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

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INTRODUCTION

Oxygen and Carbon isotopes and radiometric dates are sporadically but largely well exposed in the southwestern Montana sequence of the Eocene and Oligocene. Modern exposure is very large across the state, but most of the samples exist on the surface or are exposed in road cuts. Most of the samples are in the Oligocene, with a few scattered Oligocene samples also in the Eocene. Despite this, the samples are generally unrepresentative of the entire sequence. In the Oligocene, the samples are generally from the middle and lower members of the Oligocene, but in the Eocene, the samples are generally from the upper members of the Eocene.

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Figure 1. Index map showing location of sites mentioned in text. Locations: C5, Creek Camp; D5, Diamond Peak Camp; E0, Dolly Llama; E3, Loïle Pinnacles; H3, McCardy Mountain; P3, Pajaroan Springs, S0, Sage Camp.

Douglas described some of the Palaeogene vegetation he had collected in a series of papers published between 1919 and 1908 (Douglas 1901, 1903, 1905, 1907, 1908a, 1911). Douglas was hired by the Carnegie Museum in 1902 and his large collection of Palaeogene fossils from southwestern Montana became one of the first key acquisitions made by the museum. Douglas's field notes were not, however, acquired at the time and for many years were unavailable and presumed lost (Wood et al., 1941, p. 253). In 1976 Greaves Douglas donated his father's extensive surviving papers to the Mountaineer Library of the University of Utah; these notes contain a wealth of useful information, including much more precise locality data for many of the specimens Douglas collected than had been retained in the Carnegie Museum records.

In 1974 Leif 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 thereby increasing the sample available from many of the localities previously worked by Douglas. The collection amassed by Douglas and Kay is housed at the Carnegie Museum, and Kay's field notes are the largest and historically most important collection of Palaeogene fossil locality data currently available.

Many programs in the Palaeogene of southwestern Montana have been completed by Robert W. Field and his students at the University of Michigan. During the last decade, Field and his students have been the leading proponent to investigate the stratigraphy and biostratigraphy of the Palaeogene deposits of the region. They have used the methods described in the Carnegie geology and geochronology of the Mesozoic.
southeastern Montana. These were laid in part on the fine unconsolidated, but waxy, circular, botanically studies of Eady et al. (1987) and Tollifson et al. (1992), combined with the preliminary results of some of the existing, geologic-time scale (Bergstrom et al., 1992, 1995) coupled with refinements in both the temporal nature of the western North American Land Mammal Ages (Bergstrom, 1988). Proctor and Sessions, 1992) have found that the oldest member of this age was estimated to provide a first example, published in 1993, Fig. 2) the fossiliferous member at 36.5 Ma, within the Chattean Land Mammal Age (Bergstrom and Sessions, 1992) as the Chattean at 33.3-37.0 Ma (Proctor and Sessions, 1992).

The late Oligocene through late Eocene mammalian local faunas from southeastern Montana, as defined below, differ significantly from contemporaneous mammalian assemblages known from other areas of North America. The reason for this is unlikely to be produced by similar processes in other parts of the continent. High-elevated, stratigraphic, and geographic areas have been noted for immediate paleoecology of the area and from the same time periods. The results of such analyses are shown in the following pages we report the results of our analyses of key localities in the area.

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A few closely related species in a group of closely related species in the area of Pinus sylvestris. The species share similar ecological requirements and are found in the same habitat or environmental conditions. The figure shows the distribution of these species across different regions.

**Figure 3.** Schematic diagram showing the relationship of the Pinus sylvestris species in the study area. The distribution of these species is shown in different colors, indicating their relative abundance and distribution in the region.
from the single specimens of *E. porcus* known from the Pine Creek Poppy Pocket locality.

**Figure 4.** Magnetic stratigraphy of sections in the Jefferson River Basin. A. The Little Pine Creek Poppy section of Kamel and Fields (1971). Open boxes indicate the E. burkei of Opdyke et al. (1977). B. E. Upper Piney section, filled circles are from Cliburn and Fields et al. (1977) and *"C"* indicates an unknown site.

