A new earliest Paleocene (Puercan) fauna from the Denver Formation in Colorado's Denver Basin

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This thesis entitled: A new earliest Paleocene (Puercan) fauna from the Denver Formation in Colorado's Denver Basin written by Elisa Dahlberg has been approved for the Department of Museum and Field Studies.

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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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A new earliest Paleocene (Puercan) fauna from the Denver Formation in Colorado's Denver Basin

Thesis directed by Director of the Museum and Field Studies Program, Associate Professor of Geology & Curator of Fossil Vertebrates; Jaelyn J. Eberle

Few areas preserve the Cretaceous-Paleogene (K-Pg) boundary and earliest Paleocene (Puercan) mammalian faunas better than Colorado's Denver Basin. Research conducted more than a decade ago described a diverse Puercan fauna from the Denver Basin, but many would agree that the best-known Denver Basin Puercan fauna – the Littleton fauna – probably represents a late early Puercan (i.e., late Pu1) assemblage. Renewed collecting of fossil mammals from a Puercan locality (DMNH loc. 2560) in the Denver Formation on the eastern side of the Denver Basin approximately nine meters stratigraphically above the K-Pg boundary has produced a Puercan faunal assemblage containing isolated teeth belonging to at least eleven species of fossil mammal.

Based upon its faunal composition, low diversity, absence of taxa characteristic of the Littleton fauna as well as middle and late Puercan species, and close stratigraphic proximity to the well-defined K-Pg boundary, this fauna probably represents a Puercan fauna that is earlier than the Littleton Fauna, and is similar to early Puercan (Pu1) faunas in NE Montana and Wyoming's Hanna Basin. I document the occurrence of at least three species of multituberculates including two species of *Mesodma (M. ambigua and M. formosa),* the marsupial *Thylacodon* sp., and several 'condylarth' species, including *Protungulatum donnae*, *Oxyprimus galadrielae*, *Baioconodon nordicum,* and *Mimatuta* sp. The presence of *M. ambigua*,

O. *galadrielae,* and *P. donnae* is consistent with an early Puercan (Pu1) age. The presence of *P. donnae* defines the onset of the Puercan North American Land Mammal Age (NALMA). I also report the occurrence of the 'condylarth' *Ampliconus browni* from South Table Mountain (a late early Puercan locality considered to be part of the Littleton Fauna). Its presence corroborates research by others that the South Table Mountain locality is probably correlative temporally to the late early Puercan Alexander Locality (also known as the Littleton Fauna). My study suggests that early Puercan mammalian diversity in the Denver Basin may be greater than previously thought. Future research should further not only our understanding of early Puercan mammalian diversity in the Denver Basin, but also the mammalian radiation in the Rocky Mountain Region directly after the K-Pg extinction.

DEDICATION

For my late grandfather, Jerome G. Krueger. Thank you for always supporting my interests in paleontology and providing me with many fossils, rocks, and books along the way.

ACKNOWLEDGEMENTS

This research would not have been possible without the initial research conducted during the Denver Basin Project by the Denver Museum of Nature and Science (DMNS) between 1999-2003 and again from 2004-2008. This project provided the starting point for this research.

Use of the collections and resources of the DMNS and the aid of their collections manager, Logan Ivy, was greatly appreciated. Ian Miller was incredibly kind to provide the stratigraphic column for the locality as well as time in the field helping to haul countless bags of matrix. Special recognition needs to go to DMNS volunteer Charles Nelson, who was an instrumental and invaluable asset during the field season. Charles accompanied me to the field and also taught me the ways of screen washing. He helped sort and locate many of the specimens included in this thesis even after I had to return to campus.

Much gratitude goes to Director Jeff Su and the staff at the Plains Conservation Center (PCC), owners of the West Bijou Site. The ease of access to this research site was greatly appreciated.

Greg Wilson (University of Washington) and Laura Viette (University of Wyoming Geological Museum) loaned comparative materials for this study, which was of great aid.

I would like to thank the members of the Western Interior Paleontological Society (WIPS) for providing funding for the field portion of this research.

I am forever thankful to our collections manager, Toni Culver, for making sure I had everything I needed along the way, including loaning the research material for this project as

well as providing guidance in the field of collections management along the way. Your words of wisdom will always remain.

The University of Colorado Museum (UCM) Entomology section assisted me in using their imaging station for photography of the *Ampliconus browni* specimen, and I thank Virginia Scott and Katie Wolfson for their time. Fellow MFS graduate student Emily Lannoye assisted me with complications during imaging and image clean-up. UCM paleontology volunteer Trevor Williams also assisted in sorting matrix throughout the fall 2014 semester. Much thanks to both of them.

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Endless gratitude to my advisor, Jaelyn Eberle, for her knowledge, support, patience, and guidance over the past two years on my first field and collections based research project.

I would like to thank my parents, Bonnie and Jon Krueger for their endless love and support in all of my endeavors over the years.

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INTRODUCTION

There is much to be learned about the first few geological "minutes" after the dinosaur extinction at the Cretaceous-Paleogene (K-Pg) boundary. According to O'Leary et al. (2013) and many others (e.g., Archibald, 1981, 1989; Archibald et al, 1987; Dewar, 2001, 2003; Eberle, 1999, 2003; Eberle and Lillegraven, 1998a, 1998b; Lillegraven and Eberle, 1999), earliest Paleocene (Puercan) mammals radiated quickly after the K-Pg boundary, in the absence of their non-avian dinosaurs. Within a few hundred thousand years (or less; Renne et al., 2003), many new species, particularly amongst the 'condylarths' (or archaic ungulates), appeared and dispersed across North America. Few areas preserve the K-Pg boundary and earliest Paleocene (Puercan) mammalian fauna better than Colorado's Denver Basin. Research conducted more than a decade ago described a diverse Puercan fauna from the Denver Basin (Middleton, 1983; Dewar, 1996; Eberle, 2003; Middleton and Dewar, 2004), but many would agree that the best known Denver Basin Puercan fauna—the Littleton Fauna—probably represents an assemblage from the late early Puercan (Pu1) (Middleton, 1983; Dewar, 1996; Eberle, 2003; Middleton and Dewar, 2004).

For my thesis, I conducted field research over the summer of 2014 in the eastern Denver Basin near Strasburg, CO, collecting from a Puercan site (DMNH loc. 2560) that based upon its faunal composition, low diversity, and close stratigraphic distance (~9m) above the K-Pg boundary, probably represents a Puercan mammalian fauna that is older than the Littleton Fauna. Below, I describe this fauna, which is comprised of isolated teeth that represent at least 11

species in five families, which are consistent with other early Puercan localities in the Western Interior. The study also extends the geographic range of some species and reports on the first Denver Basin occurrence for two of the species described.

History of collecting Puercan mammals in the Denver Basin

G.L. Cannon, Jr. (1893) collected what he described as the first single small mammal tooth from the Denver Basin. In the 1940s, two articles were published by Gazin and R. W. Brown reporting the discovery of early Paleocene mammals in beds above dinosaur-bearing layers at two localities in the Denver Formation - one at South Table Mountain near Golden and the other at Corral Bluffs near Colorado Springs. Gazin (1941a) named a new arctocyonid, *Baioconodon denverensis* from South Table Mountain. He also reported *Conacodon* cf. *C. entoconus*, *Carsioptychus* sp., an arctocyonid, and *Eoconodon heilprinianus*. Gazin (1963) subsequently reported the jaw of a mammal from the valley of West Bijou Creek near Colorado Springs (Middleton, 1983).

In 1973, Littleton resident Carl Alexander discovered a new locality (UCM Loc. 77267, the Alexander Locality), coined the Littleton Fauna, which greatly increased the faunal list for early Paleocene mammals. This locality consisted of fill dirt from a nearby construction site. Crews from the University of Colorado Museum collected from the locality for several years until the land was eventually taken over by developers (Middleton and Dewar, 2004).

Middleton (1983) described a diverse fauna from a number of localities in the Corral Bluffs area near Colorado Springs on the southern side of the Denver Basin as well as specimens that were collected from UCM loc. 77267 in his unpublished PhD dissertation. Middleton's PhD

dissertation was eventually published decades later by Middleton and Dewar (2004), while Dewar (1996) conducted a micro wear analysis of some members of the fauna.

In 1998, the Denver Museum of Nature and Science (DMNS) launched the National Science Foundation (NSF)-funded Denver Basin Project which ran from the late 1990s through the late 2000s (Ian Miller, personal communication, 2015).

Eberle (2003) documented the first known occurrence of *Protungulatum donnae* in the Denver Basin, collected from DMNH loc. 2557 (Nicole's Mammal Jaw) at the West Bijou Site on the eastern side of the Denver Basin, as part of the Denver Basin Project. DMNH loc. 2557 lies approximately 39 ft (12 m) above the K-Pg boundary (Barclay et al., 2003; Eberle, 2003) and approximately 9 ft (3 m) stratigraphically above DMNH loc. 2560, the locality from which the faunal assemblage described below was collected.

Background to North American Land Mammal Ages (NALMA)

North American Land Mammal Ages (NALMA) were first erected by Wood et al. (1941) for North American Cenozoic strata, based upon first, last, and unique occurrences of fossil mammal taxa. NALMAs are exceptionally useful for dating formations that contain fossil mammals Woodburne (1987; 2004) published revisions to the NALMA system. NALMAs are defined by the first and last occurrences of certain taxa and characterized by the occurrence of index taxa (Woodburne, 1987, 2004).

Puercan North American Land Mammal Age

This study focuses on faunas that are Puercan in age, an interval spanning approximately the first million years of the Paleogene directly following the mass extinction at the K-Pg boundary (Swisher et al. 1993; Archibald et al., 1987; Lofgren et al., 204)). The Puercan NALMA was originally subdivided into three interval zones (Pu1, Pu3, and Pu3; Archibald et al, 1987), representing respectively, early, middle, and late Puercan time. Subsequently, Archibald and Lofgren (1990) suggested adding a fourth interval zone (Pu0); however the fauna between Pu0 and Pu1 is often hard to differentiate and therefore Pu0 is no longer recognized (Lofgren, 1995). More recently, Lofgren et al. (2004) revised the Paleocene NALMAs. From oldest to youngest, the interval-zones are: Pu1, the *Protungulatum/Ectoconus* Interval-Zone; Pu2, the *Ectoconus/Taeniolabis taoensis* Interval-Zone; and Pu3, the *Taeniolabis taoensis/Peryptychus* Interval-Zone.

II.

GEOLOGICAL SETTING

Denver Formation

The Denver Basin is located on the eastern side of the Rocky Mountains and covers an area from Boulder in the north to Colorado Springs in the south and as far east as Limon, Colorado. The basin is asymmetrical in structure and consists of late Cretaceous and early Paleogene sediments deposited from the erosion of the Rocky Mountain Front Range during the Laramide Orogeny (Barclay, 2004). The beds are steeply dipping along the western edge and flatten out farther to the east.

The Denver Formation unconformably overlies the upper Cretaceous Laramie Formation (Soister, 1987, Raynolds, 2002). Typical exposures of the Denver Formation consist of claystone ranging from a dusky yellow to medium light gray, siltstone and very fine grained sandstone (Dewar, 1996). Carbonaceous shales and lignites are common within the formation (Raynolds, 2002).

