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Eutherian Biogeography During the Puercan North American Land Mammal Age (Paleocene, earliest Danian): Problems and potential solutions

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EUTHERIAN BIOGEOGRAPHY DURING THE PUERCAN NORTH AMERICAN LAND MAMMAL AGE (PALEOCENE, EARLIEST DANIAN): PROBLEMS AND POTENTIAL SOLUTIONS

by

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by

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ABSTRACT

The Puercan North American Land Mammal Age (NALMA) is the earliest major North American terrestrial biochron of the Cenozoic era, spanning roughly the first one million years of the Paleogene period (Paleocene epoch, Danian stage; ~66.04-65.12 Ma). It is typified by the explosive ecomorphological diversification of the mammalian clade Eutheria (particularly our subclade, Placentalia), following the annihilation of non-avian dinosaurs and “archaic” mammal groups during the Cretaceous/Paleogene (K-Pg) mass extinction event. The spatiotemporal mode and tempo of Puercan eutherian diversification has long been the subject of debate, with disagreements over biogeographic zonation. The traditional model – based largely on well-sampled, well-

constrained eutherian assemblages from Montana and Saskatchewan (Williston Basin), Wyoming (Bighorn Basin), Utah (Paradox Basin), and New Mexico (San Juan Basin) – postulates an increased norths/south dichotomy between faunal provinces and higher basin-level endemism in the later Pu2/Pu3 intervals relative to the earlier Pu1 interval, comparable to patterns observed in dinosaurian and mammalian faunas below the K-Pg boundary (Sloan, 1987; Buckley, 1994; Williamson, 1996). However, since the late 1970s-early 1980s, investigation of Pu1 faunas from the Great Divide and Hanna Basins in Wyoming, as well as the Denver Basin in Colorado, led to the proposal of a heterogeneous "transition-zone", harboring unusual endemic arctocyonids and periptychids alongside taxa more typical of Pu2/Pu3 "southern" faunas in the Denver, Paradox, and San Juan Basins (Middleton, 1983; Eberle & Lillegraven, 1998; McComas & Eberle, 2016). However, the role of lithological and collecting biases in the formulation of these hypotheses has yet to be thoroughly tested.

This study analyzed the ecological biogeography of Puercan eutherian biogeography using species-level presence data for screen-washing and surface collection sites from the Pu1 and Pu2/Pu3 intervals, taking into account virtually the entire fossil record. Values of richness, evenness, average body size, and average trophic niche for each site were compared using Kruskal-Wallis tests of differentiation, based on geographic region, basin, and lithology. NMDS ordination scatterplots and AGNES dendrograms were constructed to observe gradients and clustering of Puercan localities, with ANOSIM tests analyzing the significance of region, basing, lithology, species body mass, and species dietary mode in ordination. Results provide conflicting perspectives on the role of biases in skewing

potential biogeographic signals, though collecting methods have a first-order influence on occurrence data. There are no universal trends in differentiation due to richness, evenness, average body mass, or average diet; only Pu2/Pu3 screen-washing sites exhibited marked differentiation in all of these values except evenness. In the NMDS, ANOSIM, and AGNES analyses, similarity scores for screen-washing and surface localities in both the Pu1 and Pu2/Pu3 intervals were pulled by the large number of Williston Basin and San Juan Basin localities. Although geographic region, basin, and taxon dietary mode appear to be the dominant causes of ordinations after taking into account collecting methods, the signals are very weak.

The lack of an obvious geographic barrier to faunal dispersal in the Western Interior across the K/Pg boundary makes the notion of discrete biogeographic provinces in the Puercan rather suspect, in accordance with the results of this study. Larger samples from the Bighorn, Great Divide, Hanna, and Denver basins, as well as a more comprehensive understanding of the Paleocene paleogeography of North America and the phylogeography of early Paleocene mammals, are needed to resolve long-standing mysteries regarding the spatial scale of Puercan eutherian diversification.

Keywords

biogeography, Eutheria, Mammalia, K/Pg mass extinction, Puercan, Paleocene, taphonomy

References

Buckley, G. A. (1994). *Paleontology, geology and chronostratigraphy of Simpson Quarry (early Paleocene), Bear Formation, Crazy Mountains Basin, South-central Montana* (Doctoral dissertation, Rutgers University, New Brunswick).

Eberle, J. J., & Lillegraven, J. A. (1998). A new important record of earliest Cenozoic mammalian history: Eutheria and paleogeographic/biostratigraphic summaries. *Rocky Mountain Geology*, *33*(1), 49-117.

McComas, K. M., & Eberle, J. J. (2016). A new earliest Paleocene (Puercan) arctocyonid mammal from the Fort Union Formation, Great Divide Basin, Wyoming, and its phylogenetic position among early 'condylarths'. *Journal of Systematic Palaeontology*, *14*(6), 445-459.

Middleton M. D., (1983) E*arly Paleocene vertebrates of the Denver Basin, Colorado* (Doctoral dissertation, University of Colorado, Boulder).

Sloan, R. E. (1987). Paleocene and latest Cretaceous mammal ages, biozones, magneto zones, rates of sedimentation and evolution. In Fassett, J. E, & Rigby Jr, J. K. (eds.), *The Cretaceous–Tertiary boundary in the San Juan and Raton basins, New Mexico and Colorado*. *Geological Society of America Special Papers*, *209*, 165-200.

Williamson, T. E. (1996). The beginning of the Age of Mammals in the San Juan Basin, New Mexico: Biostratigraphy and evolution of Paleocene mammals of the Nacimiento Formation. *New Mexico Museum of Natural History & Science Bulletin*, *8*, 1- 142.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INSTITUTIONAL ABBREVIATIONS

AMNH: Division of Paleontology, American Museum of Natural History, New York, NY, USA

BYU: Museum of Paleontology, Department of Geological Sciences, Brigham Young University, Provo, UT, USA

CEUM: Prehistoric Museum. Utah State University Eastern, Price, UT, USA

DMNH: Department of Earth Sciences, Denver Museum of Natural History, Denver, CO, USA

LACM: Dinosaur Institute and Vertebrate Paleontology departments, Natural History Museum of Los Angeles County, Los Angeles, CA, USA

KUVP: Vertebrate Paleontology Collections, Biodiversity Institute & Natural History Museum, University of Kansas, Lawrence, KS, USA

MOR: Paleontology Program, Museum of the Rockies, Montana State University, Bozeman, MT, USA

NMMNHS: Paleontology Section, New Mexico Museum of Natural History & Science, Albuquerque, NM, USA

OMNH: Vertebrate Paleontology collection, Sam Noble Oklahoma Museum of Natural History, University of Oklahoma, Norman, OK, USA

PTRM: Paleontology Department, Pioneer Trails Regional Museum, Bowman, ND, USA

RAM: Raymond Alf Museum of Paleontology, The Webb Schools, Claremont, CA, USA

ROM: Vertebrate Paleontology Section, Royal Ontario Museum, Toronto, ON, Canada

RSMP: Palaeontology collection, Royal Saskatchewan Museum, Regina, SK, Canada

UALVP: Laboratory for Vertebrate Paleontology, University of Alberta, Edmonton, AL, Canada

UCM: Paleontology Section, Museum of Natural History, University of Colorado, Boulder, CO, USA

UCMP: Museum of Paleontology, University of California, Berkley, CA, USA

UMMP: Museum of Paleontology, University of Michigan, Ann Arbor, MI, USA

UMVP: Department of Earth Sciences, University of Minnesota Twin Cities, St. Paul, MN, USA

USNM: Department of Paleobiology, Smithsonian Institution National Museum of Natural History, Washington, D.C., USA

UW: Geological Museum, Department of Geology and Geophysics, University of Wyoming, Laramie, WY, USA

YPM PU: Princeton University collection, Division of Vertebrate Paleontology, Yale Peabody Museum of Natural History, New Haven, CT, USA

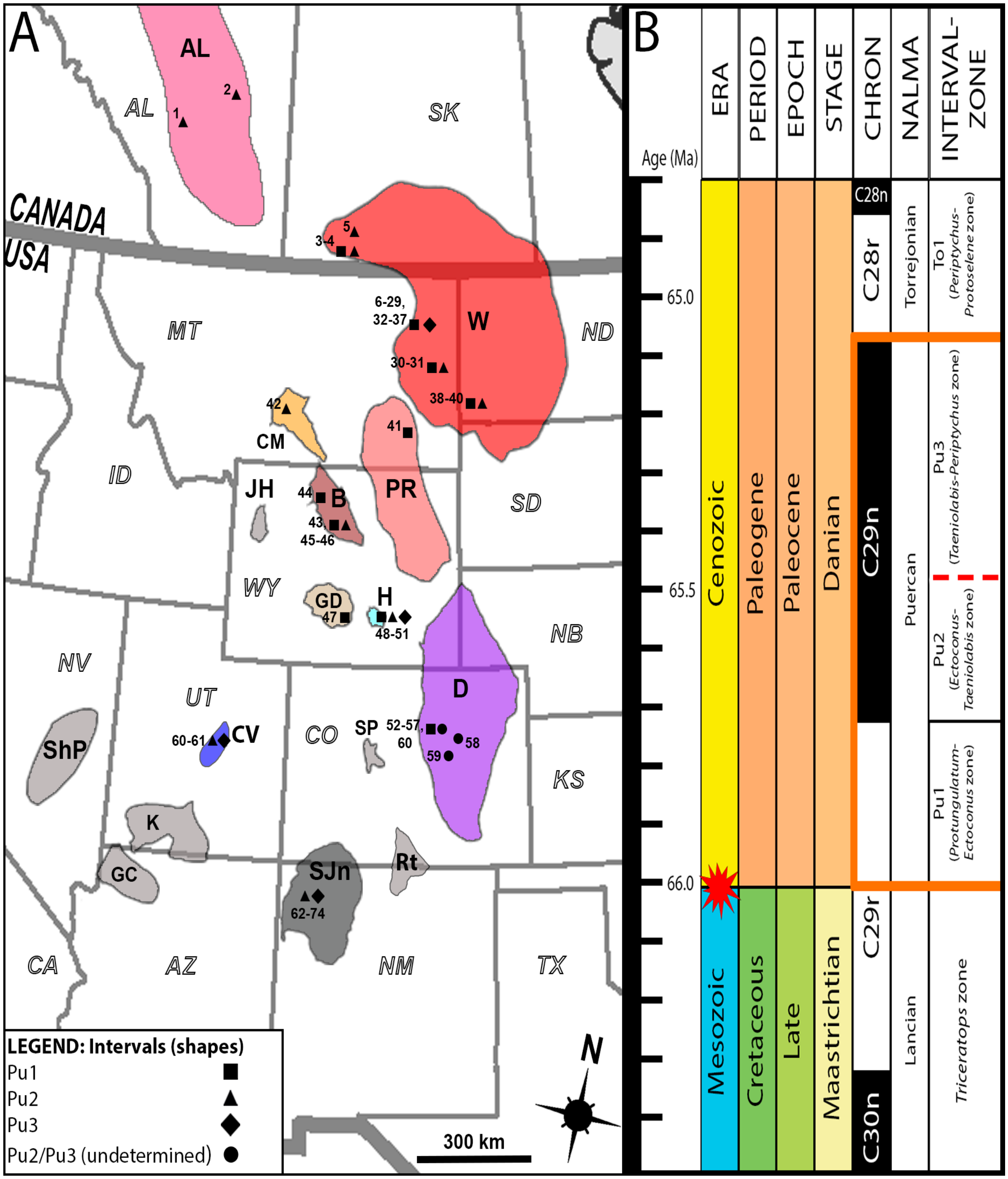
CHAPTER 1

HISTORICAL PERSPECTIVES OF PUERCAN EUTHERIAN BIOGEOGRAPHY AND BIOSTRATIGRAPHY

The Puercan North American Land Mammal Age (NALMA) is the first major terrestrial biochronological division of the Cenozoic era on the continent, encompassing at least the first million or so years of the Paleogene period (Paleocene epoch, Danian stage; ~66.04-65.12 Ma (Archibald *et al.*, 1987; Lofgren *et al.*, 2004). The Puercan is currently divided into three time-consecutive intervals: the Pu1 or *Protungulatum-Ectoconus* interval-zone (~66.04-65.75 Ma); the Pu2 or *Ectoconus*-*Taeniolabis* interval-zone (~65.75-65.49 Ma, though the upper boundary may be as old as 65.677 Ma); and the Pu3 or *Taeniolabis*-*Periptychus* interval-zone (~65.49-65.12 Ma). The Pu1 lies within the upper C29r magnetochron, whereas the Pu2 and Pu3 are usually considered to lie within the C29n chron, though Pu3 interval may extend up into C28r (Peppe *et al.*, 2013; Chester *et al.*, 2015; Sprain *et al.*, 2015 & 2018; Davis *et al.*, 2016; Clemens, 2019; see also **Figure 1.1**).

The Puercan signifies the beginning of the great adaptive radiation of the mammalian clade Eutheria (including Placentalia) following the Cretaceous-Paleogene (K/Pg) mass extinction event, which removed non-avian dinosaurs from Earth's terrestrial ecosystems (Brusatte *et al.*, 2015; Clyde *et al.*, 2016; Pires *et al.*, 2018). Eutherians were mostly unassuming insectivorous and carnivorous taxa during the Cretaceous. After the K/Pg extinction, however, they rapidly proliferated and expanded their range across western North America, which was concurrently being transformed by the gradual retreat

Figure 1.1. (overleaf) A) Schematic map of modern North America showing basins with Puercan-equivalent fossiliferous sedimentary units, and general locations of Puercan eutherian faunas. Basin abbreviations: AL = Alberta (West Canada); W = Williston; PR = Powder River; CM = Crazy Mountain; JH = Jackson Hole; B = Bighorn; GD = Great Divide; H = Hanna; D = Denver; SP = South Park; CV = Castle Valley; SJn = San Juan; Rt = Raton; K = Kaiparowits; GC = Grand Canyon Embyament; and ShP = Sheep Pass. For locality numbers, see Appendix 1. Basin outlines modified from Galloway *et al.* (2011) and Coleman Jr. & Cahan (2012). Map projection as in Coleman Jr. & Cahan (2012). **B)** Generalized geochronological timescale for the latest Cretaceous and earliest Paleocene, emphasizing the Puercan NALMA and its intervals (orange box). Tick-marks represent 100 Kyr intervals. Red star indicates the K/Pg mass extinction. Red dashed line represents uncertain age of the Pu2/Pu3 transition in C29n. Modified from Lofgren *et al.* (2004), Davis *et al.* (2016), and Sprain *et al.* (2018), though all dates remain tentative.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3-4
5
6-29,
32-37
30-31
38-40
41
42
44
43,
45-46
47
48-51
52-57,
60
58
59
60-61
62-74
LEGEND: Intervals (shapes)
Pu1
Pu2
Pu3
Pu2/Pu3 (undetermined)
300 km
N
B
Age (Ma)
ERA
PERIOD
EPOCH
STAGE
CHRON
NALMA
INTERVAL-ZONE
65.0
65.5
66.0
Cenozoic
Mesozoic
Paleogene
Cretaceous
Paleocene
Late
Danian
Maastrichtian
C28n
C28r
C29n
C29r
C30n
Torrejonian
Puercan
Lancian
To1 (Periptychus-Protoselene zone)
Pu3 (Taeniolabis-Periptychus zone)
Pu2 (Ectoconus-Taeniolabis zone)
Pu1 (Protungulatum-Ectoconus zone)
Triceratops zone

of the Western Interior Seaway and the tectonic uplift of the modern Rocky Mountain ranges. As of 2019, Puercan eutherian fossils have been found in nine of the sixteen age-equivalent terrestrial sedimentary basins in the Western Interior, encompassing a range stretching from south-central Alberta down to northwestern New Mexico (**Figure 1.1**).

While eutherian phylogenetic diversity and disparity in North America increased immediately after the K/Pg extinction (Beck *et al.*, 2014; Longrich *et al.*, 2016), it does not appear to have coincided with the origin of most modern "order-level" placental clades (i.e. Artiodactyla, Carnivora, Perissodactyla, Rodentia), which did not appear until the late Paleocene-early Eocene (Springer et al., 2003 & 2017; Halliday *et al.*, 2016, 2017, & 2019). Nor did the Puercan radiation lead to the establishment of modern ecological guilds. For instance, preliminary studies of mandibulodental and postcranial biomechanics of early Paleocene (including Puercan) eutherians, together with endocast data, indicate the exploitation of arboreal and fossorial locomotor activity and omnivorous dietary niches with no obvious modern analogs (Grossnickle & Newham, 2016; Shelley *et al.*, 2017; Napoli *et al.*, 2018). Nevertheless, the astronomically short time scale of eutherian radiation in the Puercan makes this time an interesting geological laboratory for studying mammalian macroevolution and ecology after major mass extinctions, particularly in the context of faunal richness, evenness, and heterogeneity at different spatiotemporal scales (Alroy, 1999; Meredith *et al.*, 2011; Emerling *et al.*, 2018).

Notably, the biogeography of Puercan eutherian diversification has long remained enigmatic, stifling attempts to resolve the phylogeography of major clades and the origin of Placentalia in general (Wible *et al.*, 2007 & 2009; Zack, 2009). This is due in large part to historical controversies concerning Puercan biogeographic and biostratigraphic zonation.

1.1. Early discoveries and the recognition of the Puercan NALMA

The first unambiguous Puercan eutherian assemblages were discovered in what is now known as the Nacimiento Fm. of the southern San Juan Basin (San Juan and Sandoval counties, New Mexico). Though some geological surveys of the region had been conducted by J.S. Newberry & J. N. Macomb in the 1860s (Newberry, 1876), the first paleontological collections were made 1881-1888 by prospector David Baldwin. E. D. Cope originally observed the "Puerco Beds" at Mesa de Cuba near the Rio Puerco River, but Baldwin was the first to find fossils in correlative beds further west, along Coal Creek Canyon in the De-na-zin Wash area (then frequently called "Barrel Springs Arroyo"). While Cope initially placed the Puercan faunas in the "lower Eocene", he quickly realized that the taxa unearthed were not previously reported from underlying Cretaceous and overlying Eocene assemblages; Cope (1882, 1884) described the fauna as coming from the "Puerco Epoch" or "Puerco Series" before finally placing the Puercan in the Paleocene epoch (Cope, 1888), based on faunal similarities with younger European localities such as Cernay-lès-Reims, France (de Blainville, 1841; Lemoine, 1878-1880). Cope also inconsistently reported faunal zonation within the "Puerco bed" type fauna at De-na-zin, with two time-consecutive assemblages. Unfortunately, Baldwin did not report precise provenance information for many of the specimens that later became types and other important specimens is now lost (J. Silviria, 2018 pers. observation of original AMNH specimen labels). This lack of information would lead to subsequent confusion concerning the biochronology of certain taxa, with several “Puercan” specimens actually coming from what would late be termed the “Torrejon Beds” (Williamson & Carr, 2007).

From the 1890s to the 1930s, the AMNH conducted several follow up expeditions to the De-na-zin wash, as well as new localities in the Gallegos Canyon area, along the Betonnie-Tsosie and Kimbetoh washes. The most productive of these expeditions included the 1892 expedition by J. L. Wortman, O. A. Peterson, and T. Rafferty; the 1912-1913 expeditions by W. Granger & W. J. Sinclair; and the 1928-1929 expeditions by G. G. Simpson. Additional work was conducted at Betonnie Tsosie and Kimbetoh washes in 1928-1930, by Simpson, C. L. Camp, V. L. Vanderhoof, and T. E. Reynolds. Though Osborn, Granger, Reynolds, and Simpson would make a few small contributions to resolving the taxonomy and biochronology of the “Puerco Marls” eutherian fauna (Osborn & Earle, 1895; Matthew & Granger, 1921; Reynolds, 1936; Simpson, 1936), the most prolific work was done by W. D. Matthew (1897, 1909, 1921, 1937). Matthew, along with Gardner (1910) and Sinclair & Granger (1914), noted that a postulated depositional unconformity between the “Puerco” and “Torrejon” beds did not exist, with distinctions between and within the two units solely biochronological in nature. This would eventually lead to the merging of the “Puerco” and “Torrejon” beds as the Nacimiento Fm. (see reviews by Dane, 1946; Simpson, 1951; Rainger, 1989). Unfortunately, Matthew died in 1930, leaving fellow AMNH colleagues (including Granger, W. K. Gregory, and E. H. Colbert) to complete editing of his monograph on the Paleocene mammals of New Mexico (Matthew, 1937). The resulting work would be one of the most authoritative documents of Paleocene eutherian morphology, taxonomy, biochronology, and biogeography for the remainder of the 20th century. (For a detailed history of paleomammalogical research in the San Juan Basin, see reviews in Simpson, 1981; Lucas & Williamson, 1993; Williamson, 1996; Lucas & Estep, 2000; and Kondrashov & Lucas, 2006.)

Additional work within and beyond the San Juan Basin increased the resolution of the earliest Paleocene North American eutherian fossil record. C. L. Gazin focused on faunas north of the San Juan Basin, most notably the Wagonroad Local Fauna in Emery County, Utah, first collected in 1939, which included new, supposedly endemic species of *Ectoconus*, *Desmatoclaenus*, and Haploconus (Gazin 1938 & 1941a). Another locality studied by Gazin was the South Table Mountain Local Fauna near Denver, Colorado (the type locality of *Baioconodon denverensis*), collected by R. W. Brown 1940-1941 (Gazin, 1941b; Brown, 1943). Additional work by Gazin, H. Shepard, G. F. Sternberg, and F. L. Pearce focused on the Sinclair & Granger 1913 localities in the San Juan Basin, in 1936, 1949, and 1964. Sporadic work by G. L. Jepsen in the 1930s and 1940s at the Mantua Lentil quarry in the Bighorn Basin, Wyoming, yielded a unique but low-diversity Puercan fauna older than any from the southern localities (Jepsen, 1930 & 1940; Jepsen & Van Houten, 1947); however, with the exception of the holotype of *Ragnarok nordicum*, this material would not be described until Van Valen (1978) (see review by Gingerich, 2016). Several of these workers suspected faunal provincialism in the early Paleocene of the Western Interior, citing interbasinal differences in taxonomic composition, especially among arctocyonids and periptychids.

As part of an effort to standardize schemes for the biochronological nomenclature of Cenozoic North American fossil mammal faunas, the H. E. Wood II committee (Wood II *et al.*, 1941) defined the North American Land Mammal Ages as region subdivisions of global geologic units. The Puercan NALMA was defined as the earliest biochron of the

Cenozoic era, Tertiary period, and Paleocene epoch. It was typified by "the escarpment running from northwest of Ojo Alamo about 25 miles to Arroyo Eduardo, east of Kimbetoh" (the East Flank of Kimbeto Wash *in partim*), with the Mantua Lentil quarry as a "principle correlative" (pg. 8) (see also reviews by Russel, 1967; Savage & Russell, 1986). The Puercan was originally designated as overlying the Lancian NALMA (Cretaceous period, latest Maastrichtian epoch), and underlying the Dragonian NALMA. [The "Dragonian" was based on Gazin's (1938, 1939) Dragon Local Fauna, which succeeded the Wagonroad fauna in the Castle Valley region; it was later determined via biostratigraphy and magnetostratigraphy to be synonymous with the first interval of the Torrejonian NALMA, the To1 interval-zone (Tomida, 1980; Tomida & Butler, 1980; Lofgren et al., 2004).] Unfortunately, Wood II *et al.* (1941), as well as Evernden *et al.* (1964), did not make any explicit comments concerning biogeographic provincialism within and between the NALMAs, including the Puercan.

1.2. The K/Pg mass extinction event and the spatiotemporal zonation of the Puercan

The most significant factors distinguishing differing hypotheses concerning Puercan eutherian biogeography and biochronology following Wood II et al. (1941) were differing hypotheses concerning the timescale and severity of the Cretaceous/Tertiary (K/T) mass extinction, later renamed the K/Pg event (REFS). The crux of these debates involved the explanation of why the non-avian dinosaurs suddenly and mysteriously vanished from the terrestrial ecosystems of the Lance and Hell Creek formations, to be replaced by much smaller eutherians and multituberculates. Faunas from the lower "Fort Union Group", now labeled the Ludlow and Tullock formations, in the Williston Basin (the Dakotas, Montana, and Saskatchewan) and Powder River Basin (Wyoming), were the central focus of these arguments. Although some fieldwork in the 1950s had yielded Puercan eutherian assemblages in the Fort Peck/McGuire Creek region of Montana (most notably the Harbicht Hill dry-screening sites), intensive collection in the region did not commence until the 1960s, during a series of efforts to constrain the K/Pg boundary informally called "the Hell Creek projects". The most famous sites in the Williston Basin prospected during this period included the Bug Creek Anthills Local Faunas (including Bug Creek West), and the younger Purgatory Hill and Garbani Channel Complex localities. The eutherians at these sites were described in most detail by W. A. Clemens, R. S. Sloan., and L. Van Valen (see review by Clemens & Hartman, 2014).

The first "Hell Creek project" utilized improved screen-washing techniques and increased sample sizes of delicate microfossils, which enabled complex statistical analyses of ecological structure dependent on reliable taxon abundance data (e.g. Estes, 1964). However, interpretation of the Williston Basin Puercan faunas was hindered in part by adherence to a gradualist model for the K/Pg mass extinction. In this model, cold-blooded dinosaurs were unable to compete with eutherians that were better adapted for eating the rapidly proliferating deciduous flowering plants, during a time of global cooling (Sloan and Van Valen, 1965; Sloan, 1976; Bakker, 1977; Van Valen & Sloan, 1977; Krassilov, 1981; Van Valen, 1988; but see Lofgren, 1995). Locally, this model was the result of a misinterpretation of the stratigraphy across the Hell Creek/Tullock boundary, which led to inaccurate estimates of sedimentation rates and biochronological zonation. For example, the Bug Creek and Harbicht Hill local faunas were considered latest Maastrichtian in age, but of "Paleocene aspect", with declining abundances of indigenous Mesozoic mammalian clades and an influx of “immigrant taxa” that would evolve into the characteristic faunas of the late Puercan (Rose, 1981; Archibald, 1983; Archibald & Clemens, 1984; Krause & Maas, 1990; Clemens, 2004 & 2010). Many authors considered Asia as the source of the “immigrant” eutherians in the lowermost Tullock Fm., given that a biogeographic link between Asia and North America had been repeatedly demonstrated in various Cretaceous dinosaur and Paleogene mammal faunas, as well as floras (Cracraft, 1974; Wolfe, 1975; Beard & Dawson, 1999). These authors followed in the footsteps of Matthew (1937), who also considered early Paleocene North American mammals as immigrants from central Asia. However, earliest Paleocene eutherians from Asia, specifically those from the Nanxiong and Qianshan basins of China, had no obvious phylogenetic links with any Puercan taxa (Tang & Yan, 1976; Xu, 1976 & 1977; Chiu & Li, 1977; Lucas & Williamson, 1995).

Van Valen (1973, 1978), who would name numerous new Puercan eutherian genera and species from across western North America, expanded upon the “immigrant” hypothesis. He speculated a large-scale southward dispersal of abundant, unspecialized ‘disaster taxa’ from the Williston Basin after the K/Pg boundary. In his model, the initial eutherian radiation was concentrated along river and streams, before rapid ecological expansion into non-channel habitats. Furthermore, faunal provincialism in the northern and southern Western Interior coincided with the re-establishment of pre-extinction evolutionary equilibrium (high diversity, but low origination rates of genera and species), due to interspecific competition. To emphasize differences in taxon composition and biogeographic between the early and late Puercan, he separated the early Puercan into a new land mammal age, the Mantuan (type locality Mantua Lentil). The Mantuan was typified by the immediate post-K/Pg ‘disaster taxa’ of Asian immigrants, the “*Protungulatum* community”.

The establishment of the “Mantuan” would lead to further biogeographic and biochronological subdivision of the early Puercan, incorporating additional metatherian and multituberculate occurrences. Sloan (1987) segregated the Bug Creek-Harbicht Hill faunal facies as the Bugcreekian NALMA, divided into three biochrons based on first appearances and relative abundances of ‘disaster taxa’ (e.g., *Mimatuta*, *Oxyprimus*, *Procerberus*, *Protungulatum*, *Ragnarok*). Sloan’s Mantuan NALMA *sensu stricto* consisted of two biochrons, “Ma” and “Mb”. However, he acknowledged that the earlier “Ma” biochron was unlikely to be found south of the Bighorn Basin. The supposedly younger “Mb” biochron was provisionally restricted to Denver Basin localities such as South Table Mountain, as well as the recently discovered Littleton Local Fauna at Alexander (Middleton, 1982 & 1983; Sullivan & Lucas, 1996). As with Van Valen (1978), Sloan illustrated major lineages of eutherians as arising from a few survivors of the K/Pg extinction (mainly species of *Oxyprimus* and *Protungulatum* from the Bighorn and Williston basins), with diversification intensified in the San Juan Basin during the “Pu2/Pu3” interval. Similar conclusions were reached by Johnston & Fox (1984) and Fox (1990) concerning eutherians from the lower Ravenscrag Fm. the Saskatchewan, specifically at the Medicine Brick & Hat Tile Quarry (MBHT). They divided the Canadian sample sorted into two time-consecutive faunal assemblages: 1) an older “Long Fall Horizon” of latest Maastrichtian age but “Paleocene aspect” (“Bugcreekian”); and 2) a younger “RAV W-1 Horizon” initially believed to be transitional between “Mantuan” and

"Puercan *sensu stricto*" faunas, and correlative with the Alexander Locality (see reviews by Fox & Scott, 2011; Redman *et al.*, 2015).

J. D. Archibald recognized of the "Bugcreekian" and "Mantuan" (Archibald, 1981, 1983, 1993, & 1994; Archibald & Clemens, 1984; Archibald *et al.*, 1987), but nevertheless expressed doubts concerning the utility of these divisions and the proposed ecological expansion of Puercan eutherians from streamside to overbank environments (Archibald, 1982). He and D. A. Lofgren would continue to use the traditionally defined "Bugcreekian" and "Mantuan" biochrons, albeit renamed as early intervals of the Puercan, the "Pu0" and "Pu1" respectively (Archibald & Lofgren, 1990). However, subsequent lithological investigation of the lowermost Tullock in the McGuire Creek area, as well as re-evaluation of taxonomic diversity within the 'disaster fauna', challenged prior biogeographic and biochronological models for the early Puercan. Specifically, earlier researchers overlooked that the supposedly age-controlled "Bugcreekian" assemblages came from time-averaged sandy channels of the lower Tullock incised into siltier upper Hell Creek strata, leading in reworking of older fossils into younger deposits at large geographic scales after the extinction event. (Lofgren *et al.*, 1990; Luo, 1991; Lofgren, 1995). Additionally, in contrast to prior studies, Lofgren (1995) considered the local faunas of the "Pu0" and "Pu1" intervals statistically identical in taxon composition. This led to their collapse of the "Bugcreekian" and "Mantuan" into a single, undivided Pu1 interval (Lofgren *et al.*, 2004).

A similar saga of stratigraphic uncertainty concerning Puercan assemblages unfolded in the San Juan Basin, due to misinterpretations by J. E. Fassett of the unit underlying the Nacimiento Fm., the Ojo Alamo Sandstone. The Ojo Alamo has not yet yielded vertebrate fossils but is important for local chronostratigraphic calibration (Lindsay et al., 1978; Fassett *et al.*, 1987, 2002, 2011). Fassett (2009), using palynostratigraphic and U-series data, lumped the Ojo Alamo into the same formation as the Naashoibito "member" of the Kirtland Fm. He therefore considered the dinosaurs and metatherians of the Alamo Wash Local Fauna or "*Alamosaurus* zone" (*sensu* Lehman, 1981) as a Paleocene refuge for Cretaceous taxa in the southern Western Interior, distinguishable from the northern Pu1 'disaster fauna'. [Isolated reports of Paleocene non-avian dinosaurs would come from the Williston Basin (Rigby Jr. *et al.*, 1987), but were quickly attributed to reworking (Lofgren *et al.*, 1990).] However, all other investigations of Cretaceous-Paleogene biostratigraphy and magnetostratigraphy in the San Juan Basin rejected these conclusions, demonstrating unconformities between the Kirtland, Naashoibito, Ojo Alamo, and Nacimiento formations. Currently, the Naashoibito is dated to the latest Masstrichtian, the Ojo Alamo correlative to the Pu1 interval, and the Pu2/Pu3 intervals confined to the lowermost Nacimiento (Williamson & Weil, 2008; Heizler *et al.*, 2013; Peppe *et al.*, 2013; Williamson & Brusatte, 2014; see also review in Appendix 1).

1.3. Contemporary perspectives of Puercan eutherian biogeography

Current opinions on Puercan biogeography and biochronology are based largely on work by T. E. Williamson and S. G. Lucas, who conducted the first major revision of the Nacimiento Fm. mammalian assemblages since Matthew (Williamson & Lucas, 1992; Lucas & Williamson, 1993). Williamson (1993, 1996) confirmed the suspected division between the Pu2 and Pu3 faunas in the basin, labeling them as the "*Hemithlaeus kowalevskianus*-*Taeniolabis taoensis*" and "*Taeniolabis taoensis*-*Periptychus carinidens*" zones respectively. He also investigated faunal similarity using the Simpson (1943) coefficient, a binary measure of faunal similarity (intersection or overlap) between two finite sets (sites) (Fallaw, 1979). The results demonstrate a clear distinction between the Puercan and Torrejonian NALMAs, as well as potential biogeographic zonation among the Puercan faunas. Surprisingly, the San Juan Basin Pu2/Pu3 faunal zones formed an outgroup to the rest of the sample, which was sorted into two subgroups: 1) Colorado and Utah (Gas Tank Hill, Corral Bluffs, Wagonroad); and 2) Montana and Saskatchewan (MHBT RAV W-1, Purgatory Hill, Simpson Quarry) (**Figure 1.2**). Williamson (1996) did not advocate for the presence of a sharp faunal province boundary between the northern and southern Western Interior during the Puercan, noting biogeographic uncertainties due to differential faunal preservation between fine facies (mudstone and siltstone) and coarse facies (conglomerate and sandstone). He acknowledged that the San Juan and Williston basins as strongly differentiated biogeographical endmembers, with the San Juan assemblages being more taxonomically and ecologically diverse than those in the Williston. These conclusions were broadly similar to unpublished results from Anthony & Maas (1990), who tentatively proposed a biogeographic barrier south of the Bighorn Basin by at least Pu2/Pu3 time.

