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ARTICLE

BIOSTRATIGRAPHY AND MAGNETOSTRATIGRAPHY OF THE MID-MIOCENE RAILROAD CANYON SEQUENCE, MONTANA AND IDAHO, AND AGE OF THE MID-TERTIARY UNCONFORMITY WEST OF THE CONTINENTAL DIVIDE

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ABSTRACT—The Barstovian of the northern Rocky Mountains, U.S.A., is known mainly from deposits east of the continental divide; this article provides new information from west of the divide. The biostratigraphic, geologic, magnetostratigraphic, and lithostratigraphic setting is reported for an unusually complete Arikareean, Hemingfordian, and Barstovian stratigraphic section known as the Railroad Canyon Sequence in Montana and Idaho. At least 35 taxa of fossil vertebrates collected from 50 different localities are placed in stratigraphic context. Lithostratigraphic attributes indicate the presence of a freshwater lake during the Arikareean, intermittent saline lakes through much of the Hemingfordian, a late Hemingfordian unconformity (the Mid-Tertiary Unconformity), and absence of persistent lakes through the Barstovian. The sequence records the development of increasingly arid conditions in the depositional basin. A change in bedding attitude and generally coarser sediments above the Mid-Tertiary Unconformity indicate uplift of the region during the Barstovian, possibly accompanied by slight structural tilting. The analysis helps date Barstovian faunas, and provides a useful tie point for correlating the Barstovian Land-Mammal Age to the magnetostratigraphic and radioisotopic scale in the western Rockies, and ultimately to the Global Polarity Time Scale (GPTS). It also suggests that the Mid-Tertiary unconformity is approximately coeval on the eastern and western flanks of the mountains, supporting tectonic models that require regional uplift between ca. 16.8 and 17.5 Ma.

INTRODUCTION

Chronologic control on middle Miocene mammal faunas and tectonic events in the northern Rocky Mountains, U.S.A, has been difficult to establish west of the continental divide (Tedford et al., 1987, 2004). This, in turn, has hampered: (1) biostratigraphic dating of rocks across the western United States; (2) evolutionary, paleoecological, and biostratigraphic studies that rely on temporal sorting of taxa; (3) paleobiogeographic studies, as the northern Rockies are the transition zone between western and eastern biogeographic provinces (Barnosky, 1986a; Storer, 1989; Tedford et al., 2004); and (4) a clear understanding of Miocene geological history in the region. The primary purpose of this paper is to establish a lithostratigraphic and magnetostratigraphic framework and to document the fossil mammals from the Railroad Canyon Sequence (RCS) in Idaho and Montana (Fig. 1), to refine the temporal control for this region.

Secondarily, this work helps constrain the age of the Mid-Tertiary Unconformity (MTU) on the western edge of the Rocky Mountains. The MTU has figured prominently in vertebrate paleontological literature of the northern Rockies (Fields et al., 1985; Hanneman and Wideman, 1991; Barnosky, 2001; Hanneman et al., 2003; Rasmussen, 2003), inasmuch as it extends through most of the intermontane basins of at least southwestern Montana and provides a physical-stratigraphic marker separating earlier Miocene from later Miocene faunas. The MTU also has tectonic implications for interpreting those aspects of regional geological history that can be attributed to continental-scale plate-tectonic processes (Stewart, 1978, 1998; Hooper and Conrey, 1989; Janecke, 1994; Hooper, 1997; Liu, 2001; Tikoff et al., 2001; Dickinson, 2002; Kohn et al., 2002), versus more local events related to the mid- to late-Miocene passage of the Yellowstone Hotspot as it migrated from southeastern Oregon to its present position (Anders, 1994; Smith and Braile 1994; Parsons et al., 1998; Colgan et al., 2004).

Biostratigraphic Context

So far, only one sequence in the northern Rockies located east of the continental divide has provided information about how the Barstovian NALMA correlates to the Global Polarity Time Scale (GPTS). That sequence, the Hepburn's Mesa Formation in the Yellowstone Valley, Montana, spans from ca. 16.8 to perhaps as young as 13.8 Ma (Barnosky and LaBar, 1989; Burbank and Barnosky, 1990), as determined from magnetostratigraphic and radioisotopic dating; it has yielded characteristically early late Barstovian taxa in the middle and upper parts of the section. Combined with lithostratigraphic and biostratigraphic information from the Colter Formation to the south in Jackson Hole, Wyoming (Barnosky, 1986a, b), the Hepburn's Mesa sequence helped to establish an age of 16.8 to 17.5 Ma for the development of the MTU on the eastern flank of the Rockies.

West of the divide, fossils from the RCS have long been known, but their usefulness in regional biochronology has been

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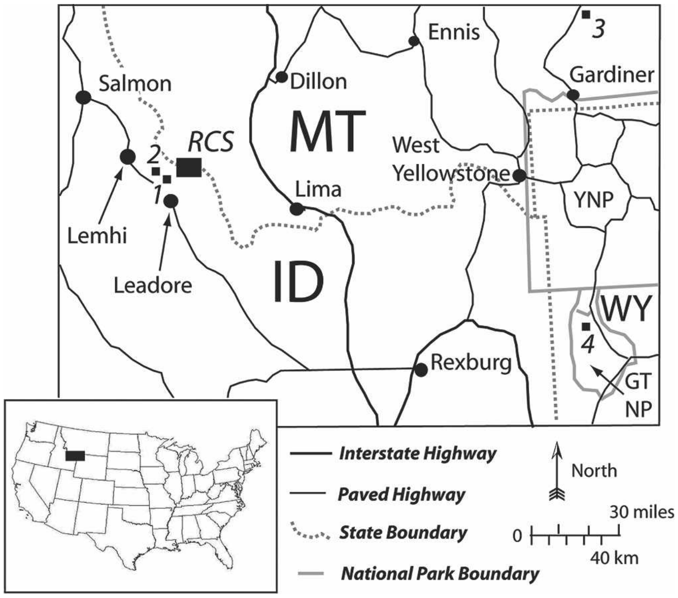


FIGURE 1. Location of the Railroad Canyon Sequence (RCS) and other relevant Miocene localities (small black squares). **1**, Mollie Gulch, and **2**, Peterson Creek areas, Lemhi Valley. **3**, Hepburn's Mesa localities, Yellowstone Valley. **4**, Colter Formation localities, Jackson Hole.

limited because the local stratigraphic relationships of the many collecting sites have not been well documented. The entire RCS was previously referred to the early Barstovian NALMA (Fields et al., 1985; Tedford et al., 1987; Barnosky, 2001; Nichols, 2001). The biostratigraphic, paleomagnetic, radioistotopic, and tephrachronologic data discussed in this paper, however, provide the most comprehensive information yet reported for the Barstovian of the Rockies west of the continental divide (Fig. 1), and indicate that the RCS extends from at least late Hemingfordian to late Barstovian, with underlying Arikareean deposits. These data also bracket the MTU between ca. 16.7 and 17.3 Ma.

Mid-Tertiary Unconformity

The MTU is one of the most prominent of several unconformities recognized in Tertiary basins of the northern Rocky Mountains and has important tectonic and climatic implications (Hanneman and Wideman, 1991; Rasmussen, 2003; Hanneman et al., 2003). Tectonically, the development of the MTU heralded the formation of basins and ranges more or less in their modern configuration (Fields et al., 1985; Rasmussen, 2003). Elevation began to increase as the MTU developed and continued to increase after deposition recommenced, at least in the area where Wyoming, Montana, and Idaho come together (Barnosky and LaBar, 1989; Burbank and Barnosky, 1990), and probably throughout mountainous Montana and Wyoming (Love, 1960; McKenna and Love, 1972; McKenna, 1980; Thompson et al., 1981, 1982; Fields et al., 1985). From a climatic perspective, a regionally moist climate during development of the MTU gave way to more arid conditions as deposition recommenced (Thompson et al., 1981, 1982). Also coincident with the commencement of redeposition was a global warming event at about 17 Ma as recorded by oceanic oxygen-isotope records (Zachos et al., 2001). These tectonic and climatic events associated with the MTU appear to have affected mammalian evolution and distribution (Barnosky, 2001; Barnosky and Carrasco, 2002).

Lithostratigraphic Context

The gray, green, and whitish mudstones, siltstones, sandstones, and gravel lenses below the MTU in the study area belong to the Renova Formation. Pinkish and tannish mudstones, siltstones, sandstones, and gravel lenses above the MTU belong to the Sixmile Creek Formation (Rasmussen, 2003). Both formations, usually separated by the MTU, are also found in other intermontane basins in the region (Hanneman et al. 2003; Rasmussen, 2003). Nearby formations that correlate with the Sixmile Creek include the Hepburn's Mesa Formation (Barnosky and LaBar, 1989) and the Madison Valley Formation (Douglass, 1903).

Collectively the outcrops of Renova and Sixmile Creek formations between Leadore, Idaho, and Bannock Pass on the Idaho-Montana border are called the RCS, which is the focus of this article. Correlative deposits known as the Peterson Creek and Mollie Gulch beds, which also are discussed subsequently, crop out in the adjacent Lemhi Valley north of Leadore (Fig. 1). The Peterson Creek beds and lower Mollie Gulch beds are part of the Renova Formation. The upper Mollie Gulch beds are part of the Sixmile Creek Formation.

METHODS

Abbreviations

Institutional Abbreviations—AMNH, American Museum of Natural History; **CM**, Carnegie Museum of Natural History; **IMNH**, Idaho State Museum; **TTM**, Texas Tech Museum; **UCMP**, University of California Museum of Paleontology; **UM**, University of Montana Department of Geology; **UO**, University of Oregon Condon Museum; **UWBM**, Thomas Burke Memorial Washington State Museum.

Other Abbreviations—AP, maximum dimension measured anteroposteriorly on tooth; **CHEV**, lingual dentine tract height (as illustrated in Barnosky, 1986a)**; GPTS**, Global Polarity Time Scale; **LEH**, labial enamel height (as illustrated in Barnosky, 1986a); **MTU**, Mid-Tertiary Unconformity; **NALMA**, North American Land-Mammal Age; **RCS**, Railroad Canyon Sequence; **TA**, maximum width of anterior transverse loph measured perpendicular to AP; **TP**, maximum width of posterior transverse loph measured perpendicular to AP; **TR**, maximum width of tooth measured perpendicular to AP.

Geology

Exposures of the RCS within the study area were located by air photos and on-the-ground reconnaissance (Fig. 1). The best exposed and most fossiliferous outcrops were plotted on 7.5' USGS quad basemaps (Figs. 2, 3) and measured stratigraphically with a Jacob's staff and Brunton hand transit. Orientations of representative bedding planes were recorded with compass declination set at 0°, and are reported as dip azimuth (i.e., direction of dip expressed as compass bearing between 0° and 359°) and dip angle (expressed as degrees from the horizontal plane). Strike is perpendicular to the dip azimuth. At each measured section, lithologic features were described at 1 m intervals to construct a detailed stratigraphic and lithologic framework in which to place fossils and sample localities (Figs. 4, 5). Correlations between exposures were accomplished by walking along marker beds or by matching repetitive lithologies that in most cases included distinctive marker beds. In all cases correlations were made initially only by lithological criteria. Later comparisons of magnetic polarities in overlapping parts of exposures supported the lithologic correlations. In this report, the notation "+ xx m" refers to xx m above the base of a measured local exposure. A notation such as "meter 25" refers to 25 meters above the base of the composite section that was constructed by correlating all of the local exposures.

Tephrachronology

Glass shards of 11 tephras from throughout the RCS were subjected to microprobe analysis by B. Nash and M. Perkins,

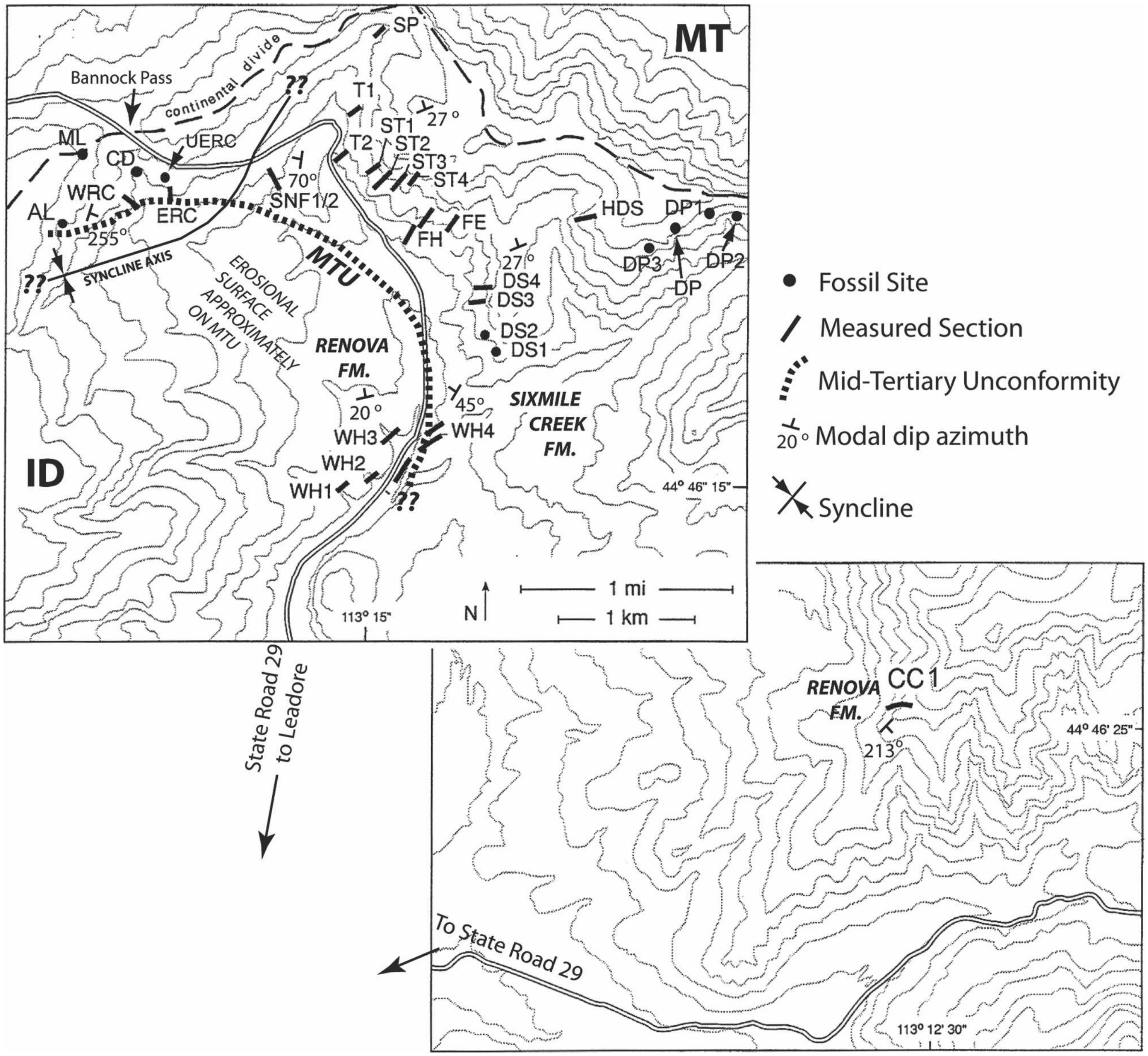


FIGURE 2. Location of measured sections, fossil localities, and geological features in the Railroad Canyon Sequence discussed in the text. Base maps are portions of the 1965 Bannock Pass (east half of upper map) and 1965 (photorevised 1988) Deadman Pass (west half of upper map and entire lower map) 7.5' USGS quadrangles.