**Table 3.** West Easter Lily localities. Jefferson Basin. Localities in NE and SW 1/4, SE 16, and NW 32, T23W RSW, Jefferson County, Montana. Dotted line represents the Jefferson River. Source Formation. Late Chattian.

**Figure 5.** West Easter Lily localities. Localities in NE and SW 1/4, SE 16, and NW 32, T23W RSW, Jefferson County, Montana. Dotted line represents the Jefferson River. Source Formation. Late Chattian.
null
section, and it should eventually prove possible to biogeographically zone the beds, although this is beyond the scope of the present chapter. In his 1967 field notes, Douglass divided the McCarty's Mountain beds into two biogeographically distinct zones (I and II) following Z (Roth). Most of the specimen that Douglass collected still retain their original field labels and, based on a comprehensive field catalog and two cross-sectional sketches of his field notes, can be assigned to their appropriate position in the McCarty's Mountain stratigraphic sequence (Taber, 1966). Felt (1955, plate 2) plotted the present location of the specimens he collected for the University of Missouri on a general geologic sketch to a scale of 1:234 feet (or 1:71 meters) on the orthogonal geologic map of the area. Most of Felt's specimens can be shown to lie on the northeastern portion of the map, which was measured by Douglass's geologic section measured by Felt (1966). Dedicated locality and stratigraphic data are also available from the University of Washington collection (Amsden, 1964).

Wood et al. (1941, p. 25) questioned both the unity and age of the McCarty's Mountain fauna, stating that McCarty's Mountains, so far as available knowledge goes, is a nearly locality term for Olivenite exposures on its slopes or at its base. Douglass divided the exposures into several distinct faunal horizons, which, although undated, have not been located, each or all of the Olivenite geosyncline in the eastern part of the state. The small oolitic Olivenite province is probably the most common material in available collections, but Olivenite's oolitic Olivenite, which are common in the same areas of the faunal province, are not 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, 1906) and subsequent authors regarded the McCarty's Mountain beds as "Lower Olivenite," Wood et al. (1941) questioned the age of the McCarty's Mountain fauna, and Kie et al. (1958) noted that the fauna is essentially the same as the present-day fauna. The fauna was first described by Douglass in 1904, but no further detailed study of the fauna has been conducted. However, less than half the fauna from the McCarty's Mountain locality has ever been formally described. The problem is that several of the taxa that have been described are now extinct, and thus it is difficult to assign the remaining taxa to their appropriate position in the evolutionary history of the fauna. However, it is possible to assign the McCarty's Mountain deposits to "the middle part of the Chladon formation," although some of these taxa have been recorded from the Chladon Formation in the Great Plains region. Wood et al. (1941, p. 25) suggested, based on the presence of Arvicola occidentalis in both the beds, that the middle part of the Chladon formation. Although some of the taxa have been recorded from the Chladon Formation in the Great Plains region, Wood et al. (1941, p. 25) suggested, based on the presence of Arvicola occidentalis in both the beds, that the middle part of the Chladon formation.
next common mammals in the McCarty’s Mountain fauna, is present in the middle Chadronian Pine River Springs 12. McCarty’s Mountain and Pine River Springs share only a few relatively long-ranging species. The McCarty’s Mountain fauna contains 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 Deer Creek Formation in the Three Forks Basin. The isolated fauna from Thompson Creek is not very diverse, but several taxa are shared with McCarty’s Mountain. Cibelecerops, Prorhacosuchus, Ornithosuchus, and Losolophus plesiosaurs are present in both the McCarty’s Mountain and Thompson Creek fauna but are not represented in the much more diverse Pine River Springs 12. At University of Montana locality MV 6645 (i.e. H118 of Robinson, 1963) is the upper part of the Climbing Arrow Formation, a small laharicyclopiform with “Lepusyrurus” n. sp., aff. “L.”, sampled from McCarty’s Mountain fauna with a lower part of the Pliocene Rich River section and the Victor and Sandpoint local faunas.