Several incarnations of the Williamson (1993) test have since appeared in other evaluations of Puercan biogeography and biochronology (**Figure 1.2**). The analysis of Buckley (1994), which incorporated new occurrence data from the Simpson Quarry of the Crazy Mountain Basin, Montana, known since the 1940s but not thoroughly prospected until 1985 (Hartman et al., 1989; Buckley, 1995, 1997 & 2018; Fox *et al.*, 2015). He resolved the Pu2/Pu3 faunas of Colorado, New Mexico, and Utah as a separate biogeographic group from the rest of the Puercan faunas, due in part to the presence of the large periptychids *Carsioptychus* and *Ectoconus*. As with Williamson (1996), Buckley

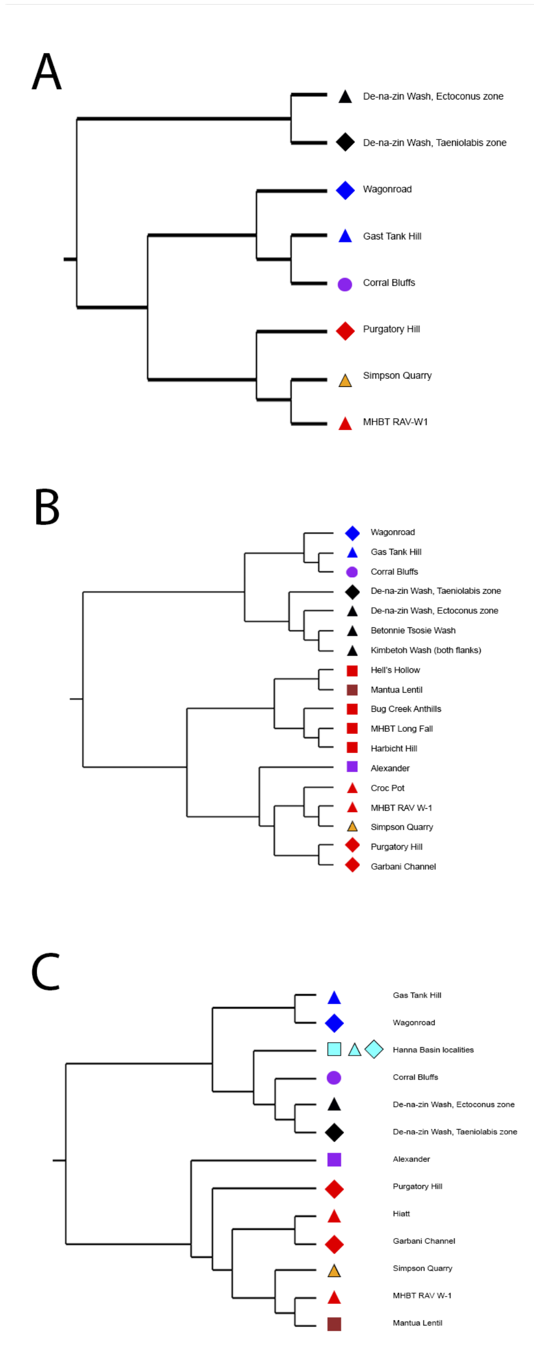


Figure 1.2. Prior biogeographic/biochronological dendrograms of Puercan mammal faunas: A) Williamson (1993, 1996), B) Buckley (1994), and C) Weil (1997). Basin colors and interval symbols as in Figure 1.1. See text for details.

agreed that the Colorado/Utah and New Mexico localities each formed their own subgroup, which in turn included distinct "Pu2" and "Pu3" groups. Interestingly, "Pu0" and "Pu1" Bighorn/Williston localities formed distinct subgroups, though as with Archibald & Lofgren (1990) and Lofgren (1995), Buckley considered the differences between the two to be minute. The rest of the Crazy Mountain/Williston sites formed discrete "Pu2" and "Pu3" groups, with the Alexander locality as an outgroup. Overall, Buckley (1994) provisionally conformed to the traditional model of Puercan biogeography, with minimal faunal heterogeneity in the Pu1 followed by regional differentiation of Pu2/Pu3 faunas.

J. Eberle, J. A. Lillegraven, and their colleagues challenged the traditional model based on description of a near-complete succession of Puercan faunas from the upper Ferris Fm. type section and the Windy Mudstone site in the Hanna Basin, Wyoming, as well as restudy of the major Denver Basin localities. Eberle & Lillegraven (1998a&b) noted the lack of clear distinctions between the hypothesized Pu1, Pu2, and Pu3 intervals in the Hanna Basin, with the local first appearances of noteworthy "Pu2/Pu3" taxa (i.e. *Ectoconus*, *Gillisonchus*, *Loxolophus*) in the Pu1. Furthermore, several taxa though to be endemic to the Alexander and South Table Mountain localities were described from the Ferris Fm., along with the Hanna Basin's own endemic taxa (Eberle, 1999 & 2003). This unexpected diversity, combined with the high number of trophic guilds at Alexander (Dewar, 1996 & 2003), led to the proposal of a heterogenous "transition zone" between the traditional northern and southern faunal provinces as early as the Pu1. According to this hypothesis, speciation within the "transition zone" was accelerated by increasing topographic complexity due to orogenic uplift and basin subsidence along the Laramide Orogeny (Lillegraven *et al.*, 2004; Clemens & Lillegraven, 2013). Conversely, Weil

(1997), following the methods of Williamson (1993), found the Hanna Basin sites to cluster with Pu2/Pu3 southern sites, while Alexander was more similar to northern sites as in Buckley (1994). However, Weil lumped the Hanna Basin material into a single assemblage, rather than splitting it into three temporally separate samples. Furthermore, additional records of supposed endemics from the Hanna and Denver basins would come from Pu1-Pu2 sites in the Williston Basin, most notably largely unpublished faunas from the PITA Flats and Merle's Mecca localities in the lower Ludlow Fm. of North Dakota (Hunter, 1999; Rook *et al.*, 2010; Lyson *et al.*, 2011).

The last major statistical analysis of Puercan biogeography and biochronology was Smith *et al.* (2018). This study was based largely from re-examination of the Pu1-Pu3 McGuire Creek local faunas of the Williston Basin by W. A. Clemens, G. Wilson, and colleagues as part of the "Hell Creek Projects II and III" (i.e., Wilson, 2005, 2013, & 2014; Smith & Wilson, 2017). Using chi-square correspondence analysis of 16 faunal assemblages, they ordinated sites and taxa into three broad clusters: 1) a homogenous Pu1 cluster Williston, Bighorn, and Denver Basin localities; 2) a Pu2/Pu3 "southern" cluster of Hanna, Utah, Denver, and San Juan Basin locales; and 3) a Pu2/Pu3 "northern" cluster of Williston Basin locales (i.e. the Garbani Channel Complex local faunas, Hiatt Local Fauna, and MHBT RAV W-1). In contrast to the aforementioned studies, the Alexander locality is somewhat closer to the Pu2/Pu3 "southern" cluster than the remainder of the Pu1 cluster. Wilson (2018, pers. comm. to J. Silviria) has expressed some rationale for reinstating the "Mantuan" as a subage of the Puercan NALMA to encompass the Pu1, given the aforementioned differences in biogeographical structuring between the Pu1 and Pu2/Pu3 intervals. Subages encompassing one or more interval-zones have been designated within other Paleogene NALMAs, as well as Asian and South American LMAs, but their usage remains infrequent and localized (Clyde *et al.*, 1994 & 1997; Polly, 1998).

Prior studies of Puercan biogeography are broadly consistent with patterns observed in western North America before the K/Pg mass extinction. These include distinct northern and southern provinces among dinosaur and mammal faunas, as well as unusually high genus-level and species-level basinal endemism (Sullivan & Lucas, 2006; Gates *et al.*, 2010, 2012; Sampson *et al.*, 2010 & 2013; but see Lucas *et al.*, 2016, and Berry, 2018). However, spatiotemporal provincialism is suspected to have significantly decreased in the Lancian NALMA of the latest Maastrichtian compared to the earlier Judithian, Kirtlandian, and Edmontonian NALMAs of the late Campanian-early Maastrichtian. In many paleogeographical models of North America across the K/Pg boundary, the retreat of the Western Interior Seaway in the Great Plains region reduced the extent of coastal habitats and thus barriers to terrestrial dispersal. This may have led to a spatially homogenous fauna in the low-lying broken foreland basins east of the Laramide and Sevier orogenies (Hunter & Archibald, 2002; Sampson & Loewen, 2005; Vavrek & Larsson, 2010). Nevertheless, controversy persists concerning the scale of orogenetic uplift and seaway retreat in the latest Lancian-earliest Puercan, and thus the role of geographic barriers in biogeographic structuring of vertebrate faunas. For example, several studies have presented supposed evidence of intertidal to benthic marine faunas (e.g., shark teeth and nematode burrows) in the upper Ferris Fm. as recently as the Pu3 interval (Wroblewski, 2004; Boyd & Lillegraven, 2011). This suggests an embayment in the Hanna Basin extending from either the north (the Cannonball Seaway) or the east (the Mississippi Embayment), with a narrow isthmus in the Montana and the Dakotas connecting the northern and southern mammalian faunal provinces (Grimaldi et al., 2000; Wroblewski, 2008). However, as with the McGuire Creek terrestrial faunas, reworking of Cretaceous material in the Hanna Basin, along with chronostratigraphic uncertainties, limit the robustness of these interpretations (Burris, 2001).

To summarize, models of eutherian biogeographic patterns during the Puercan remain extremely tentative. Most models postulate some sort of north/south dichotomy in the Western Interior despite the lack of an obvious geographic barrier to faunal dispersal (see discussion in Chapter 2). The evaluations described above paid little attention to the role of taphononmy – both from the perspective of lithological preservation biases and collecting methods – in biogeographic and biochronological interpretations. This study takes into account such factors, considering updated records of Puercan eutherians, to resolve long-standing disagreements and uncertainties.

1.4. References

Alroy, J. (1999). The fossil record of North American mammals: evidence for a Paleocene evolutionary radiation. *Systematic Biology*, *48*(1), 107-118.

Anthony & Maas (1990). Biogeographic provinciality in North American Paleocene mammalian faunas. *Journal of Vertebrate Paleontology*, *10*(S3), 12A.

Archibald, J. D. (1981). The earliest known Palaeocene mammal fauna and its implications for the Cretaceous–Tertiary transition. *Nature*, *291*(5817), 650-652.

Archibald, J. D. (1982). A study of Mammalia and geology across the Cretaceous-Tertiary boundary in Garfield County, Montana. *University of California Publications in Geological Sciences*, *122*, 1-286.

Archibald, J. D. (1983). Structure of the K/T mammal radiation in North America: speculations on turnover rates and trophic structure. *Acta Palaeontologica Polonica*, *28*(1-2), 7-17.

Archibald, J. D. (1993). The importance of phylogenetic analysis for the assessment of species turnover: a case history of Paleocene mammals in North America. *Paleobiology*, *19*(1), 1-27.

Archibald, J. D. (1994). Metataxon concepts and assessing possible ancestry using phylogenetic systematics. *Systematic Biology*, *43*(1), 27-40.

Archibald, J. D., & Clemens, W. A. (1984). Mammal evolution near the Cretaceous-Tertiary boundary. In Berggren, W. A., & Van Couvering, J. A. (eds.), *Catastrophes and Earth History. The New Uniformitarianism* (pp. 339-71). Princeton, NJ; Princeton University Press.

Archibald, J. D., Gingerich, P. D., Lindsay, E. H., Clemens, W. A., Krause, D. W., & Rose, K. D. (1987). First North American Land Mammal Ages of the Cenozoic era. In

Woodburne, M. O. (ed.), *Cenozoic Mammals of North America: Geochronology and Biostratigraphy* (pp. 24-76). Berkley: University of California Press.

Bakker, R. T. (1977). Tetrapod mass extinctions: A model of the regulation of speciation rates and immigration by cycles of topographic diversity. In Hallam, A. (ed.), *Patterns of Evolution, As Illustrated by the Fossil Record. Developments in Palaeontology and Stratigraphy*, *5*, 439-468.

Beard, K. C., & Dawson, M. R. (1999). Intercontinental dispersal of Holarctic land mammals near the Paleocene/Eocene boundary; paleogeographic, paleoclimatic and biostratigraphic implications. *Bulletin de la Société géologique de France*, *170*(5), 697-706.

Beck, R. M., & Lee, M. S. (2014). Ancient dates or accelerated rates? Morphological clocks and the antiquity of placental mammals. *Proceedings of the Royal Society B: Biological Sciences*, *281*(1793), 20141278.

Berry, K. (2018). Paleontological evidence against a major geographic barrier at about the paleolatitude of Colorado, USA, during the Late Campanian (Late Cretaceous): The conspicuous absence of endemic subclades of chasmosaurine ceratopsid (horned) dinosaurs and its significance. *The Mountain Geologist*, *55*(1), 5-18.

Boyd, D. W., & Lillegraven, J. A. (2011). Persistence of the Western Interior Seaway: Historical background and significance of ichnogenus *Rhizocorallium* in Paleocene strata, south-central Wyoming. *Rocky Mountain Geology*, *46*(1), 43-69.

Brown, R. W. (1943). Cretaceous-Tertiary boundary in the Denver basin, Colorado. *Geological Society of America Bulletin*, *54*(1), 65-86.

Brusatte, S. L., Butler, R. J., Barrett, P. M., Carrano, M. T., Evans, D. C., Lloyd, G. T., Mannion, P. D., Norell, M. A., Peppe, D. J., Upchurch, P., & Williamson, T. E. (2015). The extinction of the dinosaurs. *Biological Reviews*, *90*(2), 628-642.

Buckley, G. A. (1994). *Paleontology, geology and chronostratigraphy of Simpson Quarry (early Paleocene), Bear Formation, Crazy Mountains Basin, South-central Montana* (Doctoral dissertation, Rutgers University, New Brunswick).

Buckley, G. A. (1995). The multituberculate *Catopsalis* from the early Paleocene of the Crazy Mountains Basin in Montana. *Acta Palaeontologica Polonica*, *40*(4), 389-398.

Buckley, G. A. (1997). A new species of *Purgatorius* (Mammalia; Primatomorpha) from the lower Paleocene Bear formation, Crazy Mountains basin, south-central Montana. *Journal of Paleontology*, *71*(1), 149-155.

Buckley, G. A. (2018). Magnetostratigraphy of Upper Cretaceous (Lancian) to Middle Paleocene (Tiffanian) strata in the northeastern Crazy Mountains Basin, Montana, USA. *Rocky Mountain Geology*, *53*(2), 59-74.

Burris, J. H. (2001). Reworked Cretaceous elasmobranch teeth and provenance of the Paleocene Hanna Formation (Hanna Basin, Wyoming). *Rocky Mountain Geology*, *36*(1), 37-48.

Chester, S. G., Bloch, J. I., Boyer, D. M., & Clemens, W. A. (2015). Oldest known euarchontan tarsals and affinities of Paleocene *Purgatorius* to Primates. Proceedings of the National Academy of Sciences, *112*(5), 1487-1492.

Chiu, C. S., & Li, C. K. (1977). Miscellaneous mammalian fossils from the Paleocene of Qianshan Basin, Anhui. *Vertebrata PalAsiatica*, *15*(2), 94-102.

Clemens, W. A. (2004). *Purgatorius* (Plesiadapiformes, Primates?, Mammalia), a Paleocene immigrant into northeastern Montana: Stratigraphic occurrences and incisor proportions. In Dawson, M R., & Lillegraven, J. A. (eds.), *Fanfare for an Uncommon paleontologist: Papers in honor of Malcolm McKenna*. *Bulletin of Carnegie Museum of Natural History*, *36*, 3-13.

Clemens, W. A. (2010). Were immigrants a significant part of the earliest Paleocene mammalian fauna of the North American Western Interior?. *Vertebrata PalAsiatica*, *48*(4), 285-307.

Clemens, W. A. (2019). *Puercolestes* and *Betonnia* (Cimolestidae, Mammalia) from the early Paleocene (Puercan 3 Interval Zone) of northeastern Montana, USA. *PaleoBios*, *36*, 1-17.

Clemens, W. A., & Hartman, J. H. (2014). From *Tyrannosaurus rex* to asteroid impact: Early studies (1901-1980) of the Hell Creek Formation in its type area. In Wilson, G. P., Clemens, W. A., Horner, J. R., & Hartman, J. H. (eds.), *Through the End of the Cretaceous in the Type Locality of the Hell Creek Formation in Montana and Adjacent Areas*. *Geological Society of America Special Papers*, *503*, 1-87.

Clemens, W. A., & Lillegraven, J. A. (2013). Interpreting stratigraphic relationships and Laramide structural history of the northeastern margin of the Hanna Basin (Wyoming): *Meniscoessus* (Mammalia, Multituberculata) exposes its faults. *Rocky Mountain Geology*, *48*(2), 143-167.

Clyde, W. C., Ramezani, J., Johnson, K. R., Bowring, S. A., & Jones, M. M. (2016). Direct high-precision U–Pb geochronology of the end-Cretaceous extinction and calibration of Paleocene astronomical timescales. *Earth and Planetary Science Letters*, *452*, 272-280.

Clyde, W. C., Stamatakos, J., & Gingerich, P. D. (1994). Chronology of the Wasatchian land-mammal age (early Eocene): Magnetostratigraphic results from the McCullough Peaks section, northern Bighorn Basin, Wyoming. *The Journal of Geology*, *102*(4), 367-377.

Clyde, W. C., Zonneveld, J. P., Stamatakos, J., Gunnell, G. F., & Bartels, W. S. (1997). Magnetostratigraphy across the Wasatchian/Bridgerian NALMA boundary (early to middle Eocene) in the western Green River basin, Wyoming. *The Journal of Geology*, *105*(6), 657-670.

Coleman Jr., J., & Cahan, S. M. (2012). Preliminary catalog of sedimentary basins of the United States. *USGS Open File Report*, *2012-1111*, 1-26.

Cope, E. D. (1882). Synopsis of the Vertebrata of the Puerco Eocene epoch. *Proceedings of the American Philosophical Society*, *20*(112), 461-471.

Cope, E. D. (1884). Second addition to the knowledge of the Puerco Epoch. *Proceedings of the American Philosophical Society*, *21*(114), 309-324.

Cope, E. D. (1885). The Vertebrata of the Tertiary formations of the West. In Hayden, F. V. (ed.) *Report of the United States Geological Survey of the Territories: Volume 3* (pp. 1-1099). Washington, D.C.: U.S. Government Printing Office.

Cope, E. D. (1888). Synopsis of the vertebrate fauna of the Puerco series. *Transactions of the American Philosophical Society*, *16*(2), 298-361.

Cracraft, J. (1974). Continental drift and vertebrate distribution. *Annual Review of Ecology and Systematics, 5*(1), 215-261.

Dane, C. H. (1946). Stratigraphic relations of Eocene, Paleocene, and latest Cretaceous formations of eastern side of San Juan Basin, New Mexico. *United States Geological Survey Oil and Gas Investigation Charts*, *24*.

Davis, A. J., Peppe, D. J., Atchley, S. C., Williamson, T. E., & Flynn, A. G. (2016). Climate and landscape reconstruction of the Arroyo Chijuillita Member of the Nacimiento Formation, San Juan Basin, New Mexico: Providing environmental context to early Paleocene mammal evolution. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *463*, 27-44.

de Blainville, H. D. (1841). *Ostéographie ou description iconographique comparée du squelette et du système dentaire de cinq classes d'animaux vertébrés récents et fossiles pour servir de base à la zoologie et à la géologie, Volume 3 - Carnassiers: Vespertilio, Talpa, Sorex, Erinaceus, Phoca, Ursus, Subursus*. Paris: J.B. Baillière.

Dewar, E. W., (1996). *Mammalian paleoecology of the Early Paleocene Littleton Local Fauna (Denver Formation, Colorado)* (Master's thesis, University of Colorado, Boulder).

Dewar, E. W. (2003). Functional diversity within the Littleton fauna (early Paleocene), Colorado: Evidence from body mass, tooth structure, and tooth wear. *PaleoBios*, *23*(1), 1-19.

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J., & Collen, B. (2014). Defaunation in the Anthropocene. *Science*, *345*(6195), 401-406.

Eberle, J. J. (1999). Bridging the transition between didelphodonts and taeniodonts. *Journal of Paleontology*, *73*(5), 936-944.

Eberle, J. J. (2003). Puercan mammalian systematics and biostratigraphy in the Denver Formation, Denver Basin, *Colorado. Rocky Mountain Geology*, *38*(1), 143-169.

Eberle, J. J., & Lillegraven, J. A. (1998a). A new important record of earliest Cenozoic mammalian history: Geologic setting, Multituberculata, and Peradectia. *Rocky Mountain Geology*, *33*(1), 3-47.

Eberle, J. J., & Lillegraven, J. A. (1998b). A new important record of earliest Cenozoic mammalian history: Eutheria and paleogeographic/biostratigraphic summaries. *Rocky Mountain Geology*, *33*(1), 49-117.

Emerling, C. A., Delsuc, F., & Nachman, M. W. (2018). Chitinase genes (CHIAs) provide genomic footprints of a post-Cretaceous dietary radiation in placental mammals. *Science Advances*, *4*(5), eaar6478.

Estes, R. (1964). Fossil vertebrates from the Lance Formation, Easten Wyoming. *University of California Publications in Geological Science*, *49*, 1-187.

Evernden, J. F., Savage, D. E., Curtis, G. H., & James, G. (1964). Potassium-argon dates and the Cenozoic mammalian chronology of North America. *American Journal of Science*, *262*(2), 145-198.

Fallaw, W. C. (1979). A test of the Simpson coefficient and other binary coefficients of faunal similarity. *Journal of Paleontology*, *53*(4), 1029-1034.

Fassett, J. E. (2009) New geochronologic and stratigraphic evidence confirms the Paleocene age of the dinosaur-bearing Ojo Alamo Sandstone and Animas Formation in the San Juan Basin, New Mexico and Colorado. *Palaeontologia Electronica*, *12*, 1–155.

Fassett, J. E., Heaman, L. M., & Simonetti, A. (2011) Direct U-Pb dating of Cretaceous and Paleocene dinosaur bones, San Juan Basin, New Mexico. *Geology*, *39*, 159–162.

Fassett, J. E., Lucas, S. G., & O'Neil, M. (1987). Dinosaurs, pollen and shoes, and the age of the Ojo Alamo Sandstone, San Juan Basin, New Mexico. In Fassett, J. E, & Rigby Jr, J. K. (eds.), *The Cretaceous–Tertiary boundary in the San Juan and Raton Basins, New Mexico and Colorado*. *Geological Society of America Special Paper*, *209*, 17-34.

Fassett, J. E., Zielinski, R. A., & Budahn, J. R. (2002) Dinosaurs that did not die: Evidence for Paleocene dinosaurs in the Ojo Alamo sandstone, San Juan Basin, New Mexico. In Koeberl, C., & MacLeod, K. G. (eds.), *Catastrophic Events and Mass Extinctions: Impacts and Beyond*. *Geological Society of America Special Paper*, *356*, 307–336.

Fox, R. C. (1990). The succession of Paleocene mammals in western Canada. In Bown, T. M., & Rose, K. D. (eds.), *Dawn of the Age of Mammals in the Northern Part of the Rocky Mountain interior, North America*. *Geological Society of America Special Paper*, *243*, 516-524.

Fox R. C. Scott C. S. & Buckley G. A. (2015). A 'giant' purgatoriid (Plesiadapiformes) from the Paleocene of Montana USA: Mosaic evolution in the earliest primates. *Palaeontology*, *58*(2) 277-291.

Galloway, W. E., Whiteaker, T. L., & Ganey-Curry, P. (2011). History of Cenozoic North American drainage basin evolution, sediment yield, and accumulation in the Gulf of Mexico basin. *Geosphere*, *7*(4), 938-973.

Gardner, J. H. (1910). The Puerco and Torrejon formations of the Nacimiento group. *The Journal of Geology*, *18*(8), 702-741.

Gates, T. A., Prieto-Márquez, A., & Zanno, L. E. (2012). Mountain building triggered Late Cretaceous North American megaherbivore dinosaur radiation. *PLOS ONE*, *7*(8), e42135.

Gates, T. A., Sampson, S. D., Zanno, L. E., Roberts, E. M., Eaton, J. G., Nydam, R. L., Hutchison, J. H., Smith, J. A., Loewen, M. A., & Getty, M. A. (2010). Biogeography of terrestrial and freshwater vertebrates from the Late Cretaceous (Campanian) Western Interior of North America. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *291*(3-4), 371-387.

Gazin, C. L. (1938). A Paleocene mammalian fauna from central Utah. *Journal of the Washington Academy of Sciences*, *28*(6), 271-277.

Gazin, C. L. (1939). A further contribution to the Dragon Paleocene fauna of central Utah. *Journal of the Washington Academy of Sciences*, *29*(7), 273-286.

Gazin, C. L. (1941a). Paleocene mammals from the Denver Basin, Colorado. *Journal of the Washington Academy of Sciences*, *31*(7), 289-295.

Gazin, C. L. (1941b). The mammalian faunas of the Paleocene of central Utah, with notes on the geology. *Proceedings of the United States National Museum*, *91*(3121), 1-53.

Gingerich, P. D. (2016). Paleocene faunal evolution at Polecat Bench in the northern Bighorn Basin of Wyoming, USA. *Vertebrata PalAsiatica*, *54*(3), 212-234.

Grimaldi, D. A., Lillegraven, J. A., Wampler, T. W., Bookwalter, D., & Shedrinsky, A. (2000). Amber from Upper Cretaceous through Paleocene strata of the Hanna Basin, Wyoming, with evidence for source and taphonomy of fossil resins. *Rocky Mountain Geology*, *35*(2), 163-204.

Grossnickle, D. M., & Newham, E. (2016). Therian mammals experience an ecomorphological radiation during the Late Cretaceous and selective extinction at the K–Pg boundary. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1832), 20160256.

Halliday, T. J., dos Reis, M., Tamuri, A. U., Ferguson-Gow, H., Yang, Z., & Goswami, A. (2019). Rapid morphological evolution in placental mammals post-dates the origin of the crown group. *Proceedings of the Royal Society B: Biological Sciences*, *286*(1898), 20182418.

Halliday, T. J. D., Upchurch, P., & Goswami, A. (2016). Eutherians experienced elevated evolutionary rates in the immediate aftermath of the Cretaceous–Palaeogene mass extinction. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1833), 20153026.

Halliday, T. J., Upchurch, P., & Goswami, A. (2017). Resolving the relationships of Paleocene placental mammals. *Biological Reviews*, *92*(1), 521-550.

Hartman, J. H., Buckley, G. A., Krause, D. W., & Kroeger, T. J. (1989). Paleontology, stratigraphy, and sedimentology of Simpson Quarry (early Paleocene), Crazy Mountains Basin, South-central Montana. In French, D. E., & Grabb, R. F. (eds.), *1989 Field Conference Guidebook, Montana Centennial Edition – Geologic Resources of Montana, Volume II: Road Logs August-September 1989* (pp. 173-185). Billings, MT: Montana Geological Society.

Heizler MT, Mason A, Williamson TE, Peppe DJ, Ramezani J, et al. (2013) 40Ar/39Ar Chronostratigraphy of Cretaceous and Paleocene strata in the San Juan Basin, New Mexico: Accuracy limitations of high precision measurements. Abstract presented at 2013 Geological Society of America Annual Meeting in Denver.

Hunter, J. P. (1999). The radiation of Paleocene mammals with the demise of the dinosaurs: Evidence from southwestern North Dakota. *Proceedings of the North Dakota Academy of Science*, *53*, 141-144.

Hunter, J. P., & Archibald, J. D. (2002). Mammals from the end of the age of dinosaurs in North Dakota and southeastern Montana, with a reappraisal of geographic differentiation among Lancian mammals. In Hartman, J. H., KR Johnson, K.R., & DJ Nichols, D.J. (eds.), *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great*

Plains: An Integrated Continental Record of the End of the Cretaceous. *Geological Society of America Special Paper*, *361*, 191-216.

Jepsen, G. L. (1930). New vertebrate fossils from the Lower Eocene of the Bighorn Basin, Wyoming. *Proceedings of the American Philosophical Society*, *69*(1), 117-131.

Jepsen, G. L. (1940). Paleocene faunas of the Polecat Bench Formation, Park County, Wyoming: Part I. *Proceedings of the American Philosophical Society*, *83*(2), 217-340.

Jepsen, G. L., & Van Houten, F. B. (1947). Early Tertiary stratigraphy and correlations. In Blackstone Jr., D. L., & Sternberg, C. W. (eds.), *Field Conference in the Bighorn Basin, Guidebook: August 5-8, 1947* (pp. 142-149). Casper, WY: Wyoming Geological Association.

Johnston, P. A., & Fox, R. C. (1984). Paleocene and Late Cretaceous mammals from Saskatchewan, Canada. *Palaeontographica, Abteilung A*, *186*, 163–222.

Kondrashov, P., & Lucas, S. G. (2006). Early Paleocene (Puercan and Torrejonian) archaic ungulates (Condylarthra, Procreodi and Acreodi) of the San Juan Basin, New Mexico. Lucas, S.G., Spielmann, J. A., Hester, P. M., Kenworthy, J. P., &Santucci, V. L. (eds.), *Americas Antiquities: 100 Years of Managing Fossils on Federal Lands*. *New Mexico Museum of Natural History & Science Bulletin*, *34*, 84-97.

Krassilov, V. A. (1981). Changes of Mesozoic vegetation and the extinction of dinosaurs. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *34*, 207-224.

Krause, D. W., & Maas, M. C. (1990). The biogeographic origins of late Paleocene-early Eocene mammalian immigrants to the Western Interior of North America. In Bown, T. M., & Rose, K. D. (eds.), *Dawn of the Age of Mammals in the Northern Part of the Rocky Mountain Interior, North America*. *Geological Society of America Special Paper, 243*, 71-105.

Lehman, T. M. (1981). The Alamo Wash local fauna: a new look at the old Ojo Alamo fauna. In Lucas, S. G., Rigby, J. K., & Kues, B. S. (eds.), *Advances in San Juan Basin Paleontology* (pp. 189-221). Albuquerque: University of New Mexico Press.

Lehman, T. M. (1987). Late Maastrichtian paleoenvironments and dinosaur biogeography in the western interior of North America. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *60*, 189-217.

Lemoine, V. (1878-1880). Communication sur les ossements fossiles des terrains tertiaires inférieurs des environs de Reims. *Bulletin de la Société d'Histoire Naturelle de Reims*, 8 vols.

Lillegraven, J. A., Snoke, A. W., & McKenna, M. C. (2004). Tectonic and paleogeographic implications of late Laramide geologic history in the northeastern corner of Wyoming's Hanna Basin. *Rocky Mountain Geology*, *39*(1), 7-64.

Lindsay, E. H., Jacobs, L. L., & Butler, R. F. (1978). Biostratigraphy and magnetostratigraphy of Paleocene terrestrial deposits, San Juan Basin, New Mexico. *Geology*, *6*(7), 425-429.

Lofgren, D. L. (1995). The Bug Creek Problem and the Cretaceous-Tertiary transition at McGuire Creek. Montana. *University of California Publications in Geological Sciences*, *140*, 1-200.

Lofgren, D. L., Hotton, C. L., & Runkel, A. C. (1990). Reworking of Cretaceous dinosaurs into Paleocene channel, deposits, upper Hell Creek Formation, Montana. *Geology*, *18*(9), 874-877.

Lofgren, D. L., Lillegraven, J. A., Clemens, W. A., Gingerich, P. D., & Williamson, T. E. (2004). Paleocene biochronology: The Puercan through Clarkforkian Land Mammal Ages. In Woodburne, M. O. (ed.), *Late Cretaceous and Cenozoic Mammals of North America: Biostratigraphy and Geochronology* (pp. 43-105). New York: Columbia University Press.

Longrich, N. R., Scriberas, J., & Wills, M. A. (2016). Severe extinction and rapid recovery of mammals across the Cretaceous–Palaeogene boundary, and the effects of rarity on patterns of extinction and recovery. *Journal of Evolutionary Biology*, *29*(8), 1495-1512.

Lucas, S. G, & Estep, J. W. (2000). Field notes of Walter Granger's 1912, 1913 and 1916 expeditions to the San Juan Basin, New Mexico. In Lucas, S. G. (ed.), *New Mexico's Fossil Record 2*. *New Mexico Museum of Natural History & Science Bulletin*, *16*, 169-186.

Lucas, S. G., & Williamson, T. E. (1993). Late Cretaceous to early Eocene vertebrate biostratigraphy and biochronology of the San Juan basin, New Mexico. In Lucas, S. G. & Zidek, J. (eds.), *Vertebrate Paleontology in New Mexico*. *New Mexico Museum of Natural History & Science Bulletin*, *2*, 105-136.

Lucas, S. G., & Williamson, T. E. (1995). Systematic position and biochronological significance of *Yuodon* and *Palasiodon*, supposed Paleocene" condylarths" from China. *Neues Jahrbuch fur Geologie und Palaontologie-Abhandlungen*, *196*(1), 93-108.

Lucas, S. G., Sullivan, R. M., Lichtig, A. J., Dalman, S. G., & Jasinki, S. E. (2016). Late Cretaceous dinosaur biogeography and endemism in the Western Interior Basin, North America: A critical evaluation. In Khosla, A., & Lucas, S.G. (eds.), *Cretaceous Period: Biotic Diversity and Biogeography*. *New Mexico Museum of Natural History & Science Bulletin*, *71*, 195-213.

Luo, Z. (1991). Variability of dental morphology and the relationships of the earliest arctocyonid species. Journal of Vertebrate Paleontology, 11(4), 452-471.

Lyson, T. R., Bercovici, A., Chester, S. G., Sargis, E. J., Pearson, D., & Joyce, W. G. (2011). Dinosaur extinction: closing the '3 m gap'. *Biology Letters*, *7*(6), 925-928.

Matthew, W. D. (1897). A revision of the Puerco fauna. *Bulletin of the American Museum of Natural History*, *9*, 259-323.

Matthew, W. D. (1909). Faunal lists of the Tertiary Mammalia of the west. *U. S. Geological Survey Bulletin*, *361*, 91-120.

Matthew, W. D. (1921). Fossil vertebrates and the Cretaceous-Tertiary problem. *American Journal of Science*, *(5)II*(10), 209-227.

Matthew, W. D. (1937). Paleocene faunas of the San Juan Basin, New Mexico. *Transactions of the American Philosophical Society*, *30*, 1-510.

Matthew, W. D., & Granger, W. (1921). New genera of Paleocene mammals. *American Museum Noviates*, *13*, 1-7.

Meredith, R. W., Janečka, J. E., Gatesy, J., Ryder, O. A., Fisher, C. A., Teeling, E. C., ... & Rabosky, D. L. (2011). Impacts of the Cretaceous Terrestrial Revolution and KPg extinction on mammal diversification. *Science*, *334*(6055), 521-524.

Middleton, M. D. (1982). A new species and additional material of *Catopsalis* (Mammalia, Multituberculata) from the Western Interior of North America. *Journal of Paleontology*, *56*(5), 1197-1206.

Middleton M. D., (1983). *Early Paleocene vertebrates of the Denver Basin, Colorado* (Doctoral dissertation, University of Colorado Boulder).

Newberry, J. S. (1876). Geological report. In Macomb, J. N. (ed.), *Report of the exploring expedition from Santa Fe, New Mexico, to the junction of the Grand and Green Rivers of the great Colorado of the west in 1859*. Washington, D.C.: US Government Printing Office.

Osborn, H. F., & Earle, C. (1895). Fossil mammals of the Puerco beds: Collection of 1892. *Bulletin of the American Museum of Natural History*, *7*(1), 1-70.

Peppe, D. J., Heizler, M. T., Williamson, T. E., Masson, I. P., Brusatte, S., Weil, A., & Secord, R. (2013). New age constraints on the Late Cretaceous through early Paleocene rocks in the San Juan Basin, New Mexico. Abstract presented at 2013 Geological Society of America Annual Meeting in Denver.