who compared the elemental composition of each RCS tephra with tephra compositions in the University of Utah tephra data base. Analytical conditions followed those described by Nash (1992). One tephra (ADBR8-93) that showed initial matches from the microprobe data was further analyzed by X-ray fluorescence.

Radioistopic Age Determinations

Eleven ash samples from the RCS were submitted to Berkeley Geochronology Center for Ar-Ar dating. Standard techniques were used to separate and date the feldspars (Carl Swisher, pers. comm., October, 1992) in four of the samples, but efforts to radioisotopically date the remaining ones were abandoned when it was realized that detrital feldspars were resulting in erroneous age determinations. To contribute to potential biostratigraphic and tephrachronologic correlations, an ash from the Hepburn's Mesa Formation (CC-4; Barnosky and LaBar, 1989; Burbank and Barnosky, 1990) also was subjected to Ar-Ar dating.

Biostratigraphy

Each exposure was systematically searched for vertebrate fossils by walking along contours at approximately 2 m intervals. All fossils recovered during fieldwork directly associated with this project were located to the nearest meter within stratigraphic sections. Previously collected fossils in museum collections were used when the collector's field notes were detailed enough to place the fossil within a particular outcrop. In most cases these specimens could be placed within the upper, lower, or middle part of a measured section, but not more precisely. Nearby coeval localities were integrated into the stratigraphy if possible.

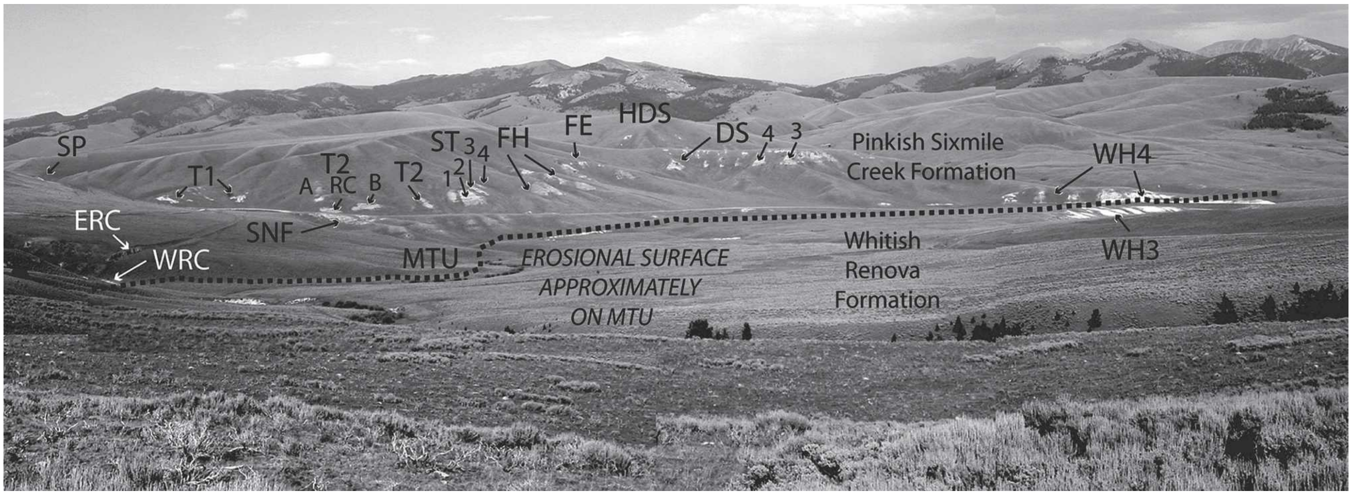


FIGURE 3. Photo composite showing the outcrops where most of the sections were measured and fossils were collected, and the approximate trace of the Mid-Tertiary Unconformity (MTU) on the surface. See Table 1 for abbreviations and locality numbers. The photos were taken approximately from the point labeled ML on Figure 2 looking southeast.

These included AMNH localities Tunnel Draw and "one mile SE of Tunnel Draw," which were collected by C. Falkenbach between 1950 and 1954, and UM localities Smith Ranch, Big Camel, Mollie Gulch, and Cottom Lane, which have been collected by R. Nichols since 1936.

Fossils were identified to at least genus (when material was sufficient) by comparisons with collections at the CM, UCMP, UWBM, UO, UM, and AMNH, and with specimens described in published literature. Fossils from the RCS that were used in this analysis reside at the UCMP, UM, AMNH, CM, and IMNH. Table 1 correlates the locality numbers of different institutions with locality names.

The maximum stratigraphic range of biostratigraphically useful taxa within the study area was determined by placement of fossils within local sections and correlation of local sections by lithostratigraphic and magnetostratigraphic criteria, which resulted in defining taxon ranges through the composite section (Fig. 6). Because most fossils had eroded out of the rocks and moved downslope to some unknown extent, most ranges (Fig. 6) depict that the taxon could occur anywhere within the respective stratigraphic interval, not through the whole interval. To determine the biochronologic ranges of taxa outside of the RCS, the definitions and characterizing taxa of the NALMAs of Tedford and colleagues (2004) were used. The fauna of the RCS were compared to all known late Oligocene and Miocene sites and taxa within the northern Rocky Mountains, the northern Great Plains, and Northwest. Those are the regions that are most likely to be in the same Miocene biogeographic province as the RCS, and the most refined biostratigraphic resolution is probably obtained by comparing sites within biogeographic regions (Tedford et al., 1987, 2004). Definitions of "northern Rocky Mountains," "northern Great Plains," and "Northwest," follow Barnosky and Carrasco (2002). Nearly all published late Oligocene and Miocene localities in Oregon, Washington, Idaho, Montana, Wyoming, North Dakota, South Dakota, and Nebraska were included, which totaled 980 localities and > 6700 taxonomic occurrences. We extracted the information from the MIOMAP database (Carrasco et al., 2005).

Magnetostratigraphy

Oriented samples of silty claystones, siltstones, and fine-grained sandstones for paleomagnetic analysis were collected under the supervision of the late Victor A. Schmidt, and most were collected at the same time one of the authors (ADB) measured the same sections. Samples were collected over five field seasons (1989–1993) at sites separated by intervals of 1 to 2 m, depending on amenable lithology and thickness of the stratigraphic section. A total of 296 paleomagnetic sites, each with three oriented samples, were extracted from 14 overlapping stratigraphic sections (Figs. 4, 5). Class A sites (sensu Lindsay et al., 1987) were used to construct the magnetostratigraphy, with auxiliary information derived from Class B and C sites. Magnetic work was performed by Zheng (1996), who reported methodological details; see also Supplementary Data (Appendix 1S, www.vertpaleo.org/jvp/JVPcontents.html).

RESULTS

Geology

Correlation of 25 measured outcrops resulted in a composite section of ca. 380 m (Fig. 5). The MTU occurs ca. 70 m above the base of the composite section (meter 70 in our terminology), which is also 70 meters above the base of the Whiskey Spring 4 exposure (WH4 in Figs. 3, 4), where the MTU is visible as a contact between predominantly white beds and predominantly pink beds. The contact also is visible about 10 m above the base of the West Railroad Cut (WRC; Figs. 3, 4). Bedding attitudes (Supplementary Data Table 1S, www.vertpaleo.org/jvp/JVPcontents.html) and projections of dip within both the Sixmile Creek and Renova formations indicate that a shallow northeast-southwest trending syncline is present in the study area, with its structural low point between East Railroad Cut (ERC) and Snowfence (SF) (Fig. 2). Corroborating evidence includes highly fractured rocks throughout the RCS with conjugate shears in some areas. For example, in the Sixmile Creek Formation at the Fence Locality (FE, Figs. 2, 3), one shear plane has a dip azimuth of 170°, dip angle 56°, and the intersecting shear plane has a dip azimuth of 10°, dip angle 58°.

On the eastern limb of the syncline where most attitudes were determined, dip directions below the unconformity spread around a modal azimuth of ca. 20°, in contrast to a mode of ca. 45° above the MTU (Supplementary Data Table 1S, www.vertpaleo.org/jvp/JVPcontents.html). The difference in attitude suggests that the axis around which beds were tilted shifted ca. 25° to the west after deposition of the Renova Formation (white

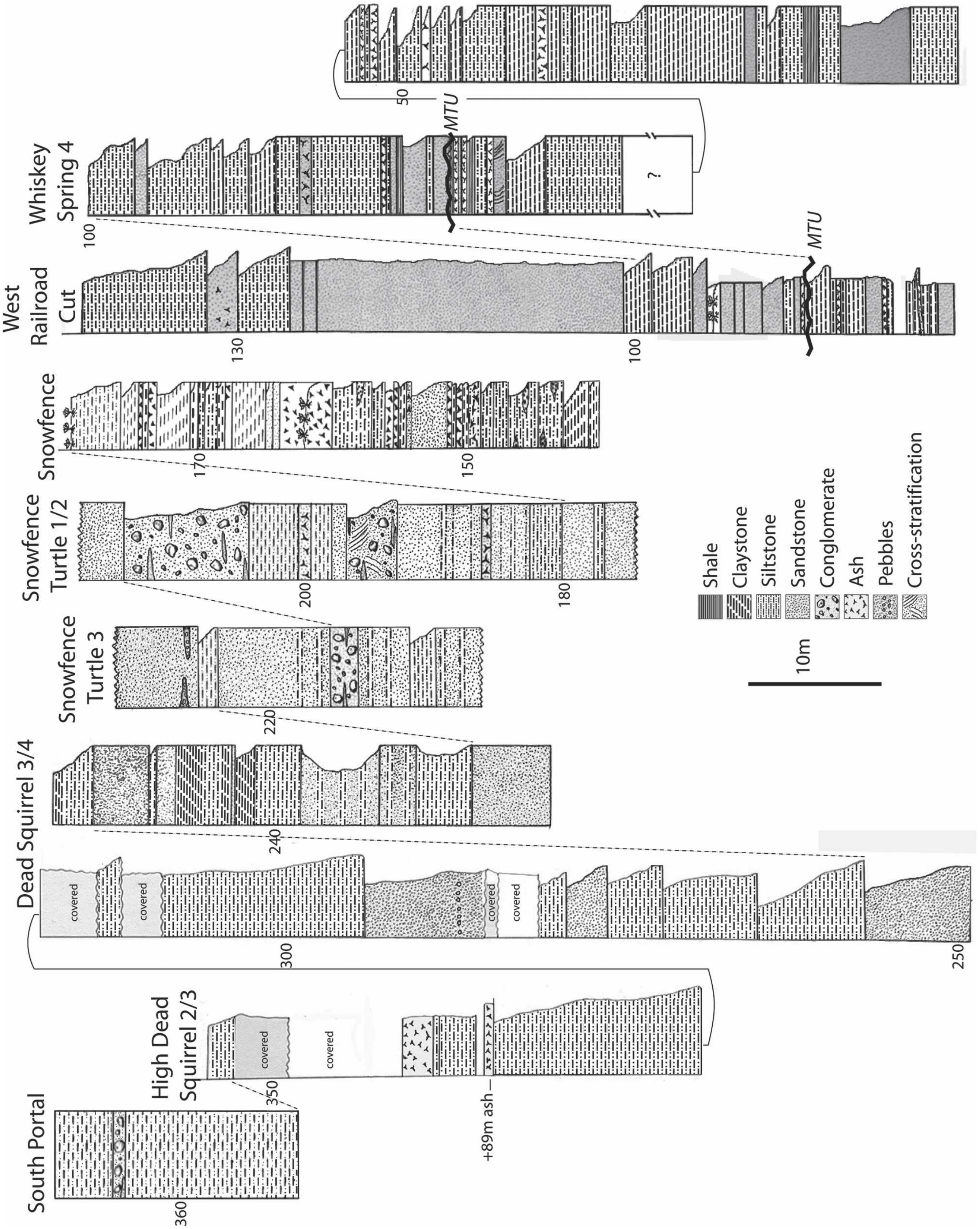
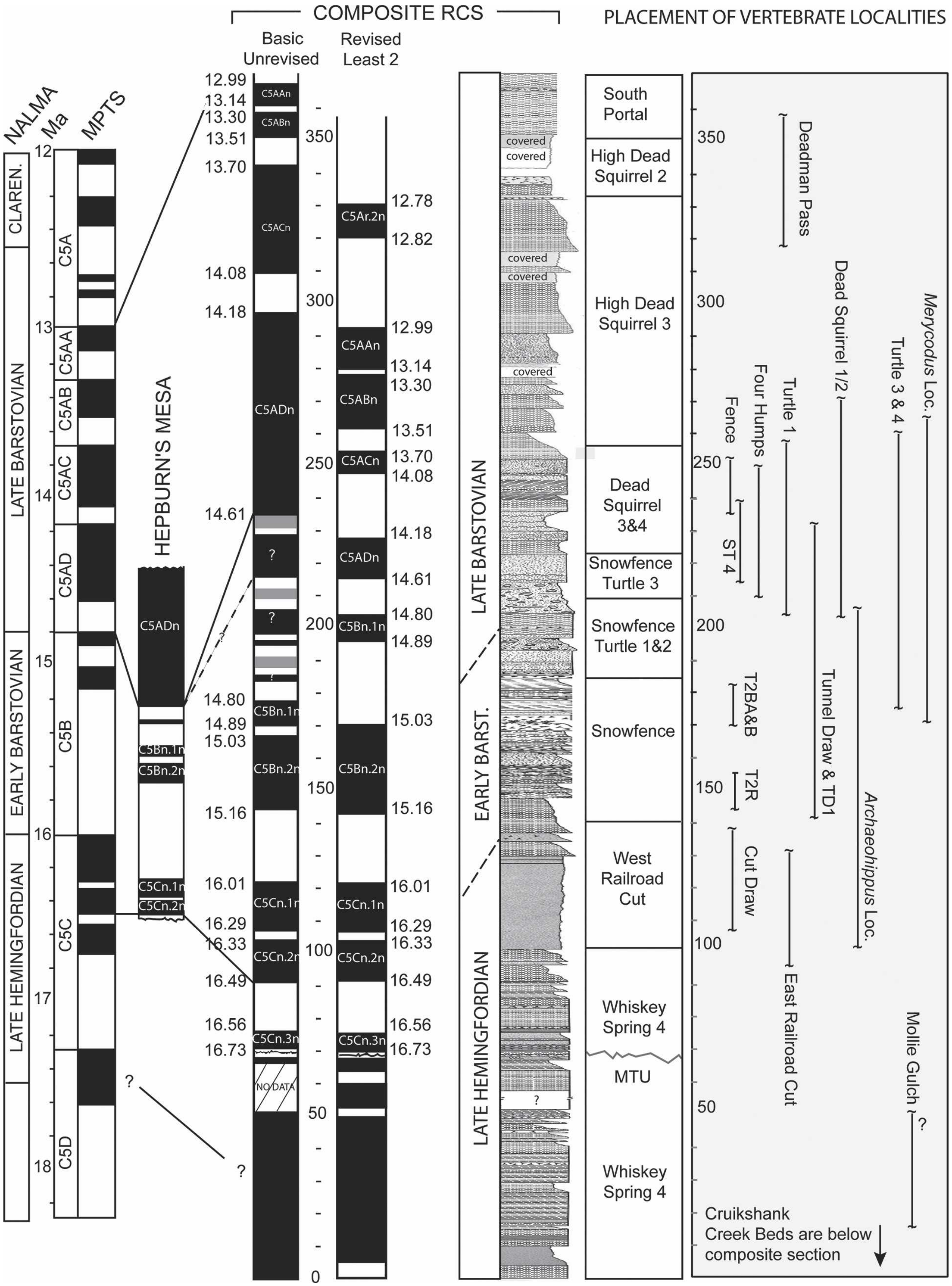