The McCarty’s Mountain fauna shares relatively few taxa with early Chadronian localities outside western Montana. However, as Emry et al. (1987) noted, McCarty’s Mountain fauna shows a fairly strong resemblance to the very limited assemblage known from the Hornby 11 of West Texas, Sandfords, Barley, and Lariosaurus occur in both, and the large condylobasal that Wilson (1971) referred to a Prosubulati- cornus minor (Merrill, curiously pre-dates of those ana- star SHIVNII and Steinberg, this volume, Chapter 25) may be the same as the large unidentified condylobasal from McCarty’s Mountain.

The McCarty’s Mountain section is very thick, and in terms of magnetostratigraphy is most significant. The rich vertebrate fauna (and McCarty’s Mountain section is considered to have been truly significant, the extreme section appears to be early Chadronian in age. The typical and most of the condylobasal, Lepusyrurus and Losolophus platysurus, and the stratigraphically lowest part of the McCarty’s Mountain section appears is more difficult to date, but Overosaurus has been described from the base of the beds (level 8 of Douglas) and "Lepusyrurus" n. sp., aff. P. victorokensis and Losolophus platysurus. Orcaella danoisei n. sp. aff. P. victorokensis and Paralophus platysurus. The stratigraphically lowest part of the McCarty’s Mountain section appears is more difficult to date, but Overosaurus has been described from the base of the beds (level 8 of Douglas) and "Lepusyrurus" n. sp., aff. P. victorokensis and Losolophus platysurus. On the basis of the condensed Ornithosuchus and Losolophus platysurus. There may be some taphonomic differences in the condylobasal Ornithosuchus and Losolophus platysurus. Schaaf and Fallhaber (1986) noted Ornithosuchus, approx. dates for a smaller specimen with “lighter” proportions than other specimens of O. arnycki and Losolophus, species understood, for a larger, more robust specimen than

Figure 3. Magnetostratigraphy of the main section at McCarty’s Mountain. Chronostatigraphic age is given in the legend. The magnetic polarity of the main section is shown in Figure 3. Polarity zones were recognized, with normal polarity occurring in rocks between 40-120 feet in 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 Chrono-11 (C11T1) which would indicate a time span of 35.5-36.6 Ma (Fig. 7).

Diamond O Ranch Local Fauna

The Diamond O Ranch 11 is a previously unpub- lished assemblage derived from five closely spaced localities, one of which is in the Climbing Arrow Formation and the other four in the Late Chadronian part of the McCarty’s Mountain section. The stratigraphically lowest part of the McCarty’s Mountain section appears is more difficult to date, but Overosaurus has been described from the base of the beds (level 8 of Douglas) and “Lepusyrurus” n. sp., aff. P. victorokensis and Losolophus platysurus. On the basis of the condensed Ornithosuchus and Losolophus platysurus. There may be some taphonomic differences in the condylobasal Ornithosuchus and Losolophus platysurus. Schaaf and Fallhaber (1986) noted Ornithosuchus, approx. dates for a smaller specimen with “lighter” proportions than other specimens of O. arnycki and Losolophus, species understood, for a larger, more robust specimen than