Pires, M. M., Rankin, B. D., Silvestro, D., & Quental, T. B. (2018). Diversification dynamics of mammalian clades during the K-Pg mass extinction. *Biology Letters*, *14*(9), 20180458.

Polly, P. D. (1998). Variability, selection, and constraints: development and evolution in viverravid (Carnivora, Mammalia) molar morphology. *Paleobiology*, *24*(4), 409-429.

Rainger, R. (1989). W. D. Matthew, fossil vertebrates and geological time. *Earth Sciences History*, *8*(2), 159-166.

Reynolds, T. E. (1936). Two new insectivores from the lower Paleocene of New Mexico. *Journal of Paleontology*, *10*(3), 202-209.

Rigby Jr., J. K., Newman, K. R., Van Der Kaars, J. S. S., Sloan, R. E., & Rigby, J. K. (1987). Dinosaurs from the Paleocene part of the Hell Creek Formation, McCone County, Montana. *Palaios*, 2(3), 296-302.

Rook, D. L., Hunter, J. P., Pearson, D. A., & Bercovici, A. (2010). Lower jaw of the early Paleocene mammal *Alveugena* and its interpretation as a transitional fossil. *Journal of Paleontology*, *84*(6), 1217-1225.

Rose, K. D. (1981). Composition and species diversity in Paleocene and Eocene mammal assemblages: an empirical study. *Journal of Vertebrate Paleontology*, *1*(3-4), 367-388.

Russell, D. E. 1967. Le Paleocene continental d'Amerique du nord. *Memoires du Museum National d'Histoire Naturelle, Série C: Sciences de la Terre*, *16*(2), 37-99.

Sampson, S. D., & Loewen, M. A. (2005). *Tyrannosaurus rex* from the Upper Cretaceous (Maastrichtian) North Horn Formation of Utah: Biogeographic and paleoecologic implications. *Journal of Vertebrate Paleontology*, *25*(2), 469-472.

Sampson, S. D., Loewen, M. A., Farke, A. A., Roberts, E. M., Forster, C. A., Smith, J. A., & Titus, A. L. (2010). New horned dinosaurs from Utah provide evidence for intracontinental dinosaur endemism. *PLOS ONE*, *5*(9), e12292.

Sampson, S. D., Lund, E. K., Loewen, M. A., Farke, A. A., & Clayton, K. E. (2013). A remarkable short-snouted horned dinosaur from the Late Cretaceous (late Campanian) of southern Laramidia. *Proceedings of the Royal Society B: Biological Sciences*, *280*(1766), 20131186.

Savage, D. E., & Russell, D. E (1986). *Mammalian Paleofaunas of the World*. Boston: Addision-Wesley.

Shelley, S. L., Williamson, T. E., & Brusatte, S. R. (2017). 'Archaic' Paleogene mammals possessed unique locomotor styles distinct from modern forms: Insights from multivariate analyses. Abstract presented at the 2017 Society of Vertebrate Paleontology Meeting, Calgary, Alberta, Canada.

Simpson, G. G. (1936). Additions to the Puerco fauna, lower Paleocene. *American Museum Noviates*, *849*, 1-11.

Simpson, G. G. (1943). Mammals and the nature of continents. *American Journal of Science*, *241*, 1–31.

Simpson, G. G. (1951). Hayden, Cope, and the Eocene of New Mexico. *Proceedings of the Academy of Natural Sciences of Philadelphia*, *103*, 1-21.

Simpson, G. G. (1981). History of vertebrate paleontology in the San Juan Basin. In Lucas, S. G., Rigby, J. K., & Kues, B. S. (eds.), *Advances in San Juan Basin Paleontology* (pp. 3-28). Albuquerque: University of New Mexico Press.

Sinclair, W. J., & Granger, W. (1914). Paleocene deposits of the San Juan Basin, New Mexico. *Bulletin of the American Museum of Natural History*, *33*(22), 297-316.

Smith, S. M., & Wilson, G. P. (2017). Species discrimination of co-occurring small fossil mammals: a case study of the Cretaceous-Paleogene multituberculate genus *Mesodma*. *Journal of Mammalian Evolution*, *24*(2), 147-157.

Smith, S. M., Sprain, C. J., Clemens, W. A., Lofgren, D. L., Renne, P. R., & Wilson, G. P. (2018). Early mammalian recovery after the end-Cretaceous mass extinction: A high-resolution view from McGuire Creek area, Montana, USA. *Geological Society of America Bulletin*, *130*(11-12), 2000-2014.

Sloan, R.E. (1976). The ecology of dinosaur extinction. In Churcher, C.S. (ed.), *Athlon: Essays on Paleontology in Honour of Loris Shano Russel* (pp.134-154). *Royal Ontario Museum Life Sciences Miscellaneous Publications*. Toronto; Royal Ontario Museum.

Sloan, R. E. (1987). Paleocene and latest Cretaceous mammal ages, biozones, magneto zones, rates of sedimentation and evolution. In Fassett, J. E, & Rigby Jr, J. K. (eds.), *The Cretaceous–Tertiary boundary in the San Juan and Raton basins, New Mexico and Colorado*. *Geological Society of America Special Papers*, *209*, 165-200.

Sloan R. E. & Van Valen L. (1965). Cretaceous mammals from Montana. *Science*, *148*(3667), 220-227.

Sprain, C. J., Renne, P. R., Wilson, G. P., & Clemens, W. A. (2015). High-resolution chronostratigraphy of the terrestrial Cretaceous-Paleogene transition and recovery interval in the Hell Creek region, Montana. *Geological Society of America Bulletin*, *127*(3-4), 393-409.

Sprain, C. J., Renne, P. R., Clemens, W. A., & Wilson, G. P. (2018). Calibration of chron C29r: New high-precision geochronologic and paleomagnetic constraints from the Hell Creek region, Montana. *Geological Society of America Bulletin*, *130*(9-10), 1615-1644.

Springer, M. S., Emerling, C. A., Meredith, R. W., Janečka, J. E., Eizirik, E., & Murphy, W. J. (2017). Waking the undead: Implications of a soft explosive model for the timing of placental mammal diversification. *Molecular Phylogenetics and Evolution*, *106*, 86-102.

Springer, M. S., Murphy, W. J., Eizirik, E., & O'Brien, S. J. (2003). Placental mammal diversification and the Cretaceous–Tertiary boundary. *Proceedings of the National Academy of Sciences*, *100*(3), 1056-1061.

Sullivan, R. M., & Lucas, S. G. (1996). *Palaeoscincosaurus middletoni*, new genus and species (Squamata: ?Scincidae) from the early Paleocene (Puercan) Denver Formation, Colorado. *Journal of Vertebrate Paleontology*, *16*(4), 666-672.

Sullivan, R. M., & Lucas, S. G. (2006). The Kirtlandian land-vertebrate "age": faunal composition, temporal position and biostratigraphic correlation in the nonmarine Upper Cretaceous of western North America. In Lucas, S. G., & Sullivan, R. M. (eds.), *Late Cretaceous Vertebrates from the Western Interior. New Mexico Museum of Natural History & Science Bulletin*, *35*, 7-29.

Tang, Y. J., & Yan, D. F. (1976). Notes on some mammalian fossils from the Paleocene of Qianshan and Xuancheng, Anhui. *Vertebrata PalAsiatica*, *14*(2), 91-99.

Tomida, Y. (1980). "Dragonian" fossils from the San Juan Basin and status of" Dragonian" land mammal age. Abstract presented at the 8th Annual Geosciences Daze (Student Presentations in the Geosciences), Tucson, Arizona.

Tomida, Y., & Butler, R. F. (1980). Dragonian mammals and Paleocene magnetic polarity stratigraphy, North Horn Formation, central Utah. *American Journal of Science*, *280*(8), 787-811.

Van Valen, L. (1973). A new evolutionary law. *Evolutionary Theory*, *1*, 1-30.

Van Valen, L. (1978). The beginning of the age of mammals. *Evolutionary Theory*, *4*, 45-80.

Van Valen, L., & Sloan, R. L. (1978). Ecology and the extinction of the dinosaurs. *Evolutionary Theory*, *2*, 37-64.

Vavrek, M. J., & Larsson, H. C. (2010). Low beta diversity of Maastrichtian dinosaurs of North America. *Proceedings of the National Academy of Sciences*, *107*(18), 8265-8268.

Weil, A. (1997). *Multituberculate phylogeny and mammalian biogeography in the late Cretaceous and earliest Paleocene Western Interior of North America* (Doctoral dissertation, University of California, Berkley).

Wible, J. R., Rougier, G. W., Novacek, M. J., & Asher, R. J. (2007). Cretaceous eutherians and Laurasian origin for placental mammals near the K/T boundary. *Nature*, *447*(7147), 1003-1006.

Wible, J. R., Rougier, G. W., Novacek, M. J., & Asher, R. J. (2009). The eutherian mammal *Maelestes gobiensis* from the Late Cretaceous of Mongolia and the phylogeny of Cretaceous Eutheria. *Bulletin of the American Museum of Natural History*, *122*, 1-123.

Williamson, T. E. (1993). *The beginning of the Age of Mammals in the San Juan Basin: Biostratigraphy and evolution of Paleocene Mammals of the Nacimiento Formation* (Doctoral dissertation, University of New Mexico, Albuquerque).

Williamson, T. E. (1996). The beginning of the Age of Mammals in the San Juan Basin, New Mexico: Biostratigraphy and evolution of Paleocene mammals of the Nacimiento Formation. *New Mexico Museum of Natural History & Science Bulletin*, *8*, 1- 142.

Williamson, T. E., & Brusatte, S. L. (2014). Small theropod teeth from the Late Cretaceous of the San Juan Basin, northwestern New Mexico and their implications for understanding latest Cretaceous dinosaur evolution. *PLOS ONE*, *9*(4), e93190.

Williamson, T. E., & Carr, T. D. (2007). Revision of the problematic early Paleocene genus *Oxyclaenus* (Mammalia: Oxyclaenidae) and a new species of *Carcinodon*. *Journal of Vertebrate Paleontology*, *27*(4), 973- 986.

Williamson, T. E., & Lucas, S. G. (1992). Stratigraphy and mammalian biostratigraphy of the Paleocene Nacimiento Formation, southern San Juan Basin, New Mexico. In Lucas, S.G., Kues, B. S., Williamson, T. E., & Hunt, A. P. (eds.), *San Juan Basin IV*. *New Mexico Geological Society Guidebook*, *43*, 265-296.

Williamson T. E., & Weil, A (2008) Metatherian mammals from the Naashoibito Member, Kirtland Formation, San Juan Basin, New Mexico and their biochronologic and paleobiogeographic significance. *Journal of Vertebrate Paleontology*, *28*, 803–815.

Wilson, G. P. (2005). Mammalian faunal dynamics during the last 1.8 million years of the Cretaceous in Garfield County, Montana. *Journal of Mammalian Evolution*, *12*(1-2), 53-76.

Wilson, G. P. (2013). Mammals across the K/Pg boundary in northeastern Montana, USA: dental morphology and body-size patterns reveal extinction selectivity and immigrant-fueled ecospace filling. *Paleobiology*, *39*(3), 429-469.

Wilson, G. P. (2014). Mammalian extinction, survival, and recovery dynamics across the Cretaceous-Paleogene boundary in northeastern Montana, USA. In Wilson, G. P., Clemens, W. A., Horner, J. R., & Hartman, J. H. (eds.), *Through the End of the Cretaceous in the Type Locality of the Hell Creek Formation in Montana and Adjacent Areas*. *Geological Society of America Special Papers*, *503*, 365-392.

Wolfe, J. A. (1975). Some aspects of plant geography of the Northern Hemisphere during the late Cretaceous and Tertiary. *Annals of the Missouri Botanical Garden*, *62*(2), 264-279.

Wood II, H. E., Chaney, R. W., Clark, J., Colbert, E. H., Jepsen, G. L., Reeside Jr., J. B., Stock, C. & Wood Committee. (1941). Nomenclature and correlation of the North American continental Tertiary. *Geological Society of America Bulletin*, *52*(1), 1-48.

Wroblewski, A. F. J. (2004). New selachian paleofaunas from "fluvial" deposits of the Ferris and lower Hanna formations (Maastrichtian–Selandian: 66–58 Ma), southern Wyoming. *Palaios*, *19*(3), 249-258.

Wroblewski, A. F. J. (2008). Paleoenvironmental significance of Cretaceous and Paleocene Psilonichnus in southern Wyoming. *Palaios*, *23*(6), 370-379.

Xu, Q. Q. (1976). New materials of Anagalidae from the Paleocene of Anhui. *Vertebrata PalAsiatica*, *14*, 242-251.

Xu, Q. Q. (1977). Two new genera of old Ungulata from the Paleocene of Qianshan Basin, Anhui. *Vertebrata PalAsiatica*, *15*(2), 119-125.

Yuanqing, W., Jin, M., Xijun, N., & Chuankui, L. (2007). Major events of Paleogene mammal radiation in China. *Geological Journal*, *42*(3-4), 415-430.

Zack, S. P. (2009). *The phylogeny of eutherian mammals: A new analysis emphasizing dental and postcranial morphology of Paleogene taxa* (Doctoral dissertation, The Johns Hopkins University School of Medicine, Baltimore).

CHAPTER 2:

AN ECOLOGICAL PALEOBIOGEOGRAPHIC ANALYSIS OF PUERCAN EUTHERIAN FAUNAS, WITH COMMENTS ON BIASES

2.1. Introduction

The Puercan North American Land Mammal Age (Paleocene, earliest Danian; 66.04-65.12 Ma) is typified by the rapid radiation of eutherian mammals in the aftermath of the Cretaceous-Paleogene mass extinction event. As reviewed in Chapter 1, however, the spatiotemporal context of this radiation remains contested, although most investigators insist on some sort of barrier to faunal dispersal south of the Bighorn Basin in Wyoming. The traditional model of Puercan eutherian biogeography posits the replacement of a spatially homogeneous Pu1 "disaster fauna" with a heterogeneous Pu2/Pu3 "recovery fauna", containing distinct "northern" and "southern" provinces); this is the model justified in prior analytical studies, albeit with a restricted number of localities from well-sampled basins. However, several authors have argued for regionalization as early as the Pu1 interval, especially about a "transition-zone" in Wyoming and Colorado, between the "northern" and "southern" faunal provinces.

However, the notion of faunal provincialism in the Puercan has persisted mainly because of its defense, rather than any verifiable evidence. Given the lack of obvious geographic barriers to dispersal which would enforce allopatric isolation (see discussion in Section 2.1.3), it is necessary to evaluate the role of other factors in supposed biogeographic ordination, particularly lithologic megabiases in specimen preservation, as well as regionally differential collection of specimens. Only after these factors are considered can the quest to resolve the ecological biogeography of Puercan eutherians resume. This endeavor is important because, while Puercan eutherians may not have foreshadowed modern mammalian ecomorphological guilds, they still provide insights into how fast and over what spatial scales mammalian communities can change during and after mass extinction events.

2.1.1. Basic principles of ecological paleobiogeography

Biogeography is the study of species' distributions in geographic space, including how such distributions change over geologic time. Traditionally, biogeography has been subdivided into two sub-disciplines: historical biogeography and ecological biogeography. Historical biogeography, which analyzes the spatiotemporal distribution of taxa, and the evolutionary 'relatedness' of areas, both using phylogenetic analysis of species (Rosen, 1988; Morrone & Crisci, 1995; Parrenti & Ebach, 2009). Ecological biogeography – the focus of this study – examines ecological and environmental influences on the spatiotemporal distribution of taxa. Ecological biogeographic studies in paleontology have mainly focused on marine biofacies (see reviews in Myers & Lieberman, 2010; Myers *et al.*, 2013 & 2015; Myers & Saupe, 2013; Saupe *et al.*, 2014); however, there has been increased focus on freshwater and terrestrial paleo-ecosystems (i.e., Maguire & Stigall, 2009; Sunderlin *et al.*, 2014; Lemus-Lauzon *et al.*, 2016; Xu *et al.*, 2017; Croft *et al.*, 2018).

Ecological biogeography emphasizing the importance of niches, relational positions of organisms to a particular habitat and to coexisting organisms, based mainly on behavioral and morphological attributes. Conventionally, niches are defined as *n*-dimensional hypervolumes with abiotic factors (temperature, humidity, elevation, latitude and longitude) and biotic factors (dispersal ability, interspecific competition, predation). These niches can be further subdivided into a) fundamental niches, encompassing all possible conditions under which an organism can survive; and b) realized niches, which the organism actually occupies in a specific place and time due to constraints from biotic factors (see reviews in Hutchinson, 1957; Wilson *et al.*, 1987; Leibold, 1995; Soberón & Peterson, 2005; Peterson *et al.*, 2011; Blonder, 2018). Niches are typically considered intrinsic properties of a species, although this is an area of ongoing research (Chase & Leibold, 2003; Soberón, 2007; Meik et al., 2015). Ecological biogeographic analyses aim to quantify fundamental and realize niches of species to evaluate niche occupation over time, and the causes of changes in niche occuptation due to abiotic and biotic factors (see reviews by Hengeveld, 1993; Urban *et al.*, 2008; Winegardner *et al.*, 2012; Leibold & Chase, 2017). Additionally, ecological biogeography aims to resolve whether and how components in niche occupation are evolutionarily inherited within clades due to "niche conservatism" (Hadly *et al.*, 2009; Peterson, 2011; DeSantis *et al.*, 2012).

Although primarily focused on individual species, ecological biogeographic analyses can combine data from taxa of multiple clades, in order to define biogeographic units. "Ecoregions" or "metacommunities" are typically defined as major, spatiotemporally constrained regions containing several ecosystems or communities, composed of multiple interacting species (McDonald et al., 2005; Kreft & Jetz, 2010; Ricklefs, 2015; Leibold & Chase, 2017). In its treatment of spatial dependence and correlation between patterns and mechanisms, ecoregional definitions generally follow Tobler's (1970) first law of geography, in which data points that are spatially (and perhaps temporally) closer to each other are more likely to be "related" or similar (Tobler, 1981; Miller, 2004). Specifically, spatially proximate "clusters" of species occurrences recovered in ecological biogeographic analyses may suggest similar niche requirements, and could be hypothesized to respond similarly to environmental change, with the localities involved interpreted as an assemblage or potential community (but see Jackson and Overpeck, 2000 for an individualistic view of community composition). Several macroecologists argue that this "law" is applicable to geographic distance decay in community composition or structure only when biotic factors (especially long-distance dispersal) drive species-level spatiotemporal turnover, rather than abiotic factors (i.e., Nekola & White, 1999; Bjorholm *et al.*, 2008). However, this hypothesis has not yet been specifically tested using paleontological data.

2.1.2. Taphonomy and paleobiogeographic analyses of terrestiral ecosystems

While prior studies of ecological paleobiogeography claim to have been reasonably successful in defining prehistoric communities (e.g., Chen et al., 2010; Forcino et al., 2010; Wang et al., 2011; Mallon et al., 2012; Sunderlin *et al.*, 2014; Vila et al., 2016), major challenges remain due to biased preservation and sampling of the fossil record (see reviews in Hoffman, 1979, 1980; Kowalewski & Flessa, 1996; Tomašových & Kidwell, 2009). Megabiases involve differences in preservation potential and time-averaging, ultimately operating on larger spatiotemporal scales than sampled localities (Kowalewski, 1996, 1997; Kowalewski & Flessa, 1996; Kowalewski, 1997; Hendy, 2011). Megabiases can affect a single taxon (within-taxon biases) or multiple taxa (among-taxon biases); the latter category includes static and dynamic megabiases. Static megabiases include differences in fossilization potential between and within clades due to organismal properties (e.g., skeletal composition) rather than geologic circumstances. An example of the former in the mammalian fossil record is that teeth are more commonly preserved regardless of depositional environment, because enamel bioapatite is more durable than the bioapatite of the rest of the skull and postcrania. Dynamic megabiases involve spatiotemporal change in fossilization potential of a clade with respect to one or more clades due to environmental gradients or ecological transitions, and severely impact occurrence estimates vital for paleocommunity analysis. While dynamic megabiases mainly affect marine shelled invertebrates with differing calcitic or phosphatic compositions, there are examples among terrestrial vertebrates; for instance, bats have more delicately constructed bones than other similarly sized mammals as a result of volancy, so their postcrania are rarely preserved in non-speleological sediments, save for a few *lagerstätten* (Brown *et al.*, 2019)

Megabiases at the regional level may arises from different sedimentological regimes (see reviews by Behrensmeyer *et al.*, 2000; Moore *et al.*, 2007; Jamniczky *et al.*, 2008). For example, conglomerates and sandstones formed in medium to high energy rivers subject to frequent advectional hydroturbation will yield more fragmented and disarticulated elements, with only the hardest parts (i.e. teeth) persisting as taxonomically diagnosable remains. Over centuries and millennia, such elements may be reworked downstream from their original environment and into younger sediments, obscuring their biogeographic and biostratigraphic context via time-averaging (Brett & Baird, 1986; Behrensmeyer, 1988; Lofgren *et al.*, 1990; Aslan & Behrensmeyer, 1996). Conversely, mudstones and siltstones formed in diffusion-dominated, lower energy rivers are less subject to severe erosion and reworking, and more likely to preserve large articulated specimens; nevertheless, specimen degradation can also occur in low-energy sedimentological regimes do to scavenging by crustaceans, mollusks, and other benthic bioturbators (Wilson, 2008; Moore & Norman, 2009; Moore, 2012; Moore & Varricchio, 2018).

Biases in vertebrate fossil sampling and preparation may compound upon organismal and lithologic megabiases. At mammalian fossil localities in western North America, including Puercan localities, the most frequently applied collecting methods are quarrying, screen-washing, and surface collecting; in many cases, at least two of these methods are performed at a single locality. Quarrying focusses on the heavy-duty excavation of macrofossils and microfossils at a site, with emphasis on the three-dimensional relationships of specimens within strata (Abler, 1984; Organ *et al.*, 2003; Evans et al., 2005). Screen-washing or sieving involves collecting specimens from unconsolidated sediments by sifting them through progressively smaller meshes, which will collect microfossils of different size classes; eventually, the smallest microfossils are isolated on the finest mesh. Screening may involve dry or wet sediment, broken down by mechanical means or soaking in liquid (McKenna, 1962; Miller, 1989; Cifelli *et al.*, 1996). Surface collecting involves the finding of isolated specimens as "float" on the outcrop surface, with minimal or no excavation (Greenwald, 1989; Ball & Davis, 1990).

Quarried and screen-washed localities generally provide more accurate depositional provenance data than most surface finds, which eroded from their original place of deposition rather than remaining in situ. However, as mentioned above, quarries and screen-washing sites are time-averaged deposits, with the exception of *lagerstätten*. Furthermore, well-sampled screen-washing localities usually provide more diverse faunas, with substantial numbers for small-bodied taxa usually represented by fragmentary remains, and thus are more realistic estimates of assemblage composition than spatially isolated surface finds. On the other hand, quarrying and surface collecting yields larger and more complete specimens, sometimes with unambiguous association of craniodental and postcranial material, in comparison to disassociated dental and postcranial fragments recovered from screen-washing; this significantly affects taxonomic assignments used to generate occurrence data, by limiting the number of specimens positively identified to described genera and species (see reviews in Rose, 1981; Leiggi *et al.*, 1994; Rogers, 1994; Kowalewski & Hoffmeister, 2003; Rogers & Brady, 2010; Peterson *et al.*, 2011). Overall, many supposedly spatiotemporal clusters of localities in ecological biogeographic analyses may be the result of the aforementioned benefits and drawbacks of collecting methods, perhaps in combination with lithological megabiases. Only after these biases are ruled out can analyses proceed with using ecological ordination gradients to clarify biogeographic trends (see reviews Wolff, 1975; Koch, 1978; Davis & Pyenson, 2007; Deline, 2009).

2.1.3. Hypotheses concerning Puercan eutherian biogeography

Current opinions concerning the ecological biogeography of Puercan eutherian mammals fall into two camps. The orthodox view, currently the most widely accepted hypothesis, postulates little or no provincialism in the Pu1 interval, with a geographically homogenous post-K/Pg "disaster taxa" in Western Interior. This is followed by increased differentiation between "northern" and "southern" faunas in the Pu2-Pu3 intervals, or at least a more pronounced north/south gradient (despite low endemism overall). Geographic differentiation is facilitated by high immigration and speciation rates in colonized basins during the recovery from the extinction (e.g., Sloan, 1987; Anthony & Maas, 1990;

Buckley, 1994; Williamson, 1996; Weil, 1997). The heterodox view asserts that faunal provincialism was already pronounced in the Pu1 interval, with a heterogeneous, highly endemic "transition-zone" between the "northern" and "southern" faunal provinces in southern Wyoming and northern Colorado. In this model, biogeographic differentiation was the result of allopatric isolation due to topographic complexity (e.g., Eberle & Lillegraven 1999; Eberle, 2003; McComas & Eberle, 2016).

Both models of Puercan eutherian biogeography agree on some sort of geographic barrier isolating "northern" and "southern" faunas. This hypothetical barrier was probably south of the Bighorn Basin around 42-43° N, in the region of the Owl Creek, Washakie, and Wind River ranges west of the Sweetwater Arch (Anthony & Maas, 1990). However, there is a lack of unambiguous evidence for orogenic or hydrological barriers anywhere in the Western Interior across the K/Pg boundary, and thus no isolating mechanism to support faunal provincialism. Despite uplift of the Laramide Orogeny due to flat-slab subduction of the Farallon Plate beneath North America (Henderson *et al.*, 1984; Liu *et al.*, 2010; Yonkee & Wei., 2015), none of the current Rocky Mountain ranges, including those near the Bighorn Basin, were formed in the Puercan. In fact, North America was tectonically quiescent in the earliest Paleocene compared to the rest of the epoch (Nilsen & McKee, 1979). Calculations of basin deposition and subsidence, based on fluvial calcite stable isotopes and leaf margin analyses, suggest that the Owl Creek range did not uplift until the Ti1/Ti2 intervals of the Tiffanian NALMA (~61.5-60 Ma and possibly later), whereas the Washakie and Wind River ranges did not rise until well after the Paleocene/Eocene boundary (Heller *et al.*, 2013; Foreman, 2014; Kraus *et al.*, 2015; Stevens *et al.*, 2016; Beaudoin *et al.*, 2018). The Table Mountain Shoshonite of the western Denver Basin (a tachyandesitic unit, indicative of stratovolcanism) also does not appear to have been a major biogeographic barrier (Kauffman *et al.,* 1990; Millikin *et al.*, 2018).

Recent reconstructions of the hydrology of North America across the K/Pg boundary indicate two major watersheds with eastward flowing tributaries, the Paleo-Mississippi/Missouri and Paleo-Bell drainages. The Paleo-Mississippi/Missouri drainage, derived from the Laramide and Sevier Belts, ultimately lead to the Gulf of the Mexico about the Mississippi Embayment. The Paleo-Bell drainage originated in the Basin-and-Range of western Wyoming, perhaps as a Paleo-Yellowstone River, flowing through the Alberta and northern Williston basins (the Saskatchewan/Nelson River area) and eventually reaching the Atlantic in what is now the Hudson Strait (Galloway *et al.*, 2000 & 2011; Mackey *et al.*, 2012; Laskowski *et al.*, 2013; Blum & Pecha, 2014). Additionally, the California paleo-river flowed from the Cordilleran continental arc northeast through the Grand Canyon Embayment of the Colorado Plateau, and into the lakes of northern Utah and southern Wyoming (Davis *et al.*, 2010; Wernicke, 2010; Dickinson *et al.*, 2012; Flowers & Farley, 2012; Ingersoll *et al.*, 2013; Young & Crow, 2014; Young & Hartman, 2014; Hill *et al.*, 2016). None of these longitudinally oriented river systems appear to have been barriers to latitudinal eutherian dispersal in the Puercan, as supported by the high number of shared taxa between sedimentary basins, especially during the Pu1 interval. Additionally, it is unlikely that any remaining embayments of the Western Interior Seaway, such as the incipient Cannonball transgression in the Williston Basin of North Dakota (Cvancara & Hogason, 1993; Kroege & Hartman, 1997) or hypothesized transgressions in the Hanna Basin (Lillegraven *et al.*, 2004; Wroblewski, 2004 & 2008; Boyd & Lillegraven, 2011), caused major barriers to faunal dispersal (Erickson, 1999; Burris, 2001; but see

DePalma *et al.*, 2019). Overall, the lack of obvious geographic mechanisms for isolating Puercan eutherian faunas suggests that the observed faunal provincialism may result from lithologically-driven megabiases and collecting methods - a sentiment that has been expressed before (i.e., Archibald, 1982 & 1994; Williamson, 1996), but not quantitatively tested.

This study adopts a different theoretical and methodological framework than prior evaluations of Puercan eutherian biogeography. Here I evaluate the following hypotheses to further elucidate eutherian biogeographic patterns across the Pu1 and Pu2/Pu3 intervals:

1) H0: The null hypothesis, in which there is no demonstrable, interpretable pattern of association in Puercan eutherian occurrence data due to either biogeography, lithology, or collecting method.

2) H1: Compositional similarity of Puercan eutherian faunas is driven by regional differences in sampling. Many "northern" localities in the Williston Basin are screen-washing sites with higher faunal diversity, especially of small-bodied taxa, and more realistic estimates of community composition (though time-averaging is a major problem at several Pu1 channels straddling the K/Pg boundary, such as Bug Creek, McKeever Ranch, and Hell's Hollow). Conversely, surface collection at Pu2/Pu3 sites in the "southern" basins (Castle Valley, Denver, and San Juan basins), leads to recovery of more large taxa compared to smaller taxa, and associated skewed estimates of composition.

3) H2: Compositional similarity of Puercan eutherian faunas is driven by lithologically-driven megabiases. Many "northern" localities are in sandstone channels with more fragmented and disarticulated remains of small taxa, while many "southern" localities occur in mudstone and siltstone facies favoring the preservation of larger taxa and allowing for the persistence of articulated craniodental and postcranial remains. This is the case across both the Pu1 and Pu2/Pu3 time intervals.

4) H3: Compositional similarity of Puercan eutherian faunas is driven by spatial proximity, temporal proximity, or both, in accordance with Tobler's (1970) first law of geography. Both of the traditionally proposed models of Puercan eutherian biogeography discussed above fall under this category.

2.2. Methods

2.2.1. Data collection and synthesis

This study is most comprehensive investigation of Puercan eutherian biogeography to date, taking into account the entire documented fossil record. I reviewed all published articles including specimen occurrences. To avoid duplication of occurrences, I supplemented this review with critical examination of available museum collection catalogs (i.e. DMNH, LACM, KUVP, NMMNHS, OMNH, UALVP, UCM, UCMP, UMVP, UW). Additionally, I visited several collections (AMNH, LACM, NMMNHS, YPM) in order to examine provenance information on specimen labels, and the verify the taxonomic identity and metric dimensions of certain published specimens (see Davis & Pyenson, 2007 for a review of general procedures regarding collection of publication and database information).

Detailed metadata was collected for the following factors: locality or locality group; geographic region; sedimentary basin; interval-zone; lithology; collecting method; abundance of each species (used to calculate richness and evenness); M1 tooth dimensions for each species (used to calculate body mass); and speculated diet of each taxon. The primary goal was to compare regions, basins, interval-zones, lithologies, and collecting methods to sampled richness, evenness, average body mass, and average dietary mode. The dataset was analyzed using the vegan package in R, with code modified from Dixon (2003) and Holland (2008).

Localities were sorted into "northern" (Alberta, Williston, Bighorn), "central" (Great Divide, Hanna), and "southern" (Denver, Castle Valley, San Juan) groups; the inclusion of a "central" group was for testing the hypothesis of high endemism in the Wyoming/Colorado transition-zone. These regions were ordered from northernmost ("1") to southernmost ("3"). Individual sedimentary basins were also ordered from northernmost ("1") to southernmost ("8").

Interval-zone assignments were ordered as "Pu1", "Pu2", or "Pu3", with the exception of poorly constrained Denver Basin localities labeled as "Pu2/Pu3 undetermined". These assignments were based on prior assessments in the literature, relying on biostratigraphic, magnetostratigraphic, and radiometric data. Pu2 and Pu3 localities were distinguished on the presence or absence of the multituberculate genus *Taeniolabis* (*T. taoensis* in "southern" localities, *T. lamberti* in "northern" localities), which is an unambiguous Pu3 index fossil (Simmons, 1987; Williamson *et al.*, 2016).

Site lithology was based on descriptions of the exact sedimentary beds where the fossils were collected, ignoring underlying and overlying lithology. At localities were multiple fossiliferous lithologies were present, the predominant lithology was considered. Sites were labeled as having either “claystone”, “mudstone”, “siltstone”, or “sandstone”. This category was ordered from fine-grained (“1”, claystone) to coarse-grained (“4”, sandstone).

Collecting methods were based on descriptions in the literature, and were labeled as either “quarry”, “screen-washing”, or “surface”. At localities where multiple collecting methods were practiced, the method which yielded the most specimens was reported.

For each species, the length and width of the M_1 tooth, reported as an average from all specimens across a species’ range, were plugged into the Conroy (1987) “all primate” body mass formula:

$$\ln(M) = (1.784\ln A + 2.54)/1000$$

In which M is body mass in kg, and A is the surface area of the occlusal surface of M_1 (length x width) in mm^2. The formula is a general linear regression based on a variety of plesiomorphic placental dental morphologies, mainly tribosphenic (i.e. dilambdodont and zalambdodont) and bunodont dentition (Strait, 1993). Although there is controversy regarding whether the Conroy formula gives accurate mass estimates of certain Paleocene placental taxa, particularly megadont ‘archaic ungulates’ with robustly proportioned postcrania (Damuth, 1990), it was considered appropriate for the purposes of this study. This is because other proposed craniodental-based regressions for mammalian body size (i.e. Gould, 1975; Legendre, 1986; Legendre & Roth, 1989) incorporate data from derived carnassialiform and lophodont dentitions (Copes & Schwartz, 2010) which are not present in any of the Puercan taxa considered. These formulas severely underestimated mass for well-known taxa compared with the Conroy (1987) equation (J. Silviria, 2018 pers. observation). If M1 data was not available for a certain species, body mass was inferred based on data from close relatives, often based on the average for its genus. For NMDS analyses, mass estimates were sorted into the following ordered bins: <100 g, 100-500 g, 500 g-1 kg, 1-2.5 kg, 2.5-5 kg, 5-10 kg, 10-20 kg, 20-30 kg, and >30 kg. Additionally, the average body mass was calculated for each locality.

The dietary mode of each taxa (herbivore, omnivore, carnivore, insectivore; ordered from "1" to "4") was based on broad predictions made in the literature, usually using dental morphology (e.g., Dewar, 2003; Wilson, 2013; see also references in **Table S1.1**). However, given the lack of good ecological data for most Puercan eutherian taxa, these niche assignments are very tentative.