FIGURE 4. Correlation of lithostratigraphic sections in the Railroad Canyon sequence. Lowest part of the sequence is Whiskey Spring 4; highest part is South Portal. Connecting lines indicate tiepoints for aligning the sections.


COMPOSITE RCS
Basic Unrevised
Revised Least 2
PLACEMENT OF VERTEBRATE LOCALITIES
NALMA
Ma
MPTS
CLAREN.
LATE BARSTOVIAN
EARLY BARSTOVIAN
LATE HEMINGFORDIAN
C5A
C5AA
C5AB
C5AC
C5AD
C5B
C5C
C5D
12
13
14
15
16
17
18
HEPBURN'S MESA
C5ADn
C5Bn.1n
C5Bn.2n
C5Cn.1n
C5Cn.2n
?
12.99
13.14
13.30
13.51
13.70
14.08
14.18
14.61
14.80
14.89
15.03
15.16
16.01
16.29
16.33
16.49
16.56
16.73
C5AAn
C5ABn
C5ACn
C5ADn
C5Bn.1n
C5Bn.2n
C5Cn.1n
C5Cn.2n
C5Cn.3n
NO DATA
350
300
250
200
150
100
50
0
12.78
12.82
C5Ar.2n
12.99
C5AAn
13.14
13.30
C5ABn
13.51
13.70
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15.03
C5Bn.2n
15.16
16.01
C5Cn.1n
16.29
16.33
C5Cn.2n
16.49
16.56
C5Cn.3n
16.73
LATE BARSTOVIAN
EARLY BARST.
LATE HEMINGFORDIAN
covered
covered
covered
covered
covered
South Portal
High Dead Squirrel 2
High Dead Squirrel 3
Dead Squirrel 3&4
Snowfence Turtle 3
Snowfence Turtle 1&2
Snowfence
West Railroad Cut
Whiskey Spring 4
MTU
Whiskey Spring 4
350
300
250
200
150
100
50
Deadman Pass
Dead Squirrel 1/2
Merycodus Loc.
Turtle 3 & 4
Turtle 1
Four Humps
Fence
ST 4
T2BA&B
T2R
Tunnel Draw & TD1
Archaeohippus Loc.
Cut Draw
East Railroad Cut
Mollie Gulch
?
Cruikshank Creek Beds are below composite section

TABLE 1. Vertebrate localities (arranged alphabetically) mentioned in the text.

UCMP loc. no.	Loc. synonym	Publication name and notes	Abbreviation
—	MV7327	"Above W RR Cut"	
—	MV7333	*Archaeohippus* Locality	AL
—	MV7320	Big Camel Loc.	BCL
—	MV7316	Cottom Lane, Lemhi Co	CL
V99455	—	Cut Draw	CD
V99208	—	Cruikshank Creek 1	CC1
—	MV7332	Cruikshank Hill	CH
V99213	MV7325	Dead squirrel 1	DS1
V99214	MV7325	Dead Squirrel 2	DS2
V99491	MV7325	Dead Squirrel 3	DS3
V99215	MV7325	Dead Squirrel 4	DS4
—	MV7331	Deadman Pass	DP
V99456	MV7331	Deadman Pass 1	DP1
V99457	—	Deadman Pass 2	DP2
V99458	—	Deadman Pass 3	DP3
V99095	—	East Crest North	ECN
V99096	—	East Crest South	ECS
—	MV7351	East Mollie Gulch	EMG
V99093	MV7330	East Railroad Cut	ERC
V99205	—	Four Humps	FH
—	—	Fence	FE
V99490	—	High Dead Squirrel 2/3	HDS2/3
V99459	—	High Dead Squirrel 4	HDS4
—	MV7326	*Merycodus* Loc, Lemhi Co.	ML
—	MV7339	Mollie Gulch #1	MG1
—	MV7340	Mollie Gulch #2	MG2
—	MV7341	Mollie Gulch #3	MG3
—	MV7352	Mollie Gulch *Merychyus*	MGM
—	MV7344	Mollie Gulch Rhino	MGR
—	AMNH	One mile SE of Tunnel Draw	TD1
V99460	—	Railroad Canyon Undifferentiated	RDU
—	MV loc.	"Road cut 20ft west of MT/ID line, highest point fossils found" similar to MV7326	
—	MV7345	Rodent Bluff, Mollie Gulch	RB
—	MV7318	Smith Ranch, Beaverhead Co.	SR
V99094	MV7338	Snowfence 1/2	SNF1/2
V99209	—	Snowfence Turtle 1	ST1
V99210	—	Snowfence Turtle 2	ST2
V99211	—	Snowfence Turtle 3	ST3
V99212	—	Snowfence Turtle 4	ST4
V99097	MV7334	South Portal	SP
—	AMNH	Tunnel Draw	TD
V99452	MV7322	Turtle 1	T1
V99202	MV7323	Turtle 2 Blowout A	T2BA
V99203	MV7323	Turtle 2 Blowout B	T2BB
V99204	MV7323	Turtle 2 Roadcut	T2R
V99453	MV7323	Turtle 2 Undifferentiated	T2U
V99454	MV7324	Turtle 3 (includes Four Humps, ST3, and Fence)	T3
—	MV7325	Turtle 4 (overlaps w/Dead Squirrel 1–4)	T4
—	MV7329	Upper East Railroad Cut	UERC
V99092	MV7328	West Railroad Cut	WRC

MV = University of Montana locality; AMNH = American Museum of Natural History locality.

beds below the MTU) but prior to the deposition of the Sixmile Creek Formation (pink beds above the MTU). Dip angle is similar in both formations (mean 9.0° in the Renova based on 19 measurements, and 8.6° in the Sixmile Creek based on 14 measurements). Assuming the beds were originally more or less flat-lying, this geometry indicates that the Renova Formation was tilted slightly to the south by the time the Sixmile Creek was deposited on top of it, possibly as the MTU developed. After the Sixmile Creek was deposited, compressional forces with a significant northwest-southeast component resulted in shallow folding that locally increased the dip angles of both the Renova and Sixmile Creek formations. Of interest is the observation that very little deformation may have accompanied the local development of the MTU. This would suggest epierogenic uplift rather than block faulting characterized the mid-Miocene tectonic event in the western part of the northern Rockies, with the majority of tilting and deformation characteristic of block-faulting not occurring until after the Sixmile Creek was deposited.

Changes in depositional environment are evident across the MTU. The Renova Formation locally consists primarily of mudstones and siltstones, some of which clearly were lake deposits. The lowest exposures, for example, the Cruikshank Creek outcrops (CC1; Fig. 2), contain laminated beds and fish fossils characteristic of freshwater lakes. Higher in the Renova are laminated mudstones that contain mud cracks, abundant gypsum and halite crystals, and interspersed zeolitized ashes, as at Whiskey Spring 3 +23 m (WH3; Figs. 2–3)—all features indicative of saline lakes. Furthermore, gravel lenses are rare in the Renova. In contrast, the Sixmile Creek Formation locally is composed primarily of siltstone and fine to medium grained sandstone, with a general coarsening upward. Gravel lenses are quite common in the Sixmile Creek, especially in the middle of the section (Fig. 4), including many cobbles up to 50 cm diameter. These gravels are extremely poorly sorted with matrix-supported clasts. The depositional environments of the Sixmile Creek primarily include aeolian, sediment-choked fluvial (siltstones and sandstones) and mudflow deposits (gravels), rather than lake deposits. Paleoenvironmentally, therefore, in pre-MTU time the Railroad Canyon area seems to have transformed from an arid, closed basin that contained freshwater lakes, into a basin with saline lakes. In post-MTU time, it became an even drier basin without widespread lakes, where sediments were reworked by wind and fluvial systems were choked by clastics derived from surrounding higher elevations.

Biostratigraphy

Fossil mammals have been recovered from 50 localities in and near the RCS (Table 1), which are distributed stratigraphically through much of the section (Figs. 5–6; Table 2). The stratigraphically lowest locality is Cruikshank Creek, which yielded numerous fish scales but only one mammal jaw, the geomyoid rodent *Entoptychus*. This genus occurs in at least 27 other locali-

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FIGURE 5. Correlation of Railroad Canyon Sequence (RCS) with local, regional (Hepburn's Mesa), and global magnetostratigraphy, and placement of fossil localities in the section. Alternative interpretations of local magnetostratigraphy are "Basic Unrevised" and Zheng's (1996) "Revised Least 2." See text for explanation; the "Basic Unrevised" is favored here. The gray shading shows where magnetic data were equivocal. Slanted dotted lines for land-mammal age boundaries in the Composite RCS column indicate that the local placement of the boundary based on fossils would be consistent with the range covered by the slanted line. Thus, from fossil evidence alone, West Railroad Cut could be either late Hemingfordian or early Barstovian age, and Snowfence-Turtle 1&2 could be either early Barstovian or late Barstovian. Localities above Snowfence-Turtle 1&2 have yielded fossils that are consistent with either a late or early Barstovian age; the magnetostratigraphy, however, indicates that this part of the section is temporally correlative with the late Barstovian elsewhere. Hepburn's Mesa magnetostratigraphy is from Burbank and Barnosky (1990); global scale from Cande and Kent (1995).

