating field. As can be seen in Figure 3, the ARM (solid squares) demagnetizes at higher fields than does the IRM (open squares), showing that the magnetic remanence is carried by fine-grained (<10 micron) particles of magnetite in the single-domain or pseudo-single-domain size range.

Because AF demagnetization does not remove overprints caused by chemical remanence from iron hydroxides, all remaining samples were analyzed by thermal demagnetization. Reversely magnetized samples had slight overprints that were typically removed at temperatures of 200°C, and a stable reversed magnetic component was isolated at temperatures of 300-500°C (Fig. 2C-D). For statistical averaging purposes, the component between 300-400°C was typically used.

Most samples came from flat-lying beds, so no fold test for stability could be conducted. However, in the McCarty's Mountain area, the dip varied between 30° and 50° from the top to the bottom of the section, and a

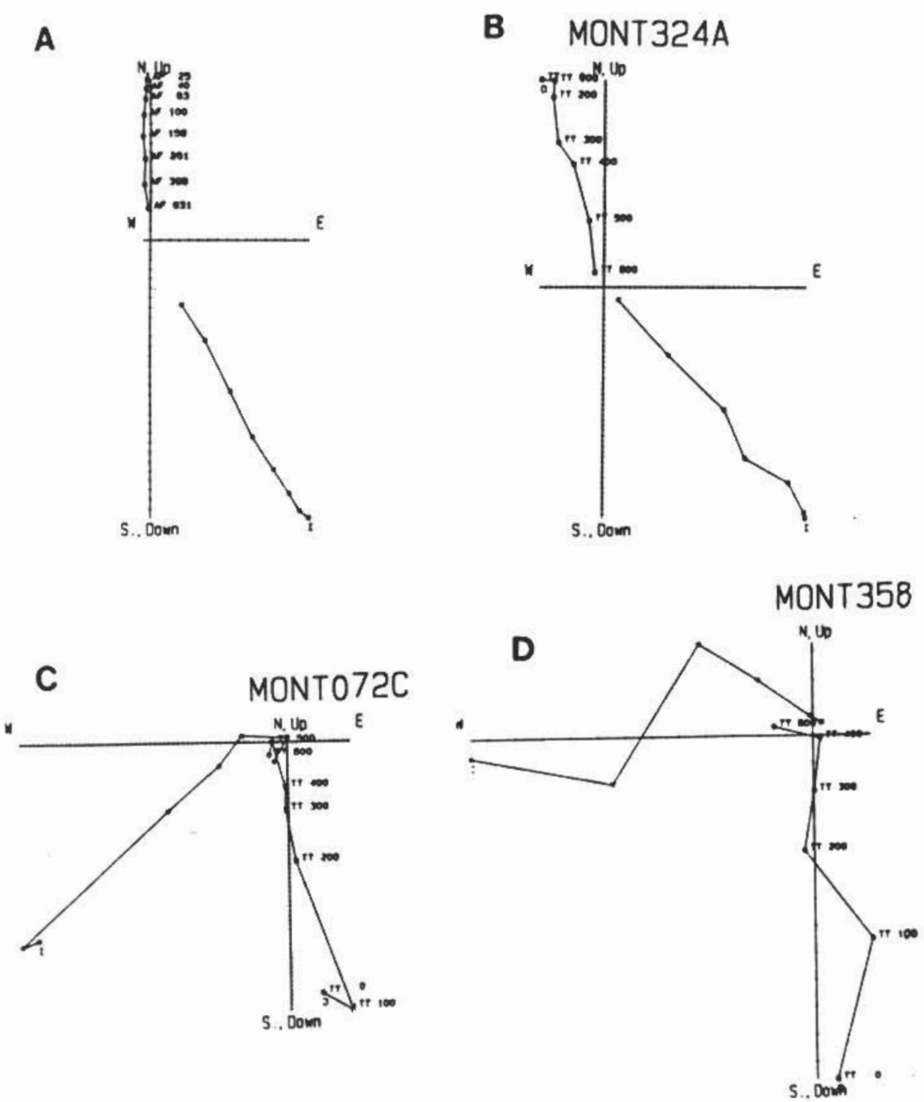

Figure 2. Orthogonal demagnetization ("Zijderveld") plots of representative samples in this study. Each increment is 10^{-7} emu. Horizontal components are indicated by open circles and vertical components by asterisks. "I" indicates NRM vector in the vertical component. A. AF demagnetization behavior, showing rapid decline in intensity from 25 to 631 Gauss. This indicates that a low coercivity mineral such as magnetite is the primary carrier of the remanence. B-D. Thermal demagnetization plots, showing vectors at temperatures ranging from NRM (TT0) to 600°C. Sample 324A (Fig. 2B) is a normally magnetized sample; sample 72C (Fig. 2C) is a reversed sample that finally reached the upper hemisphere at 400-500°C; sample 358B (Fig. 2D) is a reversed sample that reached the upper hemisphere at 200-400°C.

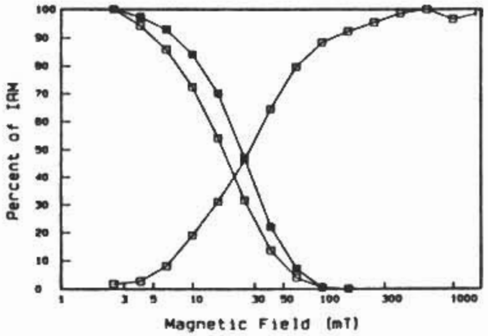

Figure 3. IRM acquisition and Lowrie-Fuller ARM test of a representative sample (see Pluhar et al., 1991, for experimental details). Open boxes indicate IRM intensity; solid boxes represent ARM intensity. The IRM acquisition curve (ascending curve on right) saturates at about 300 mT, showing that magnetite is the primary carrier of the remanence. Demagnetization of the IRM (descending curve on left with open boxes) and ARM (solid boxes) shows the ARM more resistant to AF demagnetization than the IRM. This suggests that the carrier is a fine-grained (<10 microns), single-domain or pseudo-single-domain magnetite.

modified fold test could be conducted. After demagnetization, the uncorrected magnetic vectors (D = 23.0°, I = -4.9°, k = 2.9, α_{95} = 32.4) are clearly not overprinted by a post-tilting magnetic field, because they deviate significantly from the present magnetic field. In addition, the uncorrected vectors were more scattered than the same directions after the dip correction (D = 8.2, I = 62.4, k = 5.7, α_{95} = 20.9), indicating that the magnetization was acquired prior to tilting.

Reversal tests for stability were also conducted. At McCarty's Mountain, the mean for reversed sites (D = 198.6, I = -47.7, k = 6.2, α_{95} = 13.0) was antipodal to the mean for normal sites given above. Similar results were obtained for the Dell beds (normal sites, D = 7.9, I = 59.0, k = 3.3, α_{95} = 49.7; reversed sites, D = 176.4, I = -49.8, k = 9.1, α_{95} = 12.1). This suggests that the magnetic component isolated between 300-500°C is the characteristic component of the remanence.

The stable characteristic directions for all samples at a given site were then averaged using the methods of Fisher (1953; see Butler, 1992). Sites whose samples clustered well enough that they could be distinguished from random scatter at the 95% confidence interval were designated Class I sites, following Opdyke et al. (1977). If a sample was lost or crumbled, then the mean direction of the two remaining samples was used; these were Class II sites of Opdyke et al. (1977). If two samples showed a clear polarity preference, but the third sample was divergent, then the site was designated Class III (Opdyke et al., 1977). A few sites gave highly scattered or unstable results, or showed no clear polarity preference, and were labeled indeterminate.

JEFFERSON BASIN

In 1899, Douglass discovered rich concentrations of fossil vertebrates, including abundant small mammals, at exposures near Pipestone Springs and south of Little Pipestone Creek along the western margin of the Jefferson Basin. His subsequent description (Douglass, 1901) of a variety of new mammals from the "White River Beds" of Montana, including eight new species from the Pipestone Springs area, spurred the American Museum of Natural History to send an expedition to western Montana in the summer of 1902 to further investigate these deposits. Matthew (1903) described the large collection obtained by the American Museum from the Pipestone Springs locality, naming a dozen additional new species of mammals, and first noted the presence of a younger fauna in beds exposed north of the railroad tracks. The Pipestone Springs area has since been worked by many institutions, with the largest collections being those made by Kay for the Carnegie Museum and by Fields and his students for the University of Montana.

The Cenozoic geology of the Jefferson Basin was thoroughly reviewed by Kuenzi (1966) in his Ph.D. dissertation and summarized in an influential paper published by Kuenzi and Fields (1971). Based on homotaxis and strong lithologic similarity to the Climbing Arrow and Dunbar Creek formations mapped by Robinson (1963, 1967) in the Three Forks and Toston quadrangles, Kuenzi and Fields (1971) divided the Paleogene sediments exposed in the western part of the Jefferson Basin into the Climbing Arrow and Dunbar Creek members of their newly named Renova Formation. Sediments referred to the Climbing Arrow Member are discontinuously exposed between the Pipestone Springs localities and the Little Pipestone Creek area about five miles to the south. Sediments assigned to the Dunbar Creek Member are largely restricted to the area north of the Burlington Northern Railroad tracks, although exposures in the Colbert Creek area (parts of sections 6 and 7, T1N R5W), originally included in the Climbing Arrow Member by Kuenzi and Fields (1971), have since been reassigned to the Dunbar Creek Member by Garcia (1992).

Exposures of Tertiary sediments in the western part of the Jefferson Basin are highly discontinuous. Most of the exposures are small and several have produced only very limited vertebrate assemblages. Attempts to correlate between some of these localities have proven difficult. Garcia (1992) has consequently divided the Pipestone Creek region into eight separate "collecting areas" and has recognized nine geographically and/or temporally distinct local faunas. Each of Garcia's "collecting areas" consists of either a single exposure or

a few closely related exposures; these generally coincide with the principal fossil localities illustrated on the map provided by Kuenzi and Fields (1971, fig. 3).

The most richly fossiliferous outcrops in the Jefferson Basin are the small pockets of Climbing Arrow sediments exposed in section 29, T2N R5W, near Pipestone Springs, and the small area of exposures south of Little Pipestone Creek in the SW section 8, and NW section 17, T1N R5W. Except for the few specimens reported by Matthew (1903) from exposures north of the railroad tracks, all of the specimens obtained by the early collectors appear to have been derived from these two areas.

The quality of available locality data for specimens collected from the Pipestone Springs area is highly variable. Many specimens, especially in the older collections, are simply listed as having been collected from "Pipestone Creek," "Pipestone Springs," or the "Pipestone beds" without any more specific locality information (Garcia, 1992). Field parties from the University of Montana have since divided the exposures in the region into multiple geographically and stratigraphically restricted localities, and the locality information retained in the University of Montana records is generally the most precise available for any of the larger collections of vertebrates from the area. Kay also seems to have consistently distinguished between the major localities in the large collection he made for the Carnegie Museum.

Some mixing between localities appears to be demonstrable. Many specimens that have been attributed to Pipestone Springs were actually collected from other localities. For example, information contained in Douglass's surviving field notes indicates that he made a sizable collection from the Little Pipestone Creek area, yet only a few specimens that he collected are attributed to Little Pipestone Creek in the Carnegie Museum records. The bulk of the material that Douglass obtained from Little Pipestone Creek appears to have become hopelessly mixed with his collection from the Pipestone Springs locality. Similarly, some of the specimens (e.g., "*?Limnenetes* sp.") attributed to the Pipestone Springs locality by Matthew (1903) also seem likely to have been collected from other localities, and may not even have been derived from the Jefferson Basin. Some of the other collections from the Pipestone Springs area are probably also mixed. Most, but not all, of the apparent mixing seems to involve the assignment of specimens collected from the Little Pipestone Creek area to the Pipestone Springs l.f. Because the assemblages known from the Pipestone Springs and Little Pipestone Creek localities do appear to differ somewhat in composition, and possibly in age, the many specimens from the Pipestone Springs area that have only vague or questionable locality data must be treated cautiously.

Garcia (1992) has recently comprehensively reviewed the mammalian paleontology of the Pipestone Creeks region. In the following sections we briefly review those assemblages for which we also have magnetostratigraphic data: the Pipestone Springs, Little Pipestone Creek, and Easter Lily areas. Several other nearby localities have also produced significant vertebrate faunas (Kuenzi and Fields, 1971; Garcia, 1992) but are only mentioned in passing.

Pipestone Springs Local Fauna

Specimens assigned to the Pipestone Springs l.f. are derived from three small pockets of richly fossiliferous Climbing Arrow sediments exposed in section 29, T2N R5W, about 1.5 miles west of Pipestone Hot Springs. Kay termed the most fossiliferous of these the Main Pocket and Fence Pocket localities. Collecting parties from the University of Montana have since divided Kay's Main Pocket locality into multiple geographically and/or stratigraphically restricted localities (Kuenzi and Fields, 1971; Tabrum and Fields, 1980; Lillegraven and Tabrum, 1983; Garcia, 1992). The prominent dip-slope near the northern end of the Main Pocket exposures (Orr, 1958, Photo 1), University of Montana locality MV 5811, is the richest of the Pipestone Springs localities and has probably produced the majority of the exquisite small mammal specimens known from the Pipestone Springs l.f.

A second isolated pocket of Climbing Arrow sediments occurs about 250 yards south of the Main Pocket localities and has produced the moderately diverse assemblage assigned to University of Montana locality MV 5903. Garcia (1992) called this area Pipestone Springs South, although the name South Pocket might be preferable. Lithologically and faunally these beds are indistinguishable from those at the Main Pocket exposures. Some of the specimens obtained by Kay and other collectors and attributed to Pipestone Springs Main Pocket were probably derived from the South Pocket exposures. Specimens collected from this area have traditionally been included with those from the Main Pocket (Kuenzi and Fields, 1971; Tabrum and Fields, 1980), a procedure that we follow, but do not necessarily endorse, here.

The Fence Pocket locality, University of Montana locality MV 6103, is about 0.5 miles southeast of the Main Pocket localities and is separated from them by an eastwardly projecting spur of granitic rocks of the Boulder Batholith. The thin section (only 12 m, approximately 39 feet) of sediments exposed at the Fence Pocket locality is lithologically similar to, and seems to correlate with, the most productive horizon at the Main Pocket exposures (Garcia, 1992). However, because the Fence Pocket locality is somewhat removed from the other Pipestone Springs localities we have elected to list the fauna separately in Table 1.

Table 1. Pipestone Springs local fauna, Jefferson Basin: Localities in Sec. 29, T2N R5W, Jefferson County, Montana. Climbing Arrow Member, Renova Formation. Middle Chadronian. PSMP, Pipestone Springs Main Pocket. PSFP, Pipestone Springs Fence Pocket. (* = type locality.)