There were two major periods of uplift during the deposition of the Denver Formation. The first occurred during the late Cretaceous (ca. 68 Ma) where the duration of deposition lasted approximately 4 Ma; this depositional event produced an unconformity in what has been coined the D1 sequence (Raynolds, 2002). This sequence is mostly arkosic near Colorado Springs and andesitic near Denver and intermediate in composition in the middle. There was a hiatus of about 8 Ma following deposition of the D1 sequence. Deposition resumed at the end of the Paleocene,

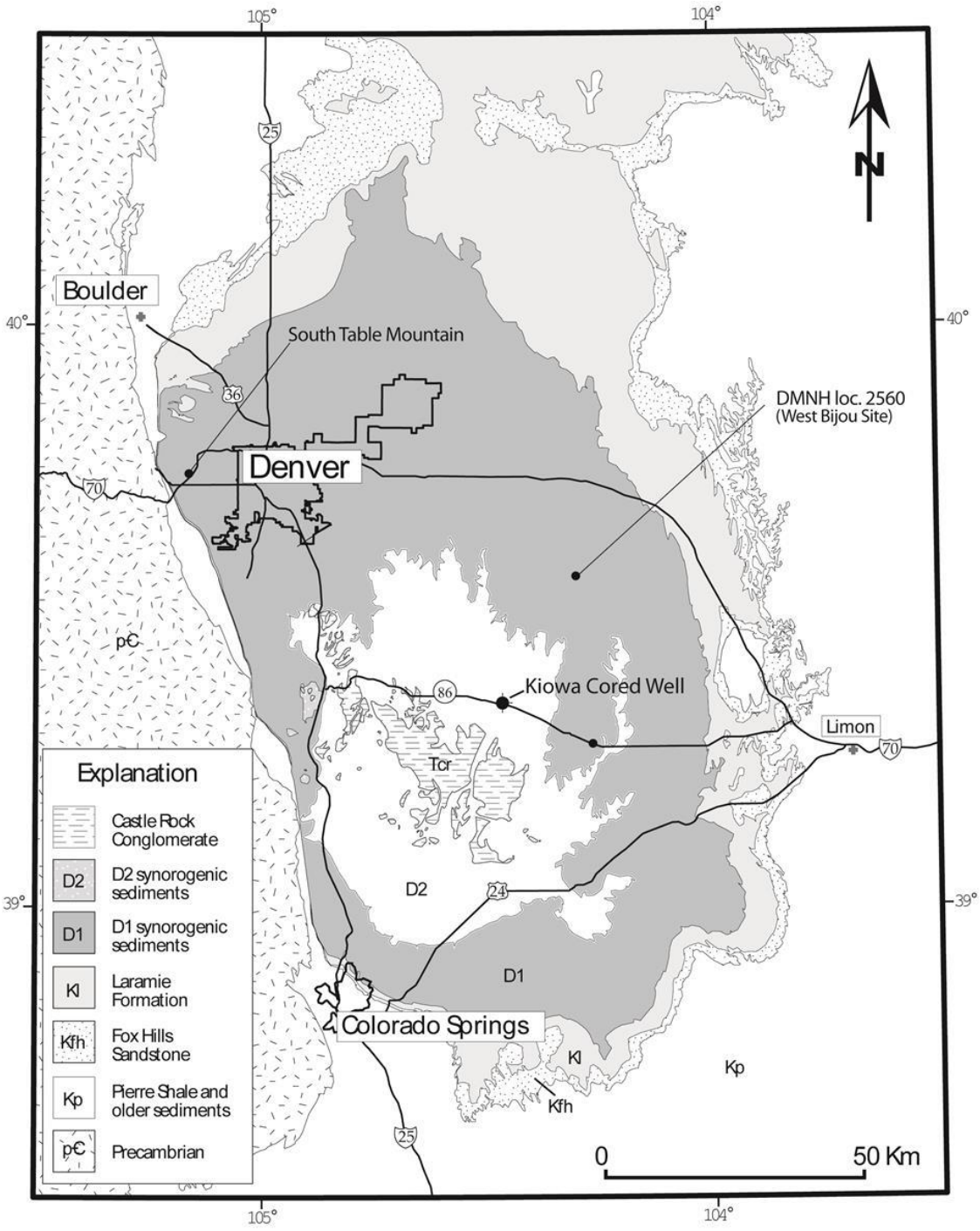
creating the D2 sequence which is derived of an arkosic megafan originating in the Pikes Peak area (Raynolds, 2002).

Due to the fine-grained nature of most of the Denver Formation, it is easily eroded and few natural outcrops are available for prospecting. Those that do occur consist of low elevation escarpments and stream cuts. Other sites have been made accessible through large construction projects across the region (Nichols and Fleming, 2002).

The depositional environment of the Denver Basin is described as fluvial, comprised of sediments deposited during uplift of the Front Range. On the western side of the basin near the mountains, the formation is composed of sandstones and conglomerates. The formation thins into claystones and lignites towards the east. Andesitic cap rock (ca. 65-64 Ma) at South Table Mountain (near Golden) appears to be the remnants of plutons in the Colorado Mineral Belt (Lovering and Goddard, 1950; Tweto, 1975; Middleton, 1983).

The K-Pg boundary, formerly known as the K-T (Cretaceous-Tertiary) boundary, is exposed in a 50 m thick section of the Denver Basin at the West Bijou Site of the Plains Conservation Center (PCC), Arapahoe County, Colorado. At this site, the K-Pg boundary has been constrained through various methods of dating including geochemical, palynological, and biostratigraphical analyses (Barclay et al, 2003). In regions where there is either not enough datable exposure or an a complete lack of outcrops, the Kiowa Core combined with oil and gas mapping are used to approximate the location of the boundary (Hicks et al., 2003; Barclay et al., 2003).

Figure 1: Geologic map of the Denver Basin, showing general location of study areas: South Table Mountain; greater Denver; and West Bijou Site (modified from Barclay et al, 2003).



Denver Basin localities included in my study

South Table Mountain

The K-Pg boundary at South Table Mountain was originally identified by Brown (1943) based upon the fossil flora and faunas. He identified Paleocene fossil leaves above dinosaur fossils and also used the geologic structure of the Denver Basin and other fossil bearing sites near Colorado Springs to estimate the position of the K-Pg boundary at South Table Mountain (Barclay et al., 2003). The K-Pg section that Brown described at South Table Mountain was in course facies that did not produce strata that could be tested geochemically or palynologically (Kauffman et al., 1990; Barclay et al., 2003).

The South Table Mountain locality was coined Brown's *Baioconodon* locality (DMNH loc. 2387 = UCM loc. 77283) when the DMNS started collecting at the site as part of the Denver Basin Project. The locality occurs along a ridge on the southeastern side of South Table Mountain. The site is on land owned by Jefferson County Open Space and is the site where Roland Brown (USGS) recovered Puercan mammals in 1939 and 1940 (Gazin, 1941). During collection for the Denver Basin Project, several more specimens were recovered which doubled the known diversity at the site (Eberle, 2003). The fossils were recovered as float and through quarrying.

The position of the K-Pg boundary at South Table Mountain was constrained by Kauffman et al., (1990) based on palynology which narrowed the interval within approximately 16ft (4.9m) above the boundary. As previously mentioned, vertebrate fossils found at the locality also corroborated the presence of the K-Pg boundary at that location, with dinosaur

fossils recovered below and early Paleocene mammal taxa occurring above the pollen-based K-Pg boundary zone.

West Bijou site

The West Bijou site is located approximately 39 miles east of Denver, Colorado and 12 miles south of Strasburg, Colorado and is on private land owned by the Plains Conservation Center (PCC; 21901 E Hampden Ave, Aurora, CO 80018). The site described here, along with many other DMNS localities discovered during the Denver Basin Project, contains one of the best known terrestrial K-Pg exposures in the world. For this study, several known and potential new sites were prospected, but only one locality, DMNH loc. 2560 (Gars Galore), proved to be a fruitful locality for recovery of early Puercan mammals. DMNH loc. 2560 is located in a natural drainage approximately nine meters above the K-Pg boundary (Barclay et al., 2003; Ian Miller, personal communication, 2015) within strata mapped as Denver Formation, and alternatively referred by Raynolds (2002) to the D1 sequence. As stated above, exposures of the Denver Formation on the eastern side of the Denver Basin are few and far between; however, the West Bijou site has considerable exposures in three natural drainages of West Bijou Creek (Barclay et al., 2003).

Lithologies of the Denver Formation (D1 sequence) at the West Bijou Site consist of mudstone, siltstone, very fine grained sandstone, and lignite and represent depositional environments of swamps, lakes, stream channels, and flood plains (Barclay and Johnson, 2002). During the Paleocene, the West Bijou site was likely characterized by meandering rivers flowing from their headwaters in the newly risen Rocky Mountains to their destination at the Cannonball

Sea to the northeast where the present day Dakotas are now located (Cvancara, 1976). It is estimated that the Paleocene exposure was deposited over the duration of approximately 216,000 years (Barclay and Johnson, 2002).

The K-Pg boundary at the West Bijou site has been constrained by palynology, vertebrate biostratigraphy, magnetostratigraphy, plant megafloral biostratigraphy, shocked quartz, and an iridium anomaly that is known to define K-Pg boundaries worldwide (Barclay et al, 2003). Palynological analysis records the extinction of the latest Cretaceous *Wodehouseia spinata* Assemblage Zone which is immediately followed by a spike in fern spores, also recorded from other K-Pg boundary sites (Barclay and Johnson, 2004). The 3-cm boundary claystone in the Denver Basin also contains shock-metamorphosed quartz grains in addition to an iridum spike of 619 +/- 32 parts per trillion (Barclay and Johnson, 2004).

Due to the presence of multiple volcanic tuff layers at the West Bijou Site, analysis of sanidine and zircon crystals was conducted using $^{40}Ar/^{39}Ar$ methods (Hicks et al, 2003; Barclay and Johnson, 2004). A tuff layer 30 m stratigraphically below the West Bijou Site K-Pg boundary dated at 65.96 +/- 0.10 Ma (Hicks et al, 2002). It should be noted, however, that more recent studies of the K-Pg boundary in Montana have yielded more refined ages for the boundary to of 66.289 ± 0.051 to 64.866 ± 0.023 Ma utilizing $^{40}Ar/^{39}Ar$ geochronology on tephras of the upper Hell Creek and lower Fort Union Formations (Sprain et al. 2014).

DMNH loc. 2560 occurs on the western side of the main road which runs north-south through the PCC property and is located on a ledge within a natural drainage roughly 3 m below the road surface. The site is approximately 9 m above the K-Pg boundary (see Fig. 3).

Figure 2**:** Stratigraphic section showing the level of DMNH loc. 2560 at the West Bijou site, redrawn after Barclay et al. (2003). The section is IM1426 in Ian Miller's field notebook. Location of the base of the section is 13S 0559620, 4380269 NAD 83 (Ian Miller, personal communication, 2015).