Occurrence datasets were created at both the generic and species levels, in order to evaluate patterns of richness, evenness, and ordination at different taxonomic scales. Coarser genus-level analyses are more prevalent in studies of paleobiogeography, because of larger sample sizes per taxon and more confident taxonomic assignments of fragmentary specimens. However, many classically accepted genera are in fact paraphyletic or even polyphyletic (Hendricks et al., 2014; Foote *et al.*, 2016). Species-level analyses are preferred when the focus is explicit identifying patterns and processes of community-specific and taxon-specific range and niche change (Hendricks *et al.*, 2014; Allmon & Yacobucci, 2016). In the species-level datasets, "sp. indet." identifications (specimens that could only identified at the genus level) were removed. Both generic and specific datasets were pruned of taxa represented by less than two specimens, and sites with less than two taxa and three specimens.

For each site, richness and evenness were calculated at both the generic and specific levels. Richness describes the number of different taxa (e.g., genera or species) in a given sample (Bambach, 1977; Ricketts *et al.*, 1999; Janis *et al.*, 2004). Because of sampling and other biases, taxon richness must be standardized between different sites. This is often achieved using rarefaction techniques, but these frequently depress true estimates of diversity (Alroy, 2010, 2015, & 2018). Multiton subsampling (*MS*) is a more recently developed approach to reduce this bias. Under this method, the target number of non-singleton taxa ("multitons"), represented by >2 specimens, increases with sample size (Alroy 2017a,b, 2018; Close *et al.*, 2018). MS-based richness estimates were calculated for each site and basin using the multiton function in R (Alroy, 2017a), with modifications based on Freymueller et al. (2019). *MS* was deduced as the number of non-singleton taxa calculated at a quorum value (Q) of 0.4.

Evenness describes the similarity of taxon abundances within sites; that is, a very "even" sample contains species all showing very similar abundances, versus a very "uneven" sample, which contains some dominant and some rare taxa (Powell & Kowalewski, 2002). In ecological studies, it is typically represented by Pielou's (1966a,b) index J, calculated from the Shannon-Weaver (1948) diversity index H. Evenness was calculated first by determining H using the diversity command in the *vegan* package, then determining J using the equation:

$$J = H/(\ln(\gamma))$$

In which γ is the raw richness (total number of species) at a given locality.

2.2.2. Basic statistical tests

The first step in evaluating potential sampling biases in the abundance and occurrence datasets was a Pearson's (1900) chi-squared contingency test for variable independence. Chi-square tests evaluate the null hypothesis that the probability distributions of two random variables are not correlated with one another. Significant results for improbably large χ^2 values indicate that the two variables are covariant and correlated, suggesting a statistical "goodness of fit" between the expected frequency distribution along a regression and the actual distribution of the data (Ludwig & Cornelius, 1987; Rice, 1989; Garson & Moser, 1995). Chi-square tests compared the categorical variables of region, basin, interval, lithology, and collecting methods, based on the number of sites which overlapped for each category. This was done for all localities, as well as those in separated Pu1 and Pu2/Pu3 time bins. If the chi-square results were significant for any two variables in the datasets, it would indicate non-random redundancy and potential bias in ordination factors employed on the data. Consequently, strongly correlated variables, as well as datasets with many such variables, were considered for exclusion from the final studies, further pruning and partitioning the dataset.

To analyze differences in the geographic distribution of taxon richness and evenness I conducted Shapiro-Wilks tests of normality. The Shapiro-Wilks method tests the null hypothesis that a given factor is normally distributed. A statistically significant result indicates that the sample is substantially different from the expected normal distribution, even if such a departure is small (Shapiro & Wilk, 1965; Power, 1993; Jenkins, 2015). This test was applied to sites based on values of richness, evenness, average body size, and average dietary mode, at both the generic and specific levels. The results of this test indicate whether further comparisons of richness, evenness, body size, and trophic disparity were done with parametric methods (for predominantly normal distributions) or nonparametric methods (for predominantly non-normal distributions).

2.2.3. Kruskal-Wallis tests

Since the Shapiro-Wilks indicated a mix of normally and non-normally distributed datasets (see **Section 2.3.1**), I used the Kruskal-Wallis one-way ANOVA test for nonparametric distributions (Kruskal & Wallis, 1952). This was to test for effects of factors (geographic region, basin, lithology, and collecting method) on richness, evenness, average body mass, and average dietary mode. The Kruskal-Wallis test compares the distribution of sampled values to that of a categorical factor. Statistically significant results indicate that at least one subsample of the data can be unambiguously differentiated from the rest; consequently, the response variable can be considered correlated to that particular pattern (Kryštufek & Griffiths, 2002; Sanapareddy *et al.*, 2012).

2.2.4. NMDS ordination

To visualize the general pattern of similarity among Puercan eutherian faunal samples, I utilized two-dimensional non-linear multidimensional scaling (NMDS), also known as non-metric multidimensional scaling (Oksanen, 2015). NMDS is a multivariate technique that produces a gradient of data points using rank-ordered distances, such that the original position of data in multidimensional space is represented as accurately as possible in far fewer dimensions. This optimizes both non-metric and linear stress (R^2), or the disagreement between low-dimensional and high-dimensional configurations. Potential explanations for the gradient are tested by visualizing factors on the resulting scatterplot. NMDS is much more efficient than canonical and principle component clustering methods at reducing pairwise dissimilarity between data points, and thus avoiding issues associated with absolute distance due to transformation; it also works well with incomplete datasets (Kruskal, 1964; Sibson, 1972; Legendre & Legendre, 2012). NMDS is frequently applied in both neoecological and paleoecological ordination studies focused on resolving the number of assemblages or communities present in a dataset of either taxic abundance or occurrence (Prentice, 1980; Kenkel & Orlóci, 1986; Cornelius & Reynolds, 1991).

The similarity metric used for the NMDS analysis was the Kulczynski (1928) measure, a semi-metric two-sample similarity index in the Sørensen-Dice family of indices. Unlike other Sørensen-Dice indices (e.g., the Jaccard index), which only measure dissimilarity, the Kulczynski metric is a measure of compositional similarity, quantifying the correlation between occurrences of two taxa at different sites (Belbin, 1991; Jost *et al.*, 2011). It was originally devised for producing ecological gradients using either presence/absence or presence-only data (Faith *et al.*, 1987; Montalvo *et al.*, 1991; Lawson *et al.*, 2010; Legendre & Legendre 2012). More importantly, prior studies of paleobiogeographic ordination yielded more geographically and stratigraphically reasonable ordinations with the Kulczynski metric than with the more widely used Jaccard index (Sallan & Coates, 2010; Cabrera *et al.*, 2018); this was confirmed in earlier versions of this study, by comparing NMDS stress values (model fit) using both Jaccard and Kulczynski metrics.

The output from NMDS analysis included similarity scores for both sites and species, which exist in the same ordination space. Gradients for site scores were analyzed based on spatiotemporal factors (basin and interval-zone), lithology, and collecting method. Gradients for species scores were analyzed based on body mass class and dietary mode.

2.2.5. AGNES and ANOSIM

To evaluate which qualitative factors contributed to the ordination observed in NMDS scatterplots, a non-parametric analysis of similarities (ANOSIM) was performed on metric vegdist similarity matrices of the dataset, again produced using the Kulczynski metric. ANOSIM analyzes ranked similarity matrix scores between two or more sets of samples, testing whether the null hypothesis that intragroup similarity is greater than or equal to intergroup similarity can be rejected. The ANOSIM statistic R, based on the difference between intergroup and intragroup rank dissimilarity, is reported as $-1<R<1$. Lower values of R indicate greater intragroup similarity, and thus suggest either no statistical differentiation between samples or incorrect coding of the categorical factor in question (Chapman & Underwood, 1999; Andrew *et al.*, 2011; Anderson & Walsh, 2013). ANOSIM tests were performed using categorical factors for site scores (geographic region, basin, interval-zone, lithology, collecting method) and species scores (body mass class, dietary mode).

Additionally, the vegdist similarity matrices were used to produced dendrograms via agglomerative nesting (AGNES), a top-down approach to hierarchical clustering. In AGNES, data points are first sorted into small clusters based on pairwise (dis)similarity, which are merged until all of the data is resolved into a few large clusters. The result includes an agglomerative coefficient (AC) describing the average degree of clustering and the overall robustness of the dendrogram, based on the dissimilarity of a data point to its first cluster, divided by the dissimilarity of the final merger; this coefficient increases with sample size. AC values closer to 0 indicate tight, well-supported clusters, while values closer to 1 indicate less well-supported clusters (Murtagh & Legendre, 2014).

2.3. Results

2.3.1. General information on datasets

The complete raw dataset (**Table S1.1**) includes data from 68 localities, encompassing 6,401 specimens (excluding "sp. ident." identifications) in 62 genera and 108 species. Chi-square tests for the total dataset (not reported) demonstrated strong correlation of each of the spatiotemporal factors (region, basin, interval-zone) to lithology and collecting method, and no correlation between lithology and collecting method. For Pu1 localities, the only strong correlation was observed between basin and collecting method; for Pu2/Pu3 localities, region and basin were robustly correlated to collecting method (**Table S2.1**). Due to the high redundancy in ordination factors for the total dataset, I partitioned it by interval-zone and collecting method, investigating each subset independently: Pu1 screen-washing sites; Pu1 surface collecting sites; Pu2/Pu3 screen-washing sites; and Pu2/Pu3 surface collecting sites. (Quarried localities were excluded from the study due to very small samples in both the Pu1 and Pu2/Pu3 time bins.) This decreased the size of the analyzed dataset to 47 localities, encompassing 5,807 specimens in 57 genera and 95 species (**Tables S1.2-1.4**).

Furthermore, since preliminary tests for this study showed similar results for both genus-level analyses and species-level analyses, I report only species-level results. This is in part due to the clear association of species with ecological and biogeographic factors, which is lacking in higher taxa (e.g. Hendricks et al. 2014). Further, the monophyly of many genera of Puercan eutherians (i.e. *Carcinodon*, *Cimolestes*, *Loxolophus*, *Oxyacodon*) remains contentious due to the current lack of an agreed-upon phylogeny for Paleocene mammals (see reviews by Archibald et al., 1983a&b; Archibald, 1998; Williamson & Carr, 2007; Kondrashov & Lucas, 2015; Atteberry & Eberle, 2018). This makes biogeographic assessments of genus-level diversity and trophic disparity problematic, due to the possibility of obscured signals from the lumping of "wastebasket genera". Thus, ecological and biogeographic traits cannot even confidently be assigned to phylogenetic clades. Conversely, as discussed above, species-level identifications are better vetted as eco-evolutionary units because they are based on diagnostic metric and non-metric dental morphologies, irrespective of exact phylogenetic placement.

Additionally, although abundance was used to calculate richness and evenness, all NMDS, ANOSM, and AGNES tests only used abundance data. While swift changes in faunal composition are more clearly illustrated using raw abundance data, I consider it difficult to use accurately and precisely when interpreting the Puercan eutherian record, due to differences in specimen discrimination between collecting methods (less discriminatory in screen-washing using multiple mesh sizes, more discriminatory in surface collecting). In any case, the Kulczynski distance metric applied in NMDS, ANOSM, and AGNES tests works best with occurrence data rather than abundance data.

Values of richness, evenness, average body size, and average dietary mode for all the sites analyzed are tabulated in **Table S1.5**. On average, a locality had 8 non-singleton taxa. Multiton subsamples are larger in well-sampled sites within the Williston, Crazy Mountain, and San Juan basins, and lower in poorly-sampled basins, obscuring broad geographic trends in richness. There are no obvious geographic or spatiotemporal trends in evenness, with an average J of 0.799, indicating relatively even faunas. The average body mass per site was about 5.602 kg; average masses are typically larger in well-sampled Pu2/Pu3 localities (especially Denver and San Juan basin localities) than Pu1 localities. Insectivory is the dominant dietary mode at most Pu1 sites, while most Pu2/Pu3 sites were dominated by herbivores. Shapiro-Wilks tests (**Table 2.1** and **Table S2.2**) demonstrate that MS differed significantly from normal distribution only at Pu1 surface sites; J was significantly non-normal at Pu1 and Pu2/Pu3 screen-washing sites as well as Pu2/Pu3 surface sites; average body mass was significantly non-normal only at Pu1 screen-washing sites; and dietary mode was significantly non-normal in all four data subsets. This mix of normal and non-normal distributions justifies use of the non-parametric Kruskal-Wallis test to evaluate differentiation within subsets.

2.3.2. Kruskal-Wallis results

Most of the Kruskal-Wallis results do not demonstrate significant correlation between factors and response variables, and thus differentiation within data subsets (**Table 2.2** and **Table S2.3**). For richness values, Pu2/Pu3 screen-washing sites can be distinguished by geographic region and basin, while Pu2/Pu3 surface collecting sites are distinguishable by lithology. Surprisingly, there are no distinctions in evenness in any of the data subsets based on geography of lithology. For average body mass, only Pu2/Pu3 screen-washing sites are differentiated based on region and basin. For dietary mode, Pu1 surface sites and Pu2/Pu3 screen-washing sites are differentiated based on region and basin, while Pu2/Pu3 surface sites are only be differentiated by region.

2.3.3. Ordination

NMDS scatterplots for Pu1 screen-washing localities are shown in **Figure 2.1**. Geographically, scores for Williston/Powder River Basin localities (i.e. Black Spring Coulee, Bug Creek Anthills, McKeever Ranch, Hell's Hollow) can be separated along NMDS1 from the Windy Mudstone locality in the Hanna Basin, as well as the Denver Basin site West Bijou Gars Galore. Sandstone and mudstone localities overlap. For species scores, no obvious spatial gradients in body mass are observed. Although insectivorous taxa have higher NMDS1 scores than most herbivores or omnivores, all 'clusters' based on dietary mode overlap. NMDS scatterplots for Pu1 surface collecting sites are not illustrated due to insufficient data, leading to stress values of R^2 = 1. Although carnivorous and insectivorous taxa have higher NMDS1 scores than most herbivores or omnivores, all 'clusters' based on dietary mode overlap. NMDS scatterplots for Pu1 surface collecting sites are not illustrated due to insufficient data, leading to stress values of R^2 = 1.

Table 2.1. Summary of Shapiro-Wilks results.

	MS	***J***	**Body mass**	**Diet**
Data subset	**Significant?**	**Significant?**	**Significant?**	**Significant?**
Pu1 sites, screen-wash	NO	YES	YES	YES
Pu1 sites, surface	YES	NO	NO	YES
Pu2/Pu3 sites, screen-wash	NO	YES	NO	YES
Pu2/Pu3 sites, surface	NO	NO	NO	YES

Table S2.2. Summary of Kruskal-Wallis results.

		MS	***J***
Dataset	**Variable**	**Significant?**	**Significant?**
Pu1 sites, screen-wash	Region	NO	NO
	Basin	NO	NO
	Lithology	NO	NO
Pu1 sites, surface	Region	NO	NO
	Basin	NO	NO
	Lithology	NO	NO
Pu2/Pu3 sites, screen-wash	Region	YES	NO
	Basin	YES	NO
	Lithology	NO	NO
Pu2/Pu3 sites, surface	Region	NO	NO
	Basin	NO	NO
	Lithology	YES	NO

Table S2.2. cont.

Dataset	Variable	Body mass Significant?	Diet Significant?
Pu1 screen-wash	Region	NO	NO
	Basin	NO	NO
	Lithology	NO	NO
Pu1 surface	Region	NO	YES
	Basin	NO	YES
	Lithology	NO	NO
Pu2/Pu3 screen-wash	Region	YES	YES
	Basin	YES	YES
	Lithology	NO	NO
Pu2/Pu3 surface	Region	NO	YES
	Basin	NO	NO
	Lithology	NO	NO

NMDS scatterplots for Pu2/Pu3 screen-washing and surface sites are shown in **Figure 2.2**. Site scores for screen-washing sites are geographically oriented along NMDS1, with a clear separation of Williston and Crazy Mountain Basin localities from those in the San Juan Basin. There is also some separation of siltstone, mudstone, and sandstone lithologies about NMDS2. While scores for most of the smaller taxa express higher NMDS1 values, there is no clear ordination of body mass classes or dietary modes.

Site scores for Pu2/Pu3 surface collecting localities again exhibit geographic orientation along NMDS1, with the two Williston Basin localities (Hiatt Local Fauna and Pine Cree Park) exhibiting higher scores than Hanna, Castle Valley, Denver, and San Juan Basin localities. Additionally, Denver Basin and Castle Valley localities are separated from the Hanna and San Juan Basin localities. There are no obvious gradients based on lithology, with claystone, mudstone, siltstone, and sandstone sites overlapping in ordination space. Nor are there obvious clusters of species scores based on size class or diet, although larger carnivorous, omnivorous, and herbivorous taxa have lower NMDS2 scores, with smaller insectivorous taxa on the fringes.

ANOSIM results (**Table 2.3** and **Table S2.5**) generally support the patterns observed in the NMDS scatterplots. For Pu1 and Pu2/Pu3 screen-washing sites, region, basin, lithology, and dietary mode all significantly contribute to ordination. None of these factors contribute to the ordination of Pu1 surface sites, but as there were only four sites, there is not enough data to thoroughly test the role of geography. For Pu2/Pu3 surface sites, only region and basin are significant contributors to ordination. Overall, spatial factors (region and basin) are resolved as the primary reasons for site and species score ordination, but site lithology and species dietary mode could not be ruled out for screen-washing sites.

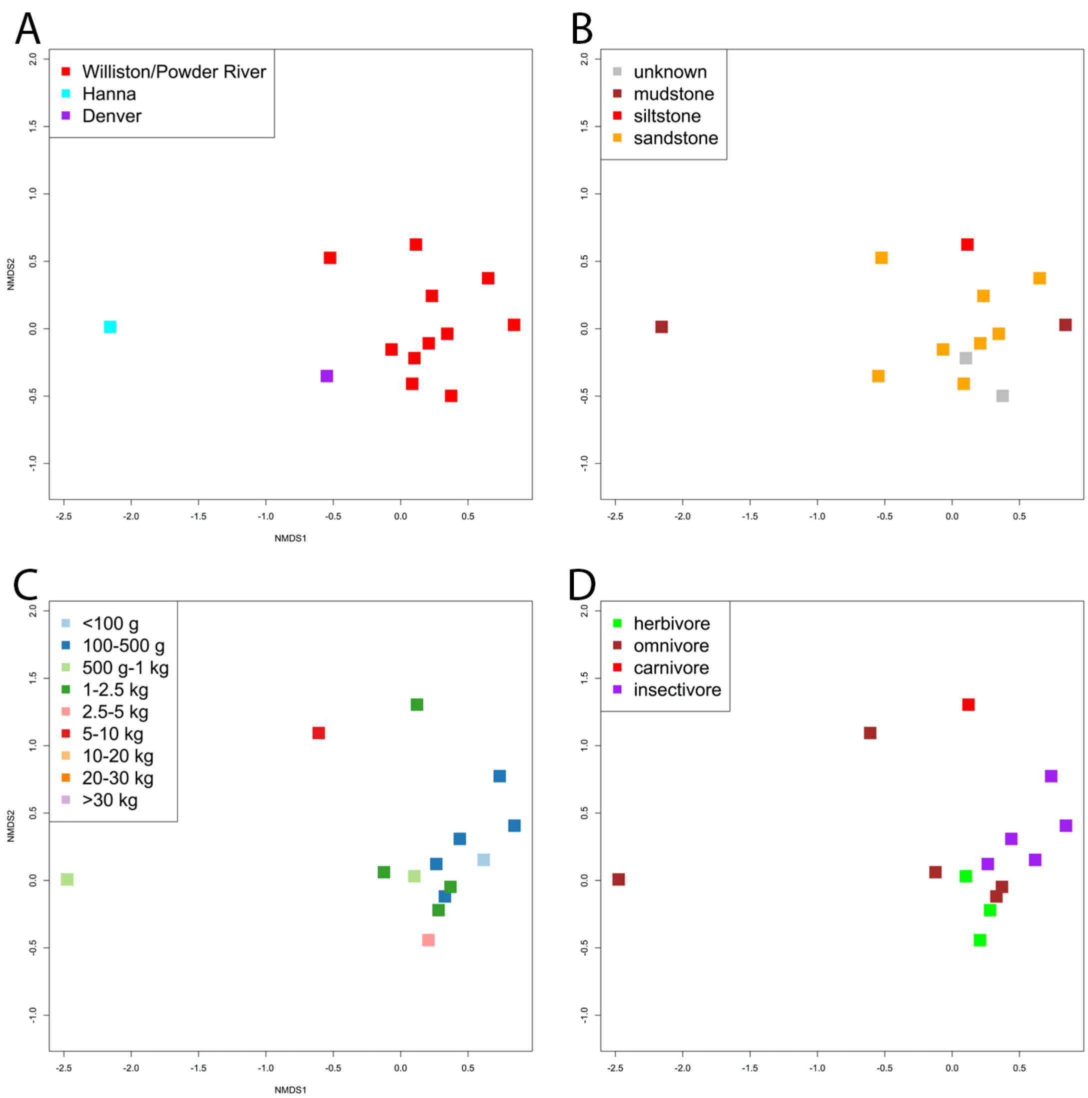


Figure 2.1. NMDS scatterplots of Pu1 screen-washing sites ($R^2_{non\text{-}metric}$ = 0.992, R^2_{linear} = 0.977). Site scores ordinated by A) basins and B) lithology; species scores ordinated by C) body size class and D) dietary mode.

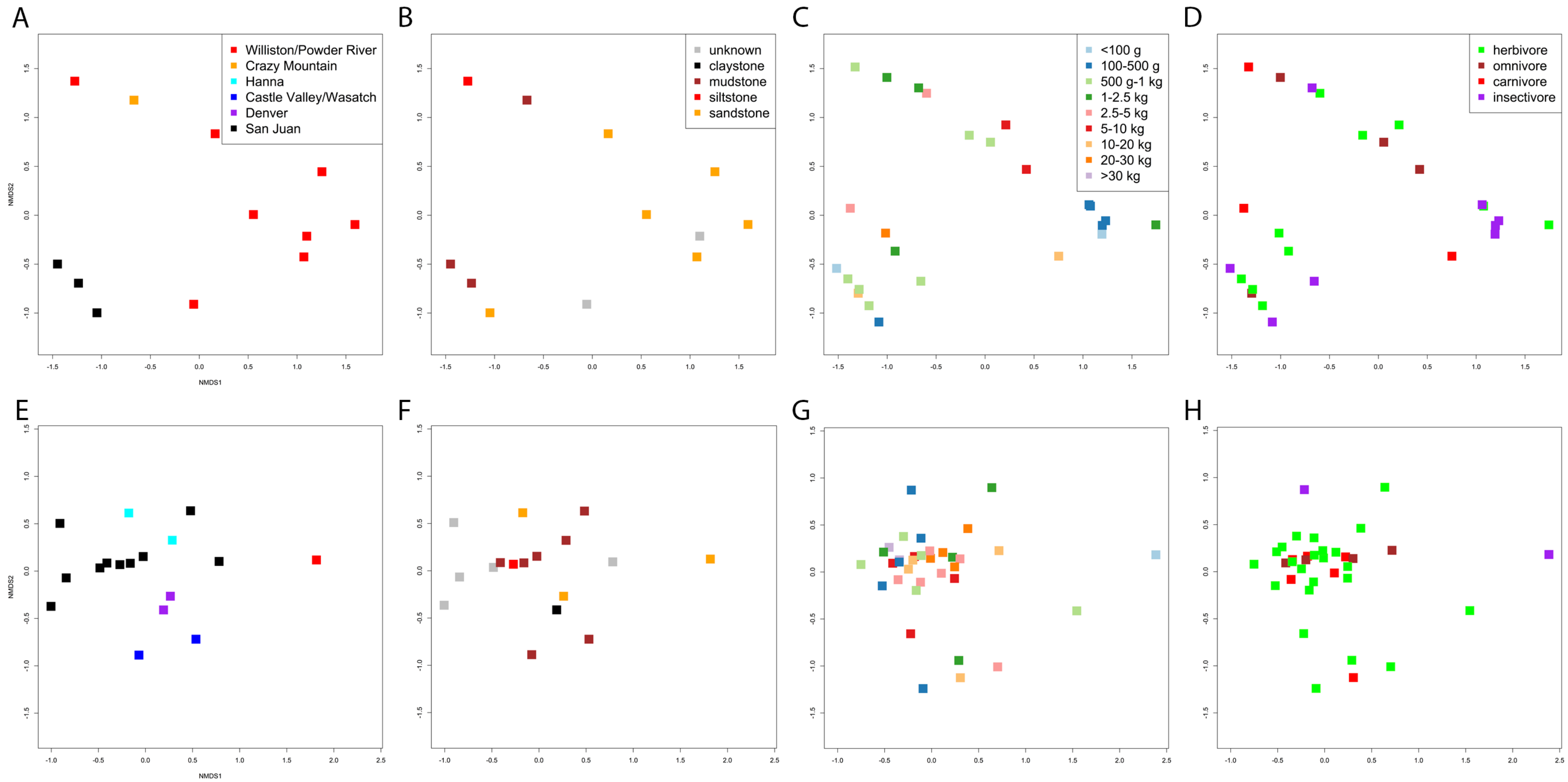


Figure 2.2. Top row: NMDS scatterplots of Pu2/Pu3 screen-washing sites ($R^2_{non\text{-}metric}$ = 0.996, R^2_{linear} = 0.977). Site scores ordinated by A) basins and B) lithology; species scores ordinated by C) body size class and D) dietary mode. **Bottom row:** NMDS scatterplots of Pu2/Pu3 surface collecting sites ($R^2_{non\text{-}metric}$ = 0.981, R^2_{linear} = 0.914). Site scores ordinated by E) basins and F) lithology; species scores ordinated by G) body size class and H) dietary mode.

Table S2.3. Summary of ANOSIM results.

Dataset	Variable	*P*
Pu1 sites, screen-wash	Basin	YES
	Region	YES
	Lithology	NO
	Body Size	NO
	Diet	YES
Pu1 sites, surface	Basin	NO
	Region	NO
	Lithology	NO
	Body Size	NO
	Diet	YES
Pu2/Pu3 sites, screen-wash	Basin	YES
	Region	YES
	Lithology	YES
	Body Size	NO
	Diet	YES
Pu2/Pu3 sites, surface	Basin	YES
	Region	NO
	Lithology	NO
	Body Size	NO
	Diet	NO

AGNES dendrograms (Appendix 3) exhibit largely identical results to the NMDS scatterplots and ANOSIM tests. All dendrograms based on site scores exhibit at least a gradient from "northern" localities (Williston and Crazy Mountain Basins) to "central" and "southern localities (Hanna, Castle Valley, Denver, and San Juan basins), if not distinct clusters containing the regions. In the case of Pu1 and Pu2/Pu3 screen-washing sites, these trees also demonstrate a broad southward transition from sandstone to mudstone and siltstone lithologies. All dendrograms of species scores exhibit markedly distinct "northern" and "central"/"southern" clusters; while each had both large and small taxa, and all dietary modes, small insectivores and omnivores were more prevalent in the "northern" cluster(s) compared to "central" and "southern" clusters.

2.4. Discussion and conclusions

2.4.1. Interpretations and implications

The original hypotheses explicitly tested in this study were that 1) there are no trends in compositional similarity among Puercan eutherian faunas; 2) compositional similarity is driven by collecting method; 3) compositional similarity is driven by lithology; and 4) compositional similarity is driven purely by spatiotemporal factors. Based on the tests conducted above, which do suggest spatially driven gradients and occasional lithological driven gradients, the first null hypothesis (H0) suggesting no trends can be safely discarded.

However, the chi-square contingency tests confirmed correlation of collecting methods to spatiotemporal factors (geographic region, basin, interval), hence the subdivision of the original occurrence data into independently analyzed datasets. This suggests regional differences in collecting methods impart a first-order influence on analyses of Puercan eutherian biogeography (Hypothesis H1). This is explained by the spatial unevenness of screen-washing sites and surface collecting in both the Pu1 and Pu2/Pu3 time bines, clearly observed in NMDS scatterplots; specifically, screen-washing is more prevalent in "northern" basins, while surface collecting is the dominant collecting method in "southern" basins. Nevertheless, the chi-square tests, as well as the Shapiro-Wilks and Kruskal-Wallis tests, suggest this regional discrepancy is not due to correlation between lithology and collecting methods. Indeed, the Kruskal-Wallis tests did not find any ubiquitous factor which led to differentiation of faunas, especially during the Pu1 interval. These results are broadly consistent with studies of later Paleogene mammalian assemblages in the Western Interior, which demonstrated flat latitudinal gradients of richness and evenness, if any at all, regardless of regional differences in specimen collection (e.g., Rose, 1981; Rose *et al.*, 2011; see also general reviews of paleolatitudinal richness and evenness gradients by Figueirido *et al.*, 2012, and Mannion *et al.*, 2014).

Taken at face value, the results suggest that once collecting methods are accounted for, the hypotheses citing spatiotemporal factors (H4) best explain the ordination of Puercan eutherian faunas; however, this factor is not particularly strong or ubiquitous through the Pu1 and Pu2/Pu3 time bins. The possibility that regional paleo-environments resulted in lithologic megabiases (H3) selecting for differential preservation of taxa (more fragments of small insectivorous taxa at "northern" sandstone sites, more complete remains of large carnivores and herbivores at "southern" mudstone and siltstone sites) is also weakened by the results of NMDS and ANOSIM tests, which indicated its significance only for Pu2/Pu3 screen-washing sites. In any case, sedimentological evidence suggests that "northern" and "southern" basins in the Western Interior contained similar habitats in the Puercan, with laterally extensive mudstones and coal lignites indicative of humid subtropical swamp forests and low-energy meandering rivers; high-energy braided conglomerate and sandstones channels were very localized in extent (Lupton *et al.*, 1980; Fastovsky & Dott Jr., 1986; Rigby & Rigby Jr., 1990; Sprain *et al.*, 2018). Climate models for the earliest Paleocene, as well as macrofloral data, suggest that while the southern Western Interior may have been slightly drier, the latitudinal temperature gradient in North America was not substantial enough to cause regional differences in sedimentary environments, mirroring the picture illustrated by faunal richness and evenness. Furthermore, as mentioned previously, sandstone channels at "northern" localities include reworked material removed from the original biogeographic and biostratigraphic context, obscuring whether lithologic megabiases are indicative of environmental factors influencing community structure. A thorough taphonomic analyses of screen-washing and surface collections – comparing abundance data of specific skeletal elements of taxa (teeth, skulls, postcrania) between sites, basins, regions, and lithologies – would be the best way to approach to further evaluate lithologic megabiases, but is beyond the scope of the present study.

Overall, the impartation of collecting methods on the occurrence datasets makes it difficult to fully evaluate Puercan eutherian biogeography for the purposes of defining ecoregional units (and biostratigraphic divisions within them), in order to track changes in the niche occupation of species and trophic structuring of ecosystems. Site species scores for both screen-washing and surface collections demonstrate a broad gradient from north to south in NMDS scatterplots and AGNES dendograms, especially for the Pu2/Pu3 time bin; in the scatterplots, spatial ordination is oriented along NMDS1. However, this trend is not exact, due to the pull of the Williston Basin and San Juan Basin localities, which are more numerous and more intensively sampled than those in other basins. For instance, in the NMDS scatterplot for Pu2/Pu3 surface collections, San Juan basin localities cluster with the Hanna Basin, rather than the geographically closer Caste Valley and Denver Basin sites as would be expected if Tobler's first law of geography were applicable. This may be the result of sampling intensity, as the Pu2/Pu3 local faunas of the Hanna Basin are represented by fewer specimens than the other localities, and have yielded many widespread and common taxa typical of the San Juan Basin (Eberle & Lillegraven, 1998). More perplexingly, the NMDS and ANOSM/AGNES result implied different conclusions regarding the role of species dietary mode; the former display no spatial gradients regardless of collecting method, whereas the latter suggested it was a significant factor in ordination, especially for screen-washing sites. These results should be treated with caution, though, given the uncertain ecology of many Puercan eutherians; for example, many small periptychids found at Pu2/Pu3 surface collecting sites, and labeled here as "herbivorous", may have been more omnivorous or insectivorous in life (T. E. Williamson, 2019 pers. comm.), weakening the gradient based on dietary mode.

Regardless of the actual patterns of spatial ordination, it is very obvious that prior hypotheses of Puercan eutherian biogeography emphasizing faunal provinciality have not taken into account collecting biases. Though several sites important in the debate over Puercan faunal provincialism – i.e., Mantua Lentil (Van Valen, 1978), the Great Divide Quarry (McComas & Eberle, 2016), and Alexander (Middleton & Dewar, 2004) – were ultimately excluded from the final study due to low sample size and low taxonomic diversity, it is unlikely that their inclusion would severely impact the results described above. Indeed, given the aforementioned lack of clearly defined topographic and hydrologic barriers to faunal dispersal in the Western Interior, I predict that future studies of Puercan eutherian biogeography, using data gathered from improved collecting techniques and great regional scope, will produce a broad latitudinal gradient of faunal differentiation, rather than discrete "northern" and "southern" (and "central"?) faunal provinces. This would be consistent with the biogeography of North America immediately preceeding the K/Pg mass extinction (; see also review in Chapter 1). A possible modern analogue may exist in the broken foreland basins along the eastern Andes Mountains in southern South America, with faunal differentiation due to via isolation by distance, rather than orogenic and hydrological obstacles enforcing allopatric isolation (Johnson *et al.*, 1990; Moreno *et al.*, 1994; Jaksic *et al.*, 2002; Lessa *et al.*, 2012).

2.4.2. Future prospects

While the provinciality of Puercan eutherian faunas is not supported by this study, interpretations of biogeographic patterns remain open for debate. The only way to resolve long-standing issues is to improve sampling. During the progress of this study, several advancements in the study of Puercan eutherians have been made, particularly reports of new occurrences of rare and problematic taxa. Screen-washing and surface collecting at Pu1 sites in the Williston Basin unearthed new specimens of the plesiadapiform *Purgatorius coracis* from the Coke's Cokemys Loca Fauna (Smith *et al.*, 2018), and the arctocyonid *Baioconodon cannoni* from Camel Butte (Emer *et al.*, 2018). New species of the periptychids *Ampliconus* and *Conacodon*, along with potential new genera, from the Great Divide Quarry Local Fauna are under study by Atteberry & Eberle (2018).

Previously undocumented occurrences of the San Juan Basin cimolestids *Betonnia*, *Chacopterygus*, and *Puercolestes* were reported by Clemens (2019) from the Pu3 Garbani Channel Local Fauna in the Williston Basin, with several new taxa to described. Lastly, a full description of screen-washing localities from the Gas Tank Hill Local Fauna is greatly anticipated (Lofrgen *et al.*, 2005). When these occurrences are fully monographed, they will be included in a future incarnation of this analysis. Additionally, more localities

More work needs to be done to chronostratigraphically constrain Puercan-equivalent sedimentary units in the Western Interior that have not yet borne eutherian fossils, but may do so in the near future. The lacustrine dolomitic limestones of the lowermost Sheep Pass Formation (Member B) in the Egan Range Nevada, which have been constrained to the K/Pg boundary based on U-Pb carbonate dating, are the most promising candidates for bearing new Puercan mammalian local faunas, having already yielded an incomplete and localized but hugely informative lagerstätten of a non-mammalian vertebrate (mostly amphibian) recovery fauna (Swain, 1987; Druschke, 2009; Druschke *et al.*, 2009; Gardner & DeMar, 2013; Henrici *et al.*, 2018). Similarily, the uppermost Canaan Peak Formation of the Kaiparowits Basin in southern Utah, and the South Park Formation (Conglomerate Member) of central Colorado, have yielded only plant fossils so far, but are additional candidates for Puercan mammal localities; both are likely equivalent to the Pu1 (Region, 1972; Schmitt *et al.*, 1991; Gregory & Chase, 1994; Lawton *et al.*, 2003; Ruleman & Bohannon, 2008).