	PSMP	PSFP
PERADECTIA		
Peradectidae		
Didelphidectes pumilus Hough*	X	
DIDELPHIMORPHIA		
Didelphidae		
Herpetotherium valens (Lambe)	X	X
Herpetotherium fugax Cope	X	X
Copedelphys titanelix (Matthew)*	X	X
PROTEUTHERIA		
Leptictidae		
Leptictis acutidens (Douglass)*	X	X
Leptictis thomsoni (Matthew)*	X	X
INSECTIVORA		
Geolabididae		
Centetodon kuenzii Lillegraven and Tabrum*	X	X
Centetodon magnus (Clark)	X	
Micropternodontidae		
Micropternodus borealis Matthew*	X	X
Apternodontidae		
Oligoryctes altitalonidus (Clark)	X	X
Oligoryctes cameronensis Hough	X	
Apternodus mediaevus Matthew*	X	X
Soricidae		
Domnina thompsoni Simpson*	X	X
Proscalopidae		
Oligoscalops? new species	X	
Insectivora, *incertae sedis*		
Cryptoryctes kayi Reed*	X	
PHOLIDOTA		
Manidae		
Patriomanis americanus Emry		
LAGOMORPHA		
Leporidae		
Megalagus brachyodon (Matthew)*	X	X
Palaeolagus temnodon Douglass*	X	X
Chadrolagus emryi Gawne	X	
RODENTIA		
Ischyromyidae		
Ischyromys veterior Matthew*	X	X
Ischyromys new species	X	X
Cylindrodontidae		
Pseudocylindrodon neglectus Burke*	X	
Cylindrodon fontis Douglass*	X	X
Aplodontidae		
Prosciurus vetustus Matthew*	X	
Sciuridae		
Protosciurus jeffersoni (Douglass)*	X	
Eutypomyidae		
Eutypomys parvus Lambe	X	
Eomyidae		
Zemiodontomys burkei (Black)*	X	
Namatomys lloydi Black*	X	X
Montanamus bjorki Ostrander*	X	
Adjidaumo minimus (Matthew)*	X	
Paradjidaumo trilophus (Cope)	X	X
Aulolithomys bounites Black*	X	
New genus and species	X	
Heliscomyidae		
Heliscomys ostranderi Korth et al.	X	
Rodentia, *incertae sedis*		
Pipestoneomys bisulcatus Donohoe*	X	
CREODONTA		
Hyaenodontidae		
Hyaenodon crucians Leidy		
Hyaenodon microdon Mellett*		
CARNIVORA		
Amphicyonidae		
Brachyrhynchocyon dodgei (Scott)	X	
Brachyrhynchocyon new species	X	
Daphoenictis sp.	X	
Canidae		
Hesperocyon gregarius (Cope)	X	X
Procyonidae		
Mustelavus priscus Clark	X	
Ursidae		
Parictis montanus Clark and Guensburg*	X	
Nimravidae		
Dinictis sp.	X	
Carnivora, *incertae sedis*		
Palaeogale sectoria (Gervais)	X	
PERISSODACTYLA		
Equidae		
Mesohippus westoni (Cope)	X	
Mesohippus portentus Douglass*		
Miohippus grandis (Clark and Beerbower)	X	X
Brontotheriidae		
Brontotheriid sp.	X	
Helaletidae		
Colodon sp., cf. *C. kayi* (Hough)	X	
Hyracodontidae		
Hyracodon sp.	X	?
Rhinocerotidae		
Rhinocerotid sp.	X	
ARTIODACTYLA		
Leptochoeridae		
Stibarus montanus Matthew*	X	
Leptochoerus sp.		
Agriochoeridae		
Agriochoerus sp.	X	
Merycoidodontidae		
Bathygenys alpha Douglass*	X	X
Merycoidodon sp.	X	X
Camelidae		
Poebrotherium sp.	X	
Protoceratidae		
"*Leptotragulus*" *profectus* (Matthew)*	X	X
Leptomerycidae		
Hendryomeryx new species	X	
Leptomeryx new species	X	
"*Leptomeryx*" *mammifer* Cope	X	X
"*Leptomeryx*" *speciosus* Lambe	X	X
"*Leptomeryx*" new species I	X	X
"*Leptomeryx*" new species M	X	

Kuenzi and Fields (1971) cited a thickness of 176 feet for the Climbing Arrow sediments exposed at the Pipestone Springs Main Pocket localities, and Prothero (1984) reported a comparable thickness of about 60 m (197 feet) in his magnetostratigraphic study of the Pipestone Springs locality. Garcia (1992) has recently measured additional stratigraphic sections in the area and reports a thickness of as much as 100 m (328 feet) for the deposits.

The Pipestone Springs l.f. is easily the most diversified and best studied mammalian fauna known from any of the intermontane basins of southwestern Montana. Pipestone Springs is particularly well known for superb specimens of small mammals and provided the first clear glimpse of a Chadronian small-mammal fauna (Matthew, 1903). If the number of type specimens collected from a locality is a measure of its significance, then the Main Pocket at Pipestone Springs is arguably the single most important locality of Chadronian age known. The type specimens of thirty currently recognized species of vertebrates are attributed to the Pipestone Springs l.f., including the type species of the lizard *Helodermoides*, and the mammals *Apternodus*, *Aulolithomys*, *Bathygenys*, *Copedelphys*, *Cryptoryctes*, *Cylindrodon*, *Didelphidectes*, *Micropternodus*, *Montanamus*, *Namatomys*, *Pipestoneomys*, *Prosciurus*, *Pseudocylindrodon*, and *Zemiodontomys*. Several additional new taxa remain to be described.

Tabrum and Fields (1980) presented a revised faunal list for the Pipestone Springs l.f. and briefly summarized the extensive literature on Pipestone Springs mammals. Since publication of their paper, additional taxa have been described from the Pipestone Springs localities by Emry and Hunt (1980), Korth (1994), Korth et al. (1991), Lillegraven et al. (1981), Lillegraven and Tabrum (1983), Ostrander (1983), and Storer (1984a). Taxonomic name changes accepted here have been introduced by de Bonis (1981), Emry and Korth (1993), Heaton (1993 and this volume, Chapter 27), Hunt (this volume, Chapter 23), Korth (1980, 1994), Storer (1981), Storer and Bryant (1993), and Wang (1994). Further study by Garcia (1992) has significantly increased the Pipestone Springs faunal list and has necessitated additional taxonomic name changes. Most of these have involved only minor taxonomic shifts; however, specimens thought to pertain to an oromerycid, and identified as "?*Eotylopus* new sp." by Tabrum and Fields (1980) are now instead believed to represent a new species of the leptomerycid *Hendryomeryx* comparable in size to the large "*Leptomeryx*" *mammifer*.

Some of the specimens that have been attributed to Pipestone Springs are now known to have been collected from other localities. Many others, including some type materials (e.g., the holotype and referred specimens of *Pipestoneomys bisulcatus* described by Donohoe, 1956), are suspected to have been derived from other localities. Two of the four species of *Hyaenodon* attributed to Pipestone Springs by Mellett (1977) were based on specimens demonstrably not collected from the Pipestone Springs localities. The single specimen of *H. horridus* (F:AM 95716) reported by Mellett was actually collected from younger beds exposed about two miles to the northeast in the Easter Lily area (Garcia, 1992), and Mellett's reference to *H. montanus* in the Pipestone Springs assemblage was based only on the type specimen, collected from the Toston area approximately 50 miles to the northeast. Matthew (1903, p. 222), in his description of the American Museum collection from Pipestone Springs, provisionally assigned "a number of lower jaws and parts of jaws" to ?*Limnenetes* sp. Matthew suggested that more than one species was represented but did not cite any specimen numbers. Schultz and Falkenbach (1956, p. 459) noted this but reported that "a tray of material from the Pipestone Springs area . . . may represent the specimens in question." This sample consisted of ten partial lower jaws of *Oreonetes anceps*. *Oreonetes anceps* is not, however, represented in any of the other collections that have been made from the Pipestone Springs area. The 1902 American Museum expedition also collected at various places in the Three Forks Basin and North Boulder Valley, at least in the general area from which specimens of *O. anceps* have been recovered, and it seems most likely that the material reported by Schultz and Falkenbach was actually collected from one of these two areas.

In the faunal list presented in Table 1 we attribute 65 mammalian taxa to the Pipestone Springs l.f. Accurate locality information is available for at least some of the specimens of all of the taxa listed in Table 1 except *Patriomanis americanus*, *Hyaenodon crucians*, *H. microdon*, *Mesohippus portentus*, and *Leptochoerus* sp. Of these we believe that the available specimens of *P. americanus*, *H. crucians*, and *H. microdon* were derived from the Main Pocket exposures. The specimens assigned to *Mesohippus portentus* and *Leptochoerus* sp., however, were collected in 1899 by Douglass and have not been duplicated in later collections from the area; they may have been collected from one of the Pipestone Springs localities or may instead have been collected from other localities in the general area.

The Pipestone Springs l.f. was designated as one of the principal correlatives of the Chadronian provincial age by the Wood Committee, who regarded the locality as early Chadronian (Wood et al., 1941, p. 28). Later, Clark and Beerbower (*in* Clark et al., 1967), based on relatively weak evidence, believed that Pipestone Springs was late Chadronian in age, about equivalent to the Peanut Peak Member of the Chadron Formation in South Dakota. The significance of this evidence was strongly disputed by Emry (1973). Based on his biostratigraphic study of the Chadronian deposits at

Flagstaff Rim, Wyoming, Emry (1973) concluded that the Pipestone Springs l.f. was not late Chadronian in age, but as old as middle Chadronian.

The age of the Pipestone Springs l.f. has since been firmly established as middle Chadronian (Prothero, 1984; Ostrander, 1985; Emry et al., 1987; Emry, 1992). Based in part on the then unpublished work of Emry et al. (1987) coupled with his own magnetostratigraphic study of the Pipestone Springs exposures, Prothero (1984) assigned an early middle Chadronian age to the Pipestone Springs l.f. and was followed in this age assignment by Fields et al. (1985). Ostrander (1985) regarded the very diverse assemblage known from Pipestone Springs as effectively the type assemblage for the middle Chadronian. Emry et al. (1987) noted that

> the taxonomically diverse fauna occurring from about 250 to 400 feet above the base of the generalized zonation section of the White River Formation in the Flagstaff Rim area of Wyoming . . . essentially duplicates the Pipestone Springs l.f., predominantly at the species level

and defined the middle Chadronian based principally on these two assemblages. The strong similarities (and some significant differences) between the assemblages known from Pipestone Springs and that part of the Flagstaff Rim section between the Ash B and Ash G levels is emphasized in the biostratigraphic range zones compiled by Emry (1992) for the Flagstaff Rim section.

Prothero (1984) sampled and described the magnetic stratigraphy of the main section at Pipestone Springs, running from NW NW SW section 29 to SE SW NW of the same section, T2N R5W Delmoe Lake 7.5' quadrangle, Jefferson County, Montana. The 130 feet of section in the Climbing Arrow Member of the Renova Formation produced reversed sites at base, followed by about 80 feet of rocks of normal polarity; the remaining section was reversed (Prothero, 1984, fig. 3). Although the polarity pattern remains unchanged from that illustrated by Prothero (1984), its interpretation (Prothero, 1984, fig. 4) has changed due to major revisions in the correlation of the Chadronian with the magnetic polarity time scale (Prothero and Swisher, 1992). Based on the latest interpretation of the Flagstaff Rim sequence, the Pipestone Springs local fauna probably correlates with Chrons C15r-C16r1, or about 35.0-35.5 Ma (Fig. 7).

Little Pipestone Creek Local Fauna

Fossil vertebrates assigned to the Little Pipestone Creek local fauna were collected from a small area of good exposures south of Little Pipestone Creek in the SW section 8, and NW section 17, T1N R5W, immediately east of Montana Highway 41. These exposures are about three miles south of the Pipestone Springs localities and include University of Montana localities MV 5905, MV 6001, and MV 8603. The small sample from Honeymoon Quarry, part of MV 5905, is one of the few quarry samples known from the Cenozoic deposits of southwestern Montana.

Kuenzi and Fields (1971) referred the sediments exposed at the Little Pipestone Creek localities to the Climbing Arrow Member of the Renova Formation. Three partially overlapping sections measured by Garcia (1992) total about 185 feet, close to the thickness of 178 feet reported for the Little Pipestone Creek section by Kuenzi (1966). The lower part of the section is poorly exposed and very sparingly fossiliferous. All of the vertebrates listed in Table 2 are believed to have been collected from the upper 75 feet of the Little Pipestone Creek section.

Kay et al. (1958) and Kuenzi and Fields (1971) provided faunal lists of the taxa known by them to have been collected from the Little Pipestone Creek area, but fossil vertebrates from Little Pipestone Creek have been much less intensively investigated than those from the main Pipestone Springs exposures. The localities are fairly rich, but of the many specimens described from the Pipestone Creek region, only the holotype of *Agriochoerus maximus* Douglass (1901) was reported to have been collected from the Little Pipestone Creek area. Some specimens that have been attributed to Pipestone Springs (e.g., CM 9287, the most complete lower jaw from the Pipestone Springs area referred to *Daphoenocyon dodgei* by Clark and Beerbower *in* Clark et al., 1967) were, however, actually collected from Little Pipestone Creek.

The Little Pipestone Creek local fauna includes at least 41 species of mammals. Of the 37 taxa that appear to be specifically determinate, all except the very rare *Agriochoerus*? *maximus* have also been recorded from the Pipestone Springs local fauna. Faunal composition, however, appears to differ markedly. "*Leptomeryx*" *speciosus*, the most common artiodactyl at the Pipestone Springs localities, is not represented at Little Pipestone Creek (Garcia, 1992) and appears to have been replaced by Garcia's "*Leptomeryx*" n. sp. M. *Cylindrodon fontis*, abundant at Pipestone Springs, is represented by only a single specimen from Little Pipestone Creek, and *Pseudocylindrodon neglectus* and *Heliscomys ostranderi*, both fairly common at Pipestone Springs, have not been recorded from the Little Pipestone Creek local fauna. The enigmatic rodent *Pipestoneomys bisulcatus*, however, is vastly more common at Little Pipestone Creek than it is at Pipestone Springs, and *Adjidaumo minimus* also appears to be relatively more common.

There also appear to be potentially significant differences in the ischyromyids and equids. *Ischyromys veterior* is much more common than *Ischyromys* n. sp. at Pipestone Springs but much less common at Little Pipestone Creek and may in fact be replaced by *Ischyromys* n. sp. in the stratigraphically highest parts of the Little Pipestone Creek section. The relative abundance of *Mesohippus westoni* and *Miohippus grandis* may also be reversed, with *Mesohippus westoni* the more common equid at Pipestone Springs and *Miohippus grandis* more common at Little Pipestone Creek.

Table 2. Little Pipestone Creek local fauna, Jefferson Basin: Localities in SW Sec. 8, and NW Sec. 17, T1N R5W, Jefferson County, Montana. Climbing Arrow Member, Renova Formation. Middle to late Chadronian. (* = type locality.)

DIDELPHOMORPHIA
Didelphidae
Herpetotherium valens (Lambe)
Herpetotherium fugax Cope
Copedelphys titanelix (Matthew)
PROTEUTHERIA
Leptictidae
Leptictis acutidens (Douglass)
INSECTIVORA
Geolabididae
Centetodon kuenzii Lillegraven and Tabrum
Micropternodontidae
Micropternodus borealis Matthew
Apternodontidae
Oligoryctes altitalonidus (Clark)
Oligoryctes cameronensis Hough
Apternodus mediaevus Matthew
Soricidae
Domnina thompsoni Simpson
Proscalopidae
Oligoscalops? new species
Insectivora, *incertae sedis*
Cryptoryctes kayi Reed
LAGOMORPHA
Leporidae
Megalagus brachyodon (Matthew)
Palaeolagus temnodon Douglass
Chadrolagus emryi Gawne
RODENTIA
Ischyromyidae
Ischyromys veterior Matthew
Ischyromys new species
Cylindrodontidae
Cylindrodon fontis Douglass
Aplodontidae
Prosciurus vetustus Matthew
Eomyidae
Adjidaumo minimus (Matthew)
Paradjidaumo trilophus (Cope)
Aulolithomys bounites Black
Rodentia, *incertae sedis*
Pipestoneomys bisulcatus Donohoe
CREODONTA
Hyaenodontidae
Hyaenodon crucians Leidy
CARNIVORA
Amphicyonidae
Brachyrhynchocyon dodgei (Scott)
Canidae
Hesperocyon gregarius (Cope)
PERISSODACTYLA
Equidae
Mesohippus westoni (Cope)
Miohippus grandis (Clark and Beerbower)
Brontotheriidae
Brontotheriid sp.
Rhinocerotidae
Rhinocerotid sp.
ARTIODACTYLA
Leptochoeridae
Stibarus montanus Matthew
Agriochoeridae
Agriochoerus? *maximus* Douglass*
Merycoidodontidae
Bathygenys alpha Douglass
Merycoidodon sp.
Camelidae
Poebrotherium sp.
Protoceratidae
"*Leptotragulus*" *profectus* (Matthew)
Leptomerycidae
Hendryomeryx new species
Leptomeryx new species
"*Leptomeryx*" *mammifer* Cope
"*Leptomeryx*" new species I
"*Leptomeryx*" new species M

Black (1965) suggested that sediments exposed in the Little Pipestone Creek area might, at least in part, be younger than those exposed at the Pipestone Springs localities. Tabrum and Fields (1980) also noted that a difference in age might be involved. Further collecting in the area subsequently led Fields et al. (1985, p. 34) to assign a "Middle to Late (?) Chadronian" age to the Climbing Arrow sediments exposed south of Little Pipestone Creek.