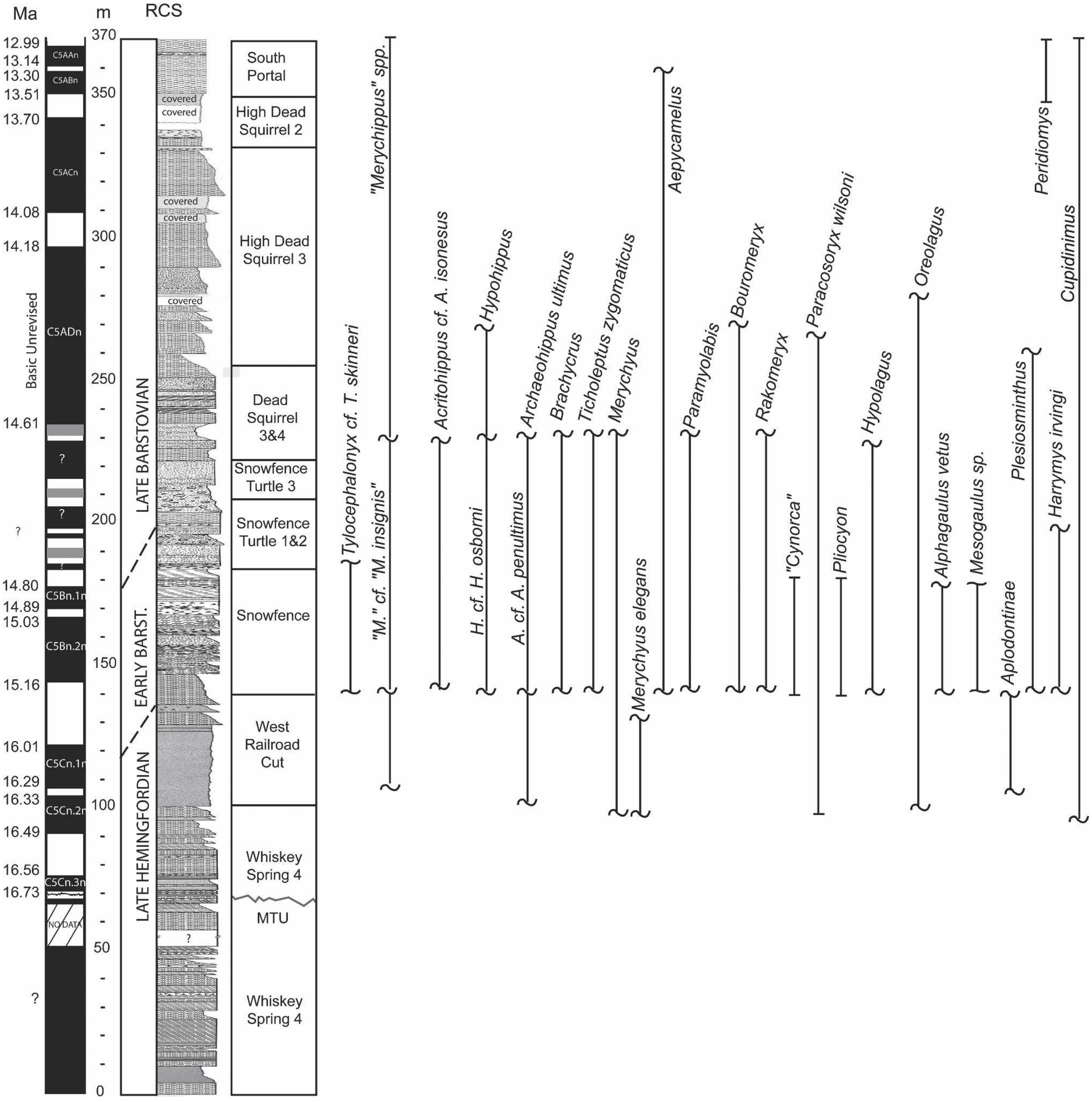

FIGURE 6. Stratigraphic ranges of biostratigraphically significant taxa within the Railroad Canyon Sequence (RCS). See text (Results, Biostratigraphy) for further explanation.

ties, mostly in Oregon, but with three in the northern Rocky Mountains and one in the northern Great Plains (Carrasco et al., 2005). All of these localities are considered Arikareean in age. Therefore the base of the RCS section almost certainly is Arikareean. The Cruikshank Creek locality lies stratigraphically below the lowest beds in the composite RCS section (Fig. 5) by an unknown thickness, so it is not presently possible to tie the Arikareean beds reliably into the composite magnetostratigraphy.

Most of the fossil localities occur between meters 100 and 270 in the composite section, with the majority of fossils from between meters 140 and 250 (Figs. 5, 6). The vertical distribution of biostratigraphically useful fossils is shown in Figure 6, a listing of taxa by locality in Table 2, and the stratigraphic ranges of the taxa known elsewhere in Table 3. In Figure 6, wavy lines at top or bottom of a range indicate that it is not possible to determine the exact placement of the taxon-range but that the range boundaries are somewhere within the illustrated vertical line. Straight horizontal lines indicate that the limits of the taxon-range are precisely located at the corresponding stratigraphic level. Thus, ranges capped by wavy lines would be shorter if exact stratigraphic occurrence of fossils were known; ranges capped by straight lines would not be shorter. Part of the difficulty in assigning exact stratigraphic ranges arises because the fossils often were found after they had eroded out of the sediments and had moved downslope, or were collected several decades ago, before it was standard practice to record exact stratigraphic position.

The presence of the following taxa suggests that meters ~150–250 are no older than late Hemingfordian (Table 3): *Pliocyon*, *Hypolagus*, *Harrymys irvini*, *Alphagaulus vetus*, *Paracosoryx wilsoni*, *Merycodus*, *Bouromeryx*, *Rakomeryx*, *Aepycamelus*, *Brachycrus laticeps*, *Archaeohippus* cf. *A. penultimus* and *A. ultimus*, and *Tylocephalonyx* cf. *T. skinneri*. A few taxa indicate an older limit of early Barstovian: *Ticholeptus zygomaticus*, "*Merychippus*" cf. "*M.*" *insignis*, and *Acritohippus* cf. *A. isonesus*. The co-occurrence of *Oreolagus*, *Plesiosminthus*, *Peridiomys*, *Paracosoryx wilsoni*, and *Hypohippus* cf. *H. osborni* in this interval precludes an age younger than late Barstovian. Two taxa (*Acritohippus* cf. *A. isonesus, Hypohippus* cf. *H. osborni*) are known elsewhere only from the Barstovian, and another three ("*Cynorca*," *Pliocyon*, and *Alphagaulus vetus*) purportedly have their last appearance in the early Barstovian (Tedford et al., 2004).

Above meter 130, the co-occurrence of *Acritohippus* cf. *A. isonesus, Hypohippus* cf. *H. osborni, Archaeohippus ultimus, Ticholeptus zygomaticus*, and "*Merychippus*" cf. "*M.*" *insignis* indicate an early Barstovian age assignment. The presence of an *Archaeohippus* specimen resembling *A. penultimus* (R. H. Tedford, pers. comm., January, 2003) would require a slight range extension for that species, otherwise known only from the late Hemingfordian (Table 3). *Harrymys irvini* is known elsewhere only from the Split Rock fauna of central Wyoming (Munthe, 1988), which is generally considered late Hemingfordian but may in part be earliest Barstovian (Liter et al., 2003). *Harrymys irvini, Archaeohippus ultimus*, and *Archaeohippus* cf. *A. penultimus* would be consistent with the Hemingfordian-Barstovian boundary lying between meters 120 and 140.

Taxa above meter 180 would be consistent with either an early or late Barstovian age. The boundary between early and late Barstovian dates to about 14.8 Ma (Woodburne and Swisher, 1995; Tedford et al., 2004) east of the continental divide in the northern Rockies and at the type area for the Barstovian in California (Burbank and Barnosky, 1990). The magnetostratigraphy discussed below assigns that age to about meter 175 in the RCS composite section, which is consistent with the faunal evidence.

Pertinent to biostratigraphic interpretation of the RCS are fossils from the nearby Lemhi Valley sequence, which has lithologically similar rocks, suggesting deposition coeval with that of the RCS. The fossils from the Lemhi Valley sequence locally establish a biostratigraphic age for the Renova below the MTU, and add corroborating evidence for the age of the Sixmile Creek. The composite Lemhi Valley sequence is pieced together from the Peterson Creek and Mollie Gulch sections that crop out from ca. 15–25 km north of Leadore, Idaho, on the east side of the Lemhi Valley (Fig. 1). Although key specimens have been reported in the literature, the stratigraphic relationships of these geographically discrete outcrops have not been clearly documented previously, nor have faunal lists been differentiated as to occurrence within and between outcrops. Hence some critical details are reported here.

Farthest to the north are the Peterson Creek beds, which have produced a characteristically late early Arikareean fauna (Nichols, 1976, 1979). Near Nichols' Peterson Creek localities, but possibly from a higher stratigraphic level, Falkenbach collected the presumably late Arikareean rhino *Diceratherium niobrarense* from a locality he called "Peterson Gulch" in his field notes of 1950 (R. H. Tedford, pers. comm., January, 2003).

About 10 km closer to Leadore (to the south) than Nichols' Peterson Creek localities are the Mollie Gulch beds, which span at least 40 meters. Fossil mammals from the Mollie Gulch beds are younger than those from Peterson Creek. Observations of R. Nichols and field notes of C. Falkenbach (recorded in August, 1950) and A. D. Barnosky (recorded in July, 2003) describe the Mollie Gulch beds as a whitish siltstone or blocky sandy clay in the lower part giving way to darker tan colored sandstones in the upper part. The whitish siltstones have yielded abundant specimens of *Merychyus*, including *Merychyus? elegans* collected from stratigraphically less than about 8 m (25 feet) above the "lower part of the deposits along the Lemhi Valley" (Schultz and Falkenbach, 1947:186–187). It is these whitish siltstones that also likely yielded *Michenia*, *Miolabis*, *Oxydactylus*, and *Protolabis*, although precise stratigraphic placement of the specimens is not possible. Neither is precise placement possible for a maxilla Shultz and Falkenbach (1947:187) identified as *Merycochoerus*. From about the middle of the whitish siltstones R. Nichols identified *Diceratherium*. A non-diagnostic phalanx of a chalicothere (Skinner, 1968) also may have come from the whitish siltstones. From the higher part of the Mollie Gulch section, within the tan sandstones, *Alphagaulus vetus* and *Merychippus* were recovered, and a similar stratigraphic level probably produced Falkenbach's specimens of *Aepycamelus* (R. H. Tedford, pers. comm., January, 2003). These specimens are in UM, CM, AMNH, and TTM collections.

The taxa from the Lemhi Valley therefore suggest a late early Arikareean component from Peterson Creek, and a late Arikareean component from Peterson Gulch. Although Tedford and colleagues (2004) questionably referred Mollie Gulch beds to late Arikareean, in fact it is unknown whether any Arikareean rocks are present there—some might be if the reports of *Merycochoerus* and *Diceratherium* withstand scrutiny. Without further study it is not possible to draw firm inferences from reports of those two taxa, however, and conclusive study seems unlikely because the exact geographic location of the *Merycochoerus* specimen is unknown and the *Diceratherium* specimen was damaged after its initial identification. Taxa from most of the whitish siltstones at Mollie Gulch imply a Hemingfordian age. The overlying upper tan sandstones yield taxa indicative of early Barstovian age. Therefore, most Mollie Gulch beds are younger than suggested by Tedford and colleagues (2004).

The whitish siltstones at Mollie Gulch are lithologically very similar to those below the MTU in the RCS, and the tan sandstones at Mollie Gulch are similar to the sandstones near and above the MTU in the RCS. The similarity in lithologic sequence and the geographic proximity suggest the whitish siltstones of the Mollie Gulch beds are coeval with the base of the RCS at Whiskey Spring. If so, the base of the RCS would be within the late Hemingfordian, 16.0–17.5 Ma.

Radioisotopic Dating and Tephrachronology

Independent chronologic control on middle Miocene mammal faunas is only moderate in the northern Rockies, as the area had little local volcanism through the pertinent time. Although tephra layers are numerous in deposits of this age, most of them represent ash blown in from distant sources, usually the Great Basin or Pacific Northwest, and are at least mildly reworked after deposition. It has therefore been difficult to obtain reliable radioisotopic dates. The RCS is no exception; it was not possible to obtain reliable Ar-Ar dates from any of the numerous ash beds that were sampled. The nearest pertinent Ar-Ar date, 15.82 ± 0.21 Ma (5794R, Berkeley Geochonrology Lab), was obtained from CC-4 of the Hepburn's Mesa Formation, Yellowstone Valley, Montana (Fig. 1). This date is ca. 0.64 million years older than a tephrachronological date on the same ash (see below); due to detrital contamination affecting Ar-Ar dates in the Hepburn's Mesa area, the tephrachronology may be more reliable. Taxa at CC-4 that are associated with this dated ash and also found in the RCS include *Hypohippus*, "*Merychippus*," and *Alphagaulus*. This is consistent with placing the occurrence of these taxa at RCS in the early Barstovian, though they are

TABLE 2. Taxa reported at each locality.

Taxon	Localities														
	South Portal	Deadman Pass 1 or 2	High Dead Squirrel 4	High Dead Squirrel 2/3	*Merycodus* Loc.	Turtle 4	Turtle 3	Cruikshank Hill	Dead Squirrel 1/2	Turtle 1	Four Humps	Dead Squirrel 3 & 4	Snowfence-Turtle 3	Snowfence-Turtle 4	Tunnel Draw*
Reptilia															
Testudinidae							x			x			x	x	
Mammalia															
Insectivora															
Talpidae	x	x		x											
Erinaceidae	x														
Carnivora															
Amphicyonidae															
Pliocyon sp.															
Genus indet.															x*
Canidae															
Lagomorpha															
Ochotonidae															
Oreolagus sp.						x				x					
Leporidae															
Hypolagus sp.															x*
Rodentia															
Sciuridae	x														
Dipodidae															
Plesiosminthus sp.										x					
Geomyidae															
Entoptychus sp.															
Harrymys irvini															
Cupidinimus sp.	x									x					
Peridiomys sp.	x														
Mylagaulidae															
Mesogaulus sp.															
Alphagaulus vetus															
Genus indet.										x					
Aplodontidae															
Aplodontinae, genus indet.															
Perissodactyla															
Archaeohippus ultimus															
Archaeohippus cf. *A. penultimus*															x*
Hypohippus sp.					x					x					
Hypohippus osborni															x*
"*Merychippus*" sp.	x	x	x	x		x	x	x	x	x	x	x	x		
"*Merychippus*" cf. "*M.*" *insignis*															x*
Acritohippus cf. *A. isonesus*															
Chalicotheriidae															
Tylocephalonyx cf. *T. skinneri*															
Artiodactyla															
Tayassuidae															
"*Cynorca*" cf. "*C.*" *occidentale*															
Palaeomerycidae															
cf. *Bouromeryx* sp.						x									
Rakomeryx cf. *R. kinseyi*															x*
Oreodontidae															
Merychyus sp.															x
Merychus? *elegans*															
Ticholeptus zygomaticus															x
Brachycrus laticeps															x
Antilocapridae															
Paracosoryx wilsoni										x					
Merycodus sp.															x*
Merycodontinae genus indet					x										
Moschidae															
Blastomeryx sp.															
Camelidae															
Aepycamelus sp.		x													x*
Miolabinae															
Paramiolabis cf. *P. singularis*															x*

Locality codes: a, Rodent Bluff, Mollie Gulch, MV7345; b, CM locality 2221, "Railroad Canyon, Idaho"; c, Cottom Lane, MV7316; d, Big Camel locality, MV7320; e, IMNH locality 2125, occurs 20–25 m above the West Railroad Cut, but is not exactly the same as MV7327; f, AMNH Ia-7-44, "road cut 20 feet west of MT/ID line", g, CM locality 2225, "Railroad Canyon, Head of, Idaho", h, AMNH Ida-7-32, from "one mile SE of Tunnel Draw."
*Information from R.H. Tedford (pers. comm., May, 2002); see Table 3.
†Localities are in the Lemhi Valley or Bannock Pass region but physically separated from the measured Railroad Canyon sequence.
x, present at a locality within the measured Railroad Canyon Sequence; x′, known from at least one of the localities.