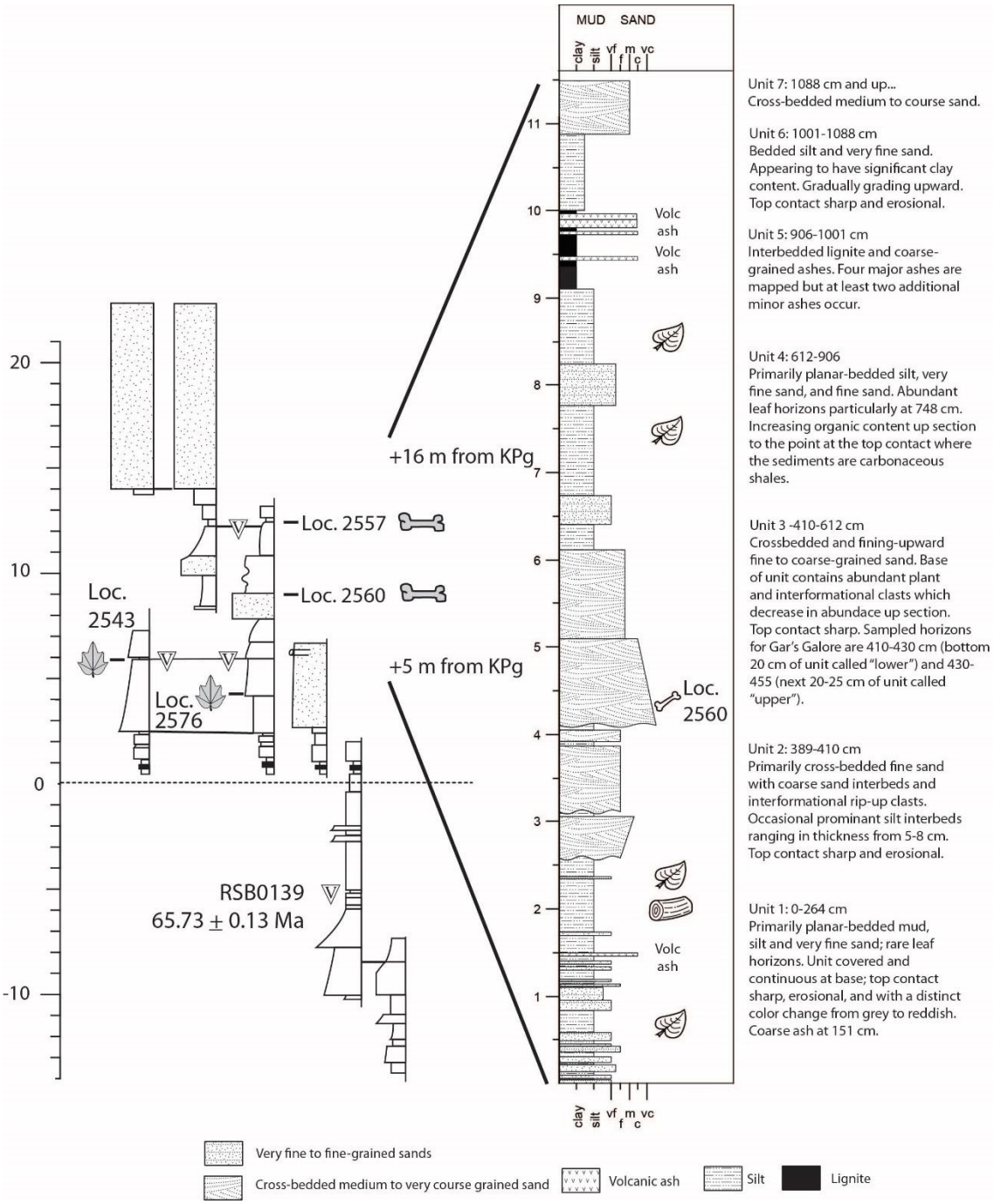


Figure 3: DMNH loc. 2560 (Gars Galore) at the West Bijou Site, Arapahoe County, Colorado with myself for scale.

Figure 4: DMNH loc. 2560 (Gars Galore) at the West Bijou Site, Arapahoe County, Colorado showing upper and lower channel lag with DMNS volunteer Charles Nelson (left of center) and DMNS paleontologist Joe Sertich (far right) for scale.

Taphonomic Biases

Several factors affecting taphonomic biases should be considered in relation to fossil preservation of the Denver Basin. DMNH loc. 2560 consists of fine to medium grained channel lag sandstone, inferring that vertebrate fossil specimens may have initially been transported from a location west of where they were finally deposited. During the Paleocene, the Denver Basin hosted a wetter, subtropical environment bordered by the newly risen Rocky Mountains in the west which gave birth to rivers that ultimately flowed in a northeasterly direction until reaching the Cannonball Sea (Cvancara, 1976). Sediments closer to river headwaters contain larger grain sizes, and fossil mammal sites on the western side of the Denver Basin contain more complete and larger specimens relative to what has been collected at the West Bijou Creek site. West Bijou is located approximately 48 miles west of the South Table Mountain and Alexander localities and produces isolated teeth and much smaller microfossils. Not only are the mammalian specimens small, the fossils from non-mammalian species (crocodilians, turtles, gars, etc.) are also very small in size, suggesting that they may have been transported via river and streams from areas closer to the mountains and deposited at West Bijou. Many of the specimens from DMNH loc. 2560 show significant wear and breakage, which may be due to being tumbled in a fluvial paleoenvironment.

III.

MATERIALS AND METHODS

Paleontological Methods

Field work was conducted over the 2014 summer field season, in collaboration with Drs. Joe Sertich and Ian Miller from the DMNS. Fieldwork included prospecting for new localities and collecting from known DMNS localities. While prospecting during our first day in the field, a partial right mammalian dentary (DMNH 67750) was recovered by Eberle on the slope face of DMNH loc. 2560. The specimen is very worn, most likely due to abrasion resulting from fluvial transport. I am unable to identify the specimen to genus or species due to its extremely worn and broken condition. It's presence at the locality, however, encouraged us to collect bulk matrix in the hopes it would produce more mammalian specimens.

After removal of overburden, collected matrix at DMNH loc. 2560 was divided into an upper and lower part, coined Upper Gar's Galore and Lower Gar's Galore based on distinct channel lag deposits within the site. The majority of fossils have thus far been recovered from what is the Lower Gars Galore part of the site, which is composed of larger grain sizes.

Over the summer, approximately 2,985 lbs. of sedimentary matrix was collected and transported to the DMNS, where it was screen-washed in the paleontology preparation lab by myself and another DMNS volunteer, Charles Nelson. This matrix was sorted under a microscope by myself, Charles, and UCM paleontology section volunteer Trevor Williams. By the end of this study, approximately a third of the matrix collected and screen-washed has been

sorted. An additional approximately 1,300 lbs. of sedimentary matrix (Joe Sertich, personal communication, 2014) was collected in October 2014 by Sertich and Miller from DMNH. loc. 2560. The additional matrix was not part of this study due to time constraints, but is available for future studies.

Thus far, mammalian teeth along with multiple tooth fragments have been identified through comparison with Puercan mammal specimens from the UCM, DMNS, The University of Wyoming (UW), the New Mexico Museum of Natural History and Science (NMMNH). The mammalian teeth identified from this Denver Basin locality assists in temporal correlation to other known Puercan sites in the western United States, including localities in Wyoming and NE Montana.

Additionally, I studied a specimen previously collected, but not yet described, from South Table Mountain near Golden, Colorado. The specimen was found by a father and son hiking near the known Brown's *Baioconodon* Site (DMNH loc. 2387), but it was given its own locality number (DMNH loc. 2814) because it is unknown as to whether the specimen was recovered from the same site as DMNH loc. 2387.

Specimens were measured using an Ehrenreich Photo Optical Shopscope on loan from J. Lillegraven (University of Wyoming), and specimens were oriented following those given by Archibald (1982) and Novacek and Clemens (1977). Cusp terminology follows Van Valen (1966).

Specimens are cataloged, curated and housed in the DMNS vertebrate paleontology collection, and are on loan to the UCM for my thesis research. Non-mammalian lower vertebrate specimens were also collected as float during prospecting. All non-mammalian specimens not described in this study have been curated at the DMNS.

Institutional Abbreviations

AMNH: The American Museum of Natural History, New York, New York; **DMNH**: The Denver Museum of Nature and Science, Denver, Colorado; **NMMNH**: New Mexico Museum of Natural History and Science, Albuquerque; **UCM**: The University of Colorado Museum of Natural History, Boulder, Colorado; **UW**: The University of Wyoming, Laramie, Wyoming.

Dental Terminology and Measurements

The dental terminology proposed by Van Valen (1966) was utilized for this study.

Upper Case Letters (e.g., M1)	Designate teeth from upper jaws
Lower Case Letters (e.g. m1)	Designate teeth from lower jaws
L	Designates Left tooth (e.g., Lm2)
R	Designates Right tooth (e.g., Rm2)
M/m	Molar
P/p	Premolar

Figure 5: Diagram of occlusal view therian lower molar measurements (modified from Archibald, 1983 and McComas, 2014).

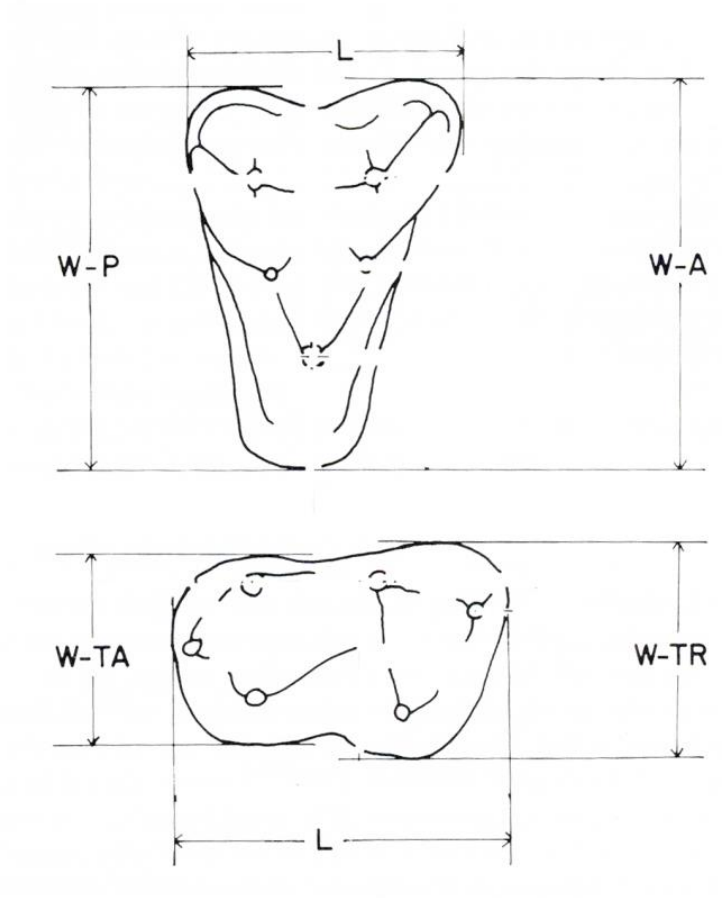


Figure 6: Occlusal views of A: upper and B: lower metatherian (marsupial) molar measurements (modified from Clemens, 1966).