Garcia (1992), however, later concluded that the entire Little Pipestone Creek sequence was middle Chadronian in age and that the Little Pipestone Creek l.f. was about equivalent in age to the Pipestone Springs l.f. Garcia's conclusions were based on the strong similarities between the stratigraphic sections exposed in the two areas, coupled with the fact that all of the species recorded from the Little Pipestone Creek localities, except *Agriochoerus*? *maximus*, have also been reported from the Pipestone Springs l.f. He correlated the Little Pipestone Creek stratigraphic section even more closely with that preserved in the Delmoe Ditch area about one mile to the east in Sec. 9, T1N R5W, suggesting that the strata preserved in the Delmoe Ditch section were the same as those preserved in the upper part of the Little Pipestone Creek section. The very limited fauna known from the Delmoe Ditch area (University of Montana locality MV 6106) includes a specimen assigned to *Eutypomys thompsoni* by Kuenzi and Fields (1971). This specimen appears to be correctly identified and represents a species that is clearly distinct

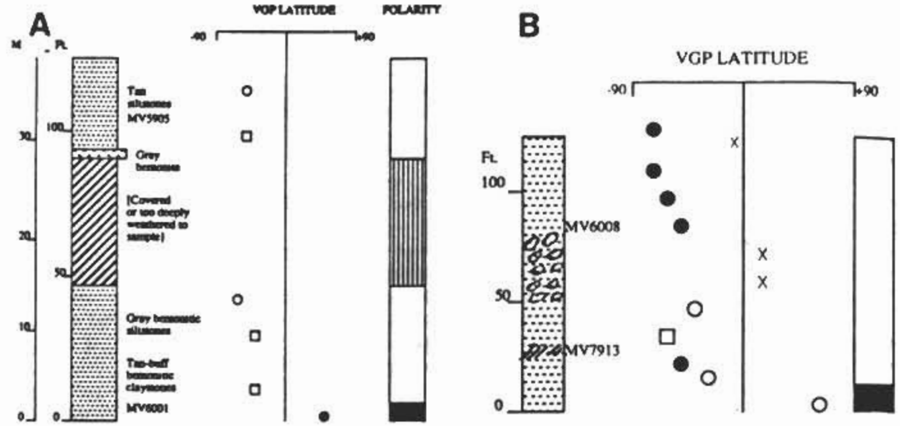

Figure 4. Magnetic stratigraphy of sections in the Jefferson River Basin. A. The Little Pipestone Springs section of Kuenzi and Fields (1971). Open boxes indicate Class II sites of Opdyke et al. (1977). B. Easter Lily section. Solid circles are Class I sites of Opdyke et al. (1977); open circles are Class III sites of Opdyke et al. (1977). "x" indicates an indeterminate site.

from the single specimen of *E. parvus* known from the Pipestone Springs Fence Pocket locality.

Emry et al. (1987, p. 138) listed the first appearance of "*Eutypomys* near *E. thompsoni*" as indicative of a late Chadronian age, and on this basis at least part of the Delmoe Ditch section is late Chadronian in age. If Garcia's (1992) correlation based on lithostratigraphic criteria is correct, then part of the Little Pipestone Creek section would also appear to be late Chadronian in age, which may, in the absence of any obvious differences in ecology, help to account for some of the clear differences in faunal composition between the Pipestone Springs and Little Pipestone Creek localities.

At least part of the Little Pipestone Creek section is, however, demonstrably of middle Chadronian age. The middle Chadronian index taxon "*Leptomeryx*" *mammifer* has been recovered from the stratigraphically lowest Little Pipestone Creek locality, MV 6001, and possibly from the somewhat higher MV 5905, but not from the stratigraphically highest locality, MV 8603. *Ischyromys veterior* has also not been recovered from MV 8603, although *Ischyromys* n. sp. is fairly common. University of Montana locality MV 6001 is middle Chadronian in age, MV 8603 possibly late Chadronian, and MV 5905 apparently intermediate in age between the two. All may be somewhat younger than the Pipestone Springs local fauna.

About 120 feet of section in the Climbing Arrow Member of the Renova Formation were sampled at Little Pipestone Creek (Fig. 4). The stratigraphic section followed the transect shown in Kuenzi and Fields (1971, fig. 3), and began in the lowest exposures in NE NW NW section 17 and followed a northeasterly traverse to the uppermost continuous exposures in SE SE SW section 8, T1N R5W Vendome 7.5' quadrangle, Jefferson County, Montana. Although the middle part of the section was too deeply weathered or too covered for sampling, the remaining section (except for the lowest site) was entirely of reversed polarity. Based on the middle to late Chadronian age of the fauna and the similarity to the Pipestone Springs local fauna, the Little Pipestone Creek l.f. probably correlates with Chrons C13r-C15r, or about 34.5-35.0 Ma (Fig. 7).

Easter Lily section

Sediments assigned to the Dunbar Creek Member of the Renova Formation by Kuenzi and Fields (1971) are moderately well exposed north of the Burlington Northern Railroad tracks, about two miles northeast of the Pipestone Springs exposures. Matthew (1903) equated these beds with the Oreodon Beds of South Dakota and Colorado and first reported the presence of *Eumys* and other taxa indicative of an age younger than that of the Pipestone Springs l.f.

Two principal areas of good exposures are present: the Easter Lily (or Easter Lily Mine) section in sections 16 and 21, T2N R5W, and the apparently stratigraphically higher Palisades (also known as the Palisades Cliff or Palisade Cliffs) section about one mile to the east in sections 15 and 22. Kuenzi and Fields (1971) reported a thickness of 275 feet for the Dunbar Creek sediments discontinuously exposed in the Easter Lily section and 320 feet for the stratigraphically higher Palisades section.

Kuenzi and Fields (1971) assigned an Orellan age to the fossil vertebrates collected from both the Easter Lily and Palisades sections. However, further work has since established that most of the Easter Lily section is Chadronian in age (Lillegraven and Tabrum, 1983; French, 1988; Garcia, 1992). Kuenzi (1966) and Kuenzi and Fields (1971) assigned all of the vertebrates collected from the Easter Lily section, regardless of stratigraphic position, to the single University of Montana locality MV 6008, and their published faunal list (Kuenzi and Fields, 1971, table 2) consequently appears to consist of a mixture of Chadronian and Orellan taxa.

Table 3. West Easter Lily local fauna, Jefferson Basin: Localities in NE and SW Sec. 16, and NW Sec. 21, T2N R5W, Jefferson County, Montana. Dunbar Creek Member, Renova Formation. Late Chadronian.

DIDELPHIMORPHIA
- Didelphidae
  - *Herpetotherium valens* (Lambe)

INSECTIVORA
- Geolabididae
  - *Centetodon kuenzii* Lillegraven and Tabrum
- Aptenodontidae
  - *Apternodus mediaevus* Matthew

LAGOMORPHA
- Leporidae
  - *Megalagus brachyodon* (Matthew)
  - *Palaeolagus temnodon* Douglass
  - *Palaeolagus haydeni* Leidy

RODENTIA
- Ischyromyidae
  - *Ischyromys veterior* Matthew
  - *Ischyromys* sp.
- Eomyidae
  - *Paradjidaumo trilophus* (Cope)

CARNIVORA
- Canidae
  - *Hesperocyon*? sp.

PERISSODACTYLA
- Equidae
  - *Mesohippus bairdi* Leidy
  - *Miohippus obliquidens* (Osborn)
- Brontotheriidae
  - Brontotheriid sp.
- Hyracodontidae
  - *Hyracodon* sp.
- Rhinocerotidae
  - *Trigonias* sp., cf. *T. osborni* Lucas

ARTIODACTYLA
- Merycoidodontidae
  - *Merycoidodon* sp., cf. *M. culbertsoni* Leidy
- Leptomerycidae
  - "*Leptomeryx*" new species I
  - "*Leptomeryx*" new species M

Field work initiated in 1978 by Tabrum, C. C. Swisher III, R. Nichols, and later by L. B. French, resulted in the establishment of six new geographically and stratigraphically restricted localities in the Easter Lily exposures (French, 1988) and the recognition of two stratigraphically separated and biostratigraphically distinct local faunas. The name Easter Lily l.f. is retained for the Orellan assemblage recovered from the small area of exposures east of the access road to the Easter Lily Mine in the SW SE section 16. The late Chadronian West Easter Lily l.f. was derived from stratigraphically lower exposures in areas to the west and north (see French, 1988; Garcia, 1992).

The Easter Lily section is not richly fossiliferous, and unfortunately none of the specimens collected prior to 1978 retains sufficiently precise locality information to allow their unequivocal assignment to either the Easter Lily or West Easter Lily l.f. In addition to the taxa listed in Tables 3 and 4, specimens of *Cryptoryctes kayi*, *Cylindrodon fontis*, *Hyaenodon horridus*, *H. crucians*, *H. microdon*, *Agriochoerus* sp., and "*Leptotragulus*" *profectus* have been recovered from the Easter Lily section (Garcia, 1992). Although most of these appear to be Chadronian forms, available locality information is at present inadequate to allow assignment of any of these specimens to either of the local faunas currently recognized from the Easter Lily section. The following discussions of the West Easter Lily and Easter Lily local faunas are based entirely on specimens for which we have precise geographic and stratigraphic data.

West Easter Lily Local Fauna

Fossils recovered from University of Montana localities MV 7913, MV 7915, and MV 8105, in the SE SW section 16, and the NE NW section 21, T2N R5W, west of the unimproved dirt road that runs through the area, are assigned to the West Easter Lily l.f. The most fossiliferous and stratigraphically lowest locality, MV 7913, is approximately 44 m (144 feet) above the base of the Easter Lily section; MV 8105 is approximately 55 m (180 feet), and MV 7915 approximately 57 m (187 feet) above the base of the Easter Lily section (French, 1988). A fourth locality, MV 8111, from a separate area of exposures in the SW NE section 16, has produced a very sparse fauna that does not appear to differ from that known from the other localities and is also tentatively included in the West Easter Lily l.f.

As currently known, the West Easter Lily l.f. includes at least eighteen mammalian taxa (Table 3). Most of the available specimens were collected from MV 7913, the stratigraphically lowest locality. However, the only specimens of *Centetodon kuenzii* and *Mesohippus bairdi* known from the West Easter Lily l.f. were collected from MV 8105, and the only material of "*Leptomeryx*" n. sp. M was derived from MV 8111.

Although most of the species in the rather limited assemblage known from the West Easter Lily l.f. also occur in the much more diverse Pipestone Springs and Little Pipestone Creek local faunas, advances in the

Table 4. Easter Lily local fauna, Jefferson Basin: Localities in SE Sec. 16, and NE Sec. 21, T2N R5W, Jefferson County, Montana. Dunbar Creek Member, Renova Formation. Early Orellan.

- DIDELPHIMORPHIA
  - Didelphidae
    - *Herpetotherium valens* (Lambe)
    - *Herpetotherium fugax* Cope
    - *Copedelphys titanelix* (Matthew)
- INSECTIVORA
  - Geolabididae
    - *Centetodon kuenzii* Lillegraven and Tabrum
- LAGOMORPHA
  - Leporidae
    - *Palaeolagus haydeni* Leidy
    - "*Palaeolagus*" *intermedius* Matthew
    - "*Palaeolagus*" *burkei* Wood
- RODENTIA
  - Aplodontidae
    - *Prosciurus relictus* (Cope)
  - Cricetidae
    - *Eumys* sp., aff. *E. obliquidens* Wood
    - *Eumys* sp., cf. *E. cricetodontoides* White
- CARNIVORA
  - Canidae
    - *Hesperocyon*? sp.
- PERISSODACTYLA
  - Equidae
    - *Mesohippus bairdi* Leidy
    - *Miohippus obliquidens* (Osborn)
- ARTIODACTYLA
  - Leptomerycidae
    - *Leptomeryx* sp., cf. *L. evansi* Leidy

equids and possibly in the leporids suggest that the West Easter Lily l.f. is significantly younger than either Pipestone Springs or Little Pipestone Creek. The West Easter Lily l.f. is best regarded as late Chadronian in age. The most significant difference seems to be in the equids, where *Mesohippus bairdi* and *Miohippus obliquidens* have replaced the characteristic Pipestone Springs and Little Pipestone Creek species *Mesohippus westoni* and *Miohippus grandis* (Garcia, 1992). Both of these species first appear in the late Chadronian (Prothero and Shubin, 1989; see summary chapter to this volume).

Garcia (1992) has also identified specimens of both *Palaeolagus temnodon* and *P. haydeni* in the small sample of lagomorphs (mostly isolated teeth) known from MV 7913. This sample may be comparable to the large sample from the Orella A beds of Nebraska referred to *P. hemirhizis* by Korth and Hageman (1988), who suggested that some late Chadronian samples might also represent this species. Prothero and Whittlesey (in press) have suggested that *P. hemirhizis* is an artificial composite that includes specimens of both *P. temnodon* and *P. haydeni* and that these two species overlap slightly in range.

A magnetic section through the main sequence of the Easter Lily section was collected in 1980, starting at the lowest exposures in the wash in SE SE SW SW section 16, and ending at the top of the hill in the NE SW SW SE section 16. About 125 feet of section were sampled (Fig. 4B), and except for the lowest site, the entire section was of reversed polarity. Given the late Chadronian-early Orellan fauna, this section most likely correlates with Chron C13r, or about 33.7-34.3 Ma (Fig. 7).

Easter Lily Local Fauna

Fossil vertebrates assigned to the Easter Lily l.f. were collected from three closely related localities in a small area of fairly continuous exposures in the SW SW section 16, T2N R5W, east of the road that leads to the Easter Lily Mine. All specimens were derived from a single thick unit of massive tuffaceous mudstone with occassional calcareous horizons. The stratigraphically lowest specimens assigned to the Easter Lily l.f. were collected approximately 67 m (220 feet) above the base of the Easter Lily section (French, 1988).

The Easter Lily l.f. is a very limited assemblage that as presently known consists of only fourteen species of mammals (Table 4). About half of the species represented are shared with either the West Easter Lily l.f. or with earlier local faunas from the Pipestone Creeks area. Biochronologically important taxa that first appear in the Easter Lily l.f. include "*Palaeolagus*" *intermedius*, "*P.*" *burkei*, *Prosciurus relictus*, *Eumys*, and a species of *Leptomeryx* that is closely comparable to *L. evansi*. The Easter Lily l.f. also includes the last known occurrence of *Centetodon* in western Montana.

The presence of *Palaeolagus haydeni*, "*P.*" *intermedius*, "*P.*" *burkei*, *Prosciurus relictus*, possibly two species of *Eumys*, and *Leptomeryx* sp. cf. *L. evansi* all indicate an Orellan age for the Easter Lily l.f. The vertebrates from this stratigraphic level were assigned an early Orellan age by Lillegraven and Tabrum (1983) and Fields et al. (1985). The unstated reasons for this age assignment were: (1) the relatively short stratigraphic separation, without an obvious hiatus, between these localities and localities of demonstrable late Chadronian age; and (2) the presence of a morphologically primitive species of *Eumys* similar to, but larger than, *E. obliquidens*, then regarded, following Galbreath (1953), as probably indicative of a relatively early Orellan age. An early Orellan age assignment also seemed to be supported by the presence of *Eumys cricetodontoides* (or *E. elegans* if one accepts the synonymy of Martin, 1980) in the stratigraphically higher Palisades l.f. from exposures about one mile to the east.

An early Orellan age assignment for the Easter Lily l.f. also seems to be supported by the magnetic polarity stratigraphy of this part of the Easter Lily section (if we are correct in our belief that no major, unrecognized hiatus is present in the Easter Lily section). The sites sampled by Prothero in this part of the Easter Lily section were all of reversed polarity and appear to represent a continuation of the interval of reversed polarity sampled in the late Chadronian part of the section, interpreted here as Chron C13r, and would suggest an age of about 33.5-33.7 Ma for the Orellan part of the Easter Lily section.

If this interpretation is correct, then both *Eumys* and "*Palaeolagus*" *burkei* occur significantly earlier in southwestern Montana than they do in the central Great Plains region. In western Nebraska and eastern Wyoming, *Eumys* first appears late in Chron C13n in deposits of Orella B age, and "*P.*" *burkei* early in Chron C12r in deposits of Orella C age (Korth, 1989; Prothero and Emry, this volume, Summary chapter). Storer (1994) has recently reported the presence of an *Eumys obliquidens*-like cricetid in the "latest Chadronian" Kealey Springs West l.f. of Saskatchewan. Although this l.f. is likely of Orellan age, rather than Chadronian as Storer suggested, the occurrence of *Eumys* seems certainly to predate the first record of the genus in Nebraska and Wyoming. Available evidence thus seems to suggest that the first appearance of *Eumys* is diachronous in different parts of the Great Plains region, and an unusually early record of *Eumys* in southwestern Montana does not seem unreasonable.