Additionally, besides obvious comparisons of eutherian biogeographic and biostratigraphic ordination in the Puercan with penecontemporaneous metatherians and multituberculates, the spatiotemporal ordination of other groups of organisms during this time period must also be considered. The plant record of the Puercan holds the most promise. Ongoing restudy of floras from the upper Ojo Alamo (late Pu1) and lower Nacimiento (Pu2/Pu3) of the San Juan Basin, as well as the Pu1 of the Denver Basin, has shown that the "southern" macrofloral and palynofloral assemblages are considerably more diverse than those of the Hanna and Williston basins (Wheeler *et al.*, 1995; Johnson & Ellis, 2002; Barclay *et al.*, 2003; Johnson *et al.*, 2003; Peppe, 2010; Abbuhl *et al.*, 2015; Crystal, 2017). This is strikingly consistent with the north/south gradient observed in the eutherian faunas, but preservation biases due to lithology, as well as collecting biases, should also be considered.

Lastly, a thorough phylogenetic revision of Puercan eutherian and other Paleocene mammals needs to be accomplished, starting completely from scratch in many cases, and reconsidering the monophyly of traditionally recognized genera and species, especially "wastebasket" taxa (e.g., Williamson & Carr, 2007; Williamson & Weil, 2011; Shelley *et al.*, 2015 & 2018; Williamson *et al.*, 2016; Shelley, 2018). This will allow for the inclusion of accurate genus-level data in ecological biogeographic studies, to compare with species-level analyses. Furthermore, a robust phylogeny of Paleocene mammals, complete with ancestral area reconstruction of particular clades and of Eutheria as a whole, will allow for detailed comparison of ecological biogeographic ordination with historical biogeographic reconstruction, and evaluate past speculations concerning the immigration of eutherians both into and within western North America.

2.5. Conclusions

The biogeography of eutherians during the Puercan North American Land Mammal Age has long been the subject of debate, with prior analytical studies relying on a restricted number of localities with low sample sizes, and not taking into account potential biases due to lithology and collecting methods. This study attempted to ameliorate longstanding issues by evaluating the ecological biogeography of all described Puercan eutherians. Unfortunately, collecting methods impart a first-order influence on Puercan eutherian occurrence data, leading to the separate analysis of screen-washing and surface collections from the Pu1 and Pu2/Pu3 intervals. While both screen-washing and surface sites display some sort of latitudinal ordination, the effect is surprisingly weak, and more likely due to the pull of similarity scores toward well-sampled Williston Basin and San Juan Basin localities. Furthermore, there is no obvious gradient in lithology with exception of NMDS scores for Pu2/Pu3 screen-washing sites, and therefore no link between lithologic megabiases and collecting methods. Additionally, there was no consistent correlation of geography or lithology to richness and evenness, as well as the average body mass and dietary mode per site. While these results are disappointingly vague and inconclusive, they make sense given the lack of hard evidence for geographic barrriers enforcing faunal provincialism during the Puercan, indicating that a broad north-south gradient produced via isolation by distance may be more realistic. Nevertheless, I suggested that future studies of Puercan eutherian biogeography will require a) larger samples sizes with more geographic coverage, yielded using multiple collecting methods; b) a clearly defined phylogeography for Paleocene eutherians; and c) additional datasets from other contemporaneous clades of organisms. Only after all this is done can the Puercan NALMA finally shed a spotlight on the responses of mammalian paleo-metacommunities after drastic ecological change, and perhaps inform biogeographic patterns resulting from future mass extinctions.

2.5. References

Abbuhl, B., Peppe, D. J., & Flynn, A. (2015). Lateral floral variability in the early Paleocene Nacimiento Formation San Juan Basin NM. Paper presented at the 2015 GSA Annual Meeting, Baltimore, Maryland.

Abler, W. L. (1984). A three-dimensional map of a paleontological quarry. Rocky Mountain *Geology*, *23*(1), 9-14.

Alroy, J. (2010). Fair sampling of taxonomic richness and unbiased estimation of origination and extinction rates. *Paleontological Society Papers*, *16*, 55-80.

Alroy, J. (2015). The shape of terrestrial abundance distributions. *Science Advances*, *1*(8), e1500082.

Alroy, J. (2017a). Macroecology and macroevolution: Analytical methods. *Macquarie University Department of Biology*. Retrieved at https://bio.mq.edu.au/~jalroy/lambda5.R.

Alroy, J. (2017b). Effects of habitat disturbance on tropical forest biodiversity. *Proceedings of the National Academy of Sciences*, *114*(23), 6056-6061.

Alroy, J. (2018). Limits to species richness in terrestrial communities. *Ecology Letters*, *21*(12), 1781-1789.

Anthony, M. R. L., & Maas, M. C. (1990). Biogeographic provinciality in North American Paleocene mammalian faunas. *Journal of Vertebrate Paleontology*, *10*(S3), 12A.

Aslan, A., & Behrensmeyer, A. K. (1996). Taphonomy and time resolution of bone assemblages in a contemporary fluvial system: The East Fork River, Wyoming. *Palaios*, *11*(5), 411-421.

Archibald, J. D. (1982). A study of Mammalia and geology across the Cretaceous-Tertiary boundary in Garfield County, Montana. *University of California Publications in Geological Sciences*, *122*, 1-286.

Archibald, J. D. (1994). Metataxon concepts and assessing possible ancestry using phylogenetic systematics. *Systematic Biology*, *43*(1), 27-40.

Archibald, J. D. (1998). Archaic ungulates ("Condylartha"). In Janis, C.M., Scott, K. M., & Jacobs, L. L. (eds.), *Evolution of Tertiary Mammals of North America - Volume 1: Terrestrial Carnivores, Ungulates, and Ungulatelike Mammals* (pp. 292-331). Cambridge: Cambridge University Press.

Archibald, J. D., Rigby Jr, J. K., & Robison, S. F. (1983a). Systematic revision of *Oxyacodon* (Condylarthra, Periptychidae) and a description of *O. ferronensis* n. sp. *Journal of Paleontology*, *57*(1), 53-72.

Archibald, J. D., Rigby, J. K., & Schoch, R. M. (1983b). A new subfamily, Conacodontinae, and new species, *Conacodon kohlbergeri*, of the Periptychidae (Condylarthra, Mammalia). *Postilla*, *191*, 1-24.

Atteberry, M., & Eberle, J. (2018). Phylogeny of new earliest Paleocene (Puercan) periptychid 'condylarths' from the Great Divide Basin. Poster present at the Joint 70th Annual Rocky Mountain GSA Section/114th Annual Cordilleran GSA Section Meeting, Flagstaff, Arizona.

Ball, K. M., & Davis, L. C. (1990). Efficiency in collecting fossils. *Journal of the Arkansas Academy of Science*, *44*(1), 13-15.

Barclay, R. S., Johnson, K. R., Betterton, W. J., & Dilcher, D. L. (2003). Stratigraphy and megaflora of a KT boundary section in the eastern Denver Basin, Colorado. *Rocky Mountain Geology*, *38*(1), 45-71.

Beaudoin, N., Lacombe, O., Roberts, N. M., & Koehn, D. (2018). U-Pb dating of calcite veins reveals complex stress evolution and thrust sequence in the Bighorn Basin, Wyoming, USA. *Geology*, *46*(11), 1015-1018.

Behrensmeyer, A. K. (1988). Vertebrate preservation in fluvial channels. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *63*(1-3), 183-199.

Behrensmeyer, A. K., Kidwell, S. M., & Gastaldo, R. A. (2000). Taphonomy and paleobiology. *Paleobiology*, *26*(S4), 103-147.

Belbin, L. (1991). Semi-strong hybrid scaling, a new ordination algorithm. *Journal of Vegetation Science*, *2*(4), 491-496.

Bjorholm, S., Svenning, J. C., Skov, F., & Balslev, H. (2008). To what extent does Tobler's 1st law of geography apply to macroecology? A case study using American palms (Arecaceae). *BMC Ecology*, *8*(1), 11.

Blonder, B. (2018). Hypervolume concepts in niche-and trait-based ecology. *Ecography*, 41(9), 1441-1455.

Blum, M., & Pecha, M. (2014). Mid-Cretaceous to Paleocene North American drainage reorganization from detrital zircons. *Geology*, *42*(7), 607-610.

Boyd, D. W., & Lillegraven, J. A. (2011). Persistence of the Western Interior Seaway: Historical background and significance of ichnogenus *Rhizocorallium* in Paleocene strata, south-central Wyoming. *Rocky Mountain Geology*, *46*(1), 43-69.

Brett, C. E., & Baird, G. C. (1986). Comparative taphonomy: A key to paleoenvironmental interpretation based on fossil preservation. *Palaios*, *1*(3), 207-227.

Buckley, G. A. (1994). *Paleontology, geology and chronostratigraphy of Simpson Quarry (early Paleocene), Bear Formation, Crazy Mountains Basin, South-central Montana* (Doctoral dissertation, Rutgers University, New Brunswick).

Burris, J. H. (2001). Reworked Cretaceous elasmobranch teeth and provenance of the Paleocene Hanna Formation (Hanna Basin, Wyoming). *Rocky Mountain Geology*, *36*(1), 37-48.

Cabrera, F., Martínez, S., & Verde, M. (2018). Continental Late Cretaceous gastropod assemblages from Uruguay: Paleoecology, age, and the oldest record of two families and a genus. *Historical Biology*.

Chapman, M. G., & Underwood, A. J. (1999). Ecological patterns in multivariate assemblages: information and interpretation of negative values in ANOSIM tests. Marine ecology progress series, 180, 257-265.

Chase, J. M., & Leibold, M. A. (2003). *Ecological niches: linking classical and contemporary approaches*. University of Chicago Press.

Chen, Z. Q., Tong, J., Liao, Z. T., & Chen, J. (2010). Structural changes of marine communities over the Permian–Triassic transition: ecologically assessing the end-Permian mass extinction and its aftermath. Global and Planetary Change, 73(1-2), 123-140.

Cifelli, R. L., Madsen, S. K., & Larson, M. E. (1996). Screenwashing and associated techniques for the recovery of micro vertebrate fossils. In Cifelli, R. L. (ed.), *Techniques for Recovery and Preparation of Microvertebrate Fossils*. *Oklahoma Geological Survey Special Publication*, *96-4*, 1-24.

Clemens, W. A. (2019). *Puercoleste*s and *Betonnia* (Cimolestidae, Mammalia) from the early Paleocene (Puercan 3 Interval Zone) of northeastern Montana, USA. *PaleoBios*, *36*, 1-17.

Close, R. A., Evers, S. W., Alroy, J., & Butler, R. J. (2018). How should we estimate diversity in the fossil record? Testing richness estimators using sampling-standardized discovery curves. *Methods in Ecology and Evolution*, *9*(6), 1386-1400.

Conroy, G. C. (1987). Problems of body-weight estimation in fossil primates. *International Journal of Primatology*, *8*(2), 115-137.

Copes, L. E., & Schwartz, G. T. (2010). The scale of it all: Postcanine tooth size, the taxon-level effect, and the universality of Gould's scaling law. *Paleobiology*, *36*(2), 188-203.

Cornelius, J. M., & Reynolds, J. F. (1991). On determining the statistical significance of discontinuities with ordered ecological data. *Ecology*, *72*(6), 2057-2070.

Croft, D. A., Su, D. F., & Simpson, S. W. (eds.). (2018). *Methods in Paleoecology: Reconstructing Cenozoic Terrestrial Environments and Ecological Communities*. Berlin: Springer.

Crystal, V. (2017). A new earliest Paleocene, mountain proximal, mature forest floor fossil leaf site in the Denver Basin, Colorado, USA: Implications for the origins of rainforests. Paper presented at the 2017 GSA Annual Meeting in Seattle, Washington.

Cvancara, A. M., & Hoganson, J. W. (1993). Vertebrates of the Cannonball Formation (Paleocene) in North and South Dakota. Jo*urnal of Vertebrate Paleontology*, *13*(1), 1-23.

Damuth, J. (1990). Problems in estimating body masses of archaic ungulates using dental measurements. In Damuth, J., and MacFadden, B. J. (eds.), *Body Size in Mammalian Paleobiology* (pp. 229–253). Cambridge: Cambridge University Press.

Davis, E. B., & Pyenson, N. D. (2007). Diversity biases in terrestrial mammalian assemblages and quantifying the differences between museum collections and published accounts: a case study from the Miocene of Nevada. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *250*(1-4), 139-149.

Davis, S. J., Dickinson, W. R., Gehrels, G. E., Spencer, J. E., Lawton, T. F., & Carroll, A. R. (2010). The Paleogene California River: evidence of Mojave-Uinta paleodrainage from U-Pb ages of detrital zircons. *Geology*, *38*(10), 931-934.

Deline, B. (2009). The effects of rarity and abundance distributions on measurements of local morphological disparity. *Paleobiology*, *35*(2), 175-189.

DePalma, R. A., Smit, J., Burnham, D. A., Kuiper, K., Manning, P. L., Oleinik, A., ... & Gurche, L. (2019). A seismically induced onshore surge deposit at the KPg boundary, North Dakota. *Proceedings of the National Academy of Sciences*, 201817407.

DeSantis, L. R., Tracy, R. A. B., Koontz, C. S., Roseberry, J. C., & Velasco, M. C. (2012). Mammalian niche conservation through deep time. PloS one, 7(4), e35624.

Dewar, E. W. (2003). Functional diversity within the Littleton fauna (early Paleocene), Colorado: Evidence from body mass, tooth structure, and tooth wear. *PaleoBios*, *23*(1), 1-19.

Dickinson, W. R., Lawton, T. F., Pecha, M., Davis, S. J., Gehrels, G. E., & Young, R. A. (2012). Provenance of the Paleogene Colton Formation (Uinta Basin) and Cretaceous–Paleogene provenance evolution in the Utah foreland: Evidence from U-Pb ages of detrital zircons, paleocurrent trends, and sandstone petrofacies. *Geosphere*, *8*(4), 854-880.

Dixon, P. (2003). VEGAN, a package of R functions for community ecology. *Journal of Vegetation Science*, *14*(6), 927-930.

Druschke, P. A. (2009). *The Sheep Pass Formation, a record of late Cretaceous and paleogene extension within the Sevier hinterland, East-Central Nevada* (Doctoral dissertation, University of Nevada, Las Vegas).

Druschke, P., Hanson, A. D., & Wells, M. L. (2009). Structural, stratigraphic, and geochronologic evidence for extension predating Palaeogene volcanism in the Sevier hinterland, east-central Nevada. *International Geology Review*, *51*(7-8), 743-775.

Eberle, J. J. (2003). Puercan mammalian systematics and biostratigraphy in the Denver Formation, Denver Basin, Colorado. *Rocky Mountain Geology*, *38*(1), 143-169.

Eberle, J. J., & Lillegraven, J. A. (1998). A new important record of earliest Cenozoic mammalian history: Eutheria and paleogeographic/biostratigraphic summaries. *Rocky Mountain Geology*, *33*(1), 49-117.

Emer, H. W., Sargis, E. J., Wilson, G. P., Lyson, T. R., & Chester, S. G. (2018). Earliest Paleocene multituberculates from the Camel Butte locality of the Fort Union Formation, southeastern Montana. Poster presented at the 78th Annual Society of Vertebrate Paleontology Meeting, Albuquerque, New Mexico.

Erickson, J. M. (1999). Closing of the late Cretaceous Western Interior Seaway. *Proceedings of the North Dakota Academy of Science*, *53*, 124-129.

Evans, T., Poole, K., Smith, J., & Novak, S. (2005). A simple, cheap, non-invasive, and fast quarry mapping system with comparisons to common quarry mapping techniques. *Journal of Vertebrate Paleontology*, *25*(3), 55A.

Faith, D. P., Minchin, P. R., & Belbin, L. (1987). Compositional dissimilarity as a robust measure of ecological distance. *Vegetatio*, *69*(1-3), 57-68.

Fastovsky, D. E., & Dott Jr, R. H. (1986). Sedimentology, stratigraphy, and extinctions during the Cretaceous- Paleogene transition at Bug Creek, Montana. *Geolog*y, *14*(4), 279-282.

Figueirido, B., Janis, C. M., Pérez-Claros, J. A., De Renzi, M., & Palmqvist, P. (2012). Cenozoic climate change influences mammalian evolutionary dynamics. Proceedings of the National Academy of Sciences, 109(3), 722-727.

Foote, M., Ritterbush, K. A., & Miller, A. I. (2016). Geographic ranges of genera and their constituent species: structure, evolutionary dynamics, and extinction resistance. *Paleobiology*, *42*(2), 269-288.

Forcino, F. L., Stafford, E. S., Warner, J. J., Webb, A. E., Leighton, L. R., Schneider, C. L., Michlin, T. S., Palazzolo, L. M., Morrow, J. R., & Schellenberg, S. A. (2010). Effects of data categorization on paleocommunity analysis: A case study from the Pennsylvanian Finis Shale of Texas. Palaios, 25(3), 144-157.

Foreman, B. Z. (2014). Climate-driven generation of a fluvial sheet sand body at the Paleocene–Eocene boundary in northwest Wyoming (USA). *Basin Research*, *26*(2), 225-241.

Flowers, R. M., & Farley, K. A. (2012). Apatite $^{4}He/^{3}He$ and (U-Th)/He evidence for an ancient Grand Canyon. *Science*, *338*(6114), 1616-1619.

Galloway, W. E., Ganey-Curry, P. E., Li, X., & Buffler, R. T. (2000). Cenozoic depositional history of the Gulf of Mexico basin. *AAPG Bulletin*, *84*(11), 1743-1774.

Galloway, W. E., Whiteaker, T. L., & Ganey-Curry, P. (2011). History of Cenozoic North American drainage basin evolution, sediment yield, and accumulation in the Gulf of Mexico basin. *Geosphere*, *7*(4), 938-973.

Gardner, J. D., & DeMar, D. G. (2013). Mesozoic and Palaeocene lissamphibian assemblages of North America: a comprehensive review. *Palaeobiodiversity and Palaeoenvironments*, *93*(4), 459-515.

Garson, G. I., & Moser, E. B. (1995). Aggregation and the Pearson chi-square statistic for homogeneous proportions and distributions in ecology. *Ecology*, *76*(7), 2258-2269.

Gould, S. J. (1975). On the scaling of tooth size in mammals. *American Zoologist*, *15*(2), 353-362.

Greenwald, M. T. (1989). Techniques for collecting large vertebrate fossils. *The Paleontological Society Special Publications*, *4*, 264-274.

Gregory, K. M., & Chase, C. G. (1994). Tectonic and climatic significance of a late Eocene low-relief, high-level geomorphic surface, Colorado. *Journal of Geophysical Research: Solid Earth*, *99*(B10), 20141-20160.

Grinnell, J. (1917). The niche-relationships of the California Thrasher. *Auk*, *34*(4), 427-433.

Hadly, E. A., Spaeth, P. A., & Li, C. (2009). Niche conservatism above the species level. Proceedings of the National Academy of Sciences, 106(Supplement 2), 19707-19714.

Heller, P. L., Mathers, G., Dueker, K., & Foreman, B. (2013). Far-traveled latest Cretaceous–Paleocene conglomerates of the Southern Rocky Mountains, USA: Record of transient Laramide tectonism. *Geological Society of America Bulletin*, *125*(3-4), 490-498.

Henderson, L. J., Gordon, R. G., & Engebretson, D. C. (1984). Mesozoic aseismic ridges on the Farallon plate and southward migration of shallow subduction during the Laramide orogeny. *Tectonics*, *3*(2), 121-132.

Hendricks, J. R., Saupe, E. E., Myers, C. E., Hermsen, E. J., & Allmon, W. D. (2014). The generification of the fossil record. *Paleobiology*, *40*(4), 511-528.

Hendy, A. J. (2011). Taphonomic overprints on Phanerozoic trends in biodiversity: lithification and other secular megabiases. In *Taphonomy* (pp. 19-77). Springer, Dordrecht.

Hengeveld, R. (1993). Ecological biogeography. *Progress in Physical Geography*, 17(4), 448–460.

Henrici, A. C., Druschke, P., Hilton, R. P., & Bonde, J. W. (2018). Redescription and phylogenetic reassessment of the enigmatic anuran *Eorubeta nevadensis* (Amphibia) based on new specimens from? latest Cretaceous–Paleocene beds of the Sheep Pass Formation, Nevada. *Journal of Vertebrate Paleontology*.

Hill, C. A., Polyak, V. J., Asmerom, Y., & P. Provencio, P. (2016). Constraints on a Late Cretaceous uplift, denudation, and incision of the Grand Canyon region, southwestern Colorado Plateau, USA, from U-Pb dating of lacustrine limestone. *Tectonics*, *35*(4), 896-906.

Hoffman, A. (1979). Community paleoecology as an epiphenomenal science. Paleobiology, 5(4), 357-379.

Hoffman, A. (1980). Ecostratigraphy: the limits of applicability. Acta Geologica Polonica, 30(1), 97-110.

Holland, S.M. (2008). UGA Stratigraphy Lab: Software. Retrieved from http://strata.uga.edu/software/.

Hutchinson, G.E. (1957). Concluding remarks. Cold Spring Harbor Symposia on Quantitative Biology, 22(2), 415–427.

Ingersoll, R. V., Grove, M., Jacobson, C. E., Kimbrough, D. L., & Hoyt, J. F. (2013). Detrital zircons indicate no drainage link between southern California rivers and the Colorado Plateau from mid-Cretaceous through Pliocene. *Geology*, *41*(3), 311-314.

Jaksic, F. M., Iriarte, J. A., Jiménez, J. E., & Martínez, D. R. (2002). Invaders without frontiers: cross-border invasions of exotic mammals. *Biological invasions*, *4*(1-2), 157-173.

Jamniczky, H. A., Brinkman, D. B., & Russell, A. P. (2008). How much is enough? A repeatable, efficient, and controlled sampling protocol for assessing taxonomic diversity and abundance in vertebrate microfossil assemblages. In Sankey, J. T., & Baszio, S. (eds.), *Vertebrate microfossil assemblages: their role in paleoecology and paleobiogeography* (pp. 9-16). Bloomington, IN: Indiana University Press.

Jenkins, D. G. (2015). Estimating ecological production from biomass. Ecosphere, 6(4), 1-31.

Johnson, K. R., & Ellis, B. (2002). A tropical rainforest in Colorado 1.4 million years after the Cretaceous-Tertiary boundary. *Science*, *296*(5577), 2379-2383.

Johnson, K. R., Reynolds, M. L., Werth, K. W., & Thomasson, J. R. (2003). Overview of the Late Cretaceous, early Paleocene, and early Eocene megafloras of the Denver Basin, Colorado. *Rocky Mountain Geology*, *38*(1), 101-120.

Johnson, W. E., Franklin, W. L., & Iriarte, J. A. (1990). The mammalian fauna of the northern Chilean Patagonia: a biogeographical dilemma. *Mammalia*, *54*(3), 457-470.

Jost, L., Chao, A., & Chazdon, R. L. (2011). Compositional similarity and β (beta) diversity. In Magurran, A. E., & McGill, B. J. (eds.), *Biological Diversity: Frontiers in Measurement and Assessment* (pp. 66-84). Oxford: Oxford University Press.

Kauffman, E. G., Upchurch Jr., G. R., & Nichols, D. J. (1990). The Cretaceous-Tertiary boundary interval at South Table Mountain, near Golden, Colorado. In Kauffman, e. g., & Walliser, O. H. (eds.), *Extinction Events in Earth History - Proceedings of the Project 216: Global Biological Events in Earth History*. Lecture Notes in Earth Sciences, *30*, 365-392.

Kenkel, N. C., & Orlóci, L. (1986). Applying metric and nonmetric multidimensional scaling to ecological studies: some new results. *Ecology*, *67*(4), 919-928.

Koch, C. F. (1978). Bias in the published fossil record. *Paleobiology*, *4*(3), 367-372.

Kondrashov, P. E., & Lucas, S. G. (2015). *Loxolophus* and *Protogonodon* (Mammalia, "Arctocyonidae") from the early Paleocene of the San Juan Basin. In Sullivan, R. M., & Lucas, S. G. (eds.), *Fossil Record 4*. *New Mexico Museum of Natural History & Science Bulletin*, *67*, 107-119.

Kowalewski, M. (1996). Time-averaging, overcompleteness, and the geological record. *The Journal of Geology*, *104*(3), 317-326.

Kowalewski, M. (1997). The reciprocal taphonomic model. *Lethaia*, *30*(1), 86-88.

Kowalewski, M., & Flessa, K. W. (1996). Improving with age: the fossil record of lingulide brachiopods and the nature of taphonomic megabiases. *Geology*, *24*(11), 977-980.

Kowalewski, M., & Hoffmeister, A. P. (2003). Sieves and fossils: Effects of mesh size on paleontological patterns. *Palaios*, *18*(4-5), 460-469.

Kraus, M. J., Woody, D. T., Smith, J. J., & Dukic, V. (2015). Alluvial response to the Paleocene–Eocene Thermal Maximum climatic event, Polecat Bench, Wyoming (USA). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *435*, 177-192.

Kreft, H., & Jetz, W. (2010). A framework for delineating biogeographical regions based on species distributions. Journal of Biogeography, 37(11), 2029-2053.

Kroeger, T. J., & Hartman, J. H. (1997). Paleoenvironmental distribution of Paleocene palynomorph assemblages from brackish water deposits in the Ludlow, Slope, and Cannonball Formations, southwestern North Dakota. *Rocky Mountain Geology*, *32*(1), 115-129.

Kruskal, J. B. (1964). Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika*, *29*(1), 1-27.

Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, *47*(260), 583-621.

Kryštufek, B., & Griffiths, H. I. (2002). Species richness and rarity in European rodents. *Ecography*, *25*(1), 120-128.

Kulczynski, S. (1928). Die pflanzenassoziationen der pieninen. *Bulletin International de L'Academie Polonaise des Sciences et des Lettres, Classe des Sciences Mathematiques et Naturelles, B*, *S2*(1927), 57–203.

Laskowski, A. K., DeCelles, P. G., & Gehrels, G. E. (2013). Detrital zircon geochronology of Cordilleran retroarc foreland basin strata, western North America. *Tectonics*, *32*(5), 1027-1048.

Lawson, B. E., Ferrier, S., Wardell-Johnson, G., Beeton, R. J. S., & Pullar, D. V. (2010). Improving the assessment of species compositional dissimilarity in a priori ecological classifications: evaluating map scale, sampling intensity and improvement in a hierarchical classification. *Applied Vegetation Science*, *13*(4), 473-484.

Lawton, T. F., Pollock, S. L., & Robinson, R. A. J. (2003). Integrating sandstone petrology and nonmarine sequence stratigraphy: application to the Late Cretaceous fluvial systems of southwestern Utah, USA. *Journal of Sedimentary Research*, *73*(3), 389-406.

Legendre, P., & Legendre, L. F. (2012). *Numerical Ecology* (2nd edition). Amsterdam: Elsevier.

Legendre, S. (1986). Analysis of mammalian communities from the late Eocone and Oligocene of southern France. *Palaeovertebrata*, *16*, 191-212.

Legendre, S., & Roth, C. (1989). Correlation of carnassial tooth size and body weight in recent carnivores (Mammalia). *Historical Biology*, *1*(1), 85-98.

Leibold, M. A. (1995). The niche concept revisited: mechanistic models and community context. *Ecology*, *76*(5), 1371-1382.

Leibold, M. A., & Chase, J. M. (2017). *Metacommunity Ecology*. Princeton, NJ: Princeton University Press.

Leiggi, P., Schaff, C. R., & May, P. (1994). Macrovertebrate collecting: Field organization and specimen collecting. In Leiggi, P., & May, P. (eds.), *Vertebrate Paleontological Techniques: Volume 1* (pp. 59-76) Cambridge: Cambridge University Press.

Lemus-Lauzon, I., Bhiry, N., & Woollett, J. (2016). Assessing the effects of climate change and land use on northern Labrador forest stands based on paleoecological data. *Quaternary Research*, *86*(3), 260-270.

Lessa, E. P., D'Elía, G., & Pardiñas, U. F. J. (2012). Mammalian biogeography of Patagonia and Tierra del Fuego. In Patterson, B. D., & Costa, L. P. (eds.), *Bones, Clones, and Biomes: The History and Geography of Recent Neotropical Mammals* (pp. 379-398). Chicago: University of Chicago Press.

Lillegraven, J. A., Snoke, A. W., & McKenna, M. C. (2004). Tectonic and paleogeographic implications of late Laramide geologic history in the northeastern corner of Wyoming's Hanna Basin. *Rocky Mountain Geology*, *39*(1), 7-64.

Liu, L., Gurnis, M., Seton, M., Saleeby, J., Müller, R. D., & Jackson, J. M. (2010). The role of oceanic plateau subduction in the Laramide orogeny. *Nature Geoscience*, *3*(5), 353.

Lofgren, D. L., Hotton, C. L., & Runkel, A. C. (1990). Reworking of Cretaceous dinosaurs into Paleocene channel, deposits, upper Hell Creek Formation, Montana. *Geology*, *18*(9), 874-877.

Lofgren, D. L., Scherer, B. E., Clark, C. K., & Standhardt, B. (2005). First record of *Stygimys* (Mammalia, Multituberculata, Eucosmodontidae) from the Paleocene (Puercan) part of the North Horn Formation, Utah, and a review of the genus. *Journal of Mammalian Evolution*, *12*(1-2), 77-97.

Ludwig, J. A., & Cornelius, J. M. (1987). Locating discontinuities along ecological gradients. *Ecology*, *68*(2), 448-450.

Lupton, C., Gabriel, D., & West, R. M. (1980). Paleobiology and depositional setting of a Late Cretaceous vertebrate locality, Hell Creek Formation, McCone County, Montana. *Rocky Mountain Geology*, *18*(2), 117-126.

Mackey, G. N., Horton, B. K., & Milliken, K. L. (2012). Provenance of the Paleocene–Eocene Wilcox Group, western Gulf of Mexico basin: Evidence for integrated drainage of the southern Laramide Rocky Mountains and Cordilleran arc. *Geological Society of America Bulletin*, *124*(5-6), 1007-1024.

Maguire, K. C., & Stigall, A. L. (2009). Using ecological niche modeling for quantitative biogeographic analysis: a case study of Miocene and Pliocene Equinae in the Great Plains. Paleobiology, 35(4), 587-611.

Mallon, J. C., Evans, D. C., Ryan, M. J., & Anderson, J. S. (2012). Megaherbivorous dinosaur turnover in the Dinosaur Park Formation (upper Campanian) of Alberta, Canada. Palaeogeography, Palaeoclimatology, Palaeoecology, 350, 124-138.

McComas, K. M., & Eberle, J. J. (2016). A new earliest Paleocene (Puercan) arctocyonid mammal from the Fort Union Formation, Great Divide Basin, Wyoming, and its phylogenetic position among early 'condylarths'. *Journal of Systematic Palaeontology*, *14*(6), 445-459.

McDonald, R., McKnight, M., Weiss, D., Selig, E., O'Connor, M., Violin, C., & Moody, A. (2005). Species compositional similarity and ecoregions: Do ecoregion boundaries represent zones of high species turnover?. Biological Conservation, 126(1), 24-40.

McKenna, M. C. (1962). Collecting small fossils by washing and screening. *Curator*, *5*(3), 221-235.

Meik, J. M., Streicher, J. W., Lawing, A. M., Flores-Villela, O., & Fujita, M. K. (2015). Limitations of climatic data for inferring species boundaries: insights from speckled rattlesnakes. PloS one, 10(6), e0131435.

Mihlbachler, M. C. (2008). Species taxonomy, phylogeny, and biogeography of the Brontotheriidae (Mammalia: Perissodactyla). *Bulletin of the American Museum of Natural History*, *84S*, 1-475.

Miller, B. B. (1989). Screen-washing unconsolidated sediments for small macrofossils. *The Paleontological Society Special Publications, 4*, 260-263.

Miller, H. J. (2004). Tobler's first law and spatial analysis. *Annals of the Association of American Geographers*, *94*(2), 284-289.

Millikin, A. E., Morgan, L. E., & Noblett, J. (2018). $^{40}Ar/^{39}Ar$ geochronology and petrogenesis of the Table Mountain Shoshonite, Golden, Colorado, USA. *Rocky Mountain Geology*, *53*(1), 1-28.

Montalvo, J., Casado, M. A., Levassor, C., & Pineda, F. D. (1991). Adaptation of ecological systems: compositional patterns of species and morphological and functional traits. *Journal of Vegetation Science*, *2*(5), 655-666.

Moore, J. R. (2012). Do terrestrial vertebrate fossil assemblages show consistent taphonomic patterns? *Palaios*, *27*(4), 220-234.

Moore, J. R., & Norman, D. B. (2009). Quantitatively evaluating the sources of taphonomic biasing of skeletal element abundances in fossil assemblages. *Palaios*, *24*(9), 591-602.

Moore, J. R., Norman, D. B., & Upchurch, P. (2007). Assessing relative abundances in fossil assemblages. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *253*(3-4), 317-322.

Moore, J. R., & Varricchio, D. J. (2018). Taphonomic pathways in vertebrate fossil assemblages Illustrated by a bovine mass drowning event. *Palaios*, *33*(4), 174-184.

Moreno et al., 1994 Moreno, P. I., Villagrán, C., Marquet, P. A., & Marshall, L. G. (1994). Quaternary paleobiogeography of northern and central Chile. *Revista Chilena de Historia Natural*, *67*, 487-502.

Morrone, J. J., & Crisci, J. V. (1995). Historical biogeography: introduction to methods. *Annual review of ecology and systematics*, *26*(1), 373-401.

Murtagh, F., & Legendre, P. (2014). Ward's hierarchical agglomerative clustering method: which algorithms implement Ward's criterion? *Journal of classification*, *31*(3), 274-295.

Myers, C. E. (2013). *Paleobiogeography of the North American Late Cretaceous Western Interior Seaway: The impact of abiotic vs. biotic factors on macroevolutionary patterns of marine vertebrates and invertebrates* (Doctoral dissertation, University of Kansas, Lawrence).

Myers, C. E., & Lieberman, B. S. (2010). Sharks that pass in the night: Using Geographical Information Systems to investigate competition in the Cretaceous Western Interior Seaway. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1706), 681-689.

Myers, C. E., MacKenzie, R. A., & Lieberman, B. S. (2013). Greenhouse biogeography: the relationship of geographic range to invasion and extinction in the Cretaceous Western Interior Seaway. *Paleobiology*, *39*(1), 135-148.

Myers, C. E., & Saupe, E. E. (2013). A macroevolutionary expansion of the modern synthesis and the importance of extrinsic abiotic factors. *Palaeontology*, *56*(6), 1179-1198.

Myers, C. E., Stigall, A. L., & Lieberman, B. S. (2015). PaleoENM: applying ecological niche modeling to the fossil record. Paleobiology, 41(2), 226-244.