TABLE 2. *(Continued)*

	Localities											
Taxon	Snowfence-Turtle 2	*Archaeohippus* Loc.	Turtle 2 Blowout A or B	Turlte 2 Roadcut	Snowfence	Cut Draw	Upper East Railroad Cut	East RAilroad Cut	"Above W RRC" = MV7327	West Railroad Cut	Cruikshank Creek	Locality Near RCS†
Reptilia												
Testudinidae			x							x		a
Mammalia												
Insectivora												
Talpidae												
Erinaceidae												
Carnivora												
Amphicyonidae												
Pliocyon sp.					x							
Genus indet.					x							
Canidae			x′	x′								
Lagomorpha												
Ochotonidae												
Oreolagus sp.					x			x		x		b
Leporidae												
Hypolagus sp.			x′	x′	x							
Rodentia												
Sciuridae												
Dipodidae												
Plesiosminthus sp.			x′	x′								
Geomyidae												
Entoptychus sp.											x	
Harrymys irvini									x			
Cupidinimus sp.								x				
Peridiomys sp.												
Mylagaulidae												
Mesogaulus sp.			x′	x′								
Alphagaulus vetus			x′	x′	x′							a, c, d
Genus indet.			x′	x′	x			x				
Aplodontidae												
Aplodontinae, genus indet.								x				
Perissodactyla												
Archaeohippus ultimus		x	x		x							
Archaeohippus cf. *A. penultimus*												
Hypohippus sp.			x		x							
Hypohippus osborni												
"*Merychippus*" sp.	x	x	x	x	x	x		x	x	x		
"*Merychippus*" cf. "*M.*" *insignis*												
Acritohippus cf. *A. isonesus*					h*							
Chalicotheriidae												
Tylocephalonyx cf. *T. skinneri*									e			
Artiodactyla												
Tayassuidae												
"*Cynorca*" cf. "*C.*" *occidentale*					x							
Palaeomerycidae												
cf. *Bouromeryx* sp.		x	x									
Rakomeryx cf. *R. kinseyi*												
Oreodontidae												
Merychyus sp.					x							
Merychus? *elegans*								x				
Ticholeptus zygomaticus												
Brachycrus laticeps												
Antilocapridae												
Paracosoryx wilsoni												
Merycodus sp.												
Merycodontinae genus indet			x		x							
Moschidae												
Blastomeryx sp.								x				f*
Camelidae												g
Aepycamelus sp.					x							
Miolabinae							x					
Paramiolabis cf. *P. singularis*												

TABLE 3. Known biochronologic ranges in the northwestern quarter of the U.S.A (sensu Barnosky and Carrasco, 2002) of mammals identified in the Railroad Canyon sequence.

	NALMA								
Taxon	EEAR	LEAR	ELAR	LLAR	EHEM	LHEM	EBAR	LBAR	< BAR
Pliocyon sp.						*g	g		
Hypolagus sp.					?	*	g	g	g
Oreolagus sp.			?		*g	g	g	g	
Plesiosminthus sp.	*g	g	g	g	g	g	g	g	
Cupidinimus sp.					*		g	g	g
Peridiomys sp.						g	g	g	
Harrymys irvini						s	s		
Entoptychus sp.		*g	g	g					
Mesogaulus sp.					*s				
Alphagaulus vetus						s	s		
"*Cynorca*" sp.		*g		g		g	g		
Paracosoryx wilsoni						g	g	?	
Merycodus sp.						*g	g	g	g
Bouromeryx sp.					?	*g	g	g	g
Rakomeryx cf. *R. kinseyi*						*g	g	g	g
Blastomeryx sp.				*g	g	g	g	g	g
Paramiolabis cf. *P. singularis*						g	s		s
Miolabis sp.				*		g	g	g	g
Aepycamelus sp.						*g	g	g	g
Merychus sp.			*g	g	g	g	g	g	g
Merychyus? elegans			g	g	g	g	g	g	
Brachycrus laticeps						*s	s		
Ticholeptus zygomaticus					*		s	s	s
Hypohippus sp.		?			*	g	g	g	g
Hypohippus cf. *H. osborni*							s	s	
Archaeohippus ultimus			*			s	s		
Archaeohippus cf. *A. penultimus*						s			
"*Merychippus*" sp.		?			*	g	g	g	g
"*Merychippus*" cf. "*M. insignis*"							s	s	s
Acritohippus cf. *A. isonesus*						*	s	s	
Tylocephalonyx cf. *T. skinneri*						s		g	s

Ranges are from the MIOMAP database (Carrasco et al., 2005). Abbreviations: EEAR, early Early Arikareean; LEAR, late Early Arikareean; ELAR, early Late Arikareean; LLAR, late Late Arikareean; EHEM, Early Hemingfordian; LHEM, Late Hemingfordian, EBAR, Early Barstovian, LBAR, Late Barstovian, < BAR, younger than Barstovian.
*Genus characterizes beginning of NALMA division (Tedford et al., 2004).
?: Questionable identification or age placement in older literature; g, same genus as in RCS; s, same species as in RCS.

known to occur together from the late Hemingfordian to the late Barstovian.

Results from tephrachronology are consistent with a late Hemingfordian or early Barstovian age for parts of the RCS. One RCS ash mineralogically matched well with the same CC-4 ash noted above (B. Nash, pers. comm., September, 1994), and also with an ash from the Virgin Valley (VVY93-12), Nevada (B. Nash and M. Perkins, pers. comm., September, 2005), which was dated to 15.18 +/-0.03 Ma (Perkins et al., 1998). However, this RCS ash (ADBR8-93) was collected from a small exposure (Deadman Pass 2) that cannot be conclusively tied to the measured sections. An ash from +23 m in Whiskey Spring 3 (ADBR6-93) is a peralkaline tephra that would be consistent with mineralogy of the 16.6–15.8 Ma McDermitt volcanic field (M. Perkins, pers. comm., September, 2005). The ash sample comes from near the MTU, but the nature of the exposure precludes detailed correlation. This peralkaline RCS tephra also resembles a tephra in Stewart Valley, Nevada, dated to ca. 14.3 Ma, but given its stratigraphic position near the MTU, that match seems unlikely.

Magnetostratigraphy

The considerations noted above indicate that the rocks are of late Hemingfordian to Barstovian age, providing a temporal window into which to fit the magnetostratigraphy. Although precise placement within this temporal window is not as secure as would be ideal, the magnetostratigraphy itself is robust, with most samples producing strong, clearly interpretable signals.

Presented here are two slightly different interpretations (Fig. 5). The first magnetostratigraphy, labeled "Basic Unrevised" (Fig. 5) includes only Class A sampling sites and was constructed as follows. The Class A sites reported by Zheng (1996) and additional Class A sites from the South Portal section were plotted against the lithological sections (Fig. 5). Also plotted were the ambiguous magnetic signatures (gray patterns) that characterized the coarse sediments between meters 180 and 240. It was assumed based on biostratigraphic considerations discussed above that the boundary between late Hemingfordian and early Barstovian was captured somewhere between meters 120 and 140 in the RCS composite section. That assumption would chronologically anchor some part of the interval between meters 120 and 140 to around 16.0 Ma. That part of the RCS magnetostratigraphy was then compared with the magnetostratigraphy at Hepburn's Mesa, Montana, which encompasses C5ADn to C5Cn.2n (ca. 14.5–16.5 Ma), and to the GPTS (Berggren et al., 1995; Cande and Kent, 1995). The best visual match suggested that meters 90–250 record the same paleomagnetic sequence as the Hepburn's Mesa section (Fig. 5). This would place the top of the RCS at about 13 Ma and the cessation of the MTU at ca. 16.7 Ma. The bottom of Whiskey Spring 4 would be at least 17.3 Ma (C5Dn), but could be older, depending on how much time the MTU cuts out of the section. The normal interval at the base of the RCS composite section lacks independent age control, other than it is younger than the stratigraphically lower Arikareean Cruikshank Creek beds. If the biostratigraphic and lithologic correlation discussed above between the RCS and the Lemhi Valley sequence holds, the normal polarity interval at the base of the RCS would most likely be Chron C5Dn, which dates from 17.3–17.6 Ma.

The alternative magnetostratigraphic interpretation, the "Least Squares 2 match" (Fig. 5), was published by Zheng (1996). Using Class A and selected Class B and C sites (excluding South Portal), he looked for the best statistical match between his composite section and the GPTS. Zheng's (1996) statistical method assumed that the best match between the polarity intervals observed in the stratigraphic column and those dated in the GPTS was the match that exhibited the least variance between sedimentation rates calculated for each magnetic polarity interval. Intervals above and below the MTU were treated separately.

Above the MTU, computation by the least squares method produced three possible matches (i.e., three correlations that produced the lowest variance in sedimentation rate), Zheng's "Least 1," "Least 2," and "Least 3" matches. Zheng then applied linear regression to test for statistical significance between the sedimentation rate calculated for each polarity interval in the stratigraphic section and the amount of time represented by corresponding intervals in the MPTS. Only the Least 2 match was both statistically significant and within the biostratigraphic age constraints.

Below the MTU, each of the Least 1, 2, and 3 matches were statistically significant in the regression analysis. Zheng (1996) favored the Least 2 match both above and below the MTU (Fig. 5) because it resulted in the fewest differences in sedimentation rates calculated per polarity interval, and also because it is the most compatible with the biostratigraphic data. The Least 2 match places the youngest beds below the MTU at about 17.3 Ma, which is consistent with but independent of the biostratigraphic discussion above.

A difference between the Basic Unrevised match and the Least 2 match is apparent only above C5Bn.2n. Given the lack of independent age control, there is no strong basis for favoring one of these correlations over the other. However, here the Basic

Unrevised magnetostratigraphy is favored because it includes only Class A sites, and because lithologies and consequently sedimentation rates clearly do change through the section, especially in the interval where the two proposed correlations diverge, between meters 170 and 240. Either interpretation of the RCS composite magnetostratigraphy is fully consistent with the stratigraphic distribution of taxa and with placing localities between meters 120 and 140 temporally near the boundary between late Hemingfordian and early Barstovian. Either interpretation also would indicate that deposition after the MTU had recommenced by 16.7 Ma, and that the top of the RCS is no younger than ca. 13 Ma. Thus we regard these conclusions as reasonably robust.

SYSTEMATIC PALEONTOLOGY

Reported here are the specimens important enough to warrant description. Systematic Paleontology of other specimens, including AMNH specimens previously identified by R. H. Tedford (Table 2S) is recorded as Supplementary Data (Appendix 2S, www.vertpaleo.org/jvp/JVPcontents.html). The faunal list (Table 2) combines specimens listed here and in the Supplementary Data.

Class MAMMALIA Linnaeus, 1758
Order CARNIVORA Bowdich, 1821
Family AMPHICYONIDAE Haeckel, 1866
Subfamily AMPHICYONINAE Haeckel, 1866
Genus *PLIOCYON* Matthew and Gidley, 1904

Pliocyon sp.
(Fig. 7)

Occurrence—UM MV7338.

Referred Material—Left dentary with p2 (fragment) and m1, UM 9287.

Description—Mid-sized amphicyonid. Lower jaw robust and deep. Anteroposterior length of canine alveolus ≥30 mm. Premolar row crowded, as in *Pliocyon* but unlike other Miocene species *Cynelos*, *Amphicyon*, and *Ischyrocyon*. Alveoli of p1 indicate strongly canted first premolar relative to rest of toothrow. Posterior alveolus of p3 and anterior alveolus of p4 closely appressed, well below top of alveoli; no diastema present. Anteroposterior length of m1 = 36 mm. Talonid worn flat with light vertical wear facet present on anterolateral face. Base of protoconid inflated, resulting in broad, robust tooth. Hypoconid placed slightly laterad. Distinguished from *Pseudocyon* by absence of deep vertical wear groove on anterolateral talonid of m1 (Hunt, 1998).