The presence of "*Palaeolagus*" *burkei* in the Easter Lily l.f. is more problematic. However, an obvious ancestor for "*P.*" *burkei* is lacking in the central Great Plains region, and the species appears to have been an immigrant to the Wyoming-Nebraska region early in Chron C12r. The association of "*P.*" *burkei* with a "primitive" species of *Eumys* in the Easter Lily l.f., coupled with the interpretation that this part of the Easter Lily section was deposited during C13r, suggests that "*P.*" *burkei* occurs significantly earlier in southwestern Montana than it does in the central Great Plains region.

BEAVERHEAD BASIN

Paleogene sediments referable to the Renova Formation are sporadically but locally well exposed in the Beaverhead Basin and have produced significant vertebrate assemblages from several localities. The two most diverse assemblages currently known are the early Chadronian fauna from the McCarty's Mountain locality, initially reported by Douglass (1905, 1908), and the previously almost entirely unreported late Duchesnean Diamond O Ranch l.f.

McCarty's Mountain Local Fauna

Fossil vertebrates were first recovered from the thick section of Tertiary sediments exposed at the McCarty's Mountain locality by Earl Douglass, collecting for the Carnegie Museum, on July 4 or 5, 1903. The fossiliferous sediments are moderately well exposed over an area of about one quarter square mile in section 28, T4S R8W, Madison County, on the north side of the Big Hole River about five miles south-southeast of McCarty's (now McCartney) Mountain.

Douglass worked the McCarty's Mountain locality, and other localities in the general area, for about four weeks, making a sizable collection. The Carnegie Museum collection was greatly enhanced by subsequent work conducted by Kay, who spent parts of several field seasons between 1937 and 1960 collecting at the locality. Several other institutions have also worked the McCarty's Mountain locality, with by far the largest and most important of these later collections those made by S. J. Riel for the University of Montana and by J. M. Rensberger and M. Asnake for the Burke Museum of the University of Washington.

Douglass (1905) briefly described the McCarty's Mountain deposits and variously referred to them as the "*Titanotherium* Beds" and "Lower White River Beds." Riel (1963), in his comprehensive review of the McCarty's Mountain locality, referred to the deposits only as "Lower Oligocene beds." Hoffman (1972) assigned the McCarty's Mountain beds to the Renova Formation, and Asnake (1984) later referred them to the Climbing Arrow Member. The beds exposed at the McCarty's Mountain locality do not, however, particularly closely resemble the type Climbing Arrow Formation in the Three Forks Basin, or sediments referred to the Climbing Arrow Formation or to the Climbing Arrow Member of the Renova Formation in other basins of southwestern Montana, and are probably best regarded as undifferentiated Renova Formation.

The McCarty's Mountain sediments dip 30-45° to the southwest and are discontinuously exposed in small fault blocks, complicating measurement of an accurate stratigraphic section. Douglass (1905) reported that the beds were more than 700 feet thick, and Riel (1963) cited a thickness of at least 1200 feet for the deposits. The stratigraphic section measured by Prothero (Fig. 5) followed Riel's (1963, plate 2) locality map and extended from the stratigraphically lowest deposits exposed near the center of section 28 (from a short distance northeast of the 5232' hill illustrated on the Block Mountain 7.5' Quadrangle) to the uppermost beds exposed in the NE SW section 28. Approximately 850 feet of continuous section were measured. This stratigraphic section appears to span nearly all of the McCarty's Mountain sequence.

Precise locality information is available for many of the specimens collected from the McCarty's Mountain section, and it should eventually prove possible to biostratigraphically zone the beds, although this is beyond the scope of the present chapter. In his 1903 field notes, Douglass divided the McCarty's Mountain beds into stratigraphically successive levels Q (lowest) through Z (highest). Most of the specimens that Douglass collected still retain their original field labels and, based on a comprehensive field catalog and two cross-sectional sketches in his field notes, can be assigned to their approximate position in the McCarty's Mountain stratigraphic sequence (Tabrum, 1994). Riel (1963, plate 2) plotted the precise location of the specimens he collected for the University of Montana on a greatly enlarged (scale: 1 inch = 234 feet) copy of the then preliminary USGS topographic map of the area. Most of Riel's specimens can be directly tied to the magnetostratigraphic section measured by Prothero. Detailed locality and stratigraphic data are also available for the University of Washington collection (Asnake, 1984).

Wood et al. (1941, p. 25) questioned both the unity and age of the McCarty's Mountain fauna, noting that

> McCarty's Mountain, so far as available knowledge goes, is merely a locality term for Oligocene exposures on its slopes or at its base . . . Douglass divided the exposures into several successive fossiliferous levels, but his unpublished notes have not been located; much or all of the Oligocene may be represented.

There was some justification for their concern, in that Douglass (1905) had indicated that he had collected specimens from more than one locality. These potential problems were not clarified by Kay et al. (1958), who included in their McCarty's Mountain faunal list some taxa that were based on specimens demonstrably collected from localities other than McCarty's Mountain. The concerns expressed by the Wood Committee were finally resolved in Riel's (1963) careful study of the McCarty's Mountain locality and by the subsequent recovery of Douglass's field notes. We restrict, as have most authors, the term "McCarty's Mountain fauna" to include only specimens derived from exposures in section 28, T4S R8W.

The known vertebrate fauna from the McCarty's Mountain locality includes turtles, lizards, and a moderately diversified assemblage of mammals. However, less than half the taxa in the McCarty's Mountain fauna have ever been formally described. For several of those that have, much larger samples are now available than are reflected in the moderately extensive but widely scattered literature. Good biostratigraphic data are available for many of the specimens, and further study of the McCarty's Mountain fauna should prove extremely profitable. Only the following elements of the fauna have thus far been described: the lizard *Helodermoides* (Douglass, 1908; Gilmore, 1928; Sullivan, 1989); leptictids (Douglass, 1905); *Centetodon* (Lillegraven et al., 1981); *Epoicotherium* (Douglass, 1905; Simpson, 1927); *Ischyromys* (Black, 1968; Wood, 1976); *Ardynomys* (Burke, 1936; Wood, 1970); *Pseudocylindrodon* (Burke, 1938; Black, 1974); *Colodon*? (Radinsky, 1963); *Triplopides* (Radinsky, 1967); *Protoreodon* (Wilson, 1971); the oreodonts *Limnenetes* and *Oreonetes* (Loomis, 1924; Thorpe, 1937; Scott, 1940; Schultz and Falkenbach, 1956); and *Montanatylopus* (Prothero, 1986). Wood (1980) attributed *Cylindrodon fontis* to the McCarty's Mountain fauna but did not list any referred specimens, and Black (1978) indicated that two specimens in the Carnegie Museum collection represented a new species of *Hendryomeryx* but did not describe the material. Storer (1984b) briefly discussed the McCarty's Mountain leptomerycids and concluded that *Hendryomeryx* was not present, a view endorsed here. In addition, Novacek (1976) has provided useful commentary on the leptictids.

The small oreodont *Oreonetes anceps* is probably the most common mammal in available collections, but *Colodon*? *cingulatus*, *Ischyromys douglassi*, and one or more species of *Pseudocylindrodon* are also represented by fairly large samples. Many of the small mammals, especially the marsupials, insectivores, and some of the smaller rodents, common in most of the other Paleogene local faunas of southwestern Montana, are not well represented in existing collections from McCarty's Mountain. Several of the small mammal species that were probably very common are known from only one or two specimens. A revised list of the McCarty's Mountain fauna is presented in Table 5.

Although Douglass (1905, 1908b) and subsequent authors regarded the McCarty's Mountain beds as "Lower Oligocene," Wood et al. (1941) questioned the age of the McCarty's Mountain fauna, and Kay et al. (1958), based in part on specimens that were not collected from the McCarty's Mountain locality, cited an age range of Chadronian to Whitneyan for the deposits. Riel (1963) recovered fragmentary brontothere remains from the uppermost exposures and firmly established the upper age limit of the McCarty's Mountain locality as Chadronian. However, the precise placement of the McCarty's Mountain fauna within the Chadronian has been disputed.

Based on the presence of *Oreonetes anceps* and *Limnenetes platyceps*, Schultz and Falkenbach (1956) assigned the McCarty's Mountain deposits to "the middle part of the Chadron formation," although neither of these taxa has ever been reported from the Chadron Formation in the Great Plains region. Wood (1974) suggested, based on the presence of *Ardynomys occidentalis* in both and the similar stage of evolution exhibited by *Ischyromys douglassi* and *I. blacki*, that the McCarty's Mountain fauna was most nearly equivalent in age to, but slightly younger than, the Porvenir fauna of West Texas, now considered to be late Duchesnean in age. Wood (1980, table 1) later revised this correlation slightly and listed the McCarty's Mountain fauna as about the same age as the early Chadronian Little Egypt l.f. Ostrander (1985) believed, based on the presence of *Cylindrodon fontis* and *Oreonetes*, that McCarty's Mountain was middle Chadronian in age. Emry et al. (1987) only peripherally discussed the McCarty's Mountain fauna, but noted similarities to the Airstrip l.f., which they assigned a middle Chadronian age. On their correlation chart (Emry et al., 1987, fig. 5.3) the McCarty's Mountain and Airstrip localities are illustrated as about equivalent in age, with both somewhat older than the Pipestone Springs and Ash Springs local faunas. More recently, Emry (1992) has suggested that the Airstrip l.f. is early Chadronian in age. Storer (1984b) strongly argued for an early Chadronian age for the McCarty's Mountain fauna based on the leptomerycids and suggested that McCarty's Mountain correlated in at least a general way with the lower part of the Flagstaff Rim section and with the Yoder, Southfork, and Titus Canyon local faunas. Storer (1989) later assigned a late Duchesnean age to these assemblages, but his definition of the Duchesnean/Chadronian boundary (Storer, 1990) approximates the early/middle Chadronian boundary of most other authors, and he has since abandoned this age assignment (Storer, this volume, Chapter 12).

Table 5. McCarty's Mountain local fauna, Beaverhead Basin: Localities in Sec. 28, T4S R8W, Madison County, Montana. Renova Formation undifferentiated. Early Chadronian. Carnivores identified by H. N. Bryant. (* = type locality.)

DIDELPHIMORPHIA
  Didelphidae
    Herpetotherium valens (Lambe)
    Copedelphys sp., cf. *C. titanelix* (Matthew)
PROTEUTHERIA
  Leptictidae
    Leptictus montanus (Douglass)*
    Leptictis major (Douglass)*
INSECTIVORA
  Geolabididae
    Centetodon magnus (Clark)
  Micropternodontidae
    Micropternodus sp.
  Apternodontidae
    Apternodus sp., cf. *A. mediaevus* Matthew
PALAEANODONTA
  Epoicotheriidae
    Epoicotherium unicum (Douglass)*
LAGOMORPHA
  Leporidae
    Megalagus? new species
    Palaeolagus sp.
RODENTIA
  Ischyromyidae
    Ischyromys douglassi Black*
  Cylindrodontidae
    Pseudocylindrodon medius Burke*
    Ardynomys occidentalis Burke*
    Cylindrodon sp., cf. *C. fontis* Douglass
  Eomyidae
    Paradjidaumo sp., cf. *P. trilophus* (Cope)
    Paradjidaumo new species, aff. *P. trilophus* (Cope)
  Heliscomyidae
    Heliscomys sp., cf. *H. ostranderi* Korth, Wahlert, and Emry
CREODONTA
  Hyaenodontidae
    Hyaenodon sp.
CARNIVORA
  Miacidae
    "*Miacis*" new species A
  Amphicyonidae
    Daphoenine (cf. *Daphoenictis*) new species
  Canidae
    Hesperocyon sp.
PERISSODACTYLA
  Equidae
    Mesohippus sp.
  Brontotheriidae
    Brontotheriid sp.
  Helaletidae
    Colodon? *cingulatus* Douglass
  Hyracodontidae
    Triplopides rieli Radinsky*
    Hyracodon sp.
  Rhinocerotidae
    Rhinocerotid sp.
ARTIODACTYLA
  Agriochoeridae
    Protoreodon minimus (Douglass)
  Merycoidodontidae
    Bathygenys sp., cf. *B. alpha* Douglass
    Oreonetes anceps (Douglass)
    Limnenetes platyceps Douglass
    Merycoidodontid large sp.
  Oromerycidae
    Montanatylopus matthewi Prothero*
  Camelidae
    Paratylopus? sp.
  Leptomerycidae
    "*Leptomeryx*" new species, aff. "*L.*" *speciosus* Lambe
    "*Leptomeryx*" new species

Based principally on the occurrence of *Ischyromys douglassi*, *Pseudocylindrodon medius*, *Ardynomys occidentalis*, *Colodon*? *cingulatus*, *Triplopides rieli*, *Protoreodon minimus*, *Oreonetes anceps*, *Limnenetes platyceps*, *Montanatylopus matthewi*, and the small leptomerycids here referred to "*Leptomeryx*" n. sp. aff. "*L.*" *speciosus* and "*Leptomeryx*" n. sp., the McCarty's Mountain fauna is considered to be early Chadronian in age. None of these species, which include some of the most common mammals in the McCarty's Mountain fauna, is present in the middle Chadronian Pipestone Springs l.f. McCarty's Mountain and Pipestone Springs share only a few relatively long-ranging species.

The McCarty's Mountain fauna correlates most closely with the early Chadronian part of the composite Thompson Creek fauna of authors, derived from the upper part of the Climbing Arrow Formation and possibly the lower part of the Dunbar Creek Formation in the Three Forks Basin. The described fauna from Thompson Creek is not very diverse, but several key taxa are shared with McCarty's Mountain. *Colodon? cingulatus*, *Protoreodon minimus*, *Oreonetes anceps*, and *Limnenetes platyceps* are present in both the McCarty's Mountain and Thompson Creek faunas but are not represented in the much more diverse Pipestone Springs l.f. At University of Montana locality MV 6403 (= loc. f158 of Robinson, 1963) in the upper part of the Climbing Arrow Formation, a small leptomerycid conspecific with "*Leptomeryx*" n. sp. aff. "*L.*" *speciosus* from McCarty's Mountain occurs with a larger leptomerycid that appears to be "*Leptomeryx*" *yoderi* and supports correlation of the McCarty's Mountain fauna with the lower part of the Flagstaff Rim section and the Yoder and Southfork local faunas.

The McCarty's Mountain fauna shares relatively few key taxa with early Chadronian localities outside western Montana. However, as Emry et al. (1987) noted, McCarty's Mountain does show a fairly strong resemblence to the very limited assemblage known from the Airstrip l.f. of West Texas. *Ardynomys*, *Bathygenys*, and *Limnenetes* occur in both, and the large oreodont that Wilson (1971) referred to ?*Prodesmatochoerus meekae* (*Merycoidodon presidioensis* of Stevens and Stevens, this volume, Chapter 25) may be the same taxon as the large unidentified oreodont from McCarty's Mountain.

The McCarty's Mountain section is very thick, and there is mounting evidence that some faunal turnover occurred during the course of deposition of the McCarty's Mountain beds. In the most detailed analysis of any group of mammals from the McCarty's Mountain fauna, Asnake (1984) divided the *Pseudocylindrodon medius* lineage into five stratigraphically superposed species. Some of his samples were small, and although we are presently unable to evaluate his work, at least some of the species Asnake recognized are probably valid. The McCarty's Mountain section also appears to document the transition between *Paradjidaumo* n. sp. aff. *P. trilophus* and *Paradjidaumo trilophus*. There also may be some discernible change in the oreodonts *Oreonetes* and *Limnenetes*. Schultz and Falkenbach (1956) named *Oreonetes anceps douglassi* for a smaller specimen with "lighter" premolars than other specimens of *O. anceps*, and ?*Limnenetes*, species undetermined, for a larger, more robust specimen than the holotype of *L. platyceps*; both specimens come from the stratigraphically highest part of the McCarty's Mountain sequence (Level Z of Douglass).