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The Diamond O Ranch R.J. lacks the modern disease awareness of our ancestors that do not know the Diamond O Ranch R.J. Wagonmewen, head of the Diamond O Ranch, states that the Diamond O Ranch R.J. Wagonmewen is a species of Ragonmewen that is in perfect condition, as far as we know.
The Sag Bridge Formation, comprising the Sag Bridge Formation of Wood as a series of facies of the lake sediments and exposed by the
Exterior further investigations of the Cretaceous group and eutrophication paleontogogical characteristics of the Sag Bridge Basin include in Tullgrens in 1977 have greatly increased the information available from the area and have largely resolved the principal problems noted by the earlier investigators. Paleontological areas exposed in the area west of the Sag Bridge Formation are shown in the Bridgetown Sag Bridge Formation, the Otisville B beds, and the Charlestown-Otisville Cook Ridge Formation (Fields et al., 1965). The Half Spring basin (as Sag Bridge Basin of Schenker et al., 1955) broadly intervenes between the Sag Bridge Formation and the Otisville B beds, and was illustrated in Fields et al. (1965, p. 46) as a unit in which age and base of the area. Further study indicates that the Half Spring Basin is probably best treated as an upper member of the Sag Bridge Formation.

During the course of his investigations, Tullgren was able to examine specimens from most of the key stratigraphic horizons in the area, including additional material of two of the three taxa reared by Douglas (1952). Several specimens of Haldaneana nanus, two of which duplicate Douglas's specimen of "Haldaneana" were collected from the type Sag Bridge Formation of Wood (1954), stratigraphically below the horizon that marks the contact between the Sag Bridge Formation and the overlying bed, which produced the "Upper Extinct" fossils reported by Hough (1955). These and a few additional specimens from the type locality establish the age of the type Sag Bridge Formation as middle or late Bridgeman. Other locations in the Sag Bridge Formation have produced specimens of early Bridgeman age. The presence of early Bridgeman species now identified as Eustoeum sp. and Polychaetae sp. in the Sag Bridge Formation were briefly noted by Hough (1955) and Smarty (1964). An ammonite jaw from elsewhere in the area at the Dull beds about 0.3 miles northeast of the type locality of the Sag Bridge Formation is stratigraphically below the specimen reported by Douglas from his second Sag Bridge locality. The specimens from Douglas's second locality, Arystonos sp., cf. A. uenikos and Coladus sp., cf. C. wrighti, now seem certain to have been collected from the Dull beds, possibly from exposure on the east side of Dull Bridge (Douglas, 1964, p. 45, fig. 1) in the Narragansett Tuckahoe River (now Tuckahoe RI), 30 miles northeast of the Dull Bridge locality. These specimens are from the same horizon as the Dull beds and are associated with Tullgren's. This age is in agreement with Tullgren's suggestion that the area was the probable site of Douglas's second Sag Bridge locality, a conclusion supported by information contained in Douglas's (1952) field notes. Tullgren's field work in the Sag Bridge Basin was significantly supplemented by the measurement of five supermagnetostratigraphic sections by Professor Schenker. These were measured through the "Haldane," "middle," and "upper" parts of the Cook Ridge Formation in Wood (1952). In 1987, Tullgren and his field crew sampled two magnetostratigraphic sections in the Dull beds, and in the following sections we briefly summarize the biostratigraphic and magnetostratigraphic data now available for the Dull beds and Cook Ridge Formation in the major part of the Sag Bridge area bounded by Wood (1950) and Hough (1953, 1955).

Dull Beds

Based on Tullgren's work in the Sag Bridge Basin, the "Dull beds" was introduced in Fields et al. as a formal unit of biostratigraphic nomenclature that unconformably overlies the Sag Bridge Formation of Wood (1954) and "Half Spring basin" (Sag Bridge Basin of Schenker et al., 1955). The Dull beds are not described elsewhere in the area, and, in fact, are not mentioned in the area of the same name in the north of the state of Little Spring Gap (see, J. 31 and T21, R20W).

The Dull beds consist largely of poorly sorted fossiliferous sandstone and gravelly sandy limestones interbedded with sandstone and conglomerates. Most of the conglomerates occur as lenses or small-scale channels and locally contain abundant debris reworked from the Sag Bridge Formation and Half Spring Gap. Broadly elliptical cobblestones and occasional gravelly sandstone and thin sandstone layers were collected from the type area. This unit is about 15 feet thick and is associated with the Dull beds in the area at the Dull Bridge locality.