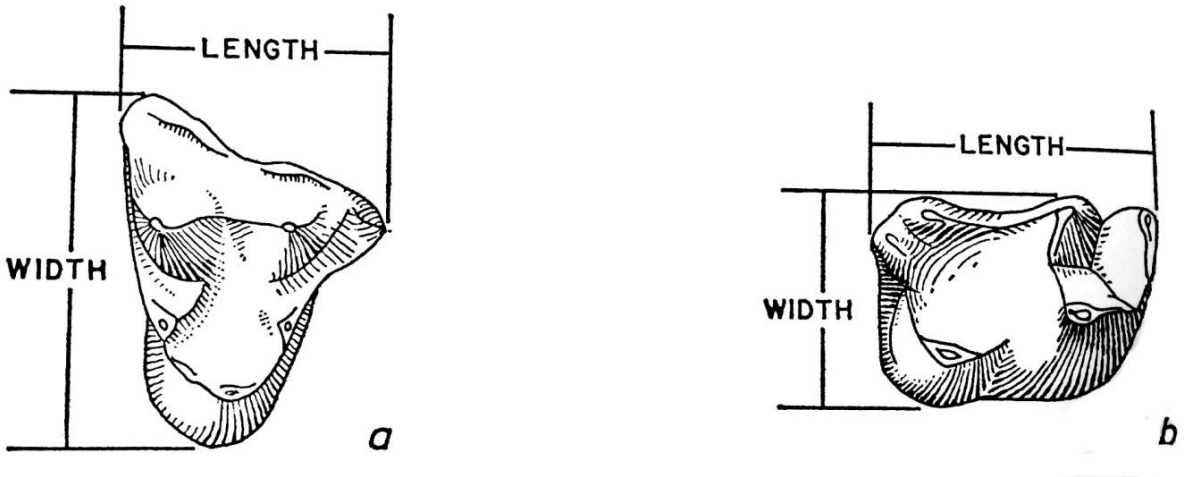
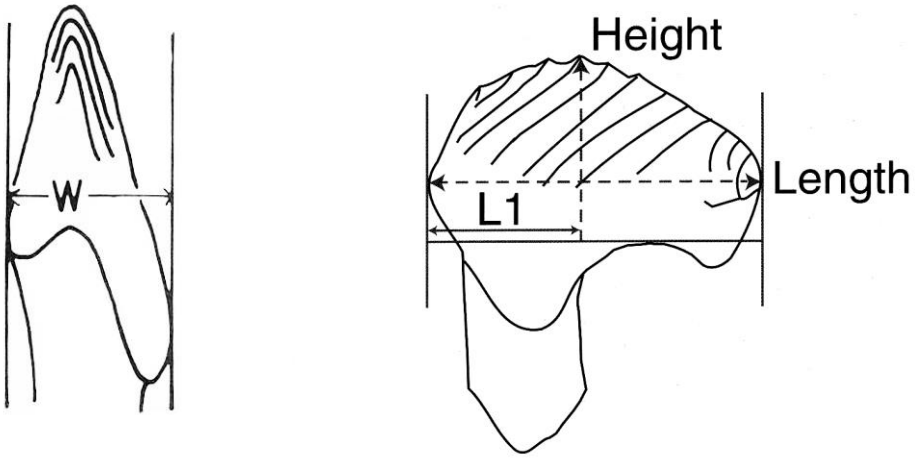


Figure 7: Anterior (A) and labial (B) view of a multituberculate p4 (from Archibald, 1983)



A B

IV.

SYSTEMATIC PALEONTOLOGY

Class **MAMMALIA** Linnaeus 1758

Subclass **ALLOTHERIA** Marsh 1880

Order **MULTITUBERCULATA** Cope 1884a

Suborder **PTILODONTOIDEA** Gregory and Simpson, 1926

Family **NEOPLAGIAULACIDAE** Ameghino, 1890

Mesodma Jepsen, 1940

Mesodma formosa Marsh 1889f

(Table 1)

Referred Specimens and Locality: DMNH EVP.67774, left m1; DMNH EVP.67788, left P2; DMNH EVP.68170, left m2; DMNH EVP.68186, left M2; DMNH EVP.68191, right m2; DMNH EVP.69005, left m1; DMNH EVP.69006, right m2; DMNH EVP.69011, left P4; DMNH EVP.69014, left m1; DMNH EVP.69016, left m1; all specimens from DMNH loc. 2560, Denver Fm., Denver Basin, Colorado.

Known Distribution: Ravenscrag Formation, Saskatchewan, Canada (Lancian and/or early Puercan); Lance Formation, Montana (Lancian); Tullock Formation, Montana (early Puercan);

Bear Formation, Montana (early Puercan); Ferris Formation, Hanna Basin, Wyoming (early, middle, late Puercan); Nacimiento Formation, San Juan Basin, New Mexico (Puercan).

Description and Discussion: *Mesodma formosa*, while morphologically very similar to other species of *Mesodma*, can be distinguished primarily by its small size. Unfortunately, none of the lower or upper molars from this locality have been found with associated P4/p4s, which are diagnostic for species of *Mesodma*. They are slightly larger and fall just outside the range of *M. hensleighi*, the smallest species of *Mesodma*. All *M. hensleighi* specimens described by Archibald (1982) show a length less than 2 mm and a width less than 1 mm. The specimens found at this locality DMNH loc. 2560 all have length and width measurements that are greater than those of *M. hensleighi*. Consequently, I assign the DMNH specimens to *M. formosa* solely based on their similar morphology to specimens described by Clemens (1963) and Archibald (1982), and their size.

Presence of *Mesodma formosa* in the Denver Basin closes the geographic gap between its occurrences in the north in Montana., Wyoming and Canada, and its occurrence to the south in New Mexico.

Table 1: Measurements of teeth of *Mesodma formosa* from DMNH loc. 2560 in the Denver Formation.

Specimen Number	Element	Length	Width	Cusp Count
DMNH EVP.67774	LM1	2.05**	1.40**	5.4.4**
DMNH EVP.67788	LP2	.45	.25	3
DMNH EVP.68170	LM2	1.21	1.04	3.2.1
DMNH EVP.68186	LM2	1.24	1.09	3.1
DMNH EVP.68191	Rm2	1.48	1.27	3.2
DMNH EVP.69005	Lm1	2.11	1.46	6.4
DMNH EVP.69006	Rm2	1.32	1.04	3.2
DMNH EVP.69011	LP4	3.10	1.20	7:4
DMNH EVP.69014	Lm1	2.07	1.04	6.4
DMNH EVP.69016	Lm1	2.25	1.04	6.4

**DMNH 67774 is broken at the medial anterior part of the tooth, making measurements and cusp count incomplete.

Mesodma ambigua Jepsen, 1940

(Table 2)

Referred Specimens and Locality: DMNH EVP.68178, left M1; DMNH EVP.68196, left P4; DMNH EVP.68198, left P4; all specimens from DMNH loc. 2560, Denver Fm., Denver Basin, Colorado.

Known Distribution: Tullock Formation, Montana (early Puercan); Upper Ferris Formation, Hanna Basin, Wyoming (early and middle Puercan).

Description and Discussion: I identify three specimens from the Denver Basin as *Mesodma ambigua*. While many species of *Mesodm*a are well documented, the upper dentition of *Mesodma ambigua* is poorly documented. Middleton (1983) tentatively described *Mesodma* cf. *M. ambigua* from the Littleton Fauna. Eberle and Lillegraven (1998a) also reported *M. ambigua* in the Ferris Formation of the western Hanna Basin based on similar morphology combined with larger sized when compared to *M. thompsoni*. I base the identification of the DMNH specimens on their morphology which is similar to other species of *Mesodma* and their larger size. DMNH EVP.68178, a LM1, is larger than typical specimens of *Mesodma garfieldensis, M. thompsoni, Mesodma* sp. (large) (this study; below) and *Mesodma* sp. (this study; below). Also, it has the same morphology as many of the M1s of M. ambigua described by Clemens (1964).

Both DMNH EVP.68196 and EVP.68198 (LP4s) are larger than LP4s of *Mesodma thompsoni* and *Mesodma garfieldensis*. They compare very closely with the UW specimens described by Eberle and Lillegraven (1998a). Expected mean lengths of *M. ambigua* P4s as

described by Eberle and Lillegraven (1998a) range between 2.49 mm and 3.39 mm, based on calculations by Novacek and Clemens (1977). The mean length of the P4 in the UW specimens used for comparison in this study is 3.33 mm, which is at the higher end of the expected range for *M. ambigua* (Eberle and Lillegraven, 1998a). The mean length for DMNH EVP.68196 and DMNH EVP.68198 is 2.72 mm, which falls within the range of Novacek and Clemens' (1963) calculations. Based on close morphological similarity to *Mesodma ambigua* and their size, DMNH EVP.68178, 68196 and 68198 are identified as *M. ambigua*.

Table 2: Measurements of teeth of *Mesodma ambigua* from UW loc. V-91004 in the Ferris Formation and DMNH loc. 2560 in the Denver Formation.

Specimen Number	Element	Length	Width	Cups Count
DMNH EVP.68178	LM1	3.46	1.21	8:7:3
DMNH EVP.68196	LP4	3.05	1.09	7:3
DMNH EVP.68198	LP4	2.39	1.25	7:3
UW 26009	RP4	3.15	1.82	4:7:0
UW 26018	RP4	3.51	1.9	3:7:0
UW 26007	RM1	3.77	1.82	8:8:5

Mesodma sp. (large)

(Table 3; Figure 8)

Referred Specimens and Locality: DMNH EVP.67760, left p4; DMNH EVP.68165, right P4; DMNH EVP.68175, left p4; DMNH EVP.69012, right p4; DMNH EVP.69015, left p4; all specimens from DMNH locality 2560, Denver Formation., Denver Basin, Colorado.

Known Distribution: Upper Hell Creek Formation, Montana (early Puercan); Tullock Formation, Montana (early Puercan); Ferris Formation, Hanna Basin, Wyoming (early, middle, late Puercan); Fort Union Formation, Wyoming (early Puercan).

Description and Discussion: Similar to the problem associated with smaller species of *Mesodma* (*M. hensleghi* and *M. formosa*), the differentiation of the larger species *Mesodma thompsoni* and *Mesodma garfieldensis* is difficult, especially with isolated teeth.

The p4s described here are, unfortunately, very similar in morphology and size to eachother and to described specimens of *M. thompsoni* and *M. garfieldensis*. They are also worn, complicating proper identification. The anterolingual side of DMNH EVP.69015 has been sheared off, making serration count on that side impossible. The labial walls on both teeth are thicker and longer than the lingual side. The profiles show an asymmetrical low arch and align with that of p4s of Neoplagiaulacidae and are very similar to that of *Mesodma*, but identification to species is not possible due wear. Therefore, I assign these teeth to *Mesodma* sp. (large species)

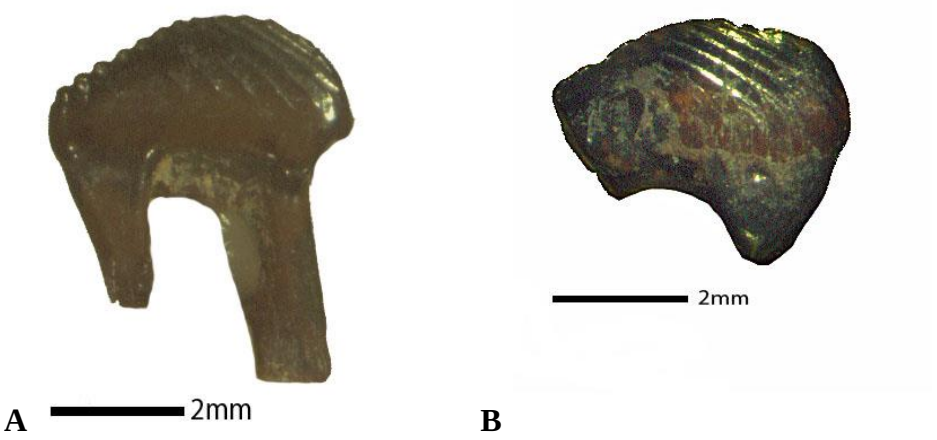
simply because they are larger than those of *M. formosa* and *M. hensleighi* and smaller than those of *M. ambigua*. They fall within the range of both *M. thompsoni* and *M. garfieldensis*,

The P4 referred to *Mesodma* sp. (large) has eight cusps on the medial row and three on the external row. The cusps have a columnar shape and are rather close together in comparison with other *Mesodma* species, specifically *M. formosa*. This was also observed by Clemens (1963) and noted as a way to distinguish between the two species.

Table 3: Measurements of teeth of *Mesodma* sp. (large) from DMNH loc. 2560 in the Denver Formation.