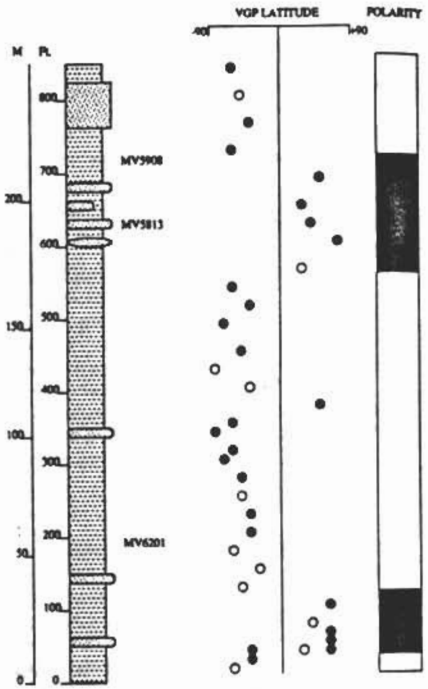

Figure 5. Magnetic stratigraphy of the main section at McCarty's Mountain. Conventions as in Figure 4.

Although our present knowledge of the biostratigraphy of the McCarty's Mountain locality is inadequate, the entire section appears to be early Chadronian in age. The holotype and most of the referred specimens of *Ischyromys douglassi* were collected from the stratigraphically highest part of the sequence (Level Z of Douglass), as were referred specimens of *Oreonetes anceps* and *Limnenetes platyceps*. The stratigraphically lowest part of the McCarty's Mountain sequence is more difficult to date, but *Oreonetes* has been recovered from near the base of the beds (Level R of Douglass) and "*Leptomeryx*" n. sp. aff. "*L.*" *speciosus* from only slightly higher in the section (Level S).

The magnetic stratigraphy and location of the main fossil localities are shown in Figure 5. Five polarity zones were recognized, with normal polarity occurring in rocks between 40-120 feet, and 550-720 feet on the local section; all of the remaining section was of reversed magnetic polarity. Based on the early Chadronian character of the mammalian fauna, the McCarty's Mountain section is correlated with Chrons C16r1 to C17n1, which would indicate a time span of 35.5-36.7 Ma (Fig. 7).

Table 6. Diamond O Ranch local fauna, Beaverhead Basin: Localities in Sec. 20, T5S R7W, Beaverhead County, Montana. Climbing Arrow Member, Renova Formation. Late Duchesnean. Carnivores identified by H.N. Bryant.

- DIDELPHIMORPHIA
  - Didelphidae
    - *Herpetotherium valens* (Lambe)
    - *Copedelphys* sp., cf. *C. titanelix* (Matthew)
- PROTEUTHERIA
  - Leptictidae
    - *Leptictis* sp.
- INSECTIVORA
  - Geolabididae
    - *Centetodon* sp., cf. *C. kuenzii* Lillegraven and Tabrum
  - Apternodontidae
    - *Oligoryctes* sp., cf. *O. cameronensis* Hough
    - *Apternodus* sp., cf. *A. mediaevus* Matthew
  - Soricidae
    - *Domnina* sp., cf. *D. thompsoni* Simpson
  - Proscalopidae
    - Proscalopid sp.
  - Insectivora, *incertae sedis*
    - *Cryptoryctes kayi* Reed
    - New genus and species
- PALAEANODONTA
  - Epoicotheriidae
    - *Epoicotherium* sp.
- LAGOMORPHA
  - Leporidae
    - *Megalagus*? new species
    - *Palaeolagus* sp.
- RODENTIA
  - Ischyromyidae
    - *Ischyromys* sp., cf. *I. douglassi* Black
  - Cylindrodontidae
    - *Pareumys*? sp.
    - *Pseudocylindrodon* sp.
    - *Ardynomys occidentalis* Burke
  - Eutypomyidae
    - *Eutypomys* sp.
  - Eomyidae
    - *Adjidaumo* new species, aff. *A. minimus* (Matthew)
    - *Paradjidaumo* new species, aff. *P. trilophus* (Cope)
- CREODONTA
  - Hyaenodontidae
    - *Hyaenodon* sp.
- CARNIVORA
  - Miacidae
    - "*Miacis*" new species B
  - Canidae
    - *Hesperocyon*? sp.
- PERISSODACTYLA
  - Equidae
    - *Mesohippus* sp.
  - Brontotheriidae
    - Brontotheriid sp.
  - Helaletidae
    - *Colodon*? *cingulatus* Douglass
  - Hyracodontidae
    - *Hyracodon*? sp.
  - Rhinocerotidae
    - Rhinocerotid sp.
- ARTIODACTYLA
  - Agriochoeridae
    - *Protoreodon* sp.
  - Leptomerycidae
    - *Hendryomeryx* sp., cf. *H. defordi* (Wilson)

Diamond O Ranch Local Fauna

The Diamond O Ranch l.f. is a previously unpublished assemblage derived from five closely related localities (University of Montana localities MV 6726 to MV 6730) on the north side of the Beaverhead River in section 20, T5S R7W, Beaverhead County, about seven miles southeast of the McCarty's Mountain localities and about two miles west of Beaverhead Rock. The Diamond O Ranch localities were first discovered by D. S. Hoffman in 1967 and the fauna was described by him in his unpublished Ph.D. dissertation (Hoffman, 1972). In 1984 Tabrum began reworking the localities, and sampling of a short magnetostratigraphic section was attempted by Prothero in 1987.

Hoffman (1972) assigned the relatively thin sequence (<100 feet) of gray bentonitic mudstones and interbedded sandstones exposed at the Diamond O Ranch localities to the Renova Formation, named by Kuenzi (1966) in his Ph.D. dissertation. Lithologically similar, but somewhat younger sediments about two miles to the east were subsequently assigned to the Climbing Arrow Member of the Renova Formation by Petkewich (1972). The Diamond O Ranch deposits are lithologically similar and approximately equivalent in age to part of the type Climbing Arrow Formation in the Three Forks Basin and to sediments referred to the Climbing Arrow Member of the Renova Formation in several of the other intermontane basins of southwestern Montana.

The Diamond O Ranch localities have produced a moderately diversified mammalian fauna, although only a single lower jaw of *Herpetotherium valens*, briefly mentioned by Korth (1994, p. 380), has previously been reported in the published literature. A small blowout near the base of the sequence, University of Montana locality MV 6726, is particularly noteworthy as the source of abundant well-preserved small-mammal specimens.

A list of the mammals from the Diamond O Ranch l.f. is presented in Table 6. A new species of *Megalagus*, comparable in size to species of *Palaeolagus*, is by far the most common mammal in the available collections, although its apparent abundance may in part be due to the ease with which isolated lagomorph teeth can be seen and collected. Other common small mammals include *Paradjidaumo* n. sp., *Apternodus* sp. cf. *A. mediaevus*, and *Herpetotherium valens*. The most common large mammals are *Hendryomeryx* sp. cf. *H. defordi*, followed by *Colodon*? *cingulatus* and *Mesohippus* sp.

Hoffman (1972) assigned a Chadronian age to the Diamond O Ranch l.f. Based principally on the presence of *Ardynomys occidentalis* and *Colodon*? *cingulatus* in both, as well as some similarities in other groups of mammals, Hoffman suggested that the Diamond O Ranch and McCarty's Mountain faunas were approximately contemporaneous. Further study, however, has indicated that the faunal similarities are not so great as Hoffman believed and that Diamond O Ranch is significantly older than McCarty's Mountain. The Diamond O Ranch l.f. appears to fall very near the Duchesnean/Chadronian boundary and is tentatively assigned a late Duchesnean age.

The Diamond O Ranch l.f. lacks the moderately diverse assemblage of oreodonts that dominates the McCarty's Mountain fauna and also lacks other taxa that are here considered indicative of an early Chadronian age. The leptomerycid at Diamond O Ranch is a species of *Hendryomeryx* that is probably conspecific with *H. defordi* from the late Duchesnean Porvenir fauna of West Texas and differs significantly from the small species of "*Leptomeryx*" present in McCarty's Mountain.

Only a few of the taxa present in the Diamond O Ranch l.f. are not known from Chadronian or younger faunas. *Hendryomeryx defordi* is otherwise known only from the late Duchesnean Porvenir fauna, although the apparently closely related *H. esulcatus* occurs in the middle Chadronian Calf Creek l.f. of Saskatchewan (Storer, 1981). An as yet unnamed new genus and species of insectivore (Adapisoricidae, gen. et sp. indet., in part, of Storer, 1984a) is also known from the late Uintan Swift Current Creek l.f. and the Duchesnean Lac Pelletier Lower Fauna of Saskatchewan and from the early Duchesnean Badwater locality 20 of Wyoming. *Pareumys* has also not been recorded from localities younger than Duchesnean in age.

Several specimens in the Diamond O Ranch l.f. seem to pertain to the leporid *Palaeolagus*, which has generally been regarded as first appearing in the Chadronian Mammal Age (e.g., Wood et al., 1941; Emry et al., 1987; Lucas, 1992). *Palaeolagus* first appears in the central Great Plains in the early Chadronian (Emry and Gawne, 1986) and is the earliest lagomorph recorded from the region. However, *Palaeolagus* appears to occur earlier in southwestern Montana than in the Great Plains region and may well occur much earlier if undescribed specimens from the Mantle Ranch l.f. of early or middle Duchesnean age are correctly identified.

The Diamond O Ranch l.f. contains the earliest known records of a number of lineages of small mammals that continue into or through the Chadronian of southwestern Montana, and form an important component of indigenous Chadronian small-mammal faunas. Species conspecific with or closely related to *Herpetotherium valens*, *Copedelphys titanelix*, *Apterno-dus mediaevus*, *Domnina thompsoni*, *Cryptoryctes kayi*, *Adjidaumo minimus*, and *Paradjidaumo trilophus* are all first recorded from the Diamond O Ranch l.f. The records of *Herpetotherium*, *Copedelphys*, and *Crypto-ryctes* are at present the earliest known for these genera.

Although about 100 feet of Renova Formation were exposed at the Diamond O Ranch localities, the bulk of the section proved too coarse-grained and poorly indurated for magnetic sampling. Only a single site near the base of the section at the main fossil locality was suitable for magnetic analysis, and it was of normal polarity. Such limited polarity information does not produce an unambiguous correlation, but based on the magnetic pattern of such late Duchesnean sequences as the Chambers Tuff which produces the Porvenir local fauna (Prothero, this volume, Chapter 9), the Diamond O ranch strata probably correlate with some part of the long episode of normal polarity during Chron C17n (Fig. 7).

SAGE CREEK BASIN

The Sage Creek Basin has produced the temporally most extensive suite of Cenozoic vertebrate localities currently known from any of the intermontane basins of southwestern Montana. Horizons of Bridgerian, Uintan, Chadronian, Orellan, Whitneyan, Arikareean, Hemingfordian, and Barstovian ages are all represented, with at least two biostratigraphically distinct horizons present in the Bridgerian, Uintan, Chadronian, and Orellan parts of the sequence. Bridgerian through Orellan sediments and associated volcanics are locally well exposed along the crest and eastern flank of the Red Rock Hills, north and west of Sage Creek. The most extensive, most fossiliferous, and historically most important of these deposits are discontinuously exposed over an area of approximately five square miles on the southeast flank of the Red Rock Hills, northwest of the "Big Bend" of Sage Creek.

Douglass (1909, p. 281) early noted that the Tertiary sediments exposed in the Sage Creek Basin appeared to be "partly of Eocene, partly of Oligocene, and partly of Miocene age." The complicated Cenozoic stratigraphy of the Sage Creek Basin has, for a variety of reasons, proven exceptionally difficult to unravel, principally because exposures are discontinuous, distinctions between some of the stratigraphic units are subtle, and the area has been extensively faulted. Interpretation of that part of the Tertiary sequence in the Sage Creek Basin traditionally regarded as Eocene in age has been particularly controversial, with conflicting or partially conflicting views presented by Wood (1934), Hough (1955, 1958), Scholten et al. (1955), and Fields et al. (1985).

Much of the interest in the Cenozoic deposits of the Sage Creek Basin stems from the early description by Douglass (1903) of four fragmentary vertebrates of Eocene age that he collected in 1897 from deposits he called the Sage Creek Beds. Douglass's four fossils—here identified as *Helaletes nanus*, *Hyrachyus douglassi*, *Colodon* sp. cf. *C. woodi*, and *Amynodon* sp. cf. *A. advenus*—were derived from two localities "about a half mile apart" (Douglass, 1903, p. 158). Douglass was somewhat equivocal about assigning an age to the Sage Creek Beds and did not suggest that his four fossils were all necessarily of the same age. Subsequent authors (Matthew, *in* Osborn and Matthew, 1909; Wood, 1934; Hough, 1955, 1958; Kay et al., 1958), however, all concluded that only a single horizon was represented, although earlier in his paper Wood (1934) had suggested the possibilty that both Bridgerian and Uintan horizons might be present. Because considerable taxonomic manipulation is required to interpret Douglass's four fossils as all of the same age, each has had a checkered taxonomic history.

In a largely unsuccessful attempt to resolve the apparent discrepancy posed by Douglass's four fossils, H. E. Wood briefly investigated the Sage Creek area in the summers of 1931 and 1933. The principal result of his first trip was the recovery of a small collection of "middle Oligocene" vertebrates from east-facing exposures opposite the Cook Sheep Company Home Ranch (Rock Island Ranch on the USGS 7.5' Quadrangle, now the Matador Ranch). Wood (1934) formally proposed the name Cook Ranch Formation for these beds.

Douglass (1903, p. 146) had described the locality that produced the specimens here identified as *Helaletes nanus* and *Hyrachyus douglassi* as "composed of stratified material, and it contains quartz geodes, tubes lined with crystals both of calcite and quartz, and calcified trunks and twigs of trees." On his second trip to the Sage Creek Basin, Wood succeeded in relocating this site. Wood (1934, p. 255) failed to find any additional identifiable Eocene fossils but eventually concluded that all four of Douglass's fossils were of "Lower Uinta age" and formally defined the Sage Creek Formation as consisting of "regularly bedded, fine-grained, greenish-gray sandstones, with interspersed, coarser, cross-bedded channel sandstones, ranging into conglomerates in some places." Wood noted that the contact between the Sage Creek Formation and the immediately overlying beds, which he referred to the Cook Ranch Formation, was strongly unconformable and marked by a unit of recemented debris derived from the Sage Creek Formation. The hiatus between the Sage Creek Formation and the overlying sediments referred to the Cook Ranch Formation was interpreted as representing the interval between "Lower Uinta" and "Middle Oligocene" time.

Shortly after publication of Wood's paper, Kay began collecting in the Sage Creek Basin for the Carnegie Museum. In 1937 he secured a few specimens of Eocene age from beds overlying the type Sage Creek Formation of Wood (1934). In 1939 Kay made a slightly larger collection of Eocene vertebrates from exposures about one half mile east of the Sage Creek type locality in the area between Draws 2 and 3 of Hough (1955, fig. 1—Hough and Kay Draws of this chapter). At least part, perhaps all, of Kay's 1937 collection also appears to have been derived from this area, and in 1940 a much larger collection was made from this locality. Kay devoted much of the 1940 field season to collecting in the Sage Creek Basin, also developing a late Chadronian quarry assemblage from exposures of the Cook Ranch Formation on the north side of Little Spring Gulch, about six miles north of the Cook Ranch type exposures. Kay continued to work intermittently at these and other localities in the area until his retirement from the Carnegie Museum in 1957.

In the early 1950s Hough became interested in the fossil vertebrates from the Sage Creek Basin, particularly the Eocene vertebrates, and conducted limited field investigations in the area during the 1950 through 1953 field seasons. Hough (1955) described some of the material that Kay and she had collected from Eocene beds overlying the type Sage Creek Formation of Wood (1934). Douglass (1903, p. 156) had stated (possibly erroneously) that the holotype of his *Hyrachyus*? *priscus* (= *H. douglassi*) was collected from "a breccia formed by the breaking up and recementing of the sandstone" and that "it was found a few feet below the specimen of *Heptodon*? [= *Helaletes nanus*]." This statement by Douglass, combined with the failure of later collecting parties to secure any additional specimens, or even bone scrap, from the greenish-gray sandstones of Wood's type Sage Creek Formation and the subsequent recovery of a moderately diverse and demonstrably Eocene fauna from the overlying beds, led Hough (1955, 1958) to conclude that all four of Douglass's Eocene specimens had been derived from the beds overlying the type Sage Creek Formation of Wood. Hough (1955, p. 25) suggested that the name Sage Creek beds more properly applied to these higher beds, noting that "the Sage Creek beds are obviously those beds from which Douglass obtained his fossils, i.e. the pinkish gray, fossiliferous tuffs above the disconformity at the type locality." Hough (1955, 1958) ultimately concluded that only a single Paleogene unit of formational rank was present in the Sage Creek area and synonymized the Cook Ranch Formation with the Sage Creek Formation, interpreting the Sage Creek Formation of Wood as a stream-channel facies of her redefined and expanded unit.