Douglas Bridge Local Fauna

In the western area and from widely scattered localities in Secs. 28, 29, and 33, T21 W2, there have been grouped together, provisionally, as the "Douglas Bridge" fauna. The available specimens were collected from various horizons stratigraphically below the marine transgression in the uppermost part of the "Dull beds" and the specimens assigned below to the Douglas Bridge. Localities established by Synopsis and one of the species collected now form a group of 10 specimens that appear to represent a single species. The species described by Douglas (1953) from his second Sag Bridge locality—here assigned to Coladus sp., C. wrighti and Arystonos sp., cf. A. uenikos—are probably derived from this part of the section, almost certainly from exposures on the east side of Dull Bridge. A few specimens collected by the Explorers' Club for the Carnegie Museum remain local data which might indicate that they are not identical to this part of the Dull beds.

Douglas Bridge Level Fauna

In the eastern area, from widely scattered localities in Secs. 28, 29, and 33, T21 W2, there have been grouped together, provisionally, as the "Douglas Bridge" fauna. The available specimens were collected from various horizons stratigraphically below the marine transgression in the uppermost part of the "Dull beds" and the specimens assigned below to the Douglas Bridge. Localities established by Synopsis and one of the species collected now form a group of 10 specimens that appear to represent a single species. The species described by Douglas (1953) from his second Sag Bridge locality—here assigned to Coladus sp., C. wrighti and Arystonos sp., cf. A. uenikos—are probably derived from this part of the section, almost certainly from exposures on the west side of Dull Bridge. A few specimens collected by the Explorers' Club for the Carnegie Museum remain local data which might indicate that they are not identical to this part of the Dull beds.
Utah age assignments. The presence of both Cobolites lax and Cobolites sp. of C. wood (if C. wood is valid) and Douthit's specimens is correctly identified as later in the sequence than to C. (sp.) in the Douglass Draw if, may indicate that the lower level is represented. It may also indicate that part or all of the Douglass Draw strata is equivalent in age to the Badwater late Uintian localities near the middle part of the Cedar City area. (Fig. 6). Based on the late Uintian age of the fauna, the Douglass Draw section probably contains the early part of the Middle Eocene, about 40-50 Ma.

Douglass Draw Local Fauna

Specimens assigned to the Douglass Draw if, were obtained from exposures of the Deli beds on the west side of Kay Draw and from several places along the upper western branch of Douglass Draw in the NE Sec. 33, and the southeastern part of the SE Sec. 28, T21S R15W (the area of location C. D. of H. K. Hough) (1955). Specimens were derived from the stratigraphically highest part of the Deli beds, from an approximately 20-foot section of marine faunas (126) and exposed before the contact of the Deli beds with the Creek Ranch Formation. This is nearly the most lowermost part of the Deli beds, and most of the specimens collected from Kay and Hough were derived from this stratigraphic level. Four Deli beds of Morrison localities (MV 0805, MV 7629, MV 7379, and MV 7375) were established, all four are stratigraphically equivalent but refer to slightly different collecting areas.

As previously known, the Douglass Draw if, includes a broad maximum marine taxa (Table 6). The fauna is dominated by Porcellanodon print and Pseudocomodon sp. Pseudocomodon is a very common genus. MACOMERIA sp. is also common in most samples. It is the most common small mammal, but the available material is too small to make a detailed comparison of species. Hough (1955) assigned a "Douthitian" age to the faunal assemblage from the upper part of the Douglass Draw area, the fauna from this area is similar to the fauna that occurs in the lower part of the Douglass Draw area, suggesting that the Douglass Draw localities may be late Uintian or early Middle Eocene, about 40-50 Ma (Fig. 7).
from the type exposures was designated as a "triangular crenulation" of the Orellan Provincial Age by (Hedlund et al., 1961). Further collecting in this area has less than 15 large and diverse forms of Orellan fauna. Other localities in the Cook Ranch Formation has produced significantly older assemblages. An assemblage developed by Kaw from exposures on the north side of Little Spring Gulch, stratigraphy and end in low in the Cook Ranch Formation, includes abundant specimens of "euryembryonic" palaeopods and "eury- mantic" species, but lacks the characteristic middle Chazomena species. "Lepidopon" now appears to be of late Chazomena. The other most commonly known from the Little Spring Gulch area, also consistent with a late Chazomena age assignment. Clark and Bershov (in Clark et al., 1965) report specimens of Diplomocyclus (diplostrophochoora) dredge from this locality, and it is likely that the upper stratigraphy from Little Spring Gulch which led Clark and Bershov to assign "Cook Ranch" to the late Chazomena on their correlation chart (Clark and Bershov, 1963, p. 14).  