Specimen Number	Element	Length	Width	Height	Cups Count	Serrations
DMNH EVP.67760	Lm1	3.41	1.29	--	7:8:5	NA
DMNH EVP.68165	RP4	3.10	1.49	--	8:3	--
DMNH EVP.68175	Lp4	4.39	1.06	1.47	--	12
DMNH EVP.68195	Rp4	4.02	1.04	1.49	--	12
DMNH EVP.69012	Rp4	4.08	1.21	1.17	--	12
DMNH EVP.69015	Lp4	4.22	1.31	2.26	--	12

Figure 8: Lingual images of *Mesodma* sp. (large) lower p4. A: DMNH EVP.68175; and B: DMNH EVP.69012 from DMNH loc. 2560.



A **B**

Mesodma sp. indet.

(Table 4)

Referred Specimens and Locality: DMNH EVP.67760, left M1; DMNH EVP.67761 left m1; DMNH EVP.67779, left M1; DMNH EVP.67780, left M2; DMNH EVP.68153, right M2; DMNH EVP.68155, right M2; DMNH EVP.68166, right m1; DMNH EVP.68170, left M2; DMNH EVP.68172, right P1; DMNH EVP.68177, left m1; DMNH EVP.68182, right M2; DMNH EVP.68183, right M2; DMNH EVP.68187, left M2; DMNH EVP.68190, left M2; DMNH EVP.68193, right M1; DMNH EVP.68194, right M1; DMNH EVP.69010, left m1; all specimens from DMNH loc. 2560, Denver Formation, Denver Basin, Colorado.

Known Distribution: Ferris Formation, Hanna Basin, Wyoming (early, middle, late Puercan); Lance Formation, Wyoming (Lancian).

Description and Discussion: Several M2s from DMNH loc. 2560 are morphologically similar to those of *Mesodma* sp. described by Clemens (1964) and specimens of *M. garfieldensis* described by Archibald (1982). In accordance with Clemens' description and diagnosis, the cusp formula for M2s of *Mesodma* sp. are 1:2 to 4:2 to 4, with the first of the two to four internal conical cusps equal or larger in size that the second. The cusp count of all but two of the M2s from the Denver Basin have a cusp count of 3.3.1, with the remaining two specimens (DMNH EVP.67780 and DMNH EVP.68155) having a 3.2.1 cusp count. Several of the teeth are worn, with a reduced crown and almost horizontal surface probably from being tumbled in a fluvial environment.

Typically, the M2s of *Mesodma* are morphologically undiagnostic, and in the past, size alone has been used to determine specific species (Clemens, 1963). The size range of the DMNH teeth fall within the ranges of at least two species of *Mesodma* (*M. garfieldensis* and *M. thompsoni)* and for this reason, I identify them only as *Mesodma* sp. indet.

Table 4: Measurements of teeth from *Mesodma* sp.indet. from DMNH loc. 2560 in the Denver Formation.

Specimen Number	Element	Length	Width	Cups Count
DMNH EVP.67760	LM1	341	1.29	7.8.5
DMNH EVP.67761	Lm1	2.50	1.20	6.4
DMNH EVP.67779	LM1	349	1.23	?.8-5
DMNH EVP.67780	LM2	2.01	1.19	3.2.1
DMNH EVP.68153	RM2	2.21	1.23	3.3.1
DMNH EVP.68155	RM2	2.04	2.05	3.2.1
DMNH EVP.68166	Rm1	2.12	1.20	6.4
DMNH EVP.68172	RP1	1.18	1.23	--
DMNH EVP.68177	Lm1	2.45	1.40	6.4
DMNH EVP.68182	RM2	1.43	1.09	3.3.1
DMNH EVP.68183	RM2	1.16	1.07	3.3.1
DMNH EVP.68187	LM2	1.39	1.30	3.3.1
DMNH EVP.68190	LM2	1.12	1.18	3.3.1
DMNH EVP.68193	RM1	3.17	1.40	7.8.4
DMNH EVP.68194	RM1	3.36	1.15	6.8.3
DMNH EVP.69010	Lm1	3.00	1.25	6.4

Neoplagiaulacidae gen. and sp. indet.

Comments: Several isolated anterior upper premolars (DMNH EVP.67775, DMNH EVP.68197, DMNH EVP.67758, DMNH EVP.67759, DMNH EVP.69007, DMNH EVP.69008, DMNH EVP.68188, and DMNH EVP.69001) as well as a P3 (DMNH EVP.68169), p4 (DMNH EVP.68176) and P4 (DMNH EVP.67759) from DMNH loc. 2560 were identified only as Neoplagiaulacidae gen. and sp. indet. isolated anterior upper premolars of neoplagiaulacids are taxonomically non-diagnostic (Clemens, 1964; Eberle and Lillegraven, 1998a). One anterior upper premolar (DMNH 69001) bears three cusps and two roots. DMNH 68188 is also double-rooted and bears four cusps. The remaining specimens are worn or broken and cannot be identified beyond Family. It is likely that these anterior premolars belong to *Mesodma* given the presence of at least two species at DMNH locality 2560. The premolars look similar to those of *Mesodma* described by Clemens (1964).

The isolated P4/p4s recovered from the site are in poor shape and badly worn. While they are in poor condition, they share a similar profile shape with P4/p4s of Neoplagiaulacidae and do not look similar to Ptilodontids from the Puercan. I, therefore, assign them simply to Neoplagiaulacidae gen. and. sp. indet.

Family **PTILODONTIDAE** Gregory and Simpson, 1926

Ptilodontidae gen. and sp. indet

(Table 5; Figure 9)

Referred Specimen and Locality: DMNH EVP.68167, left p4; DMNH EVP.68174, right p4; both specimens from DMNH loc. 2560, Denver Formation, Denver Basin, Colorado.

Description and Discussion: Two p4s (DMNH EVP.68167 and DMNH EVP.68174) were recovered from DMNH loc. 2560. While p4s are typically diagnostic for multituberculates, due to wear and breakage these two specimens are not able to be identified confidently below the familial level. The teeth share a similar arch profile to p4s of the Ptilodontidae, and in contrast with that of Neoplagiaulacidae. DMNH EVP.68174 is in such poor condition that the serration count cannot be determined. The specimens do, however, suggest the presence of Ptilodontidae at DMNH loc. 2560.

Table 5: Measurements of teeth of Ptilodontidae from DMNH loc. 2560 from the Denver Formation.

Specimen Number	Element	Length	Width	Height	Serrations
DMNH EVP.68167	Lp4	4.15	1.03	2.42	12
DMNH EVP.68174	Rp4	4.40	1.47	2.30	NA

Figure 9: Labial and lingual images of **A**, DMNH EVP.68167; and B, DMNH EVP.68174, identified as Ptilodontidae gen. and. sp. indet. from DMNH Loc. 2560

A

B

Subclass **THERIA** Parker and Haswell, 1897

Supercohort **MARSUPIALIA** Illiger, 1811

Cohort **ALPHADELPHIA** Marshall, Case, and Woodburne, 1990

Order **PERADECTIA** Marshall, Case, and Woodburne, 1990

Superfamily **PERADECTOIDEA** Crochet, 1979

PERADECTIDAE Crochet, 1979

PERADECTINAE Crochet, 1979

***Thylacodon* sp.** Matthew and Granger, 1921

(Table 6; Figure 10)

Referred Specimens and Locality: DMNH EVP.68173, right m1; DMNH EVP.69002, right m3; DMNH EVP.69003, right m2; all specimens from DMNH loc. 2560, Denver Formation, Denver Basin, Colorado.

Known distribution: Tullock Formation, Montana (early Puercan); Polecat Bench Formation, Wyoming (early Puercan); Denver Formation, Colorado (early Puercan); Nacimiento Formation (middle Puercan), San Juan Basin, New Mexico.

Description and Discussion: For morphological and size comparison, *Peradectes* cf. *P pusillus* (UCM 35070) described by Middleton (1983) was utilized. *Peradectes pusillus* has since been synonymized with *Thylacodon*. UCM 35070 is the only known m1 in the UCM collection for

for *Peradectes* cf. *P. pusillus*. DMNH EVP.69002 is an isolated Rm3. DMNH EVP.69002 is incomplete on the anterior/labial end displaying a partially broken talonid basin. The metaconid is completely missing. This breakage does not allow for full measurements of the specimen and therefore only estimates are given. The paraconid and protoconid are connected via a paracristed. There is a small cingulid on the labial side of the paraconid. The cusps are smaller than that of *Alphadon*, which tends to have a slightly indented hypoflexid. The entoconulid and hypoconulid are very close together and connected with a shallow crisitid. The hypoconulid is much larger than the entoconid and hypoconid and is positioned on the buccal margin of the talonid basin. The talonid basin is deep and closed lingually by the entocristed and entoconid, which is all very close to UCM 35070. The talonid basin is shallow and small. The protoconid is roughly 1/3 higher than the metaconid, a feature that Dewar (2003) also described. The cusps of the talonid on the DMNH specimens are relatively small with shorter cristids when compared to the UCM specimen.

DMNH EVP.69003 is an isolated Rm2, in fairly good condition. It measures slightly smaller than DMNH EVP.69002. The trigonid is a bit narrower than the talonid, unlike DMNH EVP.69002, where there is little difference in the width of the trigonid and talonid. The protoconid is the tallest of the three main cusps with a well-developed protocristid connecting it to the metaconid. The hypoconulid and entocnid are well developed and separate. The smallest trigonid cusp (paraconid) is offset lingually in relation to the metaconid. The talonid is slightly wider than the trigonid with the cristid oblique intersecting labial to the protocristid notch. The postcristid connecting the hypoconid and hypoconulid shows wear, most likely due to abrasion incurred during fluvial transport.

DMNH EVP.68173, a right m1, is more complete than DMNH EVP.69002 but shows signs of wear. The protoconid is tall and robust, connected to the paraconid via a v-shaped paracristed. An anterior cingulum is present. The talonid basin is also deep. The entoconid and hypoconulid are twinned and connected by shallow cristid. The entoconid and hypoconid do not appear to be quite as close as seen on DMNH EVP.69002, as they appear to be positioned more posteriorly than what is seen in DMNH 69002.

Middleton (1983) referred UCM 35070 to *Peradectes* cf. *P. pusillus* from the Denver Formation and the specimen was identified from the Alexander Locality based on a partial dentary with teeth (UCM 35070). The only discernible difference between the specimens from DMNH loc. 2560 and those described by Middleton (1983) is a variable size difference. UCM specimen is slightly smaller than Clemens (1961) and Archibald (1981), but the size difference is <10 % (Middleton, 1983). While the DMNH specimen is a bit smaller than the specimen from the Alexander locality, it compares morphologically to both *T. pusillus* and *T. montanensis.*

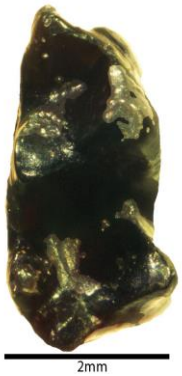
Williamson et al., (2012) named a new species of *Thylacodon, T. montanensis,* from the Nacimiento Formation in New Mexico. While this species was identified based on the presence of upper molars alone and falls slightly outside the range of measurements of *T. pusillus,* the morphology is virtually identical. Specimens from DMNH. loc. 2560 overlap in size between *T. pusillus* and *T. montanensis* making identification difficult. Therefore, I refer DMNH EVP.69002, EVP.69003, and DMNH EVP.68173 to *Thylacodon* sp. based on this issue alone.

Table 6: Measurements of teeth of *Thylacodon* sp. DMNH EVP.68173, DMNH EVPP.69002, DMMH EVP.69003 from DMNH loc. 2560 and UCM 35070, *Peradectes* cf. *P. pusillus*, from UCM loc. 77267, in the Denver Formation.