Extensive further investigations of the Cenozoic geology and vertebrate paleontology of the Sage Creek Basin initiated by Tabrum in 1977 have greatly increased the collections available from the area and have largely resolved the principal problems noted by the earlier investigators. Paleogene strata exposed in the area west of Sage Creek are divisible into the Bridgerian Sage Creek Formation, the Uintan Dell beds, and the Chadronian-Orellan Cook Ranch Formation (Fields et al., 1985). The Hall Spring basalt (= Sage Creek basalt of Scholten et al., 1955) locally intervenes between the Sage Creek Formation and the Dell beds, and was illlustrated in Fields et al. (1985, fig. 4) as a unit intermediate in age between the two. Further study indicates that the Hall Spring basalt is probably best treated as an upper member of the Sage Creek Formation.

During the course of his investigations, Tabrum was able to recover specimens from most of the key stratigraphic horizons in the area, including additional material of two of the four taxa reported by Douglass (1903). Several specimens of *Helaletes nanus*, two of which duplicate Douglass's specimen of *"Heptodon?"* were collected from the type Sage Creek Formation of Wood (1934), stratigraphically below the breccia that marks the contact between the Sage Creek Formation and the overlying Dell beds, which produced the "Upper Eocene" fossils reported by Hough (1955). These and a few additional specimens from the type locality establish the age of the type Sage Creek Formation as middle or late Bridgerian. Other localities in the Sage Creek Formation have produced specimens of early Bridgerian age. The presence of early Bridgerian specimens now identified as *Eotitanops* sp. and *Palaeosyops fontinalis* in the Sage Creek Formation was briefly noted by Wallace (1980) and Stucky (1984).

An amynodont jaw collected from exposures of the Dell beds about 0.75 miles northeast of the type locality of the Sage Creek Formation is conspecific with the specimen reported by Douglass from his second Sage Creek locality. The specimens from Douglass's second locality, *Amynodon* sp. cf. *A. advenus* and *Colodon* sp. cf. *C. woodi*, now seem certainly to have been collected from the Dell beds, probably from exposures on the east side of Douglass Draw (= Draw no. 6 of Hough, 1955, fig. 1) in the NW Sec. 33, T12S R8W. Wood (1934, p. 255) also suggested that this area was the probable site of Douglass's second Sage Creek locality, a conclusion further supported by information contained in Douglass's 1897 field notes.

Tabrum's field work in the Sage Creek Basin was significantly supplemented by the measurement of five magnetostratigraphic sections by Prothero. Sections were measured through the "lower," "middle," and "upper" parts of the Cook Ranch Formation in 1980 (Prothero, 1982). In 1987, Prothero and his field crew sampled two stratigraphic sections in the Dell beds. In the following sections we briefly summarize the biostratigraphic and magnetostratigraphic data currently available for the Dell beds and Cook Ranch Formation in the classic part of the Sage Creek area worked by Wood (1934) and Hough (1955, 1958).

Dell Beds

Based on Tabrum's work in the Sage Creek Basin, the name Dell beds was introduced in Fields et al. (1985) for an informal unit of formational rank that unconformably overlies the Sage Creek Formation (of Wood, 1934) and "Hall Spring basalt" (= Sage Creek basalt of Scholten et al., 1955). The Dell beds are in turn disconformably overlain by the Cook Ranch Formation. The formation is widely exposed in the area worked by Wood (1934) and Hough (1955, 1958), especially in Secs. 20, 21, 28, 29, and 33, T12S R8W, and is sporadically exposed along the crest and eastern flank of the Red Rock Hills as far north as the north side of Little Spring Gulch (Secs. 31 and 32, T12S R8W).

The Dell beds consist largely of poorly sorted tuffaceous mudstone and pebbly to cobbly tuffaceous mudstones interbedded with sandstone and conglomerate. Most of the conglomerates occur as lenses or steep-sided channel fills and locally contain abundant debris reworked from the Sage Creek Formation and Hall Spring basalt. Brightly colored cobbles and boulders of rhyolitic ash-flow tuff with sanidine phenocrysts occur as matrix-supported clasts in some of the tuffaceous mudstone units, in some of the conglomeratic units dominated by other rock types, and in monolithologic channel fills. Cobbles of this type have not been observed in any other part of the Cenozoic stratigraphic sequence in the Sage Creek Basin and appear to be restricted to the Dell beds.

The uppermost unit of the Dell beds is an approximately 60-foot thick unit of massive, well indurated tuffaceous mudstone which has produced most of the fossils known from the formation. Vertebrates recovered from this unit are referred to the Hough Draw l.f. Specimens collected from stratigraphically lower horizons in the Dell beds appear to represent a faunally distinct assemblage and are assigned to the Douglass Draw l.f.

Discontinuous exposures and extensive faulting make it difficult to reliably estimate the thickness of the Dell beds. Two apparently non-overlapping sections measured by Tabrum totaled 278 feet, but did not cover the entire formation. The total thickness of the Dell beds is estimated to be at least 300 to 400 feet in the area northwest of the "Big Bend" of Sage Creek. The Dell beds appear to thicken to the north, and may be in excess of 500 feet thick on the north side of Little Spring Gulch.

Table 7. Douglass Draw local fauna, Sage Creek Basin: Localities in Secs. 27, 28, 29, and 33, T12S R8W, Beaverhead County, Montana. Lower part of "Dell beds" (see Fields, et al., 1985). Late Uintan.

- RODENTIA
  - Cylindrodontidae
    - Cylindrodontid sp.
- PERISSODACTYLA
  - Brontotheriidae
    - Brontotheriid sp.
  - Helaletidae
    - *Dilophodon leotanus* (Peterson)
    - *Colodon kayi* (Hough)
    - *Colodon* sp., cf. *C. woodi* (Gazin)
  - Amynodontidae
    - *Amynodon* sp., cf. *A. advenus* (Marsh)
  - Hyracodontidae
    - *Triplopus* sp. cf. *T. rhinocerorhinus* (Wood)
    - Hyracodontid sp.
- ARTIODACTYLA
  - Homacodontidae
    - Homacodontid sp. A
  - Agriochoeridae
    - *Protoreodon* or *Diplobunops* sp.
  - Protoceratidae
    - *Leptoreodon marshi* Wortman

Table 8. Hough Draw local fauna, Sage Creek Basin: Localities in SE Sec. 28, and NE Sec. 33, T12S R8W, Beaverhead County, Montana. Upper part of "Dell beds" (see Fields et al.,1985). Late Uintan. (* = type locality.)

- DIDELPHIMORPHIA
  - Didelphidae
    - *Peratherium* sp., cf. *P. knighti* McGrew
- PALAEANODONTA
  - Epoicotheriidae
    - *Epoicotherium* sp.
- LAGOMORPHA
  - Leporidae
    - *Mytonolagus* sp., cf. *M. petersoni* Burke
- RODENTIA
  - Ischyromyidae
    - *Ischyromys*? sp.
  - Cylindrodontidae
    - *Pareumys*? new species
    - *Pseudocylindrodon* new species
  - Sciuravidae
    - Sciuravid sp.
- CARNIVORA
  - Miacidae
    - *Tapocyon* sp., nr. *T. robustus* (Peterson)
- PERISSODACTYLA
  - Equidae
    - *Epihippus* sp., cf. *E. uintensis* (Marsh)
  - Brontotheriidae
    - Brontotheriid sp.
  - Lophiodontidae
    - *Schizotheriodes parvus* Hough*
  - Helaletidae
    - *Dilophodon leotanus* (Peterson)
    - *Colodon kayi* (Hough)*
  - Hyracodontidae
    - Hyracodontid sp., cf. *Mesamynodon medius* Peterson
- ARTIODACTYLA
  - Homacodontidae
    - Homacodontid sp. B
  - Agriochoeridae
    - *"Protoreodon pearcei"* Gazin
    - *Protoreodon* sp., cf. *P. pumilus* (Marsh)
    - *Protoreodon* small sp.
  - Protoceratidae
    - Leptotraguline sp.

Douglass Draw Local Fauna

Fossil vertebrates collected from widely scattered localities in Secs. 28, 29, and 33, T12S R8W, have been grouped together, possibly artificially, as the Douglass Draw l.f. The available specimens were collected from various horizons stratigraphically below the massive mudstone in the uppermost part of the Dell beds that has produced the specimens assigned below to the Hough Draw l.f. Localities established by Tabrum in this part of the Dell beds include University of Montana localities MV 7757, MV 8112, MV 8114, and MV 8115. The specimens described by Douglass (1903) from his second Sage Creek locality—here assigned to *Colodon* sp. cf. *C. woodi* and *Amynodon* sp. cf. *A. advenus*—appear to have been derived from this part of the section, almost certainly from exposures on the east side of Douglass Draw. A few specimens collected by Kay for the Carnegie Museum retain locality data which indicate that they also were collected from this part of the Dell beds.

The stratigraphically lower part of the Dell beds is poorly fossiliferous, and at present only a very limited fauna is known (Table 7). The only relatively commonly encountered fossils are the fragmentary remains of tortoises. Identifiable mammals are rare, with only *Leptoreodon marshi*, *Amynodon* sp. cf. *A. advenus*, and one of the species of *Colodon* currently represented by more than a single specimen.

The available material seems adequate to establish the age of the Douglass Draw l.f. as late Uintan. *Dilophodon leotanus*, *Colodon woodi*, and *C. kayi* are first recorded from late Uintan deposits, and the remainder of the known assemblage is also consistent with a late

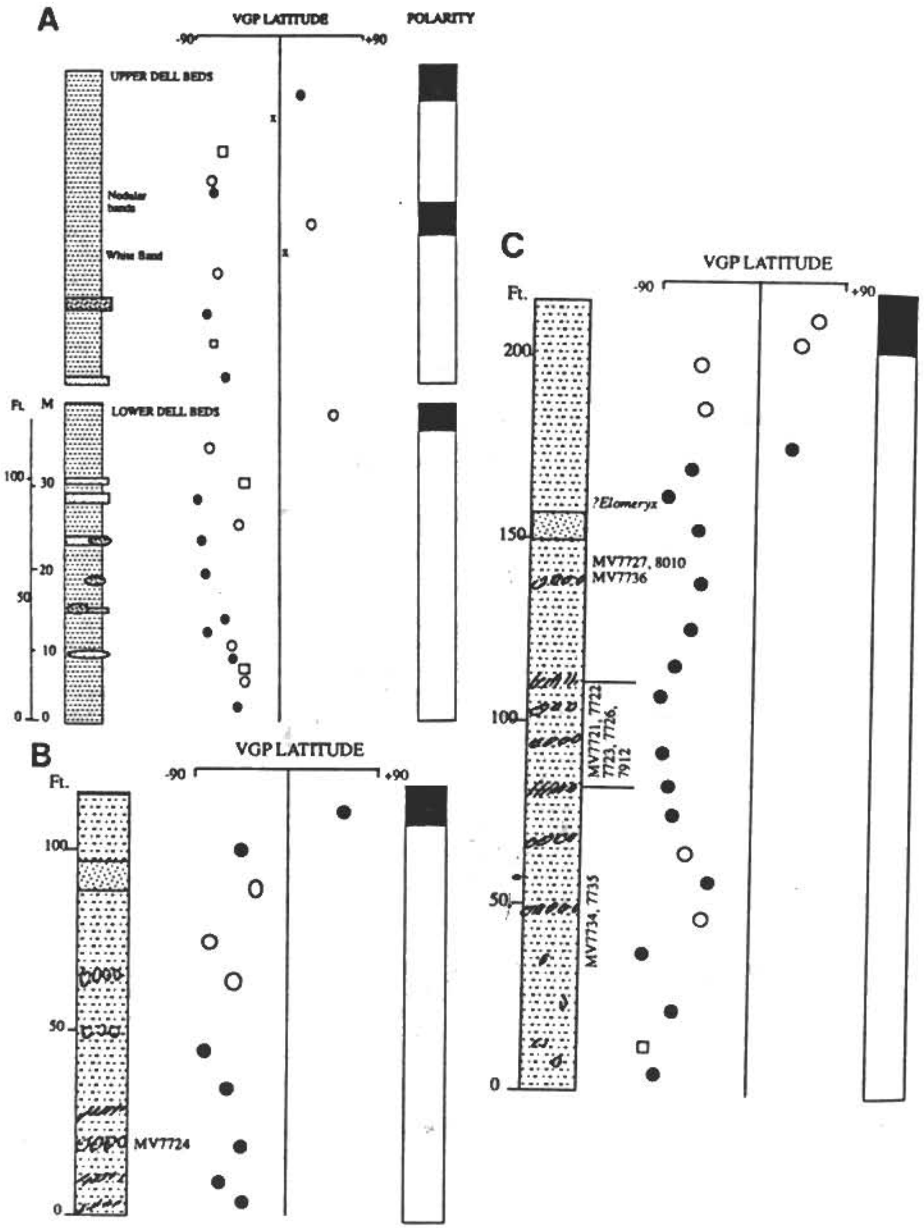

Figure 6. Magnetic stratigraphy of sections in the Sage Creek Basin. A. The late Uintan "Dell beds" (Fields et al., 1985). B. The middle-late Orellan Matador Ranch l.f. C. The late Orellan Cook Ranch l.f. All conventions as in Figs. 4 and 5.

Uintan age assignment. The presence of both *Colodon kayi* and *Colodon* sp. cf. *C. woodi* (if *C. woodi* is valid and Douglass's specimen is correctly identified as closer to this species than to *C. kayi*) in the Douglass Draw l.f. may indicate that more than one level is represented. It may also indicate that part or all of the Douglass Draw assemblage is equivalent in age to the Badwater late Uintan localities of central Wyoming.

In 1987 Prothero measured a magnetic section through the exposures on the east side of Douglass Draw in the NE NW NW Sec. 33, T12S R8W, Rock Island Ranch 7.5' Quadrangle, Beaverhead County, Montana. As noted above, the beds exposed at this locality now seem almost certainly to have been the source of Douglass's (1903) specimens here identified as *Amynodon* sp. cf. *A. advenus* and *Colodon* sp. cf. *C. woodi*. Prothero's section extended from the base of the exposures at an elevation of about 6440 feet eastward to the knob exposed at an elevation of approximately 6580 feet. The measured section totaled 133 feet, and except for the uppermost site, was entirely of reversed polarity (Fig. 6). Based on the late Uintan age of the fauna, the Douglass Draw section probably correlates with the early part of Chron C18r, about 40.7-41.0 Ma.

Hough Draw Local Fauna

Specimens assigned to the Hough Draw l.f. were collected from exposures of the Dell beds on the east side of Kay Draw and at various places along the short western branch of Hough Draw in the NE Sec. 33, and the southernmost part of the SE Sec. 28, T12S R8W (the area of localities C, D, and X of Hough, 1955, fig. 1). Specimens were derived from the stratigraphically highest part of the Dell beds, from an approximately 20-m-thick unit of massive tuffaceous mudstone exposed just below the contact of the Dell beds with the Cook Ranch Formation. This is easily the most fossiliferous part of the Dell beds, and most of the specimens collected by Kay and Hough were derived from this stratigraphic level. Four University of Montana localities (MV 6803, MV 7629, MV 7729, and MV 7730) were established; all four are stratigraphically equivalent but refer to slightly different collecting areas.

As presently known the Hough Draw l.f. includes at least nineteen mammalian taxa (Table 8). The fauna is dominated by "*Protoreodon pearcei*" and *Protoreodon* sp. cf. *P. pumilus*. *Dilophodon leotanus* and *Colodon kayi* are also reasonably common. *Mytonolagus* sp. cf. *M. petersoni* is probably the most common small mammal, but the available material consists largely of isolated teeth.

Hough (1955) assigned a ?Duchesnean age to the fossil vertebrates she reported from the Sage Creek area, correlating the fauna with those then known from the Badwater localities and from the Randlett Horizon of the Duchesne River Formation. Hough's correlation still seems to be essentially correct, although these localities are now regarded as late Uintan in age (Gazin, 1955, 1956). The Hough Draw l.f. is, however, probably somewhat advanced over that known from the late Uintan Badwater localities. *Colodon kayi* appears to be a later species than the Badwater *C. woodi* and persists into Chadronian time (Bjork, 1968). The Hough Draw specimens attributed to *Dilophodon leotanus* compare very closely to the type materials from the Randlett Horizon of the Duchesne River Formation; both are probably specifically distinct from the material from the Badwater localities referred to *D. leotanus* by Black (1979). The possible presence of *Ischyromys* in the Hough Draw l.f. also suggests an age somewhat younger than that of the Badwater late Uintan localities. The Hough Draw l.f. appears to be among the youngest Uintan local faunas known and may be of latest Uintan age. It is probably of about the same age as the Randlett Horizon of the Duchesne River Formation.