Nekola, J. C., & White, P. S. (1999). The distance decay of similarity in biogeography and ecology. *Journal of Biogeography*, *26*(4), 867-878.

Nilsen, T.H., & McKee, E.H. (1979). "Paleogene Paleogeography of the Western United States". In Amentrout, J.M., Cole, M.R., & TerBest Jr, H. (eds.), *Cenozoic Paleogeography of the Western United States: Pacific Coast Paleogeoraphy Synopsium 3* (pp. 257-276). Los Angeles: The Pacific Section Society of Economic Paleontologists and Mineralogists.

Oksanen, J. (2015). Multivariate analysis of ecological communities in R: vegan tutorial. *R Doc*, *43*, 11-12.

Organ, C. L., Cooley, J. B., & Hieronymus, T. L. (2003). A non-invasive quarry mapping system. *Palaios*, *18*(1), 74-77.

Parenti, L. R., & Ebach, M. C. (2009). *Comparative Biogeography: Discovering and classifying biogeographical patterns of a dynamic earth*. Berkley: University of California Press.

Pearson, K. (1900). On the criterion that a given system of deviations from the probable in the case of a correlated system of variables is such that it can be reasonably supposed to have arisen from random sampling. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, *50*(302), 157-175.

Peppe, D. J. (2010). Megafloral change in the early and middle Paleocene in the Williston Basin, North Dakota, USA. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *298*(3-4), 224-234.

Peterson, A. T. (2011). Ecological niche conservatism: a time-structured review of evidence. Journal of Biogeography, 38(5), 817-827.

Peterson, J. E., Scherer, R. P., & Huffman, K. M. (2011). Methods of microvertebrate sampling and their influences on taphonomic interpretations. *Palaios*, *26*(2), 81-88.

Peterson, A. T., Soberón, J., Pearson, R. G., Anderson, R. P., Martínez-Meyer, E., Nakamura, M., & Araújo, M. B. (2011). Ecological niches and geographic distributions (MPB-49) (Vol. 56). Monographs ion Population Biology, 56, 1-328.

Pielou, E. C. (1966a). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology*, *13*, 131-144.

Pielou, E. C. (1966b). Shannon's formula as a measure of specific diversity: its use and misuse. *The American Naturalist*, *100*(914), 463-465.

Powell, M. G., & Kowalewski, M. (2002). Increase in evenness and sampled alpha diversity through the Phanerozoic: comparison of early Paleozoic and Cenozoic marine fossil assemblages. *Geology*, *30*(4), 331-334.

Power, M. (1993). The predictive validation of ecological and environmental models. *Ecological Modelling*, *68*(1-2), 33-50.

Prentice, I. C. (1980). Vegetation analysis and order invariant gradient models. *Vegetatio*, *42*(1-3), 27-34.

Region, T. C. (1972). The Canaan Peak, Pine Hollow, and Wasatch Formations in the Table Cliff Region, Garfield County, Utah. *U.S. Geological Survey Bulletin*, *1331-B*, B1-B37.

Rice, W. R. (1989). Analyzing tables of statistical tests. *Evolution*, *43*(1), 223-225.

Ricklefs, R. E. (2015). Intrinsic dynamics of the regional community. Ecology letters, 18(6), 497-503.

Rigby, J. K., & Rigby Jr., J. K. (1990). Geology of the Sand Arroyo and Bug Creek Quadrangles, McCone County, Montana. *Brigham Young University Geology Studies*, *36*, 69-134.

Rogers, R. R. (1994). Collecting taphonomic data from vertebrate localities. In Leiggi, P., & May, P. (eds.), *Vertebrate Paleontological Techniques: Volume 1* (pp. 47-58). Cambridge: Cambridge University Press.

Rogers, R. R., & Brady, M. E. (2010). Origins of microfossil boneheads: Insights from the Upper Cretaceous Judith River Formation of north-central Montana. *Paleobiology*, *36*(1), 80-112.

Rose, K. D. (1981). Composition and species diversity in Paleocene and Eocene mammal assemblages: an empirical study. *Journal of Vertebrate Paleontology*, *1*(3-4), 367-388.

Rose, P. J., Fox, D. L., Marcot, J., & Badgley, C. (2011). Flat latitudinal gradient in Paleocene mammal richness suggests decoupling of climate and biodiversity. Geology, 39(2), 163-166.

Rosen, B. R. (1988). From fossils to earth history: Applied historical biogeography. In Myers, A.A., & Giller, P., (eds.), *Analytical Biogeography: An Integrated Approach to the Study of Animal and Plant Distributions* (pp. 437-481). London: Chapman & Hall.

Ruleman, C. A., & Bohannon, R. G. (2008). Geologic map of the Elkhorn quadrangle, Park County, Colorado. *US Geological Survey Scientific Investigations Map*, *304*.

Sallan, L. C., & Coates, M. I. (2010). End-Devonian extinction and a bottleneck in the early evolution of modern jawed vertebrates. *Proceedings of the National Academy of Sciences*, *107*(22), 10131-10135.

Sanapareddy, N., Legge, R. M., Jovov, B., McCoy, A., Burcal, L., Araujo-Perez, F., Randall, T. A., Galanko, J., Benson, A., Sandler, R. S., Rawls, J. F., Abdo, Z., Fodor, A. A., & Keku, T. O. (2012). Increased rectal microbial richness is associated with the presence of colorectal adenomas in humans. *The ISME Journal*, *6*(10), 1858.

Saupe, E. E., Hendricks, J. R., Portell, R. W., Dowsett, H. J., Haywood, A., Hunter, S. J., & Lieberman, B. S. (2014). Macroevolutionary consequences of profound climate change on niche evolution in marine molluscs over the past three million years. Proceedings of the Royal Society B: Biological Sciences, 281(1795), 20141995.

Schmitt, J. G., Jones, D. A., Goldstrand, P. M. (1991). Braided stream deposition and provenance of the Upper Cretaceous–Paleocene (?) Canaan Peak Formation, Sevier foreland basin, southwestern Utah. In Nations, J. D., & Eaton, J. G. (eds.), *Stratigraphy, depositional environments, and sedimentary tectonics of the western margin, Cretaceous Western Interior Seaway*. *Geological Society of America Special Paper*, *260*, 27-45.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, *27*(3), 379-423.

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). Biometrika, 52(3/4), 591-611.

Shelley, S. L. (2018). *The rise of placental mammals: The anatomy, palaeobiology and phylogeny of* Periptychus *and the Periptychidae* (Doctoral dissertation, University of Edinburgh, Edinburgh).

Shelley, S., Williamson, T. E., & Brusatte, S. L. (2015). Resolving the higher-level phylogenetic relationships of 'Triisodontidae' ('Condylarthra') within Placentalia. Abstract presented at the 75th Annual Meeting of the Society of Vertebrate Paleontology, Dallas, Texas.

Shelley, S. L., Williamson, T. E., & Brusatte, S. L. (2018). The osteology of *Periptychus carinidens*: A robust, ungulate-like placental mammal (Mammalia: Periptychidae) from the Paleocene of North America. *PLOS ONE*, *13*(7), e0200132.

Sibson, R. (1972). Order invariant methods for data analysis. *Journal of the Royal Statistical Society: Series B (Methodological)*, *34*(3), 311-338.

Simmons, N. B. (1987). A revision of *Taeniolabis* (Mammalia: Multituberculata), with a new species from the Puercan of eastern Montana. *Journal of Paleontology*, *61*(4), 794-808.

Sloan, R. E. (1987). Paleocene and latest Cretaceous mammal ages, biozones, magneto zones, rates of sedimentation and evolution. In Fassett, J. E, & Rigby Jr, J. K. (eds.), *The Cretaceous–Tertiary boundary in the San Juan and Raton basins, New Mexico and Colorado*. *Geological Society of America Special Papers*, *209*, 165-200.

Smith, S. M., Sprain, C. J., Clemens, W. A., Lofgren, D. L., Renne, P. R., & Wilson, G. P. (2018). Early mammalian recovery after the end-Cretaceous mass extinction: A high-resolution view from McGuire Creek area, Montana, USA. *Geological Society of America Bulletin*, *130*(11-12), 2000-2014.

Soberón, J. (2007). Grinnellian and Eltonian niches and geographic distributions of species. Ecology letters, 10(12), 1115-1123.

Soberón, J., & Peterson, A. T. (2005). Interpretation of models of fundamental ecological niches and species' distributional areas.

Sprain, C. J., Renne, P. R., Clemens, W. A., & Wilson, G. P. (2018). Calibration of chron C29r: New high-precision geochronologic and paleomagnetic constraints from the Hell Creek region, Montana. *Geological Society of America Bulletin*, *130*(9-10), 1615-1644.

Stevens, A. L., Balgord, E. A., & Carrapa, B. (2016). Revised exhumation history of the Wind River Range, WY, and implications for Laramide tectonics. *Tectonics*, *35*(5), 1121-1136.

Strait, S. G. (1993). Differences in occlusal morphology and molar size in frugivores and faunivores. *Journal of Human Evolution*, *25*(6), 471-484.

Sunderlin, D., Trop, J. M., Idleman, B. D., Brannick, A., White, J. G., & Grande, L. (2014). Paleoenvironment and paleoecology of a late Paleocene high-latitude terrestrial succession, Arkose Ridge Formation at Box Canyon, southern Talkeetna Mountains, Alaska. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *401*, 57-80.

Swain, F. M. (1987). Some Late Cretaceous? and Paleogene freshwater Ostracoda from central and eastern Nevada. *Revista Española de Micropaleontología*, *19*, 215-238.

Tobler, W. R. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography*, *46*(S), 234-240.

Tobler, W. R. (1981). A model of geographical movement. *Geographical Analysis*, *13*(1), 1-20.

Tomašových, A., & Kidwell, S. M. (2009). Fidelity of variation in species composition and diversity partitioning by death assemblages: time-averaging transfers diversity from beta to alpha levels. Paleobiology, 35(1), 94-118.

Urban, D., Goslee, S., Pierce, K., & Lookingbill, T. (2002). Extending community ecology to landscapes. *Ecoscience*, *9*(2), 200-212.

Vila, B., Sellés, A. G., & Brusatte, S. L. (2016). Diversity and faunal changes in the latest Cretaceous dinosaur communities of southwestern Europe. Cretaceous Research, 57, 552-564.

Wang, Y., Chen, H., Wang, X., & Huang, Y. (2011). Evolution of the Ediacaran Doushantuoian meta-paleo-community in Northeast Guizhou, South China. Acta Geologica Sinica-English Edition, 85(3), 533-543.

Warheit, K. I. (2002). The seabird fossil record and the role of paleontology in understanding seabird community structure. In Schreiber, E. A., & Burger, J. (eds.), *Biology of Marine Birds* (pp. 17-55). Boca Raton, FL: CRC Press.

Weil, A. (1997). *Multituberculate phylogeny and mammalian biogeography in the late Cretaceous and earliest Paleocene Western Interior of North America* (Doctoral dissertation, University of California, Berkley).

Williamson, T. E. (1996). The beginning of the Age of Mammals in the San Juan Basin, New Mexico: Biostratigraphy and evolution of Paleocene mammals of the Nacimiento Formation. *New Mexico Museum of Natural History & Science Bulletin*, *8*, 1- 142.

Williamson, T. E., & Carr, T. D. (2007). Revision of the problematic early Paleocene genus *Oxyclaenus* (Mammalia: Oxyclaenidae) and a new species of *Carcinodon*. *Journal of Vertebrate Paleontology*, *27*(4), 973- 986.

Williamson, T. E., Shelley, S. L., & Brusatte, S. L. (2016). A new specimen of *Triisodon crassicuspis* (Cope, 1882) provides insight on triisodontid taxonomy and phylogeny. Poster presented at the 2016 New Mexico Geological Society Annual Spring Meeting, Socorro, New Mexico.

Williamson, T. E., & Weil, A. (2011). A new Puercan (early Paleocene) hyopsodontid "condylarth" from New Mexico. *Acta Palaeontologica Polonica*, *56*(2), 247-255.

Wilson, G. P. (2013). Mammals across the K/Pg boundary in northeastern Montana, USA: dental morphology and body-size patterns reveal extinction selectivity and immigrant-fueled ecospace filling. *Paleobiology*, *39*(3), 429-469.

Wilson, J. B., Gitay, H., & Agnew, A. D. (1987). Does niche limitation exist?. Functional Ecology, 391-397.

Winegardner, A. K., Jones, B. K., Ng, I. S., Siqueira, T., & Cottenie, K. (2012). The terminology of metacommunity ecology. *Trends in ecology & evolution*, *27*(5), 253-254.

Wolff, R. G. (1975). Sampling and sample size in ecological analyses of fossil mammals. *Paleobiology*, *1*(2), 195-204.

Wroblewski, A. F. J. (2004). New selachian paleofaunas from “fluvial” deposits of the Ferris and lower Hanna formations (Maastrichtian–Selandian: 66–58 Ma), southern Wyoming. *Palaios*, *19*(3), 249-258.

Wroblewski, A. F. J. (2008). Paleoenvironmental significance of Cretaceous and Paleocene *Psilonichnus* in southern Wyoming. *Palaios*, *23*(6), 370-379.

Xu, H., Liu, Y. Q., Kuang, H. W., Liu, Y. X., & Peng, N. (2017). Jurassic–Cretaceous terrestrial transition red beds in northern North China and their implication on regional paleogeography, paleoecology, and tectonic evolution. *Palaeoworld*, *26*(2), 403-422.

Yonkee, W. A., & Weil, A. B. (2015). Tectonic evolution of the Sevier and Laramide belts within the North American Cordillera orogenic system. *Earth-Science Reviews*, *150*, 531-593.

Young, R. A., & Crow, R. (2014). Paleogene Grand Canyon incompatible with Tertiary paleogeography and stratigraphy. *Geosphere*, *10*(4), 664-679.

Young, R. A., & Hartman, J. H. (2014). Paleogene rim gravel of Arizona: Age and significance of the Music Mountain Formation. *Geosphere*, *10*(5), 870-891.

APPENDIX 1: RAW DATA

S1.1. List of Puercan eutherian localities

Locality numbers are as in Figure 1.1. More detailed information on the UCMP and NMMNHS localities is available to qualified professionals at the request of the respective institutions. Not all of the localities listed were analyzed in the final study.

S1.1.1. Alberta (West Canada) Basin

1) RCA (Research Council of Alberta) Core Hole 66-1 (*Prothryptacodon albertensis* holotype locality) [Pu2/Pu3] (Fox 1968; Johnston & Fox, 1984; Fox, 1990)

Other names: Alberta Well 66-1 Balzac West

2) **Schowalter Locality, Wintering Hills (*Pandemonium hibernalis* holotype locality) [Pu2/Pu3]** (Fox *et al.*, 2014)

Both of these localities were ultimately excluded from the analyses due to extremely low sample sizes. While RCA Core Hole 66-1 has been described as coming from the Porcupine Hills Fm., both it and the Schowalter locality are most likely in the Scollard Fm. (unnamed upper member), above the Nevis Coal Seam marking the K/Pg boundary. The Schowalter locality was constrained to the Pu2/Pu3 within C29n based on Lerbekmo *et al.* (1995 and unpublished data) and on the presence of *Pandemonium* (Van Valen, 1994) however, more work is needed to stratigraphically constrain the Alberta Puercan faunas.

S1.1.2. Williston Basin localities: Saskatchewan

3) Medicine Hat & Brick Tile (MHBT) Quarry, Long Fall Local Fauna [Pu1] (Johnston & Fox, 1984; Fox, 1989 & 1990)

Other names: Fr-1 locality

4) Medicine Hat & Brick Tile (MHBT) Quarry, RAV-W1 Local Fauna [Pu2] (Johnston & Fox, 1984; Fox, 1989 & 1990; Fox & Youzwyshyn, 1994; Fox & Scott, 2011)

Other names: Crocopot, Ravenscrag locality

Included localities: UCMP V80039

5) Pine Cree Park [Pu2] (Russell, 1974; Scott et al., 2016)

Since the majority of the fossiliferous beds at the MHBT Quarry were already destroyed in 1979 before the description of its Puercan mammalian local faunas – save for some expansion of the quarry at the *Ravenictis krausei* type locality (Fox & Youzwyshyn, 1994) – controversy persists concerning the biostratigraphy of this sites and other in southern Saskatchewan. Fox (1989, 1990) originally considered the Long Fall horzion as latest Cretaceous, though dominant by eutherians of "Paleocene aspect" (probably "Bugcreekian" *sensu* Sloan, 1987); he considered the RAV W-1 horizon as young as Pu2-Pu3. Current magnetostratigraphic and palynostratigraphic data constrains the RAV W-1 horizon and the Pine Cree Park locality to C29n (Redman *et al.*, 2015), with the referral to the Pu2 interval based on the absence of *Taeniolabis* spp. And faunal similarities to "Pu2" localities in the Crazy Mountain and Williston basins (Buckley, 1994), but this requires additional verification through the description of additional Pine Cree Park material (Scott *et al.,* 2016). The MHBT Long Fall Horizon Local Fauna is close to the contact between the Frenchman and the Ravenscrag formations, especially at the Fr-1 locality, and is currently assigned to the Pu1.

S1.1.3. Williston Basin localities: Montana (see general reviews by Sloan & Van Valen, 1965; Van Valen, 1978; Archibald, 1981, 1982; Archibald *et al.*, 1982; Archibald & Clemens, 1984; Sloan et al., 1986; Fastovsky, 1987; Rigby Jr *et al*., 1987; Hartman et al., 1989; Lofgren, 1995; Clemens, 2004; Wilson, 2005, 2013, 2014; Chester *et al.*, 2015)

6) Black Spring Coulee Channel Local Fauna [Pu1]

Other names: Black Spring Coulee North, Come Alive Condylarth, Condylarth Flats, Late Celebration

Included localities: UCMP V87030, V87031, V87033, V87123, V87124, V88044

7) Brown-Grey Channel Local Fauna (includes Lower Tedrow Channel Local Fauna *in partim*) [Pu1]

Other names: Tedrow Dinosaur Quarry C & D, BC Boneanza General

Included localities: UCMP V87040, V87071, V87072, V87152

8) Bug Creek Anthills Local Fauna ["Bugcreekian" NALMA type locality] [Pu1]

<u>Other names:</u> Bug Creek West

<u>Included localities:</u> UCMP RV8137, V65127, V70199, V70200, V70201, V70202, V70209; UMVP F304, F305

9) Capping Channel [Pu1]

<u>Included locality:</u> UCMP V91065

10) Carrie Padgett [Pu1]

<u>Other names:</u> Carrie Padgett Anthills, Carrie Padgett Southern Extension

<u>Included localities:</u> UCMP V77124, V79100, V79101, V79102, V79103, V79104

11) Cat's Meow [Pu1]

<u>Included locality:</u> UCMP V87049

12) Constenius [Pu1]

<u>Other names:</u> Tom's Constenius locality

<u>Included localities:</u> UCMP V96268, V96269

13) near Fairfield [Pu1]

<u>Included localities:</u> UCM L82030, ?L2006013

14) Harbicht Hill [Pu1]

<u>Included localities:</u> UCMP V71203, V73100 (both listed as Lancian by AMNH, UCMP, and UMVP)

15) Harley's Palate [Pu1]

<u>Included locality:</u> UCMP V77136

16) Hell's Hollow Channel Local Fauna [Pu1]

<u>Other names:</u> Hell's Hollow Champ, Hell's Hollow-E End'

<u>Included localities:</u> UCMP V74110, V76137, V76139

17) Herpijunk Promontory [Pu1]

<u>Included locality:</u> UCMP V77129

18) James Place [Pu1]

<u>Included locality:</u> UCMP V87108

19) Ja Place [Pu1]

<u>Included locality:</u> UCMP V87109

20) Little Roundtrip Channel Local Fauna [Pu1]

<u>Other names:</u> Eagle Nest Channel, Leafbranch Level, Little Roundtrip, Lower Level

Included localities: UCMP V87028, V87098, V87115, 88038

21) McKeever Ranch Local Fauna [Pu1]

Included localities: UCMP V72210, V77087

22) Muddy Mess [Pu1]

Included locality: UCMP V87067

23) Rick's Place [Pu1]

Included locality: UCMP V73098

24) Second Level Channel Local Fauna [Pu1]

Other names: Eagle High, Eagle High Extension, Eagle High South, Eagle Nest Channel, Eagle Nest Ridge West, Eagle Nest Southeast, Jaw Breaker, Juniper Tree West, Lone Juniper Tree, Rattlesnake Nest, Second Level South, Three Buttes in partim

Included localities: UCMP V86031, V87029, V87050, V87051, V87052, V87078, V87091, V87095, V87114, V87101, V87117, V87119, V87151

25) Shiprock Local Fauna [Pu1]

Other names: Grass Patch, North Edge, Bad Mouth Turtle

Included localities: UCMP V87073, V87074, V87077, V87153

26) Three Buttes Local Fauna [Pu1]

Included localities: UCMP V87079, V87080, V87081, V87082, V87083, V87084, V87085, V87086, V87087, V87088

27) Up-Up-the-Creek Local Fauna [Pu1]

Included localities: UCMP V84151, V87034, V87035, V87036, V87037, V87038

28) Worm Coulee [Pu1]

Included locality: UCMP V74111

29) Z-Line Channel Quarry Local Fauna [Pu1] [not recorded due to insufficient data]

Included locality: UCMP V84193

30) Deer Crash [Pu2]

Included locality: MOR L6426

31) Hiatt Local Fauna [Pu2]

Other names: Hiatt South

Included localities: MOR L5418, L6424

32) Biscuit Butte [Pu3]

Included locality: UCMP V73096

33) Biscuit Spring [Pu3]

__Included locality:__ UCMP V74122

34) Garbani Channel Complex Local Fauna (includes "Engdahl Ranch" faunas) [Pu3]

__Included localities:__ LACM 3099; UCMP V72125, V72126, V72127, V72128, V72129, V72130, V72131, V72134, V72135, V72136, V73080, V73082, V74120, V75230, V994

35) Kerr Butte [Pu3]

__Included localities:__ UCMP V75196-98

36) Purgatory Hill [Pu3]

__Included localities:__ UCMP 71202, UMVP F303

37) Yellow Sand Anthills local fauna [Pu3]

__Included localities:__ UCMP V74123, V75193, V75194, V75195

The nomenclature of Paleocene formations in the Powder River and Williston basins classically lumped into the "Fort Union Formation" or "Fort Union Group" has a convoluted history (McGrew & Roehler, 1960; Roberts, 1965; Robinson, 1971; Beaumont, 1979; Archibald *et al.*, 1982; Winterfeld, 1982; Ayers Jr., 1986; Pocknall & Flores, 1987; Shearer *et al.*, 1995). Currently, Puercan-equivalent localities in Montana are constrained to the Tullock Fm. (lower to middle "Nelson Ranch" Mbr.; includes the W, Y, X, and Z coals, above the K/Pg boundary in the Irz coal) in the Fort Peck/McGuire Creek area, and the Ludlow Fm. ("Limber Pines" or "Shadehill Facies" Mbr.) in the Makoshika State Park area and the Dakotas (Moore, 1976; Fastovsky & Dott, 1986; Hartman *et al.*, 1989; Rigby & Rigby Jr., 1990). However, as with the underlying Hell Creek Fm. (see reviews by Murphy *et al.*, 2002, and Hartman *et al.,* 2014), the proposed members of the Ludlow and Tullock are in need of significant revision. Potential errors in biochronological constraint occur at many Montana sites due to reworking of Lancian material in Puercan sandstone channels; this problem is most evident at the Bug Creek, Harbicht Hill, and Hell's Hollow local faunas, among other McGuire Creek localities. In the western McGuire Creek area, available magnetostratigraphic and palynostratigraphic data, in combination with $^{40}Ar/^{39}Ar$ tephra chronology, constrains the Pu1 McKeever Ranch and Hell's Hollow Channel local faunas, in between the Irz and Hauso Flats Z coals, to 66.013-65.973 Ma (within C29r); and the Garbani Channel and Purgatory Hill local fauna, age-equivalent to the Y and X coals, to 65.741-65.491 Ma and possibly later (within C29n) (Swisher III, 1993; LeCain *et al.*, 2014; Sprain *et al.*, 2015 & 2018). The assignment of Garbani Channel to Pu3 is predominantly based on the presence of the multituberculate *Taeniolabis lamberti (*Simmons, 1987) with Biscuit Butte/Spring and Yellow Sand Hills considered correlative due to similar abundances of *Prodiacodon crustulum* and *Purgatorius unio*.

The Farrand Channel and Horsethief Canyon local faunas (~65.118-65.041 Ma, straddling C29n/C28r transition) are assemblages originally assigned to the To1 interval based on the presence of characteristic Torrejonian eutherian genera (*Mimotricentes*, *Paromomys*), but also harbor a number of Puercan taxa (*Anisonchus athelas*, *Carcinodon simplex*, *C. subbituminus*, *Tricentes calenancus*), none of which are present in the earlier

Garbani Channel fauna (Clemens & Wilson, 2009). Pending further inquiry on the role of reworking, these faunas are excluded from the analyses.

S1.1.4. Williston Basin localities: North Dakota [see general reviews by Hunter, 1999; Hunter & Archibald, 2002; Hunter *et al.*, 2003; Peppe *et al.*, 2009; Rook *et al.*, 2010; Lyson *et al.*, 2011]

38) Wilkening Locality

Included locality: PTRM V02017

39) PITA Flats Local Fauna

Included locality: PTRM V86005, V97027

40) Merle's Mecca, John's Nose

Included locality: PTRM Loc. V99011

These localities were not included in the analyses of this study because the majority of the material is not described and illustrated in the peer-reviewed, with the exception of a few teeth from PITA Flats (Hunter & Archibald, 2002) and the purported *Alveugena carbonensis* mandible from Merle's Mecca (Rook *et al.*, 2010). Additionally, the PRTM is currently not credited by American Alliance of Museums, per the general guidelines for vertebrate paleontological repository. Nevertheless, the eventual description of these remains is anticipated, as several authors have cast Merle's Mecca as representing a "transitional" fauna between the Pu1 and Pu2 intervals (though within C29r), equivalent in age and faunal composition to the MHBT RAV-W1 horizon, the Hiatt Local Fauna, and Simpson Quarry. The age of the PITA Flats Local Fauna is less clear, as it harbors taxa characteristic of both Pu1 and Pu2; however, available magnetostratigraphic data places it in the upper portion of C29r as well (Hicks *et al.*, 2002; Peppe *et al.*, 2009).

S1.1.5. Powder River Basin localities

41) Lanes Little Jaw Site (LLJS) Quarry Local Fauna

Included locality: LACM 7942

This recently described locality, was originally assigned to the Cretaceous (Maastrichtian, latest Lancian) by Kelly (2014)., but probably includes material from younger deposits.

S1.1.6. Crazy Mountain Basin localities

42) Simpson Quarry Local Fauna [Pu2]

Other names: GGS 65

Included locality: MOR L4663

Although this locality was originally described by Hartman *et al.* (1989) and Hartman & Krause (1993), most paleontological and stratigraphic work has been done by Buckley (1994, 1997, & 2018) and Fox *et al.* (2015); much of it remains unpublished, and thus several new species proposed in Buckley's dissertation are not included here. Magnetostratigraphic data suggest both the quarry and the Bear/Lebo Fm. contact lie within C29n; the current absence of *Taeniolabis* spp. infers assignment to the Pu2.

S1.1.7. Bighorn Basin localities [see general reviews by Jepsen, 1930, 1940; Jepsen *et al.*, 1947; Van Valen, 1978; Gingerich *et al.*, 1980; Hartman, 1986; Clemens, 2017]

43) Cedar Mountain, lower fauna [Pu1]

Included locality: UW V82007

44) Mantua Lentil Local Fauna ["Mantuan" NALMA type locality] [Pu1]

Included locality: UMCP V8108

45) Leidy Quarry [Pu1]

46) Cedar Mountain, upper fauna [Pu2]

Included locality: UW V81064, V82010

The Mantua Lentil sandstone channel quarry is the best known and most thoroughly explored Puercan locality in the Bighorn Basin, with expeditions conducted by Princeton University in 1934-1936, 1939, 1941, 1957, and 1960 (Gingerich, 2016; see also review in Chapter 1). Less discussed is the enigmatic Leidy Quarry east of Kirby, WY, originally discovered by E. L. Simons with F. A. Jenkins and L. B. Radinsky (Gingerich, 1980). Much of the eutherian material from both quarries would not be described until Van Valen (1978), who made little mention of the stratigraphic context; Bown (1980), Gingerich *et al.* (1980), and Lofgren (1995) did not agree with Van Valen's recognition of the "Mantuan" NALMA Despite being crucial to the recognition of the Pu1 interval and the Puercan NALMA as a whole, the Leidy and Mantua Lentil quarries have fallen into obscurity, perhaps owing to their relative inaccessibility; indeed, most of the mammals, as well as all of the crocodilian and avian remains, have yet to be properly monographed. A similar situation has befallen the Pu1 and Pu2 localities at the Cedar Mountain section, not far from the Leidy Quarry, which were excluded from this study; however, an M^X from UW V-82007 was tentatively referred to *Oxyprimus* cf. *galadrielae*, and an M^3 from UW V-81064 to *Carcinodon* cf. *simplex* (Hartman, 1986).

S1.1.8. Great Divide Basin localities [see general review in McComas & Eberle, 2016]

47) Great Divide Basin Quarry Local Fauna [Pu1]

Included localities: UCM 2011033, 2011034, 2011035

This is the most recently recognized major Puercan eutherian local fauna, despite being originally prospected by J. Honey & M. McKenna in the late 1950s (McKenna, 1960; see also review by Lillegraven *et al.*, 2004), and is currently under restudy by J. Eberle and her colleagues (McComas & Eberle, 2016; Atteberry & Eberle, 2018; Templeman, 2017; see also review by Halverson & Eberle, 2018). The presence and abundance of *Protungulatum donnae* and *P. gorgun* tentatively infer a Pu1 age.

S1.1.9. Hanna Basin localities [see general reviews in Eberle & Lillegraven, 1998a&b; Lillegraven & Eberle, 1999; Eberle, 1999]

48) Ferris Formation Main Section, Pu1 local faunas [Pu1]

Included localities: UW V-91010, V-91014, V-91015, V-91031

49) Windy Mudstone Local Fauna [Pu1]

Included localities: UW V-91004, V-91005

50) Ferris Formation Main Section, Pu2 local faunas [Pu2]

Included localities: UW V-91002, V-91003, V-91018, V-91019, V-92009, V-92014, V-92016

51) Ferris Formation Main Section, Pu3 local faunas [Pu3]

Included localities: UW V-91022, V-91026, V-91027, V-91028, V-92021, V-92022, V-92024, V-92035, V-92037

The local faunas at Ferris Main Section near Seminoe Reservior are lumped for convenience due to uneven sampling between localities, despite possibly representing multiple time-consecutive local faunas. Designations for the Pu1 (4.57-91.74 m above the K/Pg boundary, designated as a "zone of uncertainty"), Pu2 (124.05-324 m), and Pu3 (329.18-534.31 m) at Ferris Main Section and Windy Mudstone were based on biostratigraphic correlations with other basins, with the base of the Pu3 defined by the presence of *Taeniolabis taoensis* at UW V-91022. Magnetostratigraphic and radiometric age estimates need to be done.

S1.1.10. Denver Basin localities [see general reviews in Middleton, 1982 & 1983; Dewar 1996 & 2003; Eberle, 2003; Middleton & Dewar, 2004; Dahlberg *et al.*, 2016]

52) Alexander [Pu1]

Other names: Littleton Local Fauna

Included localities: UCM 77267, UCMP V80001

53) Denver Oxyclaenodon site [Pu1]

Included locality: DMNH 299

54) Nicole's Mammal Jaw locality [Pu1]

Included locality: DMNH 2557

55) South Table Mountain [Pu1]

Other names: Brown's Baioconodon, Michon's Multi

Included localities: DMNH 2386, 2387, 2814; UCM 75199, UCM 77283

56) West Bijou Creek, Gars Galore Local Fauna [Pu1]

Included localities: DMNH 2560

57) near Arapahoe (*Conacodon harbourae* holotype locality) [Pu2/Pu3]

Other names: "1 km E of Alexander"

Included locality: UCM 78167

58) Big Gulch Local Fauna [Pu2/Pu3]

Other names: Denver Crockies, Taeniodont Site

Included localities: DMNH 510, 2563; UCM 91278, 91280

59) Coral Bluffs Local Fauna [Pu2/Pu3]

Other names: Alligator Rock, Austin Bluffs, Carner Site, The Dead Tree Lives, Jimmy Camp Creek, Mad Cow, Pieces of Perip

Included localities: DMNH 2544, 2548, 2551, 2555; UCM 77274, 77275, 77276, 77278, 77279, 77280, 77281, 77287, 77288, 80029, 82126, 83095, 83196, 90063, 2008193

60) West Bijou Creek, main local fauna [Pu2/Pu3]

Included locality: UCM 78191

The chronostratigraphy of Puercan eutherian localities in the Denver Basin remains poorly constrained. The current interval assignments are based largely on the magnetostratigraphy of Hicks *et al.* (2003), who placed Alexander and West Bijou Gars Galore in the upper C29r (late Pu1), and the Big Gulch and Corral Bluffs local faunas, along with at least part of West Bijou Creek, well within C29n (see also Obradovich, 2002); this is broadly concurrent with macroflora assemblages and palynostratigraphy (Nichols & Fleming, 2002; Barclay *et al.*, 2003; Johnson *et al.*, 2003; Crystal, 2017). However, the assemblages at Big Gulch and Corral Bluffs probably represent multiple time-consecutive local faunas in the Pu2/Pu3; at the Corral Bluffs, Pieces of Perip is the oldest locality, followed by Dead Tree Lives, Alligator Rock, Carner Site, and Mad Cow (Middleton, 1983; Eberle, 2003).

Most of the fauna from Big Gulch remains undescribed and unillustrated. Many Pu1 localities in the Greater Denver area (Alexander, Denver Oxyclaenodon) have been paved over and cannot be reassessed.

S1.1.11. Castle Valley Basin/North Horn Mountain localities (Wasatch Range) [see general reviews in Gazin, 1938, 1941b; Robinson,1986; Lofgren *et al.*, 2005]

61) Gas Tank Hill Local Fauna

Other names: Blue Lake Creek, Dairy Creek, Ferron Mountain, Flagstaff Peak Jason Spring

Included localities: CEUM 42Em443V, RAM V20035

62) Wagonroad Local Fauna

Other names: Wagonroad Ridge

Included locality: UCMP V5707

Originally discovered in the mid-1930s, the Gas Tank Hill and Wagonroad local faunas were thoroughly assessed by Robinson (1986) and Cifelli *et al.* (1995), with emphasis on new material from the BYU and OMNH expeditions. Current work focusses on new screen-washed microvertebrate localities from the Gas Tank Hill area (Lofgren *et al.*, 2005), which were not included in this study. Lofgren *et al.* (2004) caution against lumping the Utah local faunas because of strata slumping. All Gas Tank Hill sites are currently constrained within the lower-middle C29n, while Wagonraod straddles the C29n/C28r transition (Tomida & Butler, 1980). Both Wagonroad and at least one Gas Tank Hill site

(Ferron Mountain) bear fossils of the Pu3 index fossil *Taeniolabis taoensis*; however, following the biostratigraphic schemes of Archibald et al. (1987) and Lofgren *et al.* (2004), the traditional interval assignments for the two local faunas are maintained.