East Eough Drain Localities  

The stratigraphically lower part of the Cook Ranch Formation in the type area is very fossiliferous. Exposures just above the contact with the Delta beds in the SE SW 32, T32N, R10E. Four localities were established (University of California localities MV117, MV274, MV275, and MV276). The western localities, MV117 and MV276, appear to be stratigraphically lower than the eastern localities MV274 and MV275. The impressive area is largely covered, but based on impression of photography it appears to be completely fossiliferous.  

The section here is highly fossiliferous, with abundant forms of Orellan fauna. The assemblage is dominated, especially by MV274, by large and diverse forms of "Palaeopods" barclaysi, and a second locality possibly "Chazomena engelhardi" from the second East Eough Drain locality, MV731, at the marine margin of these exposures in the SW 32, T32N, R10E, and reported outcrops of "Lepidopon" sp., Panderopods sp., Flexopods sp., and a large number of unidentified invertebrates. The section from the top of the "Lepidopon" sp. at the top of the "Palaeopods" barclaysi, and a larger locality possibly "Chazomena engelhardi" from the marine margin of these exposures in the SW 32, T32N, R10E, and reported outcrops of "Lepidopon" sp., Panderopods sp., Flexopods sp., and a large number of unidentified invertebrates. The section from the top of the "Lepidopon" sp. at the top of the "Palaeopods" barclaysi, and a larger locality possibly "Chazomena engelhardi" from the marine margin of these exposures in the SW 32, T32N, R10E, and reported outcrops of "Lepidopon" sp., Panderopods sp., Flexopods sp., and a large number of unidentified invertebrates.
Figure 7. Temporal correlation of the sections in this study. Time scale after Siegmann et al. (1995).


The available paleohydrologic evidence, reviewed by Wing (1987), also clearly supports an uplift setting for the Paleozoic depositions of southwestern Montana. The "Beaverhead Basin" forms (from the contiguous Medicine, Little, Horse Creek, and Greenbush basins) of probable Chadronian age (Fields et al., 1983), and the apparently somewhat younger forms from the Upper Ruby River Basin, appear to represent lacustrine and fluvial-boudinault dunes that are similar to the Fort Union and Red Rock Ranch forms of Colorado and New Mexico. Wing (1987, p. 762) suggested that these forms all indicate growth at an "intermediate" elevation under a seasonally dry climate. Wing also noted that the greater diversity of coarser and more calcareous forms in the "Beaverhead Basin" forms than those in the Fort Union or Red Rock Ranch forms might indicate higher rainfall in the northern part of the Rocky Mountain than in parts of Colorado and New Mexico at comparable elevations. The apparently younger (possibly Oligocene to Miocene) Upper Ruby River forms, though generally similar to the "Beaverhead Basin" forms, appear to indicate some increase in seasonal aridity.

CONCLUSION

Although the Paleogene record in southwestern Montana is patchy, significant local facies ranging in age from Eocene to Oligocene age are present in the numerous small intramountain basins of the region. Despite geographic diversity, the principal trends in the Paleogene record in southwestern Montana, and in the generally broad-scaled formation of the High Plains appear straightforward. Liggett and Taber (1983) discussed the major
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LITERATURE CITED