A magnetic section measured by Prothero in 1987 sampled the Dell beds exposed on the east side of Kay Draw (= Draw no. 3 of Hough, 1955, fig. 1) in the NE NW NE Sec. 33, T12S R8W, Rock Island Ranch 7.5' Quadrangle, Beaverhead County, Montana. The section extended from near the bottom of the wash at approximately the 6400' contour eastward to the uppermost beds exposed slightly below the crest of the ridge (elevation 6537 feet) that separates Kay Draw from the short, western branch of Hough Draw. Approximately 130 feet of continuous section were measured. The upper 61 feet of this section sampled a massive mudstone that has produced the Hough Draw local fauna. Except for two sites, the entire section was of reversed polarity (Fig. 6). The uppermost site, and site near the base of the fossiliferous massive mudstone unit, were of normal polarity. Based on the late (possibly latest) Uintan age of the Hough Draw local fauna and the superpositional relationship of these beds to those that produced the Douglass Draw local fauna, this part of the section appears to correlate with the later part of Chron C18r, about 40.2-40.7 Ma (Fig. 7).

Cook Ranch Formation

The Cook Ranch Formation was named by Wood (1934, p. 254) for east-facing exposures in the NW Sec. 34, T12S R8W, that produced a small assemblage of "middle Oligocene" vertebrates. As originally defined by Wood, the Cook Ranch Formation included nearly all of the "buff" colored Tertiary beds exposed above the type Sage Creek Formation. As discussed above, the stratigraphically lower part of these beds has since been excluded from the Cook Ranch Formation by Tabrum and is nowassigned to the lithologically distinct Dell

Beds of late Uintan age (Fields et al., 1985).

The Cook Ranch Formation is discontinuosly exposed along the eastern flank of the Red Rock Hills in a narrow belt generally less than one mile wide, extending from the type exposures in Sec. 34, T12S R8W, northerly to Sec. 33, T11S R8W. The Cook Ranch exposures have been truncated on the east by late Cenozoic faulting, and for a distance of about three miles, from slightly north of the type exposures to the northern part of Sec. 15, the Cook Ranch Formation has been faulted out of the sequence.

In the type area, the Cook Ranch Formation rests disconformably on the Dell Beds. The contact is marked by a well developed paleosol, well exposed on the east side of Kay Draw and along the scarp at the northern end of the short western branch of Hough Draw (NE Sec. 33, and SE Sec. 28, T12S R8W) Farther to the north, in the Little Spring Gulch area, the Cook Ranch Formation has been downfaulted relative to the Dell Beds.

At the type locality, the Cook Ranch Formation is unconformably overlain by approximately 90 feet of upper Tertiary conglomerate. Exposures to the north of the type locality, as well as those immediately south of it, are faulted into contact with the Little Sage Creek Beds of Fields et al. (1985) of late Hemingfordian/early Barstovian age. Stratigraphic relationships in the Sage Creek Basin are complex, and the Little Sage Creek Beds are also locally overlain by the conglomerate that unconformably overlies the type Cook Ranch Formation.

The Cook Ranch Formation consists largely of light-colored (typically very pale orange 10YR8/2, dry) tuffaceous mudstones with abundant calcareous nodular horizons interbedded with lesser amounts of conglomerate, sandstone, and a few beds of relatively pure, but partially devitrified volcanic ash. Nodular horizons are most common and best developed in the middle and upper parts of the Cook Ranch Formation. Several channel fills in the Orellan part of the section consist largely or entirely of cobbles and boulders of penecontemporaneous basalt, possibly reworked, at least in part, from an autoclastic debris-flow breccia exposed within the Cook Ranch Formation in the southern part of Sec. 27, T12S R8W.

Pervasive faulting and discontinuous exposures make it difficult to estimate the thickness of the Cook Ranch Formation. Four apparently non-overlapping sections measured by Tabrum in the type area totaled 484 feet, but probably did not include the entire formation. A better estimate for the thickness of the Cook Ranch Formation would appear to be approximately 600 to 700 feet.

The Cook Ranch Formation ranges in age from late Chadronian to late Orellan. The small assemblage reported by A.E. Wood (1933) and H.E. Wood (1934) from the type exposures was designated as a "principal correlative" of the Orellan Provincial Age by Wood et al. (1941). Further collecting in this area has since produced a large and diversified fauna of late Orellan age. Other localities in the Cook Ranch Formation have produced significantly older assemblages. A quarry assemblage developed by Kay from exposures on the north side of Little Spring Gulch, stratigraphically very low in the Cook Ranch Formation, includes abundant specimens of "*Leptotragulus*" *profectus* and "*Leptomeryx*" *speciosus*, but lacks the characteristic middle Chadronian species "*Leptomeryx*" *mammifer*, and appears to be of late Chadronian age. The other mammals known from the Little Spring Gulch l.f. are also consistent with a late Chadronian age assignment. Clark and Beerbower (*in* Clark et al., 1967) reported a specimen of *Daphoenocyon* (=*Brachyrhynchocyon*) *dodgei* from this locality, and it appears that it is the assemblage from Little Spring Gulch which led Clark and Beerbower to assign "Cook Ranch" to the late Chadronian on their correlation chart (Clark and Beerbower *in* Clark et al., 1967, fig. 24).

East Hough Draw Localities

The stratigraphically lowest part of the Cook Ranch Formation in the type area is very sparingly fossiliferous. Exposures just above the contact with the Dell beds in the SE SW SE Sec. 28, T12S R8W (University of Montana locality MV 7733, North Hough Draw no. 1) have produced only a few isolated teeth of *Palaeolagus temnodon* and a single cylindrodontid incisor. Approximately equivalent exposures on the east side of Hough Draw in the NE NE Sec. 33, and the adjacent part of Sec. 34, have provided a slightly more diverse, but still very limited, assemblage. The stratigraphically lower of the two East Hough Draw localities, MV 7732, has produced a fragmentary lower jaw of *Herpetotherium*? sp., and isolated teeth of an unidentified ischyromyid rodent, *Palaeolagus temnodon*, and a second leporid, possibly *Chadrolagus emryi*. The second East Hough Draw locality, MV 7731, at the eastern margin of these exposures in the NW NW NW Sec. 34, has produced isolated teeth of "*Leptomeryx*" *speciosus*, *Pardajidaumo trilophus*, *Ischyromys* sp., and a lagomorph that appears to be either *Chadrolagus emryi* or a related species. The sparse fauna from this area is probably late Chadronian in age.

Prothero measured a stratigraphic section through the East Hough Draw exposures in 1980. The section (Fig. 6) began at the 6480-foot contour in the SW NE NE NE Sec. 33, and continued up the spine of a ridge to the 6600-foot contour in the SE SE SE SE Sec. 28. Approximately 170 feet of section were sampled. Nearly the entire section was of reversed polarity. Based on the probable late Chadronian age for the vertebrates collected from this part of the Cook Ranch Formation, the section most likely correlates with Chron C13r, or about 33.7-34.3 Ma (Fig. 7).

Table 9. Matador Ranch local fauna, Sage Creek Basin: Localities in NE Sec. 33, NW nd SW Sec. 34, T12S R8W, Beaverhead County, Montana. Middle part of Cook Ranch Formation. Middle and/or late Orellan.

- DIDELPHIMORPHIA
  - Didelphidae
    - *Herpetotherium fugax* Cope
    - *Copedelphys* sp., cf. *C. stevensoni* (Cope)
- INSECTIVORA
  - Soricidae?
    - Soricid? sp.
  - Proscalopidae
    - *Oligoscalops*? sp.
- LAGOMORPHA
  - Leporidae
    - "*Palaeolagus*" *burkei* Wood
    - *Palaeolagus*? sp.
- RODENTIA
  - Aplodontidae
    - *Prosciurus* sp.
  - Eomyidae
    - *Adjidaumo* sp., cf. *A. minimus* (Matthew)
  - Heliscomyidae
    - *Heliscomys* sp.
  - Cricetidae
    - *Eumys* sp., cf. *E. elegans* Leidy
    - *Eumys* new species
- CARNIVORA
  - Canidae
    - *Hesperocyon gregarius* (Cope)
- PERISSODACTYLA
  - Equidae
    - *Mesohippus* sp.
  - Hyracodontidae
    - *Hyracodon*? sp.
- ARTIODACTYLA
  - Camelidae
    - *Poebrotherium* sp.
  - Leptomerycidae
    - *Leptomeryx* sp., aff. *L. evansi* Leidy

Matador Ranch Local Fauna

Fossils collected from the "middle part" of the Cook Ranch Formation are assigned to the Matador Ranch l.f. The available specimens were collected from south-facing exposures in the SE NE, Sec. 33, and west-facing exposures in the NW Sec. 34, T12S R8W. Four localities were established (University of Montana localities MV 7724, MV 7725, MV 7728, and MV 8116). The western localities, MV 7725 and MV 8116, appear to be stratigraphically lower than the eastern localities, MV 7724 and MV 7728. The intervening area is largely covered, but based on interpretation of photolinears it appears to be complexly faulted.

The Matador Ranch l.f. (Table 9) has produced a rather limited assemblage of Orellan age. The assemblage is dominated, especially at MV 7724, by abundant specimens of "*Palaeolagus*" *burkei*. *Eumys* is also fairly common, but the remaining taxa are represented by very small samples.

The stratigraphically lower localities, MV 7725 and MV 8116, have produced only a few specimens of "*Palaeolagus*" *burkei*, *Eumys*, and *Leptomeryx*, and may differ in age from the stratigraphically higher localities, MV 7724 and MV 7728. Specimens of *Eumys* from MV 7725 and MV 8116 compare closely with *E. elegans* and are probably referable to this species. Specimens from MV 7724 and MV 7728, however, appear to represent a more derived species of *Eumys* that parallels species of *Wilsoneumys* in the presence of a slender, delicate lower incisor and higher crowned cheek teeth with a more planar occlusal surface.

The Matador Ranch localities appear to be of middle or late Orellan age. "*Palaeolagus*" *burkei* is first recorded from beds of Orella C age, mid Chron C12r, in the Central Great Plains region (Korth, 1989a; Prothero and Emry, this volume, Summary chapter), but as noted above may occur earlier in southwestern Montana. *Eumys elegans* is a long-ranging, but typically middle to late Orellan, species. The presence of a relatively derived species of *Eumys* in the stratigraphically higher localities MV 7724 and MV 7728 may indicate a late Orellan age for this part of the Matador Ranch section.

Only the stratigraphically higher part of the Matador Ranch section has been paleomagnetically sampled. A section measured by Prothero in 1980 in the SW SE NW NW Sec. 34, T12S R8W, began at the base of the exposures at the 6420-foot contour and extended northeasterly to the 6560-foot contour. The richest of the Matador Ranch localities, MV 7724, occurs in the lower part of this section. A total of 130 feet of the "middle part" of the Cook Ranch Formation was sampled, and all except the uppermost sample were of reversed polarity. The section appears to correlate with the early part of Chron C12r, suggesting an age of about 32.5-33.0 Ma for the Matador Ranch l.f.

Cook Ranch Local Fauna

Fossil vertebrates collected from the east-facing type exposures of the Cook Ranch Formation in the NW Sec. 34, T12S R8W, are assigned to the Cook Ranch l.f. At the type locality approximately 207 feet (63.0 meters) of continuous section are exposed. The Cook Ranch type section is dominated by tuffaceous mudstone and pebbly tuffaceous mudstone with numerous nodular horizons, interbedded with lesser amounts of sandstone, conglomerate, and intraformational mudstone-pebble conglomerate. Most of the available specimens were collected from the middle part of the section, from an approximately 60-foot thick

Table 10. Cook Ranch local fauna, Sage Creek Basin: Localities in NW Sec. 34, T12S R8W, Beaverhead County, Montana. Upper part of Cook Ranch Formation (= type Cook Ranch Formation of Wood, 1934). Late Orellan. (* = type locality.)

- PERADECTIA
  - Peradectidae
    - *Nanodelphys hunti* (Cope)
- DIDELPHIMORPHIA
  - Didelphidae
    - *Herpetotherium fugax* Cope
    - *Copedelphys* sp., cf. *C. stevensoni* (Cope)
- INSECTIVORA
  - Erinaceidae
    - *Ocajila* sp., cf. *O. makpiyahe* MacDonald
  - Apternodontidae
    - *Oligoryctes* sp., cf. *O. altitalonidus* (Clark)
  - Soricidae
    - *Domnina* new species, aff. *D. gradata* Cope
  - Proscalopidae
    - *Oligoscalops* new species
  - Talpidae
    - Talpid new species A
    - Talpid? new species B
- CHIROPTERA
  - Vespertilionidae
    - Vespertilionid sp.
- LAGOMORPHA
  - Leporidae
    - *Megalagus* sp., cf. *M. turgidus* (Cope)
    - *Palaeolagus* sp., cf. *P. haydeni* Leidy
    - "*Palaeolagus*" *burkei* Wood
- RODENTIA
  - Ischyromyidae
    - *Ischyromys* new species?
  - Cylindrodontidae
    - *Pseudocylindrodon* new species
  - Aplodontidae
    - *Pelycomys* sp.
    - *Prosciurus* sp., cf. *P. parvus* Korth
    - *Prosciurus*? new species
    - *Sespemys*? new species
    - Prosciurine, new genus and species
  - Castoridae
    - *Agnotocastor* sp.
  - Eomyidae
    - *Adjidaumo minimus* (Matthew)
    - *Metadjidaumo* new species
    - *Paradjidaumo* new species
  - Heliscomyidae
    - *Heliscomys gregoryi* Wood*
    - *Heliscomys* sp., cf. *H. mcgrewi* Korth
  - Cricetidae
    - *Scottimus viduus* Korth
    - *Scottimus* sp.
    - *Eumys* sp., cf. *E. parvidens* Wood
    - *Eumys* sp., cf. *E. elegans* Leidy and/or *E. cricetodontoides* White
    - *Eumys* new species, aff. *E. brachyodus* Wood
    - *Wilsoneumys* new species
- CARNIVORA
  - Canidae
    - *Hesperocyon gregarius* (Cope)
  - Carnivora, *incertae sedis*
    - *Palaeogale sectoria* (Gervais)
- PERISSODACTYLA
  - Equidae
    - *Mesohippus* sp.
  - Hyracodontidae
    - *Hyracodon*? sp.
  - Rhinocerotidae
    - *Subhyracodon* sp.
- ARTIODACTYLA
  - Anthracotheriidae
    - *Elomeryx*? sp.
  - Merycoidodontidae
    - *Merycoidodon* sp., cf. *M. culbertsoni* Leidy
    - *Miniochoerus*? sp.
  - Camelidae
    - *Poebrotherium* sp.
  - Leptomerycidae
    - *Hendryomeryx*? sp.
    - *Leptomeryx* sp., aff. *L. evansi* Leidy
    - *Leptomeryx* new species

interval 80 to 140 feet above the base. The lower half of this interval is the most richly fossiliferous part of the sequence. Identifiable vertebrates have not thus far been recovered from the upper part of the type exposures, and only a few specimens are known from the lower part of the section.

The type Cook Ranch Formation is locally faulted and slumped, and some of the exposures are separated by covered intervals. Largely for this reason, Tabrum has divided the type Cook Ranch exposures into fourteen geographically and/or stratigraphically restricted localities. The most productive of these are University of Montana localities MV 7721, MV 7722, MV 7723, and MV 7726, which are stratigraphically equivalent, but geographically separated, localities in the middle part of the Cook Ranch type section. Localities MV 7734 and MV 7735 sample the stratigraphically lower part of the section, but each has produced only a few specimens.

A. E. Wood (1933) and H. E. Wood (1934) briefly reported on the small collections of fossil vertebrates made by their parties from the type Cook Ranch Formation during the 1931 and 1933 field seasons. Additional small collections were made by Kay and Hough during the course of their field work in the Sage Creek Basin. Further work by Tabrum has since greatly increased the available collections, and a large sample is now available from the Cook Ranch l.f.