S1.1.12. S1.9. San Juan Basin localities [NMMNHS field area designations provided by T. E. Williamson, 2017-2019 pers. comm.; see also general reviews by Sinclair & Granger, 1914; Matthew, 1937; Dane, 1946; Simpson, 1951, 1981; Sloan, 1987; Williamson & Lucas, 1992; Lucas & Williamson, 1993; Williamson, 1996; Lucas & Estep, 2000; Kondrashov & Lucas, 2006; Williamson & Weil, 2011; Williamson et al., 2011]

63) NMMNHS Area 3: De-na-Zin Wash, "Ectoconus zone" [Pu2]

Other names: "lower Puerco beds, Coal Creek Canyon", "lower Puerco beds, Coal Creek Canyon", "lower Puerco beds, 2 mi. Above Ojo Alamo"

Included localities: AMNH Loc. 2; NMMNHS L6342, L6343, L6344, L6346, L6347, L6348, L8342, L8343, L8344, L8601, L8865, L8866, L8867, L8868, L12078; UALP 76105, 76106, 76107, 76126, 76127, 76128

64) NMMNHS Area 5: West Flank, Kimbeto Wash (main area) [Pu2]

Other names: "4 mi. above Kimbeoth"

Included localities: AMH Loc. 5.; NMMNHS L684, L685, L1121, L5200, L5201, L5202, L5203, L5204, L6345, L6349, L8233, L8869, L8870, L9179, L9180, L9181, L9182, L9875, L9894, L9895, L9899, L9976, L9977; UALP 76108, 76129.

65) NMMNHS Area 6: Standhardt's Black Toe Microvertebrate Locality [Pu2]

Included localities: NMMNHS L-6387; UALP 7631

66) NMMNHS Area 7: East Flank Kimbeto Wash [Puercan NALMA type locality *in partim*] [Pu2]

Other names: "3 mi. E of Kimbetoh", "Old Dolan Ranch", "Kimbeto Arroyo"

Included localities: AMNH Locs. 6 & 7; NMMNHS L645, L680, L682, L700, L701, L702, L703, L1118, L1119, L1120, L5205, L5206, L5207, L5208, L6350, L6351, L6361, L7138, L7438, L12079, L12080, L12081, L12082, L12083, L12084, L12085, L12086, L12087, L12088, L12089, L12090, L12091, L12092; UALP 76130, 76131, 76143; UCMP V1312, V2812

67) NMMNHS Areas 8 & 9: Mammalon Hill, Betonnie-Tsosie Wash [Pu2]

Other names: Tsosie, Eduardo Arroyo, Don & Barbara's Locality

Included localities: NMMNHS L317, L646, L686, L844, L1122, L1123, L1124, L2550, L2551, L2552, L5444, L5445, L5446, L5447, L5448, L6142, L6143, L6144, L6145, L6146, L6147, L6209, L6210, L6211, L6271, L6248, L6352, L6353, L6354, L6355, L6356, L6357, L6358, L6359, L6456, L6615, L6620, L7483, L8777, L9183, L9971, L9972, L10406, L10407, L10408, L10409, L10411, L10412, L10427, L10428, L10429, L10430, L10446, L10447, L10448, L10449, L10450, L10451, L10455; UALP 7225, 7226, 7246, 7526, 7469, 76132, 76133, 76134, 76135, 76136, 76137, 76138, 76139, 7743, 7895, 7902; UCMP V2811, V70168, V70169, V70170

68) "5 mi. E of Kimbeto" [NMMNHS field area unknown] [Pu2]

69) Camp's Skull [NMMNHS field area unknown] [Pu2]

Included localities: UCMP V70171

70) "Chaco Canyon" Pu2 material [NMMNHS field area unknown] [Pu2]

71) Malcom's Extension [NMMNHS field area unknown] [Pu2]

72) NMMNHS Area 1: Carson Trading Post, West Fork Gallegos Canyon [Pu3]

Included localities: NMMNHS L633, L647, L648, L649, L650, L651, L652, L653, L654, L655, L669, L670, L671, L673, L674, L1225, L1405, L2094, L2095, L2096, L2097, L2098, L2504, L2505, L2506, L2507, L2508, L2509, L2510, L2511.

73) NMMNHS Area 2: Split Lip Flats local fauna[Pu3]

Included localities: NMMNHS L2282, L2293, L2399, L4723, L4724, L4725.

74) NMMNHS Area 4: De-na-Zin Wash, "*Taeniolabis* zone" [Pu3]

Other names: "upper Puerco beds, Coal Creek Canyon", "upper Puerco beds, 2 mi. Above Ojo Alamo"

Included localities: NMMNHS locs. L390, L391, L392, L393, L394, L395, L396, L397, L626, L629, L630, L634, L636, L638, L642, L643, L644, L658, L659, L660, L661, L662, L663, L664, L665, L666, L667, L675, L676, L699,1115, L1117, L1217, L1219, L1220, L1224, L1225, L1288, L1400, L1409, L2306, L2308, L2309, L2340, L2394, L2396, L3206, L3230, L3232, L3233, L3234, L3235, L3236, L3237, L3239, L3329, L4329, L4546, L5196, L5404, L5663, L5664, L5665, L5666, L5667, L5668, L5669, L5670, L5671, L5672, L5673, L5674, L5675, L5676, L5817, L5818, L5819, L5820, L5821, L5822, L5823, L5824, L5825, L5826, L5827, L5828, L5829, L5830, L5831, L5832, L5833, L5834, L5835, L5836, L5837, L5838, L5842, L5864, L5865, L6053, L6054, L6055, L6056, L6057, L6058, L6059, L6060, L6061, L6062, L6063, L6064, L6065, L6066, L6067, L6243, L6253, L6254, L6273, L6274, L6335, L6341, L6360, L6423, L6424, L6425, L6426, L6427, L6428, L6429, L6430, L6431, L6432, L6433, L6487, L6621, L8238, L8336, L8337, L8338, L8339, L8340, L8348, L8349, L8350, L8351, L8352, L8353, L8354, L8355, L8356, L8357, L8361, L8366, L8367, L8368, L8614, L8615, L8856, L8857, L8858, L8859, L8860, L8861, L8862, L8863, L8864, L8884, L8887, L10478, L10479, L10480, L10481, L10482, L10483, L10484, L10485, L12076, L12077; UALP 7475, 7476, 7528, 7529, 7594, 76104, 76142, 7681, 7682, 7683, 7684, 7688, 7689, 7690, 7691, 7692, 7693, 7694, 7777, 7903

The San Juan Basin contains the most intensely studied and unambiguously constrained Puercan eutherian faunas. The biostratigraphic distinction between the Pu2 ("*Ectoconus ditrigonus*" or "*Hemithlaeus kowalevskianus*" zone) and Pu3 ("*Taeniolabis taoensis*" zone) is well established, with the Pu3 characterized by the absence of *Hemithlaeus kowalevskianus*, the declining abundance other small periptychids (*Conacodon*, *Gillisonchus*, *Oxyacodon*), and the appearance of *Chacomylus sladei* at Split Lip Flats. However, the reasons for the local faunal turnover between the Pu2 and Pu3 is not readily explained by lithostratigraphic data (Davis *et al.*, 2016; see also review in Chapter 1); attempts to solve this mystery using the NMDS and AGNES analyses of this study were unsuccessful. While the Puercan faunas are typically placed in the lower "Arroyo Chijuillita" Mbr. (Williamson & Lucas, 1992), the members of the of the Nacimiento Fm., as well as the underlying Ojo Alamo, are currently being revised; several traditionally recognized subdivisions may be locally restricted and time-transgressive, limiting their nomenclatural utility (Cather *et al.*, 2018). Radiometric ages are not yet available, but preliminary magnetostratigraphic, palynostratigraphic, and $^{40}Ar/^{39}Ar$ data indicate the major interval-zones (both well within C29n) are older and less temporally extensive than previously suspected, with the Pu2 at De-na-zin and Kimbeto Washes aged ~65.75 Ma, the Pu3 at De-na-zin Wash aged ~65.6 Ma (Lindsay et al., 1978; Butler & Lindsay, 1985; Williamson et al., 2008; Heizler *et al.*, 2013; Williamson & Brusatte, 2014; Abbuhl *et al.*, 2015; Davis *et al.*, 2016; Flynn *et al.*, 2016; Cather *et al.*, 2018). These age estimates are broadly consistent with those for the Williston Basin faunas. Complete stratigraphic columns for important sites in the NMMNHS field areas are in Williamson (1996) and Williamson *et al.* (2011).

S1.1.13. Additional comments

The alleged Pu3 locality Dogie (TMM 42327/LSU VL-108), located in the Black Peaks Fm. at Dawson Creek, Big Bend National Park, Texas (see reviews by Standhardt (1986, 1995)), has been reassigned to the early To2 interval-zone (lowermost C27r chron) using new biostratigraphic, magnetostratigraphic, and $^{40}Ar/^{39}Ar$ data (Leslie *et al.*, 2018); it is roughly age-equivalent to the nearby Tom's Top site (TMM 41400/LSU VL-111).

Table S1.1 (overleaf). Raw metadata for all Puercan eutherian localities. See discussion in Appendix 1 for more details on age assessments.

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Choeroclaenus	*turgidunculus*	1	3.98	2.96	1.03	Herbivore	"lower Puerco", 5 mi. E of Kimbetoh	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	unknown	unknown	Surface?	AMNH catalog
Conacodon	*cophater*	1	3.1	2.4	0.45	Herbivore	"lower Puerco", 5 mi. E of Kimbetoh	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	unknown	unknown	Surface?	AMNH catalog
Hemithlaeus	*kowalevskianus*	1	4.88	4.07	2.61	Herbivore	"lower Puerco", 5 mi. E of Kimbetoh	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	unknown	unknown	Surface?	AMNH catalog
Oxyacodon	*priscilla*	1	3.6	1.8	0.35	Herbivore	"lower Puerco", 5 mi. E of Kimbetoh	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	unknown	unknown	Surface?	AMNH catalog
Carsioptychus	*coarctatus*	1	10	9	38.7	Herbivore	0.5 km from West Bijou Creek 1	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	?	?	Surface	UCM catalog
Alticonus	*gazini*	23	4.92	2.47	1.09	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Ampliconus	*browni*	16	4.5	3.3	1.55	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Anisonchus	*sectorius*	9	5.47	3.88	2.94	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Auraria	*urbana*	4	6.38	5	6.08	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Baioconodon	*cannoni*	1	7.7	9.2	13.46	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Baioconodon	*denverensis*	54	6.62	5.39	7.43	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Carcinodon	*subbituminus*	31	3.63	2.65	0.72	Carnivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Conacodon	*delphae*	2	6.53	4.8	5.89	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Conacodon	*matthewi*	3	6.05	4.15	3.97	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Oxyacodon	*archibaldi*	4	3.4	3.9	1.27	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Oxyacodon	*priscilla*	1	3.6	1.8	0.35	Herbivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Oxyprimus	*galadrielae*	35	3.23	2.26	0.44	Insectivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Procerberus	*andesiticus*	4	2.48	1.44	0.12	Insectivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Procerberus	*grandis*	5	5.6	3.5	2.55	Insectivore	Alexander	Denver	Colorado	Pu1	Denver (Golden Mbr.)	Fine to medium sandstone & siltstone	Overbank	Quarry, Surface	UCM, UCMP catalog; Middleton, 1980; Middleton & Dewar, 2004
Betonnia	*tsosia*	2	2.4	1.6	0.14	Insectivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Bomburodon	*priscus*	5	3.6	2.9	0.83	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Bubogonia	*bombadili*	1	n/a	n/a	n/a	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Carcinodon	*antiquus*	3	8.2	4.85	9.01	Carnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Carcinodon	*olearyi*	38	5.93	3.79	3.26	Carnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Carcinodon	*simplex*	60	4.72	6	4.92	Carnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Carsioptychus	*coarctatus*	51	10	9	38.7	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Choeroclaenus	*turgidunculus*	35	3.98	2.96	1.03	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Conacodon	*cophater*	167	3.1	2.4	0.45	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Conacodon	*entoconus*	207	5.75	6.75	8.63	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Conacodon	*kohlbergeri*	3	4.08	3.04	1.13	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Desmatoclaenus	*dianae*	1	6	4.9	5.26	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Desmatoclaenus	*protogonioides*	5	6	4.7	4.88	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Ectoconus	*ditrigonus*	45	10.1	8.8	37.84	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Eoconodon	*coryphaeus*	15	11	7.85	35.94	Carnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Eoconodon	*gaudrianus*	24	7.34	5.24	8.49	Carnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Eoconodon	*ginibitohia*	1	6.6	4.3	4.94	Omnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Escatepos	*campi*	1	n/a	n/a	n/a	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Fimbrethil	*agapetillus*	59	2.9	1.5	0.17	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Gillisonchus	*gillianus*	106	4.14	3.09	1.19	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Hemithlaeus	*kowalevskianus*	358	4.88	4.07	2.61	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Loxolophus	*hyattianus*	56	5.5	4.3	3.57	Omnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Loxolophus	*priscus*	2	6.55	5.24	6.93	Omnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Onychodectes	*tisonensis*	7	6.5	6.8	10.88	Omnivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Oxyacodon	*apiculatus*	18	4.2	2.1	0.62	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Oxyacodon	*priscillla*	64	3.6	1.8	0.35	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Protogonodon	*pentacus*	11	9.19	7.76	25.55	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Puercolestes	*simpsoni*	6	3.6	2.2	0.51	Insectivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Tiznatzinia	*vanderhoofi*	2	3.2	2.9	0.67	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Valenia	*wilsoni*	2	3.14	2.57	0.52	Herbivore	Betonnie-Tsosie Wash/Mammalon Hill	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Meandering streambed	Quarry, Surface, Screenwash	AMMNH, LACM, NMMNHS, USNM, UCMP catalog; Sloan, 1987; Williamson, 1996
Carsioptychus	*coarctatus*	2	10	9	38.7	Herbivore	Big Gulch	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Surface?	DMNH catalog; Eberle, 2003
Ectoconus	*ditrigonus*	1	10.1	8.8	37.84	Herbivore	Big Gulch	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Surface?	DMNH catalog; Eberle, 2003
Eoconodon	*hutchisoni*	4	9.28	6.09	16.87	Carnivore	Biscuit Butte	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015
Prodiacodon	*crustulum*	2	2.69	1.79	0.21	Insectivore	Biscuit Butte	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015
Purgatorius	*janisae*	2	1.93	1.2	0.056	Insectivore	Biscuit Butte	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015
Purgatorius	*unio*	4	2.1	1.5	0.1	Insectivore	Biscuit Butte	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015
Crustulum	*fontanus*	1	n/a	n/a	n/a	Herbivore	Biscuit Springs	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015
Procerberus	*formicarum*	1	2.7	1.7	0.19	Insectivore	Biscuit Springs	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015
Prodiacodon	*crustulum*	22	2.69	1.79	0.21	Insectivore	Biscuit Springs	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015
Purgatorius	*janisae*	3	1.93	1.2	0.056	Insectivore	Biscuit Springs	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015
Purgatorius	*unio*	669	2.1	1.5	0.1	Insectivore	Biscuit Springs	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel fill, lignite bed	Surface, Screenwash	UCMP catalog; Sprain et al., 2015

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Mimatuta	*morgoth*	1	3.96	2.94	1	Omnivore	Black Spring Coulee Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Procerberus	*formicarum*	2	2.7	1.7	0.19	Insectivore	Black Spring Coulee Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*donnae*	1	3.92	3.01	1.03	Insectivore	Black Spring Coulee Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*gorgun*	1	4.36	3.16	1.36	Insectivore	Black Spring Coulee Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	6	5.2	4.16	3.04	Herbivore	Black Spring Coulee Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Betonnia	*tsosia*	3	2.4	1.6	0.14	Insectivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Carcinodon	*simplex*	7	4.72	6	4.92	Carnivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Chacopterygus	*minutus*	3	n/a	n/a	n/a	Insectivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Choeroclaenus	*turgidunculus*	11	3.98	2.96	1.03	Herbivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Conacodon	*cophater*	1	3.1	2.4	0.45	Herbivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Conacodon	*entoconus*	7	5.75	6.75	8.63	Herbivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Ectoconus	*ditrigonus*	1	10.1	8.8	37.84	Herbivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Eoconodon	*gaudrianus*	3	7.34	5.24	8.49	Carnivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Fimbrethil	*agapetillus*	1	2.9	1.5	0.17	Herbivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Gillisonchus	*gillianus*	3	4.14	3.09	1.19	Herbivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Hemithlaeus	*kowalevskianus*	4	4.88	4.07	2.61	Herbivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Loxolophus	*hyattianus*	2	5.5	4.3	3.57	Omnivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Onychodectes	*tisonensis*	1	6.5	6.8	10.88	Omnivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Puercolestes	*simpsoni*	14	3.6	2.2	0.51	Insectivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Tiznatzinia	*vanderhoofi*	2	3.2	2.9	0.67	Herbivore	Black Toe Microvertebrate Locality	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Screenwash	AMNH, NMMNHS catalog; Standhardt, 1980; Williamson et al., 2011
Gypsonictops	*illuminatus*	7	2.41	1.87	0.19	Omnivore	Brown-Grey Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Mimatuta	*minuial*	2	3.92	2.84	0.93	Omnivore	Brown-Grey Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Mimatuta	*morgoth*	2	3.96	2.94	1	Omnivore	Brown-Grey Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Oxyprimus	*erikseni*	19	3.3	2.17	0.42	Insectivore	Brown-Grey Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Procerberus	*formicarum*	36	2.7	1.7	0.19	Insectivore	Brown-Grey Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*donnae*	6	3.92	3.01	1.03	Insectivore	Brown-Grey Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*gorgun*	2	4.36	3.16	1.36	Insectivore	Brown-Grey Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	4	5.2	4.16	3.04	Herbivore	Brown-Grey Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Batodon	*tenuis*	1	1.18	0.7	0.009	Insectivore	Bug Creek Anthills Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Surface, Screenwash	AMNH, UCMP catalogs; Sloan & Valen, 1965; Archibald, 1982; Lofgren, 1995
Cimolestes	*incisus*	7	3.52	2.1	0.48	Insectivore	Bug Creek Anthills Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Surface, Screenwash	AMNH, UCMP catalogs; Sloan & Valen, 1965; Archibald, 1982; Lofgren, 1995
Gypsonictops	*hypoconus*	9	2.1	2.9	0.32	Omnivore	Bug Creek Anthills Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Surface, Screenwash	AMNH, UCMP catalogs; Sloan & Valen, 1965; Archibald, 1982; Lofgren, 1995
Gypsonictops	*illuminatus*	21	2.41	1.87	0.19	Omnivore	Bug Creek Anthills Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Surface, Screenwash	AMNH, UCMP catalogs; Sloan & Valen, 1965; Archibald, 1982; Lofgren, 1995
Mimatuta	*morgoth*	1	3.96	2.94	1	Omnivore	Bug Creek Anthills Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Surface, Screenwash	AMNH, UCMP catalogs; Sloan & Valen, 1965; Archibald, 1982; Lofgren, 1995
Procerberus	*formicarum*	267	2.7	1.7	0.19	Insectivore	Bug Creek Anthills Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Surface, Screenwash	AMNH, UCMP catalogs; Sloan & Valen, 1965; Archibald, 1982; Lofgren, 1995
Protungulatum	*donnae*	88	3.92	3.01	1.03	Insectivore	Bug Creek Anthills Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Surface, Screenwash	AMNH, UCMP catalogs; Sloan & Valen, 1965; Archibald, 1982; Lofgren, 1995
Protungulatum	*gorgun*	3	4.36	3.16	1.36	Insectivore	Bug Creek Anthills Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Surface, Screenwash	AMNH, UCMP catalogs; Sloan & Valen, 1965; Archibald, 1982; Lofgren, 1995
Carcinodon	*simplex*	2	4.72	6	4.92	Carnivore	Camp's Skull	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Conacodon	*cophater*	3	3.1	2.4	0.45	Herbivore	Camp's Skull	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Conacodon	*entoconus*	1	5.75	6.75	8.63	Herbivore	Camp's Skull	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Conacodon	*kohlbergeri*	1	4.08	3.04	1.13	Herbivore	Camp's Skull	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Desmatoclaenus	*protogonioides*	1	6	4.7	4.88	Herbivore	Camp's Skull	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Hemithlaeus	*kowalevskianus*	1	4.88	4.07	2.61	Herbivore	Camp's Skull	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Mimatuta	*minuial*	1	3.92	2.84	0.93	Omnivore	Carrie Padgett	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Procerberus	*formicarum*	1	2.7	1.7	0.19	Insectivore	Carrie Padgett	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Carsioptychus	*coarctatus*	1	10	9	38.7	Herbivore	Carson Trading Post	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & siltstone	Meandering streambed	Quarry, Surface	NMMNHS catalog; Williamson, 1996
Desmatoclaenus	*dianae*	1	6	4.9	5.26	Herbivore	Carson Trading Post	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & siltstone	Meandering streambed	Quarry, Surface	NMMNHS catalog; Williamson, 1996
Desmatoclaenus	*protogonioides*	1	6	4.7	4.88	Herbivore	Carson Trading Post	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & siltstone	Meandering streambed	Quarry, Surface	NMMNHS catalog; Williamson, 1996
Gillisonchus	*gillianus*	1	4.14	3.09	1.19	Herbivore	Carson Trading Post	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & siltstone	Meandering streambed	Quarry, Surface	NMMNHS catalog; Williamson, 1996
Loxolophus	*hyattianus*	2	5.5	4.3	3.57	Omnivore	Carson Trading Post	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & siltstone	Meandering streambed	Quarry, Surface	NMMNHS catalog; Williamson, 1996
Loxolophus	*priscus*	1	6.55	5.24	6.93	Omnivore	Carson Trading Post	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & siltstone	Meandering streambed	Quarry, Surface	NMMNHS catalog; Williamson, 1996
Protogonodon	*pentacus*	1	9.19	7.76	25.55	Herbivore	Carson Trading Post	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & siltstone	Meandering streambed	Quarry, Surface	NMMNHS catalog; Williamson, 1996
Mimatuta	*morgoth*	1	3.96	2.94	1	Omnivore	Cat's Meow	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Oxyprimus	*erikseni*	2	3.3	2.17	0.42	Insectivore	Cat's Meow	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Protungulatum	*donnae*	1	3.92	3.01	1.03	Insectivore	Cat's Meow	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Protungulatum	*gorgun*	1	4.36	3.16	1.36	Insectivore	Cat's Meow	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Ragnarok	*nordicum*	3	5.2	4.16	3.04	Herbivore	Cat's Meow	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Carsioptychus	*coarctatus*	3	10	9	38.7	Herbivore	Chaco Canyon	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	AMNH catalog
Conacodon	*cophater*	1	3.1	2.4	0.45	Herbivore	Chaco Canyon	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	AMNH catalog
Conacodon	*entoconus*	3	5.75	6.75	8.63	Herbivore	Chaco Canyon	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	AMNH catalog
Ectoconus	*ditrigonus*	4	10.1	8.8	37.84	Herbivore	Chaco Canyon	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	AMNH catalog
Eoconodon	*gaudrianus*	2	7.34	5.24	8.49	Carnivore	Chaco Canyon	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	AMNH catalog
Gillisonchus	*gillianus*	3	4.14	3.09	1.19	Herbivore	Chaco Canyon	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	AMNH catalog
Hemithlaeus	*kowalevskianus*	1	4.88	4.07	2.61	Herbivore	Chaco Canyon	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	AMNH catalog
Ragnarok	*nordicum*	1	5.2	4.16	3.04	Herbivore	Constenius	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Ampliconus	*browni*	1	4.5	3.3	1.55	Herbivore	Corral Bluffs Fauna	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Quarry, Surface	DMNH, UCM, USNM catalog; Middleton, 1980; Eberle, 2003
Carsioptychus	*coarctatus*	40	10	9	38.7	Herbivore	Corral Bluffs Fauna	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Quarry, Surface	DMNH, UCM, USNM catalog; Middleton, 1980; Eberle, 2003
Conacodon	*delphae*	3	6.53	4.8	5.89	Herbivore	Corral Bluffs Fauna	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Quarry, Surface	DMNH, UCM, USNM catalog; Middleton, 1980; Eberle, 2003
Conacodon	*entoconus*	3	5.75	6.75	8.63	Herbivore	Corral Bluffs Fauna	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Quarry, Surface	DMNH, UCM, USNM catalog; Middleton, 1980; Eberle, 2003

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Desmatoclaenus	*protogonioides*	2	6	4.7	4.88	Herbivore	Corral Bluffs Fauna	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Quarry, Surface	DMNH, UCM, USNM catalog; Middleton, 1980; Eberle, 2003
Ectoconus	*ditrigonus*	5	10.1	8.8	37.84	Herbivore	Corral Bluffs Fauna	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Quarry, Surface	DMNH, UCM, USNM catalog; Middleton, 1980; Eberle, 2003
Loxolophus	*hyattianus*	6	5.5	4.3	3.57	Omnivore	Corral Bluffs Fauna	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine conglomeratic sandstone	Channel-point bar	Quarry, Surface	DMNH, UCM, USNM catalog; Middleton, 1980; Eberle, 2003
Carcinodon	*antiquus*	1	8.2	4.85	9.01	Carnivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carcinodon	*olearyi*	1	5.93	3.79	3.26	Carnivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carcinodon	*simplex*	6	4.72	6	4.92	Carnivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carsioptychus	*coarctatus*	16	10	9	38.7	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Choeroclaenus	*turgidunculus*	3	3.98	2.96	1.03	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Conacodon	*cophater*	3	3.1	2.4	0.45	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Conacodon	*entoconus*	11	5.75	6.75	8.63	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Desmatoclaenus	*protogonioides*	1	6	4.7	4.88	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Ectoconus	*ditrigonus*	9	10.1	8.8	37.84	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Eoconodon	*coryphaeus*	4	11	7.85	35.94	Carnivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Eoconodon	*gaudrianus*	2	7.34	5.24	8.49	Carnivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Fimbrethil	*agapetillus*	4	2.9	1.5	0.17	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Gillisonchus	*gillianus*	10	4.14	3.09	1.19	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Hemithlaeus	*kowalevskianus*	57	4.88	4.07	2.61	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Loxolophus	*hyattianus*	10	5.5	4.3	3.57	Omnivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Onychodectes	*tisonensis*	4	6.5	6.8	10.88	Omnivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Oxyacodon	*priscilla*	8	3.6	1.8	0.35	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Paradoxadonta	*ruetimeyeranus*	1	9.22	5.41	13.5	Omnivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Protogonodon	*pentacus*	1	9.19	7.76	25.55	Herbivore	De-na-zin Wash, Ectoconus Zone	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	fine sandstone & siltstone	channel?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Bomburodon	*priscus*	3	3.6	2.9	0.83	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carcinodon	*antiquus*	14	8.2	4.85	9.01	Carnivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carcinodon	*olearyi*	71	5.93	3.79	3.26	Carnivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carcinodon	*simplex*	30	4.72	6	4.92	Carnivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carsioptychus	*coarctatus*	49	10	9	38.7	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Choeroclaenus	*turgidunculus*	36	3.98	2.96	1.03	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Conacodon	*cophater*	14	3.1	2.4	0.45	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Conacodon	*entoconus*	6	5.75	6.75	8.63	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Ectoconus	*ditrigonus*	22	10.1	8.8	37.84	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Eoconodon	*coryphaeus*	62	11	7.85	35.94	Carnivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Eoconodon	*gaudrianus*	1	7.34	5.24	8.49	Carnivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Fimbrethil	*agapetillus*	2	2.9	1.5	0.17	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Gillisonchus	*gillianus*	56	4.14	3.09	1.19	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Hemithlaeus	*kowalevskianus*	4	4.88	4.07	2.61	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Loxolophus	*hyattianus*	52	5.5	4.3	3.57	Omnivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Loxolophus	*priscus*	42	6.55	5.24	6.93	Omnivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Onychodectes	*tisonensis*	19	6.5	6.8	10.88	Omnivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Oxyacodon	*apiculatus*	29	4.2	2.1	0.62	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Oxyacodon	*priscillla*	2	3.6	1.8	0.35	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Protogonodon	*pentacus*	66	9.19	7.76	25.55	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Puercolestes	*simpsoni*	2	3.6	2.2	0.51	Insectivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Tiznatzinia	*vanderhoofi*	6	3.2	2.9	0.67	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Wortmania	*otariidens*	1	8.5	7.35	20.18	Herbivore	De-na-zin Wash, Taeniolabis Zone	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Channel-point bar?	Quarry, Surface	AMNH, KUVP, NMMNHS, UCMP catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Ragnarok	*nordicum*	1	5.2	4.16	3.04	Herbivore	Deer Crash	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Silty sandstone & shale	Channel	Surface	Hunter et al., 1997
Carcinodon	*simplex*	1	4.72	6	4.92	Carnivore	Denver Oxyclaenodon Site	Denver	Colorado	Pu1	Denver (Golden Mbr.)	fine claystone	Lignite bed	Quarry?	DMNH catalog; Eberle, 2003
Bomburodon	*priscus*	2	3.6	2.9	0.83	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carcinodon	*simplex*	4	4.72	6	4.92	Carnivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Carsioptychus	*coarctatus*	12	10	9	38.7	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Choeroclaenus	*turgidunculus*	1	3.98	2.96	1.03	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Conacodon	*cophater*	13	3.1	2.4	0.45	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Conacodon	*entoconus*	22	5.75	6.75	8.63	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Conacodon	*kohlbergeri*	4	4.08	3.04	1.13	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Desmatoclaenus	*protogonioides*	2	6	4.7	4.88	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Ectoconus	*ditrigonus*	18	10.1	8.8	37.84	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Eoconodon	*coryphaeus*	4	11	7.85	35.94	Carnivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Eoconodon	*gaudrianus*	1	7.34	5.24	8.49	Carnivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Fimbrethil	*agapetillus*	2	2.9	1.5	0.17	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Gillisonchus	*gillianus*	19	4.14	3.09	1.19	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Hemithlaeus	*kowalevskianus*	22	4.88	4.07	2.61	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Loxolophus	*hyattianus*	6	5.5	4.3	3.57	Omnivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Loxolophus	*priscus*	1	6.55	5.24	6.93	Omnivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Onychodectes	*tisonensis*	2	6.5	6.8	10.88	Omnivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Oxyacodon	*apiculatus*	1	4.2	2.1	0.62	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Oxyacodon	*priscilla*	7	3.6	1.8	0.35	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Protogonodon	*kimbetovius*	1	9.67	8.04	29.8	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Wortmania	*otariidens*	1	8.5	7.35	20.18	Herbivore	East Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Fine mudstone & silty sandstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS, USNM catalogs; Matthew, 1937; Sloan, 1987; Williamson, 1996
Oxyacodon	*ferronensis*	1	3.38	1.65	0.27	Herbivore	Engdahl Ranch	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	LACM catalog
Prodiacodon	*crustulum*	1	2.69	1.79	0.21	Insectivore	Engdahl Ranch	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	LACM catalog
Purgatorius	*unio*	2	2.1	1.5	0.1	Insectivore	Engdahl Ranch	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	LACM catalog
Conacodon	*delphae*	1	6.53	4.8	5.89	Herbivore	Ferris Main Section Pu1 Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Fine sandstone with siltstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Conacodon	*harbourae*	2	4.85	2.43	1.03	Herbivore	Ferris Main Section Pu1 Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Fine sandstone & siltstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Fimbrethil	*agapetillus*	3	2.9	1.5	0.17	Herbivore	Ferris Main Section Pu1 Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Fine sandstone with siltstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Gillisonchus	*gillianus*	1	4.14	3.09	1.19	Herbivore	Ferris Main Section Pu1 Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Fine sandstone with siltstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Maiorana	*ferrisensis*	1	4.18	2.11	0.61	Omnivore	Ferris Main Section Pu1 Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Fine sandstone with siltstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Protungulatum	*donnae*	5	3.92	3.01	1.03	Insectivore	Ferris Main Section Pu1 Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Fine sandstone with siltstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Protungulatum	*gorgun*	2	4.36	3.16	1.36	Insectivore	Ferris Main Section Pu1 Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Fine sandstone with siltstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Ampliconus	*browni*	1	4.5	3.3	1.55	Herbivore	Ferris Main Section Pu2 Fauna	Hanna	Wyoming	Pu2	Ferris (Upper Mbr.)	Fine to medium conglomeratic sandstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Carsioptychus	*coarctatus*	2	10	9	38.7	Herbivore	Ferris Main Section Pu2 Fauna	Hanna	Wyoming	Pu2	Ferris (Upper Mbr.)	Fine to medium conglomeratic sandstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Conacodon	*cophater*	1	3.1	2.4	0.45	Herbivore	Ferris Main Section Pu2 Fauna	Hanna	Wyoming	Pu2	Ferris (Upper Mbr.)	Fine to medium conglomeratic sandstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Deuterogonodon	*faulkneri*	3	n/a	n/a	n/a	Herbivore	Ferris Main Section Pu2 Fauna	Hanna	Wyoming	Pu2	Ferris (Upper Mbr.)	Fine to medium conglomeratic sandstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Ectoconus	*ditrigonus*	1	10.1	8.8	37.84	Herbivore	Ferris Main Section Pu2 Fauna	Hanna	Wyoming	Pu2	Ferris (Upper Mbr.)	Fine to medium conglomeratic sandstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Gillisonchus	*gillianus*	5	4.14	3.09	1.19	Herbivore	Ferris Main Section Pu2 Fauna	Hanna	Wyoming	Pu2	Ferris (Upper Mbr.)	Fine to medium conglomeratic sandstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Oxyacodon	*priscilla*	1	3.6	1.8	0.35	Herbivore	Ferris Main Section Pu2 Fauna	Hanna	Wyoming	Pu2	Ferris (Upper Mbr.)	Fine to medium conglomeratic sandstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Valenia	*wilsoni*	1	3.14	2.57	0.52	Herbivore	Ferris Main Section Pu2 Fauna	Hanna	Wyoming	Pu2	Ferris (Upper Mbr.)	Fine to medium conglomeratic sandstone	Channel	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Carsioptychus	*coarctatus*	4	10	9	38.7	Herbivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Conacodon	*cophater*	1	3.1	2.4	0.45	Herbivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Ectoconus	*ditrigonus*	1	10.1	8.8	37.84	Herbivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Gillisonchus	*gillianus*	3	4.14	3.09	1.19	Herbivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Loxolophus	*hyattianus*	1	5.5	4.3	3.57	Omnivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Loxolophus	*priscus*	1	6.55	5.24	6.93	Omnivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Oxyacodon	*apiculatus*	1	4.2	2.1	0.62	Herbivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Oxyacodon	*priscilla*	1	3.6	1.8	0.35	Herbivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Protungulatum	*donnae*	1	3.92	3.01	1.03	Insectivore	Ferris Main Section Pu3 Fauna	Hanna	Wyoming	Pu3	Ferris (Upper Mbr.)	Fine sandstone with mudstone and siltstone	Lacrustrine-deltaic?	Surface, Screenwash	Eberle & Lillegraven, 1998a&b
Eoconodon	*hutchisoni*	31	9.28	6.09	16.87	Carnivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Eoconodon	*nidhoggi*	12	6.9	4.6	6.03	Omnivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Mithrandir	*oligistus*	6	3.75	2.59	0.73	Herbivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Oxyacodon	*ferronensis*	4	3.38	1.65	0.27	Herbivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Procerberus	*formicarum*	3	2.7	1.7	0.19	Insectivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Prodiacodon	*crustulum*	71	2.69	1.79	0.21	Insectivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Protungulatum	*sloani*	33	3.6	2.8	0.78	Insectivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Puercolestes	*simpsoni*	3	3.6	2.2	0.51	Insectivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Purgatorius	*janisae*	140	1.93	1.2	0.056	Insectivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Purgatorius	*unio*	451	2.1	1.5	0.1	Insectivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Thangorodrim	*thalion*	5	7.09	5.64	9.1	Omnivore	Garbani Channel Local Fauna	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone with coal seams	Channel-point bar, lignite bed	Screenwash	UCMP catalog; Clemens, 2011; Chester et al., 2015
Anisonchus	*athelas*	3	4.3	2.9	1.14	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Carsioptychus	*coarctatus*	6	10	9	38.7	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Conacodon	*kohlbergeri*	1	4.08	3.04	1.13	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Desmatoclaenus	*hermaeus*	3	8.28	6.94	17.38	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Ectoconus	*ditrigonus*	10	10.1	8.8	37.84	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Ectoconus	*symbolus*	6	8.65	8.03	24.38	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Gillisonchus	*onostus*	1	4.3	2.9	1.14	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Haploconus	*elachistus*	1	3.8	2.8	0.86	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Litaletes	*gazinensis*	1	n/a	n/a	n/a	Insectivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Loxolophus	*priscus*	2	6.55	5.24	6.93	Omnivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Oxyacodon	*ferronensis*	1	3.38	1.65	0.27	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Protogonodon	*pentacus*	4	9.19	7.76	25.55	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Valenia	*wilsoni*	1	3.14	2.57	0.52	Herbivore	Gas Tank Hill Local Fauna	Paradox	Utah	Pu2	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	Robinson, 1986; Lofgren et al., 2005 & 2012
Carcinodon	*subbituminus*	1	3.63	2.65	0.72	Carnivore	Great Divide Quarry Fauna	Great Divide	Wyoming	Pu1	China Butte	Medium to coarse conglomeratic sandstone with clay and coal seams	Channel, Lignite bed	Quarry, Screenwash	UCM catalog; McComas & Eberle, 2016
Conacodon	*harbourae*	5	4.85	2.43	1.03	Herbivore	Great Divide Quarry Fauna	Great Divide	Wyoming	Pu1	China Butte	Medium to coarse conglomeratic sandstone with clay and coal seams	Channel, Lignite bed	Quarry, Screenwash	UCM catalog; McComas & Eberle, 2016
Oxyprimus	*galadrielae*	5	3.23	2.26	0.44	Insectivore	Great Divide Quarry Fauna	Great Divide	Wyoming	Pu1	China Butte	Medium to coarse conglomeratic sandstone with clay and coal seams	Channel, Lignite bed	Quarry, Screenwash	UCM catalog; McComas & Eberle, 2016
Protungulatum	*donnae*	5	3.92	3.01	1.03	Insectivore	Great Divide Quarry Fauna	Great Divide	Wyoming	Pu1	China Butte	Medium to coarse conglomeratic sandstone with clay and coal seams	Channel, Lignite bed	Quarry, Screenwash	UCM catalog; McComas & Eberle, 2016