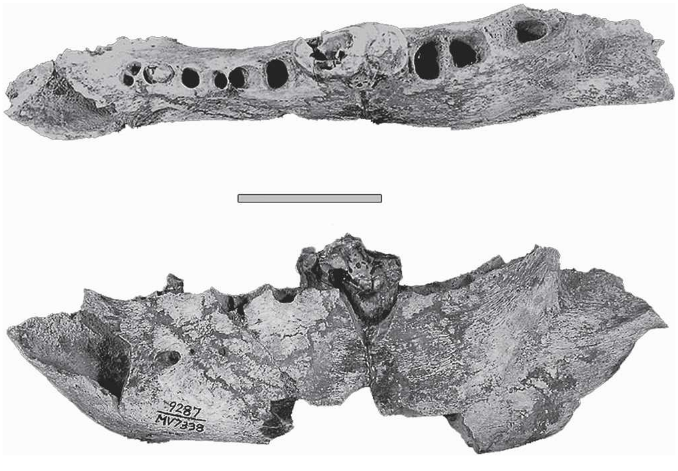

FIGURE 7. Left dentary of *Pliocyon* sp., UM 9287, in occlusal (above) and lateral (below) views. Scale bar equals 5 cm.

Comments—This specimen is slightly larger than any other species of the genus, based on the length of m1 (m1 AP = 36 mm; AP = 26–31 mm for *Pliocyon medius*, 33 mm for *Pliocyon robustus*; Hunt, 1998). The premolar crowding, while generally similar to other species of *Pliocyon*, is distinct because p1 is rotated relative to the long dimension of the toothrow; in other species of *Pliocyon*, the p3 is rotated to accommodate the shortening of the jaw. These characteristics, taken together, suggest that this specimen represents a previously unknown species of *Pliocyon*; without more complete material, however, it would be inappropriate to introduce a new name.

Order RODENTIA Bowdich, 1821
Family GEOMYIDAE Bonaparte, 1845
Subfamily ENTOPTYCHINAE Miller & Gidley, 1918
Genus *ENTOPTYCHUS* Wood, 1936
Entoptychus sp.

Occurrence—UCMP V99208.

Referred Material—Natural mold of dentary with p4–m3, UCMP 189750.

Description—This specimen does not preserve the original material of the teeth; a cast made from the natural mold, however, permitted examination of the external morphology of the tooth crowns, although features such as dentine tracts were not visible. This is clearly a member of the Entoptychinae, as indicated by the presence of a prominent anterior cingulum on the lower molar which, along with the protostylid, is separated from the protoconid by a deep cleft. This results in the distinctive anterolabial enamel reentrant present on lower molars in early wear. Referral to the Entoptychinae is also supported by the posteriorly elongated protoconid which does not join the hypoconid and the complete absence of a posterior cingulum in the lower cheek teeth. This specimen is referred to *Entoptychus* based on the reduced anterior cingulum on p4, which lacks distinct cusps. In *Gregorymys* this cingulum is much more prominent and has several distinct cuspules (Rensberger, 1971). Three species of *Entoptychus* have been described previously from Idaho and Montana (Hibbard and Keenmon, 1950; Nichols, 1976), and are the most likely species to which this specimen might be referred. Of the three, *Entoptychus sheppardi* can be eliminated, as it has the metalophid of p4 sloping forward in early wear (Nichols, 1976), whereas that is definitely not the case in this specimen. The specimen compares well with *Entoptychus fieldsi* in size (tooth row length UCMP 189750 = 7.4 mm; toothrow length = 7.6 mm in *E. fieldsi*; Nichols 1976) and morphology. The third species, *Entoptychus montanus*, cannot be eliminated, as it is known only from the upper dentition.

Subfamily HETEROMYINAE Coues, 1875
Genus *HARRYMYS* Munthe, 1988
Harrymys irvini Munthe, 1988

Occurrence—UM MV7327.

Referred Material—R dentary with p4–m2, UM 4380.

Description and Comments—The specimen is referable to *Harrymys* on the basis of the unique dental morphology that characterizes this genus, including relatively hypsodont cheek teeth with the lophs of lower cheek teeth strongly joined by a high, sharp central enamel ridge. The major cusps of the teeth are distinct and ovate or teardrop-shaped, with the long axes of the cusps extending obliquely and posteriorly from a contact with the central enamel ridge. The lower premolar is characterized by a narrow, strongly curved metalophid. The metaconid is elongate anteroposteriorly, with a labially directed anterior cingulum joining the central enamel ridge and continuing labially to connect with a series of small anterostylids and the protostylid. A diagnostic feature of *Harrymys*, also apparent in the RCS specimen, is the central position of a small enamel lake in the hypolophid surrounded by the hypoconid, entoconid, and the posterior cusp. This is present on the premolar, as well as on all molars, but is not present in superficially similar genera, such as *Lignimus* or *Mojavemys*. Early in wear this lake becomes isolated from the enamel border of the tooth, but it is deep and persists into moderate wear, disappearing just prior to disappearance of the enamel reentrant that divides the protostylid ridge from the protoconid. The lake is somewhat deeper and more persistent in the Railroad Canyon specimen than in most specimens of *H. irvini* from the type locality in Split Rock, Wyoming, but it is within the range of variation present in the species. There are 3 described species of *Harrymys*: *H. irvini*, *H. woodi*, and *H. canadensis*. The specific assignment, in this case, is made on the basis of size. The length of the tooth row from the anterior end of p4 to posterior end of m2 is 5.3 mm. Dimensions of the individual teeth (given as TR, AP, in mm) are: p4: 1.7, 1.9; m1: 1.9, 2.1; m2: 2.0, 2.0. This specimen is clearly too large to represent *H. woodi* (Black, 1961:16) or *H. canadensis* (Korth, 1995: 22). It is, however, the same size as *H. irvini* (Munthe, 1988:78); in addition, the extremely prominent central enamel ridge, the lateral union between the lophs of the p4, and the distinctly oblique orientation of the primary cusps of the teeth are consistent with the morphology of *H. irvini* from Split Rock.

Genus *CUPIDINIMUS* Wood, 1935
Cupidinimus sp.
(Fig. 8)

Occurrence—UCMP V99097, MV7330.

Referred Material—From V99097: p4, UCMP 189968; six m1, UCMP 189960, 189961, 189964, 189966, 189972, 189991; seven m2, UCMP 189958, 189967, 189980, 189985, 189986, 189987, 189995; m3, UCMP 189959; four P4, UCMP 189970, 189973, 189992, 189994; two M1, UCMP 189977, 189978; three M2, UCMP 189969, 189979, 189989; M1 or M2, UCMP 189962; M3, UCMP 189971. From MV7330: left dentary with p4–m2, UM 5866.

Description—These specimens are referred to *Cupidinimus* on the basis of their small size (Table 4) and level of hypsodonty. The protoloph of P4 is composed of one major cusp, whereas the metaloph is composed of three major cusps. M1, M2, m1, and m2 are all bilophodont, with each loph composed of three major cusps. Crown walls are straight, and roots are fused near the crown, separating distally. The metalophid of p4 is composed of two cusps, whereas the hypolophid is made up of three cusps and joins the metalophid centrally. These characters are diagnostic of *Cupidinimus* (Carrasco, 1998).

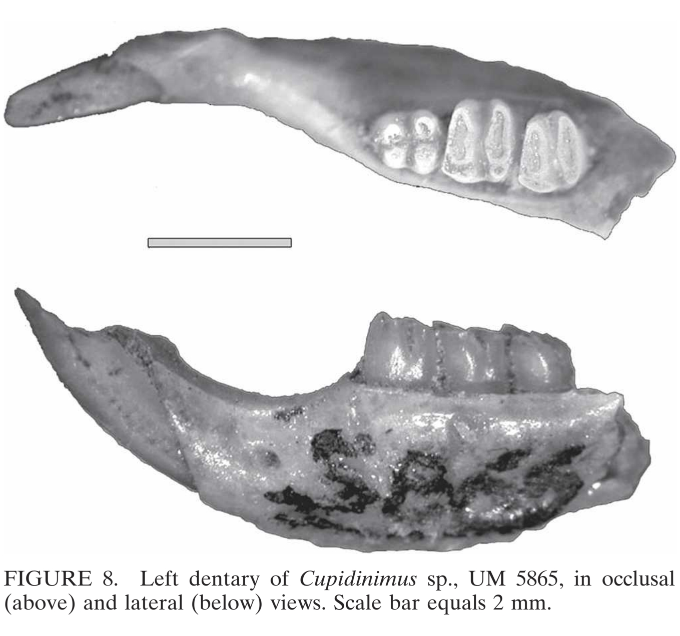

FIGURE 8. Left dentary of *Cupidinimus* sp., UM 5865, in occlusal (above) and lateral (below) views. Scale bar equals 2 mm.

TABLE 4. Comparative measurements of *Cupidinimus*.

Tooth	Measurement	n	$\bar{x}$	SD	OR
P4	AP	4	0.93	0.049	0.88–1.00
P4	TA	4	0.62	0.085	0.52–0.69
P4	TP	4	1.27	0.053	1.19–1.31
M1	AP	3	0.87	0.014	0.86–0.88
M1	TA	3	1.23	0.16	1.10–1.40
M1	TP	3	1.17	0.084	1.10–1.26
M2	AP	2	0.77	0.017	0.76–0.79
M2	TA	2	1.20	0.051	1.17–1.24
M2	TP	2	1.13	0.084	1.07–1.19
M3	AP	1	1.00	—	1.00
M3	TA	1	1.09	—	1.09
M3	TP	1	0.90	—	0.90
p4	AP	2	0.85	0.051	0.81–0.88
p4	TA	2	0.74	0.00	0.74
p4	TP	2	0.86	0.067	0.81–0.90
m1	AP	6	0.96	0.095	0.83–1.10
m1	TA	6	1.19	0.16	1.02–1.48
m1	TP	6	1.17	0.11	1.02–1.33
m2	AP	7	0.97	0.087	0.85–1.10
m2	TA	7	1.14	0.071	1.05–1.24
m2	TP	6	1.10	0.14	0.90–1.31

Abbreviations: $\bar{x}$, mean; SD, standard deviation; OR, observed range; AP, anteroposterior length; TA, anterior loph transverse width; TP, posterior loph transverse width.

Comments—The RCS *Cupidinimus* sample, although not referable to a previously described species, displays characteristics typical of the eastern group defined by Barnosky (1986b). This group is characterized by comparatively low-crowned molars and infrequent accessory cusps on P4 and includes *C. whitlocki* and *C. madisonensis* from the northern Rocky Mountains, and *C. saskatchewanensis*, *C. kleinfelderi, C. prattensis*, *C. smaragdinus*, and *C. nebraskensis* from the Great Plains. All are taxa typical of Barstovian assemblages.

The 26 specimens of *Cupidinimus* from the South Portal section (UCMP V99097) were collected from three lenses between +3 and +10 m. An additional specimen came from East Railroad Cut (MV7330). Metrics detailed in Barnosky (1986b) and Carrasco (1998) were determined for the RCS sample and overlain on the graphs published in Barnosky (1986b:figs. 6–11) and Carrasco (1998:fig. 3). Bivariate plots comparing length, width, and hypsodonty demonstrated diffuse continuous clusters of points, suggesting either a single highly variable species or more than one species whose characteristics overlap. A relatively high degree of variation could result from the time-transgressive nature of the sample.

The RCS P4s are all shorter anteroposteriorly than in any other described species of *Cupidinimus*. P4s tend to be widely divergent in occlusal dimensions between different species (Barnosky, 1986b:fig. 6); with a sample of only four specimens, it is inadvisable to use this character alone to define a new species. In molar occlusal dimensions (Table 4), the RCS sample is near or slightly below the middle of the *Cupidinimus* size range, similar to *C. madisonensis, C. boronensis,* and *C. halli*, three of the smaller species. Molars from the RCS are on average smaller than those of *C. smaragdinus, C. kleinfelderi, C. tertius, C. whitlocki, C. avawatzensis, C. cuyamensis*, and *C. bidahochiensis*, and larger than those of *C. nebraskensis, C. lindsayi,* and *C. eurekensis*. That the older East Railroad Cut specimen (UM5866: m1: AP = 1.02 mm, TA = 1.24 mm, TP = 1.19 mm) is well within the range of those from the younger South Portal lenses, suggesting that *Cupidinimus* remained at similar size in this part of the northern Rockies for 3–4 million years.

Determination of presence/absence of accessory cusps on the single South Portal p4, UCMP 189968, was difficult because the specimen is highly worn. A conspicuous fold of enamel running partway down the anterior face of the tooth may be the remnant of an anterostylid. East Railroad Cut specimen UM 5866 can be distinguished from *C. smaragdinus* in that the p4 lacks both an anterostylid and a central 'double connection' between the lophids (Korth, 1996).

The four P4s are relatively narrow (TA, TP), extremely short (AP), and all lack accessory cusps. The hypsodonty values for m1 and m2 (LEH/TR) overlap with those of *C. lindsayi* and *C. madisonensis,* whereas upper M1-M2 hypsodonty (CHEV/TR) is widely distributed, covering almost the entire range of values given by Barnosky (1986b) for species of *Cupidinimus*. CHEV/TR averaged 0.27, ranging from 0.18 to 0.45, while LEH/TR was much less variable, averaging 0.41 and ranging from 0.36 to 0.45.

The coefficient of variation (CV), defined as 100 X (standard deviation/sample mean), reflects the degree of variability in occlusal dimensions independent of sample size. TA measurements of P4, M1, and m1, and TP of m2 specimens in the RCS sample produced CVs of 13.7, 12.9, 12.6, and 13.0, respectively. These values exceed 10, the conventionally accepted maximum for a single species (Simpson et al., 1960). They are also greater than those documented for both extinct and extant heteromyines (Carrasco, 1998). Carrasco (1998) encountered a similar situation with the sample of *Cupidinimus* from Hepburn's Mesa, which is possibly nearly contemporaneous. He proposed that the high CV values reflected one of the following: (1) more than one named and/or new species; (2) introgression (reunification of previously isolated populations) event(s); or (3) an "in-progress" speciation event(s). No quantitative or morphological differences are present that allow for differentiation of multiple species within the Railroad Canyon sample. It is possible, however, that two or more species are present, with a continuum of tooth size and hypsodonty values.