After Pipestone Springs, the Cook Ranch l.f. (Table 10) is the most diverse mammalian local fauna currently known from any of the intermontane basins of southwestern Montana, but it is almost entirely undescribed. Only three specimens have thus far been formally reported in the published literature. A. E. Wood (1933) described the holotype of *Heliscomys gregoryi*, and Hough (1961) attributed two specimens to her new genus and species of marsupial, *Didelphidectes pumilus*. Both of Hough's specimens appear, however, to pertain to the common Cook Ranch didelphid *Herpetotherium fugax*.

The Cook Ranch l.f. is predominantly a small-mammal fauna and has produced a diverse assemblage of marsupials, insectivores, chiropterans, lagomorphs, and rodents. Large mammals are present, but are relatively uncommon. "*Palaeolagus*" *burkei* is the most common mammal in the available, largely surface-collected sample, as it is in the stratigraphically lower Matador Ranch l.f. *Wilsoneumys* n. sp., *Megalagus* sp. cf. *M. turgidus*, and *Herpetotherium fugax* are also represented by large samples. Other common small mammals include *Prosciurus*? n. sp., *Sespemys*? n. sp., and *Adjidaumo minimus*. *Leptomeryx* n. sp. is the only moderately common large mammal. Rare mammals include late records of an apternodontid (*Oligoryctes* sp. cf. *O. altitalonidus*) and a cylindrodontid (*Pseudocylindrodon*? n. sp.) and early occurrences of talpids and a species of *Ocajila* close to *O. makpiyahe*.

The Cook Ranch l.f. is highly endemic, which hinders attempts at correlation with approximately contemporaneous assemblages from the Great Plains region. Of the 32 Cook Ranch taxa that are here regarded as specifically determinate, only 13 appear to be conspecific with forms known from contemporaneous deposits of the Great Plains region, and most of these are relatively long-ranging forms. This figure will probably increase somewhat when some of the large mammals are more precisely identified but will probably not significantly enhance correlation.

Wood et al. (1941, p. 11) designated "Cook Ranch and other scattered Montana deposits" as the principal correlatives of the Orellan Provincial Age, even though only a small assemblage was then known from the Cook Ranch Formation, and only from the east-facing type exposures (= Cook Ranch l.f.). The large sample now known from the Cook Ranch l.f. seems to be indicative of a late, probably latest, Orellan age, equivalent to, or perhaps slightly later than, the Orella D beds of Nebraska. Because of the high degree of endemism exhibited by the Cook Ranch l.f. only a very few biostratigraphically useful species are shared with approximately contemporaneous assemblages from the Great Plains region. *Heliscomys* sp. cf. *H. mcgrewi* from the Cook Ranch l.f. (Korth and Tabrum, MS) is, however, probably conspecific with *H. mcgrewi*, otherwise known only from beds of Orella D age in Nebraska and Wyoming (Korth, 1989a). *Heliscomys* sp. cf. *H. mcgrewi* is one of the few taxa known from both the lower and middle parts of the type section of the Cook Ranch Formation; the presence of *H.* sp. cf. *H. mcgrewi* in both suggests that the entire fossiliferous part of the type section is of late Orellan age.

Several taxa from the Cook Ranch l.f. appear to be somewhat advanced over their counterparts in the most nearly contemporaneous assemblages from the Great Plains region. The cricetid *Wilsoneumys planidens* was reported by Korth (1989a) to be restricted to beds of Orella D age in the Great Plains region. *Wilsoneumys* n. sp. from Cook Ranch is a larger, dentally more derived species, which may indicate that the Cook Ranch l.f. is of very late Orella D age. Some of the Cook Ranch aplodontids also seem advanced compared to those described by Korth (1989b) from the Orellan of Nebraska: *Prosciurus*? n. sp. is comparable in size to *Prosciurus relictus* but possesses features suggestive of relationship to the Whitneyan *Haplomys liolophus*; *Sespemys*? n. sp. is a small species possibly related to the Whitneyan *Sespemys thurstoni*; and an as yet unnamed new genus and species of prosciurine exhibits some characters usually associated with allomyines. These, and other, differences between mammals from the Cook Ranch l.f. and those from approximately contemporaneous assemblages of the Great Plains region appear largely to be related to faunal endemism but possibly also reflect a slight difference in age.

The Cook Ranch l.f. most strongly resembles the late Orellan Cedar Ridge l.f. of the Badwater Creek area, central Wyoming (Setoguchi, 1978; Korth, 1989a, 1994), although only a few species are actually shared between the two. The eomyid rodent *Metadjidaumo* is known only from the Cedar Ridge and Cook Ranch local faunas; *Metadjidaumo* n. sp. from Cook Ranch is very close to the Cedar Ridge *M. hendryi*, differing principally in having slightly wider cheek teeth (Korth and Tabrum, MS). Specimens from the Cedar Ridge l.f. referred to *Paradjidaumo hypsodus* by Setoguchi (1978) appear to represent at least three distinct species of eomyid, and two small, atypical teeth may instead pertain to the new species of *Paradjidaumo* known from the Cook Ranch l.f. (Korth and Tabrum, MS). Both local faunas also possess a small species of *Adjidaumo*, which, although not conspecific, differ significantly from the contemporaneous *A. minutus* of the Great Plains region. In addition, the assemblage of cricetid rodents in both the Cedar Ridge and Cook Ranch local faunas is dominated by *Wilsoneumys*. The Cook Ranch *Wilson-eumys* is a more derived species than *W. planidens* from Cedar Ridge, which may suggest that the Cook Ranch l.f. is slightly later in age. Of the few species that are present in both the Cedar Ridge and Cook Ranch local faunas, *Heliscomys mcgrewi* is probably the most biochronologically useful and, as noted above, is restricted to beds of late Orellan (Orella D) age (Korth, 1989a).

Prothero sampled the type Cook Ranch Formation for paleomagnetic analysis in 1980. Approximately 230 feet of continuous section were measured (Fig. 6). The section ascended the east face of the prominent ridge exposed in the SW SW NE NW Sec. 34, T12S R8W

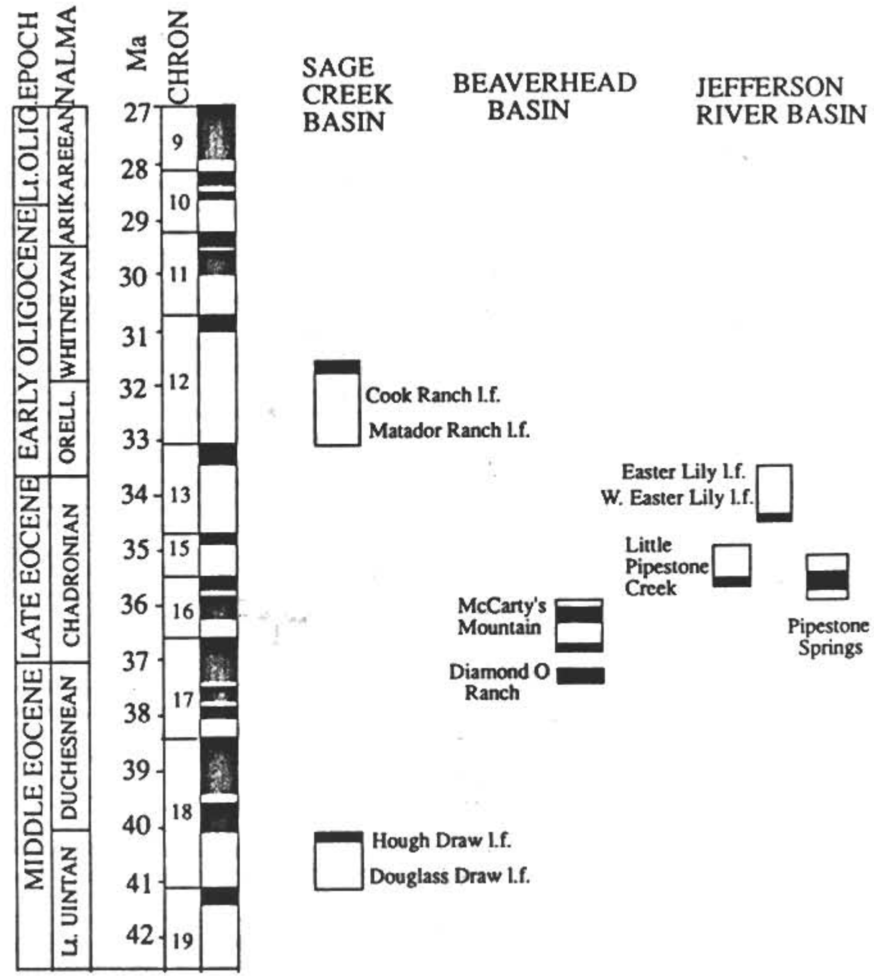

Figure 7. Temporal correlation of the sections in this study. Time scale after Berggren et al. (1995).

Rock Island Ranch 7.5' Quadrangle, Beaverhead County, Montana, beginning at the base of the exposures at the 6400-foot contour and extending due west to the uppermost exposures at the 6620-foot contour. Except for two sites, the entire section was of reversed polarity. Based on the late Orellan age of the Cook Ranch l.f., the type Cook Ranch Formation appears to correlate with the early part of Chron C12r, about 32.0-32.5 Ma (Fig. 7). The Cook Ranch l.f. seems to fall very near the Orellan/Whitneyan boundary and thus appears to be approximately 32.0 Ma in age.

DISCUSSION

The mammalian local faunas of southwestern Montana strongly reflect the significant biogeographic provincialism that characterized western North America during the Eocene-Oligocene transition. The local faunas discussed here contain many species that appear to have been endemic to the region. The largest and most diversified of these local faunas (Pipestone Springs, Little Pipestone Creek, McCarty's Mountain, Diamond O Ranch, Hough Draw, Cook Ranch) exhibit moderate to high levels of faunal endemism. The late Uintan Hough Draw local fauna and the middle Chadronian Pipestone Springs and Little Pipestone Creek local faunas each contain about 20-25% species that seem to have been endemic to southwestern Montana. Slightly more than 40% of the species in the McCarty's Mountain, Cook Ranch, and the Diamond O Ranch local faunas have not been recorded from contemporaneous localities in other parts of North America. Peak endemism thus occurs in the early Chadronian, late Orellan, and possibly in the late Duchesnean part of the Montana sequence.

Several biochronologically important mammalian taxa, including talpids, *Ocajila*, *Megalagus*, *Palaeolagus*, *Palaeogale*, and *Leptomeryx sensu stricto*, appear to occur significantly earlier in Montana that they do in the High Plains, which others, including apternodontids and cylindrodontids, persist later. Of the taxa that have earlier records in southwestern Montana than elsewhere in North America, talpids, *Palaeogale*, and *Ocajila* are either demonstrably or probably immigrants from Eurasia, which may indicate that southwestern Montana provided an environmentally more favorable dispersal route for these forms than was available in the High Plains. This is also supported by the presence in southwestern Montana of taxa closely related to those that gave rise to Asian species of *Ardynomys* and *Eomys*, both groups immigrating to Asia from North America.

The principal reasons for the significant differences between the Eocene-Oligocene mammalian faunas of southwestern Montana and the generally better-studied coeval faunas of the High Plains appear straightforward. Lillegraven and Tabrum (1983) discussed the major differences in paleoenvironmental setting between the relatively open environment of the High Plains region and that of the small intermontane basins of southwestern Montana. They concluded that the "overall large-scale habitats" represented in the two regions were demonstrably quite different (Lillegraven and Tabrum, 1983, p. 69). The generally high level of endemism exhibited in the local faunas of southwestern Montana appears to be due to the higher elevation of the sites in Montana, the much greater topographic complexity of the region, and close proximity of many of the sites to areas of significant topographic relief, coupled with differences in climatic regime.

The available paleobotanical evidence, reviewed by Wing (1987), also clearly supports an upland setting for the Paleogene deposits of southwestern Montana. The "Beaverhead Basin" floras (from the contiguous Medicine Lodge, Horse Prairie, and Grasshopper basins), of probable Chadronian age (Fields et al., 1985), and the apparently somewhat younger floras from the Upper Ruby River Basin, represent mixed coniferous and deciduous broad-leaved forests that are similar to the Florissant and Red Rock Ranch floras of Colorado and New Mexico. Wing (1987, p. 763) suggested that these floras all indicate growth at an "intermediate elevation" under a seasonally dry climate. Wing also noted that the greater diversity of conifers and mesic taxa in the "Beaverhead Basin" floras than in the Florissant and Red Rock Ranch floras might indicate higher rainfall in the northern part of the Rocky Moutains than in parts of Colorado and New Mexico at comparable elevation. The apparently younger (possibly Orellan to Whitneyan) Upper Ruby River Basin floras, though generally similar to the "Beaverhead Basin" floras, appear to indiate some increase in seasonal aridity.

CONCLUSION

Although the Paleogene record in southwestern Montana is patchy, significant local faunas ranging in age from Bridgerian to Arikareean age are preserved in the numerous small intermontane basins of the region. Magnetic stratigraphy has provided a powerful adjunct to biochronology in our continuing quest to generate progressively more precise age assignments for the local faunas known from the region. Our results confirm and strengthen the age assignments suggested by Fields et al. (1985) and add a level of precision hitherto unattainable. Our suggested correlations of the magnetic sections is summarized in Figure 7. These results show the limited temporal span of most of these intermontane sequences. Although some are thousands of feet thick, few appear to span more than a million years, and most are much shorter in duration. This demonstrates just how rapidly these fault-bounded basins were subsiding and filling up during the Paleogene.

ACKNOWLEDGMENTS

We thank Tony Barnosky, Bob Emry, John Rensberger, and John Storer for their helpful reviews of this chapter. Prothero was supported by Columbia University Department of Geology field funds during the 1980 season, and by the Donors of the Petroleum Research Fund of the American Chemical Society during the 1983 and 1986 field seasons. The 1987 field work was supported by NSF grant EAR87-08221. The 1980 research was undertaken under the supervision of Dr. Malcolm C. McKenna. Prothero thanks Chuck Denham, Bill Roggenthen, and Joe Kirschvink for graciously allowing access to their paleomagnetics laboratories. The magnetic sampling and analysis would never have been possible without the hard work and cheerful good spirits of several field crews. In 1980, they included Priscilla Duskin, Jon Frenzel, and Heidi Shlosar. In 1983, they included Rob Lander and Annie Walton. The 1986 samples were collected by Dana Gilchrist, Kecia Harris, and Allison Kozak. The 1987 samples were collected by Jill Bush, John Foster, and Steve King.

Tabrum's field work in southwestern Montana was supported by grants from Amoco Production Company, the Penrose Fund of the Geological Society of America, the STATEMAP program, and the O'Neil (to Dr. Mary Dawson) and M. Graham Netting research funds of the Carnegie Museum. Copies of Earl Douglass's field notes were also acquired via a grant from the Netting Research Fund. Heartfelt thanks are owed to many people. Dennis Dunlap provided lodging, many meals, and his great wit during the 1981 field season. Malcolm McKenna generously provided financial and logistical support for field work conducted during the 1984, 1985, and 1987 field seasons. Landowners Norman and Gay Ashcraft, and Thomas and Ann Dooling graciously allowed unlimited access to localities on their land. During the course of five extended and ten shorter field seasons devoted to the study of the Cenozoic rocks and faunas of southwestern Montana, many people assisted in the collection of materials. Principal among these were Carol Goozey, Dennis Dunlap, Andy Wyss, Ralph Nichols, Carl Swisher, Larry French, Kim Bideganeta, Barbara Pitman, and Bill Leistner. Special thanks are extended to Debbie Hanneman and Chuck Wideman for their warm hospitality and enthusiastic support of Tabrum's field work, and to Susan Vuke for providing a base of operations for the 1994 field season. The continuing support of Mary Dawson of the Carnegie Museum for field endeavors in southwestern Montana is deeply appreciated.

Garcia's field work was funded by the Museum of Paleontology, University of California, and by a grant from the Society of Sigma Xi. Landowners in the Little Pipestone Creek area, particularly the members of the Alley family, generously permitted access to the localities on their land. Assistance in the field was provided by Mark Garcia, Don Lofgren, and John Rittel. Debbie Hanneman and Chuck Wideman provided key logistical support.

Tabrum and Garcia acknowledge a tremendous debt to the late Dr. Robert W. Fields (September 17, 1920–August 23, 1995), Professor of Geology at the University of Montana, mentor, and friend. He introduced them to the wonders of the Tertiary of southwestern Montana, and unceasingly supported them during their years as graduate students at the University of Montana. We dedicate this paper to his memory.

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