Specimen Number	Element	Length	Width	WTri	WTal
DMNH EVP.68173	Rm1	2.05	--	1.12	1.20
DMNH EVP.69002	Rm3	2.21	--	.4**	.50**
DMNH EVP.69003	Rm2	2.23	--	1.31	1.36
UCM 35070	Rp3	1.26	1.14	--	--
UCM 35070	Rm1	2.20	--	.47	1.13
UCM 35070	Rm2	2.31	--	1.15	1.26
UCM 35070	Rm3	2.23	--	1.32	1.21
UCM 35070	Rm4	2.13	--	broken	1.04

****Measurements approximate due to broken/incomplete tooth**

Figure 10: Occlusal view of DMNH EVP.69173 (right m1), *Thylacodon* sp.from DMNH loc. 2560.



Order **CONDYLARTHRA** Cope, 1881b

ACRTOCYONIDAE Giebel, 1855

Protungulatum Sloan and Van Valen, 1965

Protungulatum donnae Sloan and Van Valen, 1965

(Table 7; Figure 11)

Referred specimens and Locality: DMNH EVP.68181, left P3; DMNH EVP.68180, left m2; DMNH EVP.68192, right m1; all specimens from DMNH loc. 2560, Denver Formation., Denver Basin, Colorado.

Known distribution: Possibly upper Frenchman and Ravenscrag Formation, Saskatchewan, Canada (Lancian and/or early Puercan); Upper Hell Creek Formation, Montana (early Puercan); possibly lower Tullock Formation, Montana (early Puercan); Upper Ferris Formation, Hanna Basin, Wyoming (early, middle, late Puercan); and Denver Formation, Denver Basin, Colorado (early Puercan).

Description and Discussion: Measurements of the length and width of DMNH EVP.68181 fall within the size range of P3s for *Protungulatum donnae* described by Lofgren (1995) from the Tullock Formation of eastern Montana. Based on comparisons with the case of UCM 41524 (*M. minuial*; L p3-m3). DMNH EVP.68180 is distinguished from *Mimatuta minuial w*ith shorter and steeper protoconids. *M. minuial* appears to have more robust talonid basin vs. trigonid, which is

the opposite of what is observed in this specimen of *P. donnae*. The cusps of *P. donnae* are also more robust, rounded and inflated than that what is observed in *M. minuial*.

The position of the paraconid on the m3 of *P. donnae* can serve to it from other species of *'condylarths'*. The paraconid lies on the lingual side of the trigonid basin. In contrast, it is more medial in *Mimatuta*. The valley between the paraconid and metaconid, while worn, is rather deep in contrast to the condition in *Mimatuta* (Lou, 1989). The lower molars of *P. donnae* can be distinguished from *Mimatuta* by shorter and steeper protoconal slopes (Archibald, 1982; Lou, 1989, 1991). DMNH EVP.68180 and DMNH EVP.68192 are very similar morphologically to those of the cast of UCM 108420. Based on the morphologic similarities of UCM 108420 and descriptions by Archibald (1983) and Lofgren (1995), I refer these teeth to *Protungulatum donnae.*

This is the second documented occurrence of *Protungulatum donnae* in the Denver Formation. The first known occurrence was DMNH EVP.44371 which was discovered at the nearby locality known as Nicole's Mammal Jaw (DMNH loc. 2557) by Eberle (2003) approximately four meters above DMNH loc. 2557.

Table 7: Measurements of teeth of DMNH EVP.68180, DMNH EVP.68181, and DMNH EVP.68192, *Protungulatum donnae,* from DMNH loc. 2560 in the Denver Formation.

Specimen Number	Element	Length	Width	WTri	WTal
DMNH EVP.68180	Rm2	3.21	--	2.33	2.17
DMNH EVP.68181	RM3	2.39	4.42	--	--
DMNH EVP.68192	Rm1	4.14	--	2.43	3.02

Figure 11: Occlusal images of *Protungulatum donnae*. **A,** DMNH EVP.68180 (left m2); **B**, DMNH EVP.68181 (right M3); and C, DMNH EVP.68192 (left m1), all teeth from DMNH loc. 2560.

A

B

C

Oxyprimus Van Valen, 1978

Oxyprimus galadrielae Van Valen 1978

(Table 8; Figure 12)

Referred Specimens and Locality: DMNH EVP.69017, right m2; DMNH EVP.68184, right m3 from DMNH loc. 2560, Denver Formation, Denver Basin, Colorado.

Known Distribution: Ferris Formation, Hanna Basin, Wyoming (early, middle, late Puercan); Mantua Lentil Fort Union (Polecat Bench) Formation, Bighorn Basin, Wyoming (early Puercan); Denver Formation, Denver Basin, Colorado (early Puercan).

Description and Discussion: Two isolated lower molars of *Oxyprimus galadrielae* were observed from DMNH loc. 2560. This is the second known occurrence of *Oxyprimus galadrielae* in the Denver Basin. *O. galadrielae* was first described in the Denver Basin by Middleton (1983) from the Alexander Locality. The teeth described here compare very closely in size and morphology to the specimens Middleton reported and to those described by Lofgren (1995) from the Tullock Formation of eastern Montana. As Lofgren (1995) noted, the lower dentition of *O. galadrielae* and *O. erikseni* are very similar, with the lower molars of *O. galadrielae* being slightly wider than those of *O. erikseni*. Both lower molars show a wider talonid versus trigonid and overall, are slightly smaller than specimens of *O. galadrielae* described by Eberle and Lillegraven (1998b) from the Ferris Formation of Wyoming.

The cusps on both specimens are slightly inflated, but not to the degree that is observed in *Protungulatum donnae*. The metaconid differs in the two specimens and is more elongate in DMNH EVP.68184 than in DMNH EVP.60017. Both specimens show a labially shifted paraconid with a well-developed precingulid. Both specimens display an open talonid basin, even though the talonid basin on DMNH EVP.68184 is incomplete making it difficult to determine the cusp morphology on that specimen. The lower part of the basin is still intact to some degree.

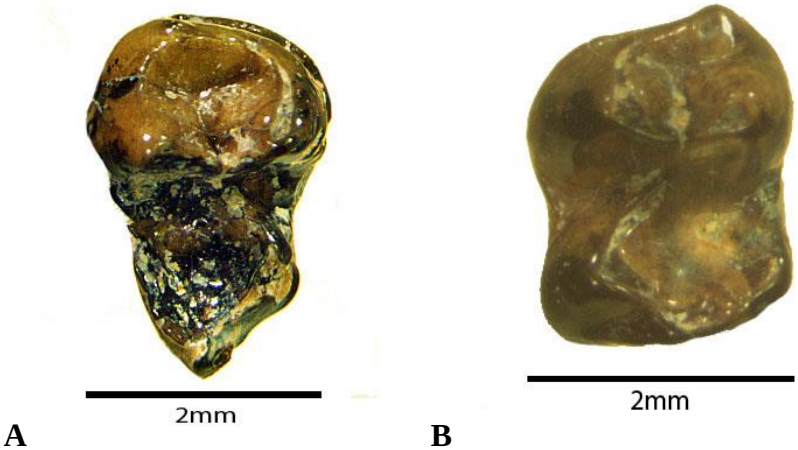
Lofgren (1995) suggested that *Oxyprimus galadrielae* and *Oxyprimus erikseni* may possibly be synonymous in the future given the inadequacy of previous diagnosis of both species in previous work. Other characters used to distinguish between the two species is based around the p4 morphology and its size relative to the m1 (Lofgren, 1995b; Eberle and Lillegraven, 1998b), however neither of these teeth are present from this locality. Both of these specimens fall within the size range of *O. galadrielae* (Lofgren, 1995) and are slightly smaller than the specimen described by Eberle and Lillegraven (1998b) from the Hanna Basin, Wyoming. I am referring these teeth to *Oxyprimus galadrielae* based on similarity to those identified by Middleton from the Alexander Locality.

Table 8: Measurements of teeth of DMNH 68184, DMNH 69017, *Oxyprimus galadrielae*, from DMNH loc. 2560, in the Denver Formation.

Specimen Number	Element	Length	WTri	WTal
DMNH EVP.68184	Rm3	3.35	2.04	*1.25
DMNH EVP.69017	Lm2	3.37	2.04	2.40

***The talonid basin is broken on the labial side making measurements approximate**

Figure 12: Occlusal view of lower molars from *Oxyprimus galadrielae* specimens A: DMNH EVP.68184, right m3; B: DMNH EVP.69017, left m2 from DMNH loc. 2560.



Oxyprimus sp.

(Table 9; Figure 13)

Referred Specimen and Locality: DMNH EVP.68168, a right M1 from DMNH loc. 2560, Denver Formation, Denver Basin, Colorado.

Known Distribution: Hell Creek Formation, Montana (early Puercan); Polecat Bench Formation, Bighorn Basin, Wyoming (early Puercan); Ferris Formation, Hanna Basin, Wyoming (early, middle, late Puercan); Denver Formation, Denver Basin, Colorado (early Puercan).

Description and Discussion: DMNH EVP.68168, an isolated upper molar, is worn. A well-developed stylar shelf. Both the parastylar and metastylar lobes are smaller than those observed on *Protungulatum donnae*. The paracone and metacone are spaced relatively far apart, much further than what is observed in *P. donnae.* The hypocone is worn at its crown, but is still distinct. A barely visible postcingulum extends towards the labial portion of the tooth from the hypocone. A well-developed precingulum extends along the mesiolingual side of the specimen.

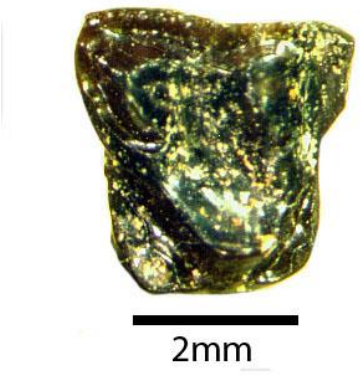
As discussed above, Lofgren (1995) noted that the upper molars of *Oxyprimus galadrielae* and *O. erikseni* are morphologically indistinguishable, and that neither species could be determined on a single isolated upper molar alone. DMNH EVP.68186 falls within the range of both species and without other associated dentition; I cannot place DMNH EVP.68168 into a species at this time. This was also observed by Eberle and Lillegraven (1998b) for *Oxyprimus*

upper molars in the Hanna Basin of Wyoming. I refer the specimen to *Oxyprimus* sp. based on these observations.

Table 9: Measurements of DMNH EVP.68168, *Oxyprimus* sp., from DMNH loc. 2560, in the Denver Formation.

Specimen Number	Element	Length	Width
DMNH EVP.68168	RM1	3.17	3.48

Figure 13**:** Occlusal view of upper molar, right M1, of *Oxyprimus* sp. (DMNH EVP.68168) from DMNH. Loc. 2560.



Subfamily **LOXOLOPHINAE** Van Valen 1978

Baioconodon Gazin, 1941a

Baioconodon nordicum Van Valen, 1978

Ragnarok nordicum Van Valen, 1978

(Table 10; Figure 14)

Referred Specimens: DMNH EVP.68189, left m1; DMNH locality 2560, Denver Formation, Denver Basin, Colorado.

Known Distribution: Tullock Formation, Montana (early Puercan); Hell Creek Formation, Montana (early Puercan); Polecat Bench Formation, Wyoming (early Puercan).