Based on the extensive overlap of dental dimensions for all but P4, it would be difficult to assert that this is a new species of *Cupidinimus*. The distinctly smaller P4 suggests that this may be a new form, but without a larger sample, especially of unworn teeth, we refrain from naming a new species. The RCS sample does increase the morphological diversity known for *Cupidinimus*, however, and pertains to a relatively low-crowned and small-sized member of the genus.

Family MYLAGAULIDAE Cope, 1881
Genus *MESOGAULUS* Riggs, 1899
Mesogaulus sp.

Occurrence—UM MV 7323.

Referred Material—Left p4, UM 4224.

Description and Comments—UM 4224 is referred to *Mesogaulus* on the basis of its low crown height and because it has only four fossettids, a condition unknown in any species other than *M. ballensis* (and only in the extremely worn type specimen of that species). All mylagaulines and *M. paniensis* have at least five fossettids on the p4 (Korth, 2000). We do not refer UM 4224 to a species because *M. ballensis* is known only from badly worn material and could be synonymous with *M. paniensis*. In addition, UM 4224 is distinct from *M. ballensis* in the configuration of the fossettids, with much less dentine exposed between the fossettids and the outer enamel boundary of the tooth. The specimen from the RCS is further differentiated because it is much smaller (7.4 mm AP) than the type of *M. ballensis* (9 mm AP; Riggs, 1899). Given these differences, it is unlikely that this specimen represents *M. ballensis*, but it is referred to *Mesogaulus* on the basis of the degree of hypsodonty. Promylagaulines all have better-developed roots and shorter crowns than this specimen (Rensberger 1980). The specimens could represent a new species of *Mesogaulus,* should further material bear out the potentially diagnostic features noted here.

Genus *ALPHAGAULUS* Korth, 2000
Alphagaulus vetus Matthew, 1924
(Fig. 9)

Occurrence—UM MV 7316, MV7320, MV7323, MV7338, MV7345.

Referred Material—From MV 7316: right dentary with p4-m2, UM 4077; from MV7320: right P4, UM 4079; from MV7323: left ramus with p4, m2–3, UM 4235, right ramus with m2-3, UM 4236; from MV7338: left P4, UM 6443, left unworn m2, UM 6444; from MV7345: left mandible with p4, m2, UM 4489.

Description—Both mylagaulid upper premolars, UM 4079 and UM 6443, are clearly attributable to the subfamily Mylagaulinae rather than the Promylagaulinae or Mesogaulinae on the basis of their large size, oval occlusal outline, and paracones with convex labial face. Within the Mylagaulinae, these P4s can be referred to *Alphagaulus* on the basis of possessing only five fossettes and retaining the outline of the mesostyle late into wear (Korth, 2000). These fossettes are more anteroposteriorly elongate and more persistent than in *Mesogaulus*. Although both upper teeth are missing parts of the lateral enamel—and hence cannot be precisely measured—their size is consistent with referred lower teeth. The lower dentitions, UM 4077, 4235, and 4489, exhibit some variation in the position and persistence of enamel lakes, likely a result of the temporal range and evolutionary time represented by the specimens. All three specimens are attributable to *Alphagaulus* on the basis of the small number of fossettids (five or six), overall size (AP = 6.5–8.6 mm, n = 5), the transversely narrow p4 (AP/TR = 1.4–2.2, n = 5), and the retention of a distinct labial inflection. The morphology of the enamel lakes is also diagnostic in being less elongate and not as straight as in *Umbogaulus monodon*, the only other mylagaulid species with an equivalent number of enamel lakes. All of the specimens are within the size range of *Alphagaulus*. All of the referred upper premolars have the labial branch of the parafossette separating earlier than the lingual branch, indicating that they represent either *A. pristinus* or *A. vetus*; this assignment is supported by the fact that all of the referred teeth are smaller than those of *A. douglassi* and *A. tedfordi*. The material is assigned to *A. vetus* on the basis of the large size and the generally straighter, narrower enamel lakes. The specimens from Railroad Canyon compare well with *A. ve-*

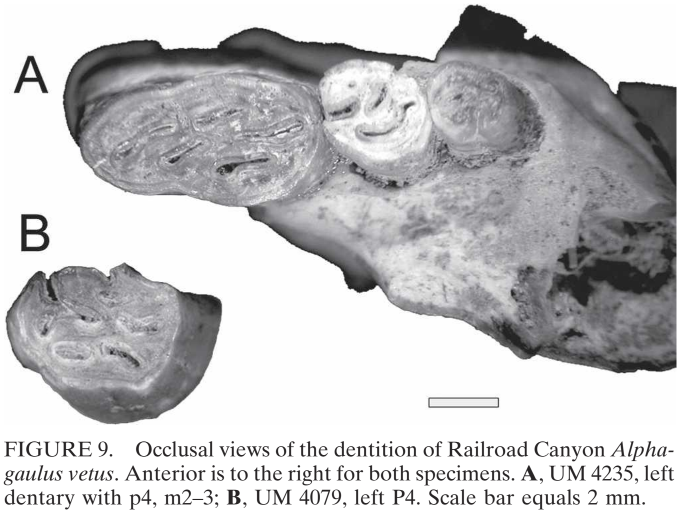

FIGURE 9. Occlusal views of the dentition of Railroad Canyon *Alphagaulus vetus*. Anterior is to the right for both specimens. **A**, UM 4235, left dentary with p4, m2–3; **B**, UM 4079, left P4. Scale bar equals 2 mm.

tus from Split Rock, Wyoming, as described by Munthe (1988). UM 4236, a lower jaw with m2-3, is also attributed to this species despite its lack of diagnostic teeth because it bears a strong resemblance to the other three mandibles assigned here, especially UM4235, from the same locality. UM 6444 is attributed to *A. vetus* because it occurs in the same locality as UM 6443 and corresponds well in size and morphology to *Alphagaulus*, although this tooth would not otherwise be diagnostic on its own.

Order PERRISODACTYLA Owen, 1848
Family EQUIDAE Gray, 1821
Genus *ARCHAEOHIPPUS* Gidley, 1906
Archaeohippus ultimus (Cope, 1886)
(Fig. 10)

Occurrence—UM MV7333, MV7323, MV7338, UCMP V99094.

Referred Material—From UM MV7333: articulated left and right dentaries with R i1–3, c1, p1–4, m1–3, L c1, p1–4, m1–3, metapodial and metapodial fragments, scaphoid, lunar, magnum, UM 4403; dentary fragment with four cheek teeth, UM 4405. From UM MV7323: maxilla fragment with LP3–M1, UM 9440; broken lower cheek tooth, UM 4300; m3, UM 4301; two broken cheek teeth, UM 4303; magnum, UM 4311. From MV7338: three broken astragali, UM 4445; fragment of left dentary with p2–4, UM 5758; broken upper cheek tooth, UM 5799; upper cheek tooth, UM 6447; lower cheek tooth, UM 6450. From UCMP V99094: right dentary with p3–p4, UCMP 189809. From unknown locality in RCS: right lower tooth, UCMP 198717.

Description—Teeth are clearly referable to *Archaeohippus* by their very small size, low crown height, and absence of cementum. Very small equid astragali and other postcranial elements also are referred to this genus. The material is referred to *Archaeohippus ultimus* on the basis of its size, as well as the relative size of the first premolar and the morphology of the anterior dentition. UM 4033 is a complete lower dentition, and has the following dental dimensions (given as AP, TR, in mm): Lp1, 6.7, 3.7; Rp1, 6.8, 3.9; Lp2, 14.1, 8.7; Rp2, 14.1, 9.0; Lp3, 12.5, 10.9; Rp3, 12.7, 10.5; Lp4, 12.5, 10.9; Rp4, 11.9, 10.9; Lm1, 11.1, 8.8; Rm1, 11.2, 9.2; Lm2, 11.2, 8.4; Rm2, 11.6, 8.4; Lm3, 13.5, 7.3; Rm3, 13.3, 7.6. The only complete tooth of UCMP 189809, a Rp3, measures 14.2 mm AP and 10.2 mm TR, slightly longer than UM 4033 but within expected range of variation. UM 9440 is an upper dentition, and provides upper dental measurements for P3 (14.5 mm AP, 16.4 mm TR), P4 (14.3 mm AP, 17.4 mm TR), and M1 (13.9 mm AP, 16.9 mm TR). These dimensions preclude referral to the smaller species of *Archaeohippus*, *A. mannulus* (lower molariforms range from 9.9–11.6 mm AP and 6.3–8.4 mm TR; O'Sullivan, 2005), *A. blackbergi* (lower molariforms range from 10.4–11.2 mm AP and 6.3–8.3 mm TR; O'Sullivan, 2005), and *A. penultimus* (lower molariforms range from 10.1–10.7 mm AP and 8.1–9.2 mm TR; Downs, 1956). The Railroad Canyon specimens are too small to pertain to *A. stenolophus* (P4 or M1 AP = 16.1 mm, TR = 19.4 mm and m3 AP = 15.5 mm, TR = 7.8 mm; Storer and Bryant, 1993). This leaves only *A. mourningi* and *A. ultimus* as species consistent in size with the Railroad Canyon *Archaeohippus*. The Railroad Canyon specimens compare favorably with the UCMP sample of *A. ultimus* from the Mascall Formation, Oregon (Downs, 1956). Comparison with *A. mourningi* from the Caliente and Punchbowl Formations of California indicates that, although the molariform teeth are similar in size, *A. mourningi* has a much larger p1 (AP = 8.2–10.0 mm, TR = 4.0–5.4 mm, n = 4), and a larger diastema separating i3 from c1. The close appression of i3 and c1 is cited by Downs (1956) as an important character of the lower dentition of the now-defunct species *A. minimus*, which O'Sullivan (2005) includes within *A. ultimus*. *A. ultimus* is also known from Montana and lends geographic support to the referral of the Railroad Canyon material to this species.

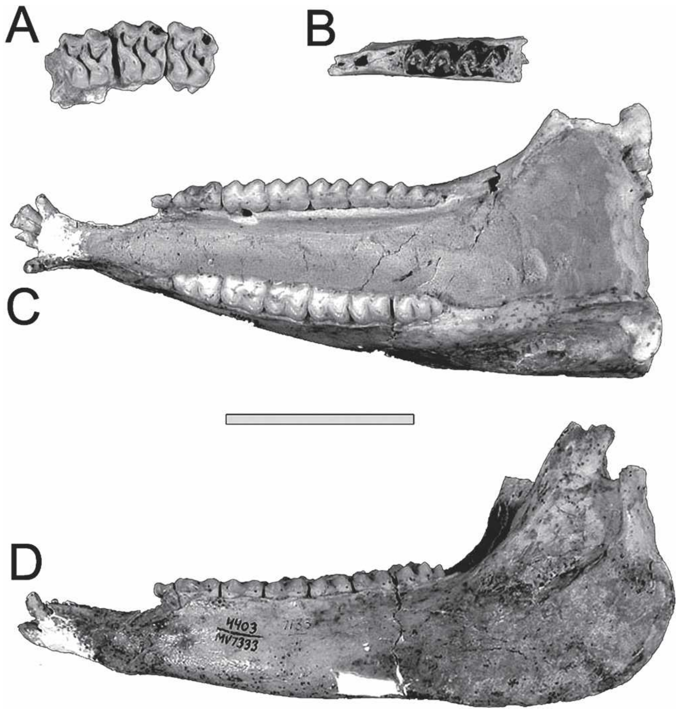

FIGURE 10. Dentition of *Archaeohippus ultimus*. **A**, UM 9440, LP3-M1, in occlusal view; **B**, UCMP 189809, right dentary with p3-p4 showing midwear occlusal morphology; **C**, UM 4033, left and right dentaries with right i1-m3, left c1-m3, all in relatively late wear, occlusal view; **D**, same as C, lateral view. Scale bar equals 5 cm.

Order ARTIODACTYLA Owen, 1848
Family TAYASSUIDAE Palmer, 1897
Genus **"***CYNORCA"* Cope, 1867
"*Cynorca*" cf. *C. occidentale* Woodburne, 1969

Occurrence—UM MV7338, UCMP V99094.

Referred Material—From MV7338: articulated left and right dentaries with Li1–3, c1 (fragment), p1, p2 (fragment), R i1–2, c1(fragment), p2–4 m1, UM 4113; cheek tooth, UM 4432; dentary fragment with p1–2, UM 5832; dentary with p2–4 and m1, UM 5831. From UCMP V99094: Lp4, UCMP 189812.

Description—The RCS specimens exhibit the following lengths: p2–m1 = 34 mm; m1 = 9.5 mm; diastema from c–p2 = 26 mm. These measurements are within the range of "*Cynorca*" specimens from Arikareean John Day (Oregon), Hemingfordian Sheep Creek (Nebraska), and Barstovian Calvert Cliffs (Maryland). UM 4113 is much too small to pertain to *Prosthennops* (in which average m2 length = 18.9 mm; Wright, 1998) or *Dyseohyus* (in which average m2 length = 13.1 mm; Wright 1998), and represents a very small tayassuid, even relative to members of "*Cynorca*."

A primary feature that distinguishes "*C.*" *proterva* (= "*Prosthennops*" *xiphidonticus,* in part; Wright, 1998) is a longitudinal ridge that extends posteriorly from the lingual side of the metaconid in m1 (Woodburne, 1969:302; Wright, 1998). This feature is discernable on a highly worn RCS tooth (UCMP 66573) but appears to be absent in UM 4113. In size, UM 4113 approximates most closely "*C.*" *sociale*. However, m1 features a strong labial cingulid as is present in "*C.*" *occidentale*, and the p4 heel, although somewhat worn, bears the vestiges of a bicuspid pattern with an anteroposteriorly elongated lingual cusp. Both these feature typically are absent in "*C.*" *sociale* (Woodburne, 1969). Furthermore, in Wright's (1998) review, "*C.*" *occidentale* is recognized as an early to mid-Miocene species and is recorded from Montana (White Sulfur Springs), whereas "*C.*" *sociale* is only known from the early Miocene of Oregon and Nebraska.