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Sigynorum	*magnadivisus*	14	3	2.28	0.39	Insectivore	Great Divide Quarry Fauna	Great Divide	Wyoming	Pu1	China Butte	Medium to coarse conglomeratic sandstone with clay and coal seams	Channel, Lignite bed	Quarry, Screenwash	UCM catalog; McComas & Eberle, 2016
Mimatuta	*morgoth*	3	3.96	2.94	1	Omnivore	Harbicht Hill	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone?	Channel fill?	Surface, Screenwash	AMNH, UMVP catalog; Van Valen & Sloan, 1965; Valen, 1978; Archibald, 1982
Oxyprimus	*erikseni*	4	3.3	2.17	0.42	Insectivore	Harbicht Hill	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone?	Channel fill?	Surface, Screenwash	AMNH, UMVP catalog; Van Valen & Sloan, 1965; Valen, 1978; Archibald, 1982
Procerberus	*formicarum*	12	2.7	1.7	0.19	Insectivore	Harbicht Hill	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone?	Channel fill?	Surface, Screenwash	AMNH, UMVP catalog; Van Valen & Sloan, 1965; Valen, 1978; Archibald, 1982
Protungulatum	*donnae*	10	3.92	3.01	1.03	Insectivore	Harbicht Hill	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone?	Channel fill?	Surface, Screenwash	AMNH, UMVP catalog; Van Valen & Sloan, 1965; Valen, 1978; Archibald, 1982
Protungulatum	*gorgun*	2	4.36	3.16	1.36	Insectivore	Harbicht Hill	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone?	Channel fill?	Surface, Screenwash	AMNH, UMVP catalog; Van Valen & Sloan, 1965; Valen, 1978; Archibald, 1982
Purgatorius	*ceratops*	2	n/a	n/a	n/a	Insectivore	Harbicht Hill	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone?	Channel fill?	Surface, Screenwash	AMNH, UMVP catalog; Van Valen & Sloan, 1965; Valen, 1978; Archibald, 1982
Ragnarok	*nordicum*	3	5.2	4.16	3.04	Herbivore	Harbicht Hill	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone?	Channel fill?	Surface, Screenwash	AMNH, UMVP catalog; Van Valen & Sloan, 1965; Valen, 1978; Archibald, 1982
Procerberus	*grandis*	1	5.6	3.5	2.55	Insectivore	Harley's Palate	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Mimatuta	*morgoth*	1	3.96	2.94	1	Omnivore	Hell's Hollow Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Oxyprimus	*erikseni*	1	3.3	2.17	0.42	Insectivore	Hell's Hollow Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Procerberus	*formicarum*	2	2.7	1.7	0.19	Insectivore	Hell's Hollow Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	7	5.2	4.16	3.04	Herbivore	Hell's Hollow Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	1	5.2	4.16	3.04	Herbivore	Herpijunk Promontory	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Eoconodon	*nidhoggi*	1	6.9	4.6	6.03	Omnivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Conglomeratic sandstone	Channel	Surface, Screenwash	Hunter et al., 1997
Loxolophus	*schizophrenus*	1	4.63	3.28	1.62	Omnivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Conglomeratic sandstone	Channel	Surface, Screenwash	Hunter et al., 1997
Oxyacodon	*apiculatus*	2	4.2	2.1	0.62	Herbivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Conglomeratic sandstone	Channel	Surface, Screenwash	Hunter et al., 1997
Oxyacodon	*ferronensis*	2	3.38	1.65	0.27	Herbivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Silty sandstone & shale	Channel	Surface, Screenwash	Hunter et al., 1997
Oxyacodon	*ferronensis*	1	3.38	1.65	0.27	Herbivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Conglomeratic sandstone	Channel	Surface, Screenwash	Hunter et al., 1997
Ragnarok	*nordicum*	1	5.2	4.16	3.04	Herbivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Silty sandstone & shale	Channel	Surface, Screenwash	Hunter et al., 1997
Ragnarok	*nordicum*	14	5.2	4.16	3.04	Herbivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Conglomeratic sandstone	Channel	Surface, Screenwash	Hunter et al., 1997
Tinuviel	*eurydice*	7	n/a	n/a	n/a	Herbivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Silty sandstone & shale	Channel	Surface, Screenwash	Hunter et al., 1997
Tinuviel	*eurydice*	5	n/a	n/a	n/a	Herbivore	Hiatt Local Fauna	Williston	Montana	Pu2	Ludlow (Shadehill Facies Mbr.)?	Conglomeratic sandstone	Channel	Surface, Screenwash	Hunter et al., 1997
Ragnarok	*nordicum*	1	5.2	4.16	3.04	Herbivore	Ja Place	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Protungulatum	*donnae*	1	3.92	3.01	1.03	Insectivore	James Place	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Eoconodon	*hutchisoni*	1	9.28	6.09	16.87	Carnivore	Kerr Butte	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Puercolestes	*simpsoni*	1	3.6	2.2	0.51	Insectivore	Kerr Butte	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Paleoungulatum	*hooleyi*	11	3.58	2.59	0.67	Herbivore	Lane's Little Jaw Site Quarry	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Claystone with conglomeratic sandstone	Floodplain mudflat with channel fill	Quarry?	LACM catalog; Kelly, 2014
Ragnarok	*nordicum*	8	5.2	4.16	3.04	Herbivore	Lane's Little Jaw Site Quarry	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Claystone with conglomeratic sandstone	Floodplain mudflat with channel fill	Quarry?	LACM catalog; Kelly, 2014
Mimatuta	*makpialutae*	1	3.9	2.85	0.93	Omnivore	Leidy Quarry	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry?	YPM catalog; Van Valen, 1978
Ragnarok	*nordicum*	1	5.2	4.16	3.04	Herbivore	Leidy Quarry	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry?	YPM catalog; Van Valen, 1978
Gypsonictops	*illuminatus*	2	2.41	1.87	0.19	Omnivore	Little Roundtop Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Mimatuta	*morgoth*	4	3.96	2.94	1	Omnivore	Little Roundtop Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Oxyprimus	*erikseni*	7	3.3	2.17	0.42	Insectivore	Little Roundtop Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Procerberus	*formicarum*	10	2.7	1.7	0.19	Insectivore	Little Roundtop Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*donnae*	6	3.92	3.01	1.03	Insectivore	Little Roundtop Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*gorgun*	2	4.36	3.16	1.36	Insectivore	Little Roundtop Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Conacodon	*cophater*	1	3.1	2.4	0.45	Herbivore	Malcom's Extension	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Conacodon	*entoconus*	2	5.75	6.75	8.63	Herbivore	Malcom's Extension	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Ectoconus	*ditrigonus*	2	10.1	8.8	37.84	Herbivore	Malcom's Extension	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Fimbrethil	*agapetillus*	1	2.9	1.5	0.17	Herbivore	Malcom's Extension	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Hemithlaeus	*kowalevskianus*	1	4.88	4.07	2.61	Herbivore	Malcom's Extension	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog
Earendil	*undomiel*	5	n/a	n/a	n/a	Herbivore	Mantua Lentil Fauna	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry	YPM, UCMP catalog; Van Valen, 1978; Gingerich et al., 1980
Eoconodon	*copanus*	2	10.4	5.5	17.24	Carnivore	Mantua Lentil Fauna	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry	YPM, UCMP catalog; Van Valen, 1978; Gingerich et al., 1980

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Maiorana	*noctiluca*	28	3.45	2.4	0.55	Omnivore	Mantua Lentil Fauna	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry	YPM, UCMP catalog; Van Valen, 1978; Gingerich et al., 1980
Mimatuta	*minuial*	87	3.92	2.84	0.93	Omnivore	Mantua Lentil Fauna	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry	YPM, UCMP catalog; Van Valen, 1978; Gingerich et al., 1980
Oxyacodon	*josephi*	5	3.1	2.1	0.36	Herbivore	Mantua Lentil Fauna	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry	YPM, UCMP catalog; Van Valen, 1978; Gingerich et al., 1980
Oxyprimus	*galadrielae*	40	3.23	2.26	0.44	Insectivore	Mantua Lentil Fauna	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry	YPM, UCMP catalog; Van Valen, 1978; Gingerich et al., 1980
Oxyprimus	*putorius*	5	n/a	n/a		Insectivore	Mantua Lentil Fauna	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry	YPM, UCMP catalog; Van Valen, 1978; Gingerich et al., 1980
Ragnarok	*nordicum*	72	5.2	4.16	3.04	Herbivore	Mantua Lentil Fauna	Bighorn	Wyoming	Pu1	Polecat Bench ("Mantua Lentil Mbr.")	medium sandstone	channel	Quarry	YPM, UCMP catalog; Van Valen, 1978; Gingerich et al., 1980
Eoconodon	*nidhoggi*	1	6.9	4.6	6.03	Omnivore	McKeever Ranch Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Quarry, Screenwash	UCMP catalog; Archibald, 1982
Mimatuta	*minuial*	6	3.92	2.84	0.93	Omnivore	McKeever Ranch Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Quarry, Screenwash	UCMP catalog; Archibald, 1982
Procerberus	*formicarum*	4	2.7	1.7	0.19	Insectivore	McKeever Ranch Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Quarry, Screenwash	UCMP catalog; Archibald, 1982
Protungulatum	*donnae*	7	3.92	3.01	1.03	Insectivore	McKeever Ranch Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone near coal seam	Channel fill, lignite bed	Quarry, Screenwash	UCMP catalog; Archibald, 1982
Alveugena	*carbonensis*	1	5.75	3.7	2.95	Omnivore	Merle's Mecca	Williston	North Dakota	Pu2	Ludlow (Shadehill Facies Mbr.)	Fine to medium sandstone	Channel	Surface	Rook et al., 2010
Carcinodon	*aquilonius*	1	4.2	2.8	1.03	Carnivore	MHBT Long Fall Fauna	Williston	Saskatchewan	Pu1	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Gypsonictops	*illuminatus*	5	2.41	1.87	0.19	Omnivore	MHBT Long Fall Fauna	Williston	Saskatchewan	Pu1	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Oxyprimus	*erikseni*	1	3.3	2.17	0.42	Insectivore	MHBT Long Fall Fauna	Williston	Saskatchewan	Pu1	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Procerberus	*formicarum*	3	2.7	1.7	0.19	Insectivore	MHBT Long Fall Fauna	Williston	Saskatchewan	Pu1	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Protungulatum	*donnae*	5	3.92	3.01	1.03	Insectivore	MHBT Long Fall Fauna	Williston	Saskatchewan	Pu1	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Baioconodon	*denverensis*	7	6.62	5.39	7.43	Herbivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Bubogonia	*saskia*	5	n/a	n/a	n/a	Herbivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Carcinodon	*aquilonius*	12	4.2	2.8	1.03	Carnivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Carcinodon	*corax*	23	4.85	3.6	2.08	Carnivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Carcinodon	*simplex*	6	4.72	6	4.92	Carnivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Litomylus	*orthronepius*	13	3.05	2	0.32	Insectivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Loxolophus	*schizophrenus*	12	4.63	3.28	1.62	Omnivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Mithrandir	*oligistus*	5	3.75	2.59	0.73	Herbivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Purgatorius	*coracis*	31	1.81	1.28	0.057	Insectivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Ravenictis	*krausei*	1	n/a	n/a	n/a	Carnivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Tricentes	*calenancus*	1	5.5	4.5	3.87	Herbivore	MHBT RAV-W1 Fauna	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium silty sandstone with clay	Channel fill, Overbank deposits	Screenwash	UALVP, UCMP catalog; Johnston & Fox, 1984; Fox, 1990
Protungulatum	*gorgun*	1	4.36	3.16	1.36	Insectivore	Muddy Mess	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Conacodon	*harbourae*	1	4.85	2.43	1.03	Herbivore	Near Arapahoe, Colorado	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	n/a	n/a	Surface?	UCM catalog
Maiorana	*noctiluca*	1	3.45	2.4	0.55	Omnivore	Near Fairfield, Montana	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCM catalog
Mimatuta	*minuial*	2	3.92	2.84	0.93	Omnivore	Near Fairfield, Montana	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCM catalog
Oxyprimus	*galadrielae*	1	3.23	2.26	0.44	Insectivore	Near Fairfield, Montana	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCM catalog
Protungulatum	*donnae*	1	3.92	3.01	1.03	Insectivore	Nicole's Mammal Jaw locality	Denver	Colorado	Pu1	Denver (Golden Mbr.)	?	?	Surface?	DMNH catalog; Eberle, 2003
Carcinodon	*aquilonius*	1	4.2	2.8	1.03	Carnivore	Pine Cree Park	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium sandstone & shale	Channel point-bar?, Overbank deposits	Surface, Screenwash	Russell, 1974; Scott et al., 2016
Purgatorius	*pinecreeensis*	6	1.75	1.23	0.049	Insectivore	Pine Cree Park	Williston	Saskatchewan	Pu2	Ravenscrag (lower Mbr.)	Fine to medium sandstone & shale	Channel point-bar?, Overbank deposits	Surface, Screenwash	Russell, 1974; Scott et al., 2016
Eoconodon	*nidhoggi*	3	6.9	4.6	6.03	Omnivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Gillisonchus	*gillianus*	1	4.14	3.09	1.19	Herbivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Haplaletes	*andakupensis*	2	n/a	n/a	n/a	Insectivore?	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Leptacodon?	*proserpinae*	5	n/a	n/a	n/a	Insectivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Mithrandir	*oligistus*	11	3.75	2.59	0.73	Herbivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Pandemonium	*dis*	23	2.58	2.01	0.24	Insectivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Procerberus	*plutonis*	7	n/a	n/a	n/a	Insectivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Protungulatum	*sloani*	3	3.6	2.8	0.78	Insectivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Purgatorius	*unio*	23	2.1	1.5	0.1	Insectivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Thangorodrim	*thalion*	6	7.09	5.64	9.1	Omnivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Tinuviel	*eurydice*	2	n/a	n/a	n/a	Herbivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Tricentes	*calenancus*	2	5.5	4.5	3.87	Herbivore	Purgatory Hill	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Surface, Screenwash	UMVP catalog; Van Valen & Sloan, 1965; Van Valen, 1978; Archibald, 1982; Van Valen, 1994
Prothryptacodon	*albertensis*	1	4.2	2.8	1.03	Omnivore	RC Core Hole 66-1	Alberta	Alberta	Pu2/Pu3	Scollard (Upper Mbr.)	siltstone	Meandering streambed?	Drillcore	UALVP catalog; Fox, 1968 & 1990
Ragnarok	*nordicum*	1	5.2	4.16	3.04	Herbivore	Rick's Place	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash?	UCMP catalog
Pandemonium	*hibernalis*	2	2.7	2.25	0.32	Insectivore	Schowalter	Alberta	Alberta	Pu2	Scollard (Upper Mbr.)	fine sandstone & siltstone	Meandering streambed	Screenwash?	UALVP catalog; Fox et al., 2014
Batodon	*tenuis*	1	1.18	0.7	0.009	Insectivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Gypsonictops	*illuminatus*	4	2.41	1.87	0.19	Omnivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Mimatuta	*minuial*	1	3.92	2.84	0.93	Omnivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Mimatuta	*morgoth*	6	3.96	2.94	1	Omnivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Oxyprimus	*erikseni*	17	3.3	2.17	0.42	Insectivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Procerberus	*formicarum*	30	2.7	1.7	0.19	Insectivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*donnae*	9	3.92	3.01	1.03	Insectivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*gorgun*	6	4.36	3.16	1.36	Insectivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	11	5.2	4.16	3.04	Herbivore	Second Level Channel Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill	Screenwash	UCMP catalog; Lofgren, 1995
Batodon	*tenuis*	1	1.18	0.7	0.009	Insectivore	Shiprock Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine mudstone & siltstone	Floodplain mudflat with paleosols	Screenwash	UCMP catalog; Lofgren, 1995
Gypsonictops	*hypoconus*	1	2.1	2.9	0.32	Omnivore	Shiprock Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine mudstone & siltstone	Floodplain mudflat with paleosols	Screenwash	UCMP catalog; Lofgren, 1995
Gypsonictops	*illuminatus*	3	2.41	1.87	0.19	Omnivore	Shiprock Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine mudstone & siltstone	Floodplain mudflat with paleosols	Screenwash	UCMP catalog; Lofgren, 1995
Oxyprimus	*erikseni*	7	3.3	2.17	0.42	Insectivore	Shiprock Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine mudstone & siltstone	Floodplain mudflat with paleosols	Screenwash	UCMP catalog; Lofgren, 1995
Procerberus	*formicarum*	25	2.7	1.7	0.19	Insectivore	Shiprock Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine mudstone & siltstone	Floodplain mudflat with paleosols	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*gorgun*	1	4.36	3.16	1.36	Insectivore	Shiprock Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine mudstone & siltstone	Floodplain mudflat with paleosols	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	5	5.2	4.16	3.04	Herbivore	Shiprock Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine mudstone & siltstone	Floodplain mudflat with paleosols	Screenwash	UCMP catalog; Lofgren, 1995
Baioconodon	*denverensis*	6	6.62	5.39	7.43	Herbivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Carcinodon	*aquilonius*	11	4.2	2.8	1.03	Carnivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Carcinodon	*corax*	14	4.85	3.6	2.08	Carnivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Conacodon	*kohlbergeri*	14	4.08	3.04	1.13	Herbivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Eoconodon	*nidhoggi*	3	6.9	4.6	6.03	Omnivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Litomylus	*orthronepius*	2	3.05	2	0.32	Insectivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Loxolophus	*schizophrenus*	1	4.63	3.28	1.62	Omnivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Oxyacodon	*archibaldi*	2	3.4	3.9	1.27	Herbivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Protogonodon	*pentacus*	2	9.19	7.76	25.55	Herbivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Protogonodon	*pentacus*	3	9.19	7.76	25.55	Herbivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Protungulatum	*sloani*	2	3.6	2.8	0.78	Insectivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Purgatorius	*titusi*	43	1.03	1.3	0.022	Insectivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Tricentes	*calenancus*	1	5.5	4.5	3.87	Herbivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Ursolestes	*perpetior*	14	4.35	3.43	1.57	Insectivore	Simpson Quarry	Crazy Mountain	Montana	Pu2	Bear (Upper Mbr.)	Mudstone & siltstone	Lacustrine-deltaic	Quarry, Screenwash	Buckley, 1994
Ampliconus	*browni*	1	4.5	3.3	1.55	Herbivore	South Table Mountain Local Fauna	Denver	Colorado	Pu1	Denver (Golden Mbr.)	fine sandstone & siltone	Meandering streambed	Surface	DMNH, UCM, USNM catalogs; Eberle, 2003; Dalhberg et al., 2016
Baioconodon	*denverensis*	8	6.62	5.39	7.43	Herbivore	South Table Mountain Local Fauna	Denver	Colorado	Pu1	Denver (Golden Mbr.)	fine sandstone & siltone	Meandering streambed	Surface	DMNH, UCM, USNM catalogs; Eberle, 2003; Dalhberg et al., 2016
Baioconodon	*jeffersonensis*	1	6	3	2.19	Herbivore	South Table Mountain Local Fauna	Denver	Colorado	Pu1	Denver (Golden Mbr.)	fine sandstone & siltone	Meandering streambed	Surface	DMNH, UCM, USNM catalogs; Eberle, 2003; Dalhberg et al., 2016
Carcinodon	*simplex*	1	4.72	6	4.92	Carnivore	South Table Mountain Local Fauna	Denver	Colorado	Pu1	Denver (Golden Mbr.)	fine sandstone & siltone	Meandering streambed	Surface	DMNH, UCM, USNM catalogs; Eberle, 2003; Dalhberg et al., 2016
Procerberus	*andesiticus*	1	2.48	1.44	0.12	Insectivore	South Table Mountain Local Fauna	Denver	Colorado	Pu1	Denver (Golden Mbr.)	fine sandstone & siltone	Meandering streambed	Surface	DMNH, UCM, USNM catalogs; Eberle, 2003; Dalhberg et al., 2016
Procerberus	*grandis*	1	5.6	3.5	2.55	Insectivore	South Table Mountain Local Fauna	Denver	Colorado	Pu1	Denver (Golden Mbr.)	fine sandstone & siltone	Meandering streambed	Surface	DMNH, UCM, USNM catalogs; Eberle, 2003; Dalhberg et al., 2016

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Betonnia	*tsosia*	4	2.4	1.6	0.14	Insectivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Bomburodon	*priscus*	2	3.6	2.9	0.83	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Carcinodon	*olearyi*	2	5.93	3.79	3.26	Carnivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Carsioptychus	*coarctatus*	5	10	9	38.7	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Chacomylus	*sladei*	9	n/a	n/a	n/a	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Choeroclaenus	*turgidunculus*	7	3.98	2.96	1.03	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Conacodon	*kohlbergeri*	3	4.08	3.04	1.13	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Fimbrethil	*agapetillus*	3	2.9	1.5	0.17	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Gillisonchus	*gillianus*	2	4.14	3.09	1.19	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Loxolophus	*hyattianus*	1	5.5	4.3	3.57	Omnivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Loxolophus	*priscus*	3	6.55	5.24	6.93	Omnivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Onychodectes	*tisonensis*	1	6.5	6.8	10.88	Omnivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Oxyacodon	*apiculatus*	1	4.2	2.1	0.62	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Protogonodon	*pentacus*	3	9.19	7.76	25.55	Herbivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Puercolestes	*simpsoni*	12	3.6	2.2	0.51	Insectivore	Split Lip Flats Local Fauna	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	Medium to coarse conglomeratic sandstone with clay	Channel	Screenwash	NMMNHS catalog; Williamson et al., 2011; Williamson & Weil, 2002 & 2011
Mimatuta	*morgoth*	1	3.96	2.94	1	Omnivore	Three Buttes Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Oxyprimus	*erikseni*	1	3.3	2.17	0.42	Insectivore	Three Buttes Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*donnae*	2	3.92	3.01	1.03	Insectivore	Three Buttes Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*gorgun*	2	4.36	3.16	1.36	Insectivore	Three Buttes Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	4	5.2	4.16	3.04	Herbivore	Three Buttes Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Carcinodon	*olearyi*	1	5.93	3.79	3.26	Carnivore	Three Gulleys Over	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog; Lofgren, 1995
Carsioptychus	*coarctatus*	2	10	9	38.7	Herbivore	Three Gulleys Over	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog; Lofgren, 1995
Eoconodon	*coryphaeus*	1	11	7.85	35.94	Carnivore	Three Gulleys Over	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog; Lofgren, 1995
Oxyacodon	*apiculatus*	1	4.2	2.1	0.62	Herbivore	Three Gulleys Over	San Juan	New Mexico	Pu3	Nacimiento (lower Arroyo Chijuillita Mbr.)	?	?	Surface?	UCMP catalog; Lofgren, 1995
Batodon	*tenuis*	2	1.18	0.7	0.009	Insectivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Gypsonictops	*illuminatus*	6	2.41	1.87	0.19	Omnivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Mimatuta	*minuial*	2	3.92	2.84	0.93	Omnivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Mimatuta	*morgoth*	3	3.96	2.94	1	Omnivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Oxyprimus	*erikseni*	5	3.3	2.17	0.42	Insectivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Procerberus	*formicarum*	47	2.7	1.7	0.19	Insectivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*donnae*	11	3.92	3.01	1.03	Insectivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*gorgun*	9	4.36	3.16	1.36	Insectivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	12	5.2	4.16	3.04	Herbivore	Up-Up-the-Creek Local Fauna	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	Fine to medium sandstone & siltstone	Channel fill?	Screenwash	UCMP catalog; Lofgren, 1995
Anisonchus	*athelas*	1	4.3	2.9	1.14	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Anisonchus	*sectorius*	1	5.47	3.88	2.94	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Carsioptychus	*coarctatus*	5	10	9	38.7	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Conacodon	*entoconus*	2	5.75	6.75	8.63	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Conacodon	*kohlbergeri*	1	4.08	3.04	1.13	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Desmatoclaenus	*hermaeus*	6	8.28	6.94	17.38	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Ectoconus	*ditrigonus*	1	10.1	8.8	37.84	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Ectoconus	*symbolus*	4	8.65	8.03	24.38	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Goniacodon	*hiawathiae*	2	n/a	n/a	n/a	Carnivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Haploconus	*elachistus*	4	3.8	2.8	0.86	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Mithrandir	*oligistus*	4	3.75	2.59	0.73	Herbivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Onychodectes	*tisonensis*	1	6.5	6.8	10.88	Omnivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Oxyacodon	*marshater*	1	n/a	n/a		Omnivore	Wagonroad Local Fauna	Paradox	Utah	Pu3	North Horn (Joe's Valley Mbr., Unit 2B)	Mudstone & siltstone	Floodplain mudflat, Lacustrine-deltaic?	Surface, Screenwash	AMNH, UCMP, USNM, OMNH catalogs; Robinson, 1986; Ciffeli et al., 1995; Lofgren, et al., 2005 & 2012
Anisonchus	*athelas*	3	4.3	2.9	1.14	Herbivore	West Bijou Creek	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine claystone	Lignite bed	Surface?	UCM catalog; Middleton, 1980; Eberle, 2003
Carcinodon	*simplex*	2	4.72	6	4.92	Carnivore	West Bijou Creek	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine claystone	Lignite bed	Surface?	UCM catalog; Middleton, 1980; Eberle, 2003
Carsioptychus	*coarctatus*	10	10	9	38.7	Herbivore	West Bijou Creek	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine claystone	Lignite bed	Surface?	UCM catalog; Middleton, 1980; Eberle, 2003
Desmatoclaenus	*protogonioides*	1	6	4.7	4.88	Herbivore	West Bijou Creek	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine claystone	Lignite bed	Surface?	UCM catalog; Middleton, 1980; Eberle, 2003
Ectoconus	*ditrigonus*	2	10.1	8.8	37.84	Herbivore	West Bijou Creek	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine claystone	Lignite bed	Surface?	UCM catalog; Middleton, 1980; Eberle, 2003
Loxolophus	*hyattianus*	1	5.5	4.3	3.57	Omnivore	West Bijou Creek	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	fine claystone	Lignite bed	Surface?	UCM catalog; Middleton, 1980; Eberle, 2003
Protungulatum	*donnae*	3	3.92	3.01	1.03	Insectivore	West Bijou Gars Galore	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	Medium to coarse sandstone with clay	Channel	Quarry, Screenwash	Dalhberg et al., 2016
Ragnarok	*nordicum*	1	5.2	4.16	3.04	Herbivore	West Bijou Gars Galore	Denver	Colorado	Pu2/Pu3	Denver (Golden Mbr.)	Medium to coarse sandstone with clay	Channel	Quarry, Screenwash	Dalhberg et al., 2016
Carcinodon	*simplex*	2	4.72	6	4.92	Carnivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Carsioptychus	*coarctatus*	7	10	9	38.7	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Choeroclaenus	*turgidunculus*	1	3.98	2.96	1.03	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Conacodon	*cophater*	3	3.1	2.4	0.45	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Conacodon	*entoconus*	17	5.75	6.75	8.63	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Desmatoclaenus	*protogonioides*	1	6	4.7	4.88	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Ectoconus	*ditrigonus*	17	10.1	8.8	37.84	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Eoconodon	*coryphaeus*	3	11	7.85	35.94	Carnivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Eoconodon	*gaudrianus*	1	7.34	5.24	8.49	Carnivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Gillisonchus	*gillianus*	4	4.14	3.09	1.19	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Hemithlaeus	*kowalevskianus*	1	4.88	4.07	2.61	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Hemithlaeus	*kowalevskianus*	4	4.88	4.07	2.61	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Oxyacodon	*priscilla*	1	3.6	1.8	0.35	Herbivore	West Flank Kimbetoh Wash	San Juan	New Mexico	Pu2	Nacimiento (lower Arroyo Chijuillita Mbr.)	Mudstone	Floodplain mudflat?	Quarry, Surface	AMNH, NMMNHS catalog; Sloan, 1987; Williamson, 1996
Alticonus	*gazini*	1	4.92	2.47	1.09	Herbivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Alveugena	*carbonensis*	1	5.75	3.7	2.95	Omnivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b; Eberle, 1999
Ampliconus	*antoni*	1	6.44	4.54	5.21	Herbivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Baioconodon	*middletoni*	1	n/a	n/a	n/a	Herbivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Ectoconus	*symbolus*	5	8.65	8.03	24.38	Herbivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Fimbrethil	*agapetillus*	1	2.9	1.5	0.17	Herbivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b

GENUS	SPECIES	No. of specimens	Avg lm1 length (mm)	Avg lm1 width (mm)	Estimated mass (kg)	Dietary mode	Site	Basin	State	Interval	Formation	Lithology	Depositional environment	Collecting methods	References
Gillisonchus	*gillianus*	1	4.14	3.09	1.19	Herbivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Loxolophus	*hyattianus*	1	5.5	4.3	3.57	Omnivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Loxolophus	*priscus*	1	6.55	5.24	6.93	Omnivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Oxyacodon	*priscilla*	1	3.6	1.8	0.35	Herbivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Oxyprimus	*galadrielae*	1	3.23	2.26	0.44	Insectivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Protungulatum	*donnae*	7	3.92	3.01	1.03	Insectivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Protungulatum	*sloani*	1	3.6	2.8	0.78	Insectivore	Windy Mudstone Fauna	Hanna	Wyoming	Pu1	Ferris (Upper Mbr.)	Mudstone & shale	Crevasse splay	Screenwash	Eberle & Lillegraven, 1998a&b
Mimatuta	*minuial*	10	3.92	2.84	0.93	Omnivore	Worm Coulee	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Mimatuta	*morgoth*	25	3.96	2.94	1	Omnivore	Worm Coulee	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Oxyprimus	*erikseni*	20	3.3	2.17	0.42	Insectivore	Worm Coulee	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Procerberus	*formicarum*	287	2.7	1.7	0.19	Insectivore	Worm Coulee	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Protungulatum	*donnae*	18	3.92	3.01	1.03	Insectivore	Worm Coulee	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Ragnarok	*nordicum*	3	5.2	4.16	3.04	Herbivore	Worm Coulee	Williston	Montana	Pu1	Tullock (Nelson Ranch Mbr.)	?	?	Screenwash	UCMP catalog; Lofgren, 1995
Eoconodon	*hutchisoni*	1	9.28	6.09	16.87	Carnivore	Yellow Sand Hills	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	UCMP catalog
Oxyacodon	*ferronensis*	1	3.38	1.65	0.27	Herbivore	Yellow Sand Hills	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	UCMP catalog
Procerberus	*formicarum*	2	2.7	1.7	0.19	Insectivore	Yellow Sand Hills	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	UCMP catalog
Prodiacodon	*crustulum*	21	2.69	1.79	0.21	Insectivore	Yellow Sand Hills	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	UCMP catalog
Purgatorius	*janisae*	2	1.93	1.2	0.056	Insectivore	Yellow Sand Hills	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	UCMP catalog
Purgatorius	*unio*	107	2.1	1.5	0.1	Insectivore	Yellow Sand Hills	Williston	Montana	Pu3	Tullock (Nelson Ranch Mbr.)	?	?	Surface, Screenwash	UCMP catalog

Table S1.2 (overleaf). Finalized occurrence dataset of Puercan eutherian screen-washing and surface collections. Sorting information for sites ant species in Tables S1.3 and S1.4 respectively.

SITE	*Alticonus gazini*	*Ampliconus antoni*	*Ampliconus browni*	*Anisonchus athelas*	*Anisonchus sectorius*	*Baioconodon denverensis*	*Baioconodon jeffersonensis*	*Baioconodon middletoni*	*Batodon tenuis*