Description and Discussion: DMNH EVP.68189, a Lm1, displays worn cusps, and is not as robust as that of *Baioconodon denverensis* nor does it display the narrow trigonid basin as seen in the m1 of *Ampliconus browni*. The cusp morphology and location on DMNH EVP.68189 is morphologically similar to that of *B. nordicum*, with a robust metaconid and moderately large, slightly lingually-shifted paraconid. DMNH EVP.68189 was compared with a cast of a right dentary containing p2-m3 of *B. nordicum* (UCM 41541). Measurements and similarities in cusp morphology were almost identical. The talonid basin on DMNH EVP.68189 is slightly narrower than the trigonid, which is a feature that Archibald (1983) also noted in his description of the talonid basin on LACM 112902. However, due to wear, it is not clear whether or not the talonid

basin is open or closed on DMNH EVP.68189. The entoconid and hypoconid are placed close together, with the hypoconid shifted slightly labially on the posterior end of the talonid basin. The closeness of the hypoconid/entoconid is also displayed on UCM 41541.

While other species of *Baioconodon* including *B. denverensis* and *B. jeffersonensis* have been described from the Denver Formation in the past (Middleton, 1983; Eberle, 2003) this is the first known occurrence of *B. nordicum* in the Denver Basin and extends the species geographic range southward from Wyoming's Hanna Basin. Gazin (1941a) was the first to record the presence of *Baioconodon* from the South Table Mountain locality. Several more specimens were recovered and described from the Alexander Locality, southeast of South Table Mountain. Based on morphologic similarity, Middleton (1983) proposed synonymy of *Ragnarok* and *Baioconodon*, which was later accepted by other authors (e.g., Sloan et al., 1986; Archibald and Lofgren, 1990; Hunter et al., 1997). I refer this specimen to *Baioconodon nordicum* based on these observations.

Table 10: Measurements of teeth of UCM 41541 from UCM loc. 77273 in the Ferris Formation and DMNH EVP.68189, *Baioconodon nordicum*, from DMNH loc. 2560, in the Denver Formation.

Specimen Number	Element	Length	WTri	WTal
DMNH EVP.68189	Lm1	5.03	3.35	3.27
UCM 41541	Rm1	5.03	3.21	3.27

Figure 14: Occlusal view of DMNH EVP.68189, left m1 of *Baioconodon nordicum* from DMNH loc. 2560.

Family **PERIPTYCHIDAE** Cope, 1882d

Subfamily **ANISONCHINAE** Osborn and Earle, 1895

Mimatuta Van Valen 1978

***Mimatuta* sp.**

(Table 11; Figure 15)

Referred Specimens and Locality: DMNH EVP.68192, right m1; DMNH EVP.69000 left M3; DMNH EVP.68163, left m2; all from DMNH loc. 2560, Denver Formation, Denver Basin, Colorado.

Known Distribution: Tullock Formation, Montana (early Puercan); Harbicht Hill, Hell Creek Formation, Montana (early Puercan); Ferris Formation, Hanna Basin, Wyoming (early, middle, late Puercan).

Description and Discussion: Three specimens from the West Bijou site have been referred to the genus *Mimatuta* based upon the morphological similarity to casts of UCM specimens of *Mimatuta.* Lower molars of *P. donnae* and *Mimatuta* can be distinguished by the labial shift in the paraconid seen in *Mimatuta*, (Archibald, 1982; Lofgren, 1995). This feature can be observed in DMNH EVP.68192. In contrast, the paraconid in *P. donnae* is lingual in position (Eberle, 2003). The entoconid and hypoconid are in close proximity to each other. The hypoconulid is positioned slightly medial along the talonid basin rim shifted more lingually along the talonid basin rim. The talonid basin is open with a narrow precingulum. The talonid on DMNH EVP.68163 measures wider than the trigonid basin which is commonly seen in early 'condylarths.' This suggests that the tooth is an m1, however when comparing the basins visually, they appear to be similar in size. These observations cannot be made definitively with these specimens. DMNH EVP.68163 also has a shallower valley between the metaconid and paraconid, in contrast to *P. donnae* (Lou, 1989).

While the size and morphology of these specimens within the species is consistent with referral to *Mimituta*, the measurements overlap with both *M. minuial* and *M. morgoth*. I am therefore refraining from naming this specimen to species.

Table 11: Measurements of teeth of DMNH EVP.68163, *Mimatuta* sp. from DMNH loc. 2560, in the Denver Formation.

Specimen Number	Element	Length	WTri	WTal
DMNH EVP. 68163	Lm1 or 2	4.03	2.43	3.02

Figure 15: Occlusal view image of DMNH EVP.68163, left m1 or 2 of *Mimatuta* sp. from DMNH loc. 2560.

Ampliconus Middleton, 1983

Ampliconus browni Middleton 1983

(Table 12; Figure 16)

Holotype: UCM 34163, partial skull containing roots of left canine and left P1, incomplete left P2, left P3-4 incomplete left M1, left M2-3, roots of right canine and right P1, and right P2-4; M1-3.

Type Locality: Alexander Locality, UCM loc. 77267, Denver Formation, Denver Basin, Colorado.

Known Distribution: Ferris Formation, Hanna Basin, Wyoming (early, middle, late Puercan); Denver Formation, Denver Basin, Colorado (early Puercan).

Referred specimen and Locality: DMNH EVP.48162, left p3-m3; right p2-4; left P3-M3; right P4, fragments. DMNH loc. 2814, Jefferson County, Denver Formation., Denver Basin, Colorado.

Description and Discussion: DMNH EVP.48162 is very similar in size and morphology to the holotype of *Ampliconus browni* (UCM 34163) described by Middleton (1983) and Middleton and Dewar (2004) from the late early Puercan Alexander locality (UCM loc. 77267).

Lower molars: DMNH EVP.48162 shares a defining characteristic of *A. browni* in that the size of the p4-m1 is nearly identical with the widest portion being across the protoconid

(Middleton, 1983). This shared characteristic is diagnostic to the species (Middleton, 1983). A small cuspule located below and lingual to the paraconid is observed on the m1. This feature was also described by Middleton (1983) for *A. browni*. Presence of this cusp, however, is variable, as it does not appear to be present on every specimen.

Both DMNH EVP.48162 and UCM 34163 (holotype) display a labially-shifted paraconid; however the paraconid on DMNH EVP.48162 is slightly larger than the paraconid observed on UCM 34163, which likely reflects size variation within the species. Both the UCM and DMNH specimens have an open talonid basin on the lower molars. The m1-3 of both UCM 34163 and DMNH EVP.48162 are worn and show little detail in the main cusps.

Upper Premolars: The P2 of UCM 34163 is as long as it is wide, with an inflated conical central cusp. The P2 also shows a distinct lingual swelling over the lingual root. The P3 is broken and worn, showing little morphological characteristics.

The P4 of DMNH EVP.48162 is not as transverse as P4 on the holotype of *A. browni* and also displays a very small metacone. The P4 also displays a slightly labially-shifted talonid basin as well as a large crista. The cones of the P4 transverses backwards, displaying hook-like parastyles and robust cones. The protocone is shifted anteriorly. The absence of other "styles" could be due to erosion or being worn off during life.

Upper Molars: The upper left M1 of *A. browni* on UCM 34163 (holotype) is marginally narrower than M1 on DMNH EVP.48162 but this observation could be due to wear that occurred during the life of the animal. If that is the case than the difference in size between the two specimens is negligible. DMNH EVP.48612 shares a similar wear pattern as that on M1-3 of the holotype of *A. browni*.

A. browni has been previously described in the Denver Basin, but not from any South Table Mountain localities. Previous to the discovery of DMNH EVP.48162 the presence of *A. browni* at the locality supports the idea that the South Table Mountain and Alexander Locality the sites are temporally correlative. It also increases the biological diversity of the South Table Mountain locality. The presence of *A. browni* along with previously discovered *Baioconodon* also suggests that the fauna from this site is more similar to the Littleton fauna.

DMNH EVP.48162 was discovered by a father and son hiking along South Table Mountain during the summer of 2003. While it is known that DMNH EVP.48162 came from South Table Mountain, probably within close range to Brown's *Baioconodon* locality (DMNH loc. 2387 = UCM loc. 77283), the locality data is a best estimate, given that no specific locality information (i.e., GPS or map coordinates) was collected. Whether or not it was surface float or in situ is not known.

Based upon observations with the holotype specimen (UCM 48162 and further written observations by Middleton, 1983), I confidently refer this specimen to *Ampliconus browni*.

Table 12: Measurements of teeth of DMNH EVP.48162, *Ampliconus browni* from DMNH loc. 2814, in the Denver Formation.

Specimen Number	Element	Length	Width	WTri	WTal
DMNH EVP.48162	LP3	3.27	4.27	--	--
DMNH EVP.48162	LP4	3.28	5.47	--	--
DMNH EVP.48162	LM1	4.03	5.49	--	--
DMNH EVP.48162	LM2	4.49	7.29	--	--
DMNH EVP.48162	LM3	3.43	3.32	--	--
DMNH EVP.48162	Lp3	2.26	3.40	--	--
DMNH EVP.48162	Lp4	4.47	3.41	--	--
DMNH EVP.48162	Lm1	4.31	--	3.47	3.41
DMNH EVP.48162	Lm2	4.40	--	4.17	3.27
DMNH EVP.48162	Lm3	4.21	--	Missing/Broken	2.34
DMNH EVP.48162	Rm2	5.02	--	4.13	3.44

Figure 16**:** Images of *Ampliconus browni*; **A**: Lingual and occlusal view of left dentary with p3-m2; **B**: Lingual and occlusal views of right dentary with p2-4, m2; **C**: Occlusal view of upper left P3-M2 from DMHH loc. 2814.

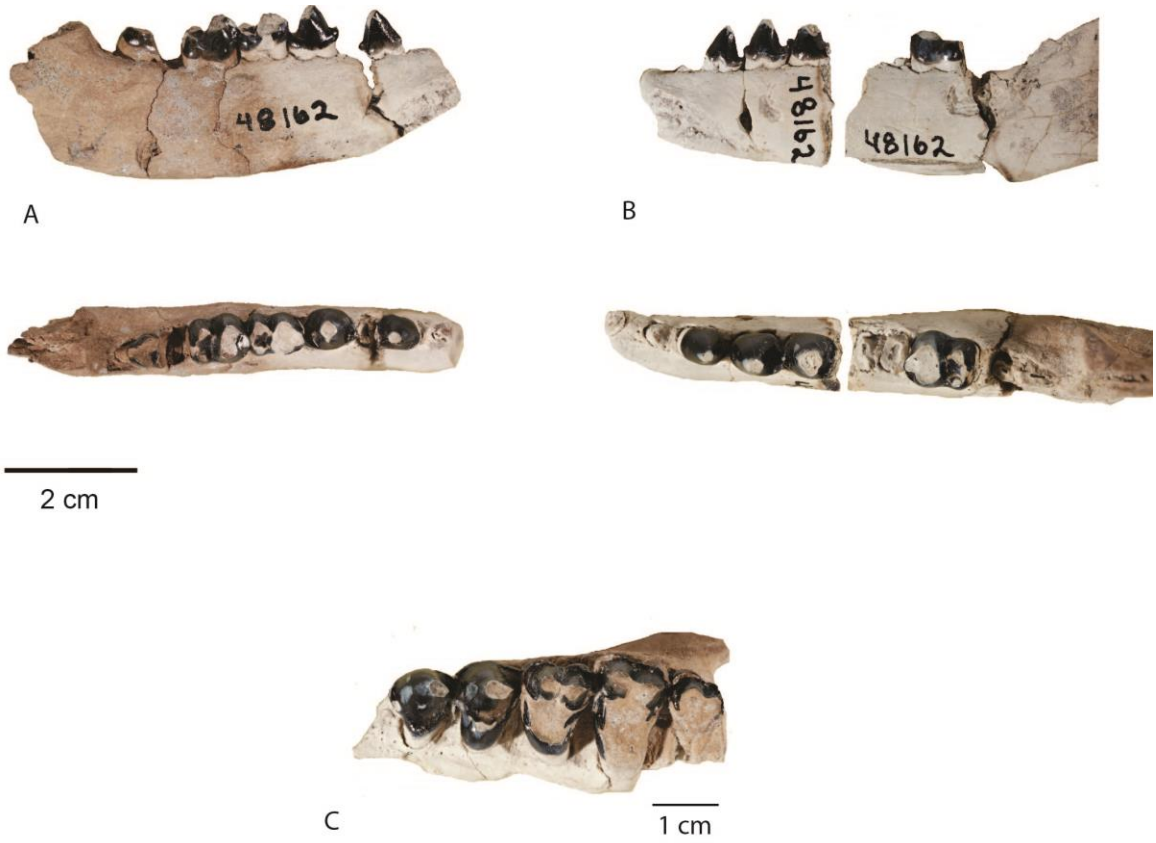


TABLE 13: Faunal list from DMNH loc. 2560 in the Denver Formation, Denver Basin, CO.