UCMP 189812 resembles p4 of UM 4113 but differs in being larger (AP = 10.3 mm in UCMP 189812, AP = 8.9 in UM 4113) and bearing a more prominent anterior cingulum. The heel is clearly made up of two distinct cuspids separated by an extension of the same longitudinal groove that demarcates the two trigonid cuspids. This condition is characteristic of "*C.*" *occidentale* and precludes assignment to "*C.*" *sociale*. UCMP 189812 is comparable in size to "*C.*" *occidentale* and "*C.*" *proterva*, and much larger than "*C.*" *sociale*.

Comments—We use quotation marks to denote the possible polyphyletic status of this genus (Wright, 1998). Given the presence of qualitative features noted above that are also found on "*C.*" *occidentale* but absent in "*C.*" *sociale*, UM 4113 is assigned to "*C.*" *occidentale*, but only tentatively because of its smaller than usual size. We also tentatively assign UCMP 189812 and 66573 to "*C.*" *occidentale*, while recognizing the difficulty in differentiating between that species and "*C.*" *proterva* given the traits preserved on the specimens.

Family ANTILOCAPRIDAE Gray, 1866
Subfamily "MERYCODONTINAE" Matthew, 1909
Genus *PARACOSORYX* Frick, 1937
Paracosoryx wilsoni Frick, 1937
(Fig. 11)

Occurrence—UM MV 7322.

Referred Material—Horn core, UM 4150; horn core fragment, UM 4331; right dentary fragment with broken molar, UM 5842.

Description—The most diagnostic specimen is an almost complete right horn core which is bifurcated and includes its attachment point and part of the frontal from just above the orbits (Fig. 11). It is missing most of the anterior tine and the distal tip of the posterior tine. The shaft is tall, measuring 9.7 cm from its base to where it begins to bifurcate; it is concave posteriorly and projects posterodorsally. The two tines are of moderate length, roughly half as long as the shaft. The anterior tine displays a slender base, smaller in cross-section than the base of the posterior tine, suggesting it would have been smaller than the posterior tine. A faint burr is present in the form of a rugose ring around the shaft, about one-third of the distance above the shaft base. In cross-section the shaft is laterally compressed towards its distal end and relatively quadrangular medially. A shallow concavity or groove runs vertically along the shaft's posterior face.

Comments—Based on its small size and simple bifurcation and the presence of a burr, UM 4150 is referred to the "Merycodontinae," a paraphyletic (Janis and Manning, 1998) grouping of antilocaprids characteristically present in early Hemingfordian to late Clarendonian assemblages. Given the height of its shaft and the relative shortness of the tines, UM 4150 does not pertain to *Merycodus* or *Meryceros* (possibly synonymous genera; Janis and Manning, 1998); those taxa are characterized by shorter shafts and tines often exceeding the shaft in length. UM 4150 resembles horn cores of the *Paracosoryx-Cosoryx* grade, which are characterized by a relatively elongate shaft maintaining fairly equal breadth throughout, and bifurcating into two tines. The presence of smaller anterior tines and a posterodorsal projection of the shaft ally this specimen with *Paracosoryx* to the exclusion of *Cosoryx*; *Cosoryx* generally has longer tines and anterolateral tilting of the shaft (Janis and Manning, 1998). The assignment to *Paracosoryx* is also supported by the relatively distal position of the burr on the shaft of UM 4150. In other Merycodontine genera, the burr is positioned much closer to the base of the horn core.

Among the species described and illustrated by Frick (1937), UM 4150 compares best with the type species, *P. wilsoni*. A reduced anterior tine, as occurs in *P. wilsoni*, is inferred from tine base on UM 4150. The posterodorsally sweeping posterior tine continuous with a slightly posteriorly curved shaft is also characteristic of *P. wilsoni*; it is unlike the posterior tine in *P. dawesensis*, which is curved anterodistally, or that of *P. loxoceros*, which is straight. The overall proportions of the specimen (the shaft is shorter than that of *P. alticornis* and the tines are shorter than those of *P. furlong)* serve to strengthen the affinity of UM 4150 with specimens of *P. wilsoni* illustrated in Frick (1937). Referral to *?P. nevadensis* is precluded by the larger size of both the dentition and horn cores in the RCS specimens.

Janis and Manning (1998) indicate that *P. wilsoni* is the basalmost antilocaprid and that all other species of the genus are more closely related to other antilocaprids than to *P. wilsoni*. In their cladogram, *P. wilsoni* is characterized by the retention of many plesiomorphies, most of which are dental characters. Other named species of *Paracosoryx* are cited as possibly having greater affinity with the other, more derived, merycodontine antilocaprids.

Paracosoryx wilsoni is known from localities in the early Hemingfordian to the early Barstovian (Janis and Manning, 1998). The locality from which UM 4150 derives (MV 7322, Turtle 1), is here assigned a maximum age of ca. 14.8 Ma (Figure 5), indicating that UM 4150 represents one of the latest-known occurrences of *P. wilsoni*.

Family MOSCHIDAE Gray, 1821
Subfamily BLASTOMERYCINAE Frick, 1937
Genus *BLASTOMERYX* Cope, 1877
Blastomeryx sp.
Fig. 12

Occurrence—UM MV7329.

Referred Material—Right dentary with p2–m3, UM 7156.

Description—UM 7156 preserves the horizontal ramus from the incisor alveolus to the posterior edge of m3. All molars display strongly 'v'-shaped labial crescents (protoconid and hypoconid), strong lingual costae on the lingual cups (paraconid and metaconid), prominent yet short ectostylids, and a well-developed anterior cingulum. Diastemata are moderately elongate. Premolars are somewhat reduced in size. Tooth lengths are (maximum anteroposterior, in mm): p2 = 4.8; p3 = 5.8; p4 = 5.9; m1 = 6.9; m2 = 8.7; m3 = 12.2; p2–p4 = 16.5; m1–m3 = 29.2. Post-symphyseal distances (distance between posterior

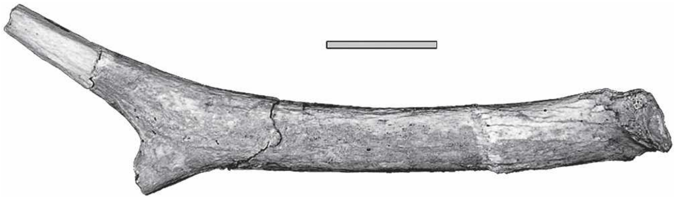

FIGURE 11. *Paracosoryx wilsoni* horn core, UM 4150, medial view. Scale bar equals 2 cm.

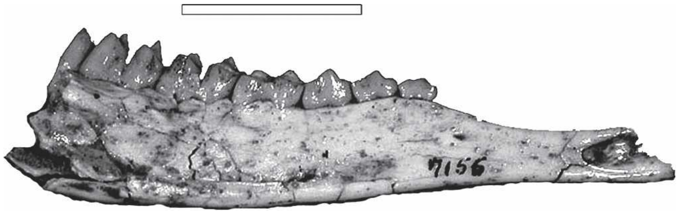

FIGURE 12. *Blastomeryx* sp. left dentary, UM 7156, lateral view. Scale bar equals 2 cm.

margin of symphysis and p2) are estimated to be between 17.5 and 20.5 mm.

Comments—The morphology of UM 7156 indicates affinities with the moschids *Blastomeryx*, *Longirostromeryx,* and *Pseudoblastomeryx*. Referral to *Blastomeryx* is based primarily on the post-symphyseal distance and the relative proportions of the premolars and molars to each other. The post-symphyseal distance was estimated from the mental foramen instead of the posterior rim of the symphysis, because the latter remains embedded in matrix. UM 7156 has a post-symphyseal distance of 38% to 47% total tooth row length. This differs from *Longirostromeryx*, which is characterized by an elongated post-symphyseal distance of 66% to 77% tooth row length (Frick 1937:table VI). Similarly, UM 7156 can be distinguished from genera with relatively shortened post-symphyseal lengths such as in *Pseudoblastomeryx* and *Parablastomeryx* (29% to 37% in Frick, 1937:table VI). UM 7156 corresponds most closely in both relative and absolute post-symphyseal and tooth row lengths to *Blastomeryx* (post-symphyseal distance = 42% to 50% tooth row length, p2–p4 = 16–19 mm, m1–m3 = 21.5–32 mm; Frick, 1937). Premolar and molar row lengths and relative sizes support the assignment of UM 7156 to *Blastomeryx* and distinguish the specimen from the other moschids. UM 7156 has a premolar row to molar row ratio of 57%, according well with that of *Blastomeryx* (54%–65%), intermediate between the relatively shortened premolar row of *Longirostromeryx* (40%–53%), and the relatively larger premolar row of *Problastomeryx, Pseudoblastomeryx*, and *Parablastomeryx* (65%–73%) described by Frick (1937:table VI).

In size, UM 7156 resembles specimens of *B. gemmifer* described and figured by Frick 1937. Comparisons with available material from UCMP ruled out affinity with *B. mollis*. UM 7156 is significantly smaller with narrower premolars than *B. mollis* specimens from the Barstovian Virgin Valley Formation, Nevada (Merriam, 1911). Among *Blastomeryx* specimens present in the UCMP, the Railroad Canyon *Blastomeryx* corresponds most closely to *B. sp*. specimens from the Barstovian Valentine Formation of Nebraska. UM 4150 has smaller premolars and simpler p2 morphology than found in the Valentine Formation specimens, however (p2 AP = 4.1–4.8, TR = 1.9–2.2; p3 AP = 4.6–6.5, TR = 1.9–2.9; p4 AP = 4.6–6.8, TR = 2.3–3.5).

CONCLUSIONS

The most fossiliferous part of the Railroad Canyon sequence occurs between meters 140 and 250 in the composite section. The taxa found in that part of the section indicate a late Hemingfordian, early Barstovian, and to some extent late Barstovian age. The stratigraphic distributions of these taxa suggest that the boundary between the late Hemingfordian and early Barstovian occurs somewhere between meters 120 and 140, but a more precise assessment is not warranted because most fossils have moved downhill or were recovered from blowouts, so that their uppermost stratigraphic limit cannot be established with confidence. This time-averaging accounts for the fact that although the section is thick, there is little detectable difference in faunal composition from bottom to top.

The composite fauna from meters 140–250 was previously considered to be early Barstovian age. The new information presented here suggests that the composite fauna from meters 140–180 should be assigned to the early Barstovian, probably to the earlier part of that interval. Above meter 180 the localities probably date to late Barstovian. Rocks at the base of the RCS (meters 0–65) do not contain vertebrate fossils, but they are lithologically similar (and therefore likely coeval, given the regional stratigraphic context) to rocks in the nearby Mollie Gulch deposits of the Lemhi Valley, which yielded a late Hemingfordian assemblage. Stratigraphically below the composite section are freshwater lake beds in the Cruikshank Creek area that appear to be Arikareean.

At present, the biostratigraphy is the most reliable anchor for the magnetostratigraphy because neither tephrachronology nor radioisotopic dating produced reliable independent dates that could be directly linked to stratigraphic sections. This means that the magnetostratigraphy cannot be regarded as independently dating the biostratigraphy, but it is possible to estimate how much time the RCS spans by using the magnetostratigraphy. The magnetostratigraphic correlation that utilizes only Class A sites indicates that, above the MTU, the RCS spans from C5Aan to C5Cn.3n, or from ca. 12.99–16.73 Ma. Below the MTU, meters 0–65 add at least one more long reversal to the sequence and probably correlate to rocks in Mollie Gulch, which biostratigraphically date to late Hemingfordian. Therefore, the lower part of the RCS below the unconformity is probably between 17.3–17.6 Ma (C5Dn). The composite section at RCS appears to span some 4.5 million years, plus whatever is represented by the Cruikshank Creek beds.

Through the approximately 4.5 million years represented by the RCS, marked environmental changes took place. Sediments indicate a change from a relatively mesic climate that produced a freshwater lake in what must have been a closed basin during the Arikareean or early Hemingfordian (>17.5 Ma), to a more arid climate when the lakes became saline during the later Hemingfordian (between 16.73 and 17.5 Ma), to an even drier climate during the Barstovian (between 12.99 and 16.73 Ma) when the lakes dried up and the depositional basin became choked with aeolian- and fluvial-derived clastics. The shift from a landscape that contained saline lakes to a landscape without lakes coincided with development of the MTU.

As the MTU formed, structural compression with a northwest-southeast component produced shallow folding that slightly tilted the beds below the MTU. Assuming the biostratigraphic anchor of the magnetostratigraphy is correct, the MTU in the RCS can be bracketed between 16.73 and probably ~17.3 Ma, coeval with development of the MTU eastern flank of the northern Rockies. If so, a broad, regional uplift is indicated, rather than progressive deformation from west to east.

These local and regional tectonic and climatic events corresponded with a global warming event, the mid-Miocene Climatic Optimum (Zachos et al., 2001) and with pronounced changes in the mammal fauna that took place both regionally (Barnosky, 2001; Barnosky and Carrasco, 2002) and on a continental scale (Tedford et al., 2004) at about 17.5 Ma. The faunal change is evident in the study area by the dominance of oreodonts, camels, chalicotheres, and rhinos in the late Hemingfordian Mollie Gulch beds, versus dominance of horses in the Barstovian component of the RCS fauna.

The geologically simultaneous occurrence of tectonic, climatic, and biotic changes in the northern Rockies brings up interesting possibilities for testing how different physical-environmental changes may interact to influence biotic change. Understanding these complex interrelationships is still in its infancy, and ultimately requires the combination of theoretical work with primary field data from additional long stratigraphic sequences like the RCS that integrate paleontological, geochronological, and geological information.

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