Order MULTITUBERCULA
Family NEOPLAGIAULACIDAE
Mesodma formosa
Mesodma ambigua
Mesodma sp. (large)
Mesodma sp. indet.
Gen and Sp. indet.

Family PTILODONTIDAE
Gen and Sp. indet.

Order MARSUPIALIA
Family DIDELPHIDAE
Thylacodon pusillus

Order CONDYLARTHRA
Family ARCTOCYONIDAE
Protungulatum donnae
Baioconodon nordicum
Oxyprimus galadrielae
Oxyprimus sp.

Family PERIPTYCHIDAE
Mimatuta sp.

TABLE 14: South Table Mountain Localities (DMNH loc. 2386 and 2387)

Order MULTITUBERCULATA
Family TAENIOLABIDIDAE
Catopsalis alexanderi

Order CONDYLARTHRA
Family ARCTOCYONIDAE
Baioconodon denverensis
Baioconodon jeffersonensis

Family CIMOLESTIDAE
Procerberus

Family PERIPTYCHIDAE
Alticonus gazini
Oxyclaenus cf. *O. simplex*
***Ampliconus browni*

**Note: All other species listed have been previously described by existing studies (Middleton, 1982; Dewar, 2003; Eberle, 2003). Here, I describe only *Ampliconus browni*, which has not previously been documented from the South Table Mountain locality, but was described from the Alexander locality (Middleton, 1982; Middleton and Dewar, 2004) and the Hanna Basin (Eberle and Lillegraven, 1998b)

V.

DISCUSSION AND CONCLUSIONS

Study of early Puercan faunas is important to our understanding of mammalian faunal turnover and recovery following mass extinction at the K-Pg boundary. While early Puercan (Pu1) faunas are known from numerous sites, NE Montana (Clemens, 1964, Lofgren, 1995, Lofgren et al., 2004) the Mantua Lentil in northern Wyoming (Van Valen, 1978; Lofgren et al, 2004) and the Hanna Basin (Eberle and Lillegraven, 1998a, 1998b), the presence of Pu1 in the Denver Basin has thus far been based upon the Littleton Fauna, which probably represents late Pu1 and is considered to be later (or a bit younger) in age than typical Pu1 faunas in Montana and Wyoming (Eberle, 2003; Middleton and Dewar, 2004; Lofgren et al., 2004). My description of the faunal assemblage from the West Bijou site (DMNH loc. 2560) indicates that a typical Pu1 fauna (like those found in Montana and Wyoming) does occur as far south as the Denver Basin.

DMNH loc. 2560 is considered a Puercan correlative because it contains the following Puercan index taxa - *P. donnae*, *Mimatuta, Oxyprimus* and *Baioconodon.* Another genus common in the Puercan of western North America is the multituberculate *Mesodma* which is found at this locality in abundance, although *Mesodma* is also documented from Torrejonian and Tiffanian NALMA (Lofgren et al., 2004). Further refining the age *Oxyprimus galadrielae* is an index fossil used to define the Pu1 interval zone (Lofgren et al. 2004). Additionally, Archibald (1998) indicated that *Baioconodon nordicum* (= *Ragnarok nordicum*) is also restricted to Pu1. Consequently, two of the ‘condylarth’ taxa at DMNH loc. 2560 support a Pu1 age. Helping to

corroborate this age determination, DMNH loc. 2560 is within nine meters of the K-Pg boundary and it lacks Pu2 and Pu3 taxa such as the large periptychids *Periptychus* and Ectoconus (whose first appearance defines the start of Pu2).

The DMNH loc. 2560 is biased in favor of multituberculate teeth, animals with smaller relative body size than their 'condylarth' counterparts. This bias could be due to fluvial size-sorting. While all of the teeth found at the site are small (<3mm in length), the smallest and most abundant of the isolated teeth belong to one of the smallest species, *Mesodma formosa*.

Another Puercan mammal locality near DMNH loc. 2560 (DMNH loc. 2557; Nicole's Mammal Jaw) from which Eberle (2003) reported a partial jaw of *Protungulatum donnae* at approximately 12 m above the K-Pg boundary suggested an early Puercan site, but the 'condylarth' taxa at DMNH loc. 2560 confirms presence of Pu1 at West Bijou.

It should also be noted that other workers have suggested occurrences in western Canada of *Protungulatum* cf. *P. donnae* at Late Cretaceous localities (Johnston, 1980; Johnston and Fox, 1984; Fox, 1990C, 1997, Archibald et al, 2011), suggesting that this archaic ungulate may have been present before the K-Pg boundary (Archibald, 2011). However, the basis for a late Cretaceous age for these localities was on stratigraphic position and palynology, and these late Cretaceous records of *Protungulatum*, or Late Cretaceous age assignment of these localities are somewhat contentious. The occurrence of *P. donnae* in the Denver Basin, in the absence of any Late Cretaceous faunal indicators (e.g., dinosaurian materials and/or late Cretaceous mammals) seems consistent with other known early Puercan faunas in Montana and Wyoming, and does not give any indication of co-occurrence of archaic ungulates with dinosaurs in the Denver Basin. However, if archaic ungulates originated in Asia as has been hypothesized by others (Archibald

et al., 2011 and references therein), then it seems plausible that *Protungulatum* may have occurred earlier at more northern localities (in Canada) relative to the Western Interior of the United States.

In addition, the occurrence of *Ampliconus browni* at the South Table Mountain locality further corroborates the hypothesis that this locality is temporally correlative with the Alexander Locality, and that both of these sites are probably a bit younger in age than DMHH loc. 2560, though both still fall within the Pu1 interval zone (Middleton, 1983; Eberle, 2003).

Biological Diversity

The faunal assemblage recovered from DMNH loc. 2560 appears to be relatively low in diversity. Eutherian and metatherian (marsupial) teeth are not abundant at DMNH loc. 2560. Multituberculate teeth make up the majority of mammalian specimens from the locality, while marsupial teeth are rare at this locality, being represented by only three specimens. This could be due to a biological pattern and the observation that only one family of marsupials made it through the K-Pg extinction event, while an estimated half of all multituberculate species survived the K-Pg boundary extinction (Archibald, 1996).

The assemblage at West Bijou lacks the larger ‘condylarth’ and multituberculate species described by Middleton (1983) from the Alexander and South Table Mountain localities, overall expressing a lower diversity in species that is consistent with its being slightly older than the Littleton fauna.

Geographic Range Extensions

Middleton described *Mesodma* cf. *M. ambigua* from the Alexander Locality. Until then, the southern-most known records of *M. ambigua* and *M. formosa* extended only as far south as southern Wyoming, making the Denver Formation the southernmost extension of both species. *M. thompsoni* has been known from as far south as the Nacimiento Formation in New Mexico, to as far north in the Ravenscrag and Frenchman formations (Fox, 1990C, 1997). If it is later determined that *Mesodma* sp. described here from DMNH loc. 2560 is definitively *M. thompsoni*, this would close a gap between the southern and most northern records. If it is later determined that *Mesodma* sp. is definitely *M. garfieldensis,* this would also extend the geographic range of this species slightly south from the Hanna Basin in south-central Wyoming. (Eberle and Lillegraven, 1998). The occurrence of *Mesodma* sp. (large) at DMNH loc. 2560, which probably belongs to one of the larger species *M. thompsoni* or *M. garfieldensis*, also closes the gap between occurrences of *M. thompsoni* and *M. garfieldensis* to the north and south.

The presence of the arctocyonid *Baioconodon nordicum* (=*Ragnarok nordicum*) is a first report of this taxon for the Denver Basin. It is also the southernmost occurrence of the species, extended south from the Hell Creek Formation in NE Montana and the Ft. Union Formation in the Big Horn Basin, Wyoming. Middleton (1983) documented the occurrence of another species of *Baioconondon, B. denveresnsis* from the Alexander locality, while Gazin (1963) initially described *B. denverensis* from South Table Mountain. More recently, Eberle (2003) reported a new species *B. jeffersonensis* at South Table Mountain, and Eberle and Lillegraven (1998b) reported the occurrence of *Baioconodon.sp. cf. B. denverensis* from the Hanna Basin in

Wyoming. The species found at West Bijou is less than 10% smaller than *B. jeffersonensis* and *B. denverensis* from the Alexander and South Table Mountain localities. (Eberle and Lillegraven, 1998b; Eberle, 2003).

Mimatuta sp., a small early periptychid, is currently known from the Ferris Formation in Wyoming (Eberle and Lillegraven, 1998b) and the Tullock Formation in Montana (Van Valen, 1978). Its occurrence at DMNH loc. 2560 is its first known occurrence in the Denver Formation, and extends its geographic range slightly south from Wyoming's Hanna Basin.

Middleton (1983) described the early Puercan occurrence of *Thylacodon pusillus* (=*Peradectes pusillus*) from the Alexander Locality. Therefore, its occurrence at the West Bijou Creek site is its second occurrence in the Denver Basin and the first from an early Puercan Denver Basin locality that appears to be a bit older in age than the late Pu1 Alexander Locality.

IV.

FUTURE RESEARCH

My research at DMNH loc. 2560 suggests the locality is among the best mammalian micro sites found on the eastern side of the Denver Basin, and consequently deserves future investigation. Taking taphonomic biases into consideration, the proximity to the K-Pg boundary, the low species diversity and key species (*P. donnae* and *Oxyprimus* sp. and the absence of Pu2 and Pu3 index taxa) present at the West Bijou site suggests that DMNH loc. 2560 represents a Puercan locality that is probably a bit older than the South Table Mountain and Alexander Localities, though still early Puercan (Pu1) in age.

DMNH loc. 2560 has the potential to produce early Puercan species new to the Denver Basin, thereby extending the geographic range of species from previously known Pu1 sites in Canada, NE Montana (Archibald, 1982), Mantua Lentil (Fort Union) Formation, Bighorn Basin, WY (Van Valen, 1978; Lofgren et al., 2004) and the Hanna Basin, WY (Eberle and Lillegraven, 1998a, 1998b). I recommend further investigation at DMNH loc. 2560 through screen-washing and sorting of matrix that is still housed at the DMNS. It should be noted that few fossil bones were found on the surface of DMNH loc. 2560 and consequently screen-washing is the best way to recover mammalian fossils from this site. While the faunal list presented in Table 13 is preliminary, further collecting at the site would likely increase the number of species. A larger mammalian assemblage would help in biostratigraphic correlation with other Puercan sites in the

Denver Basin and throughout the Western Interior and Canada, which, in turn, will help refine our understanding of mammalian biodiversity and radiation directly after the K-Pg extinction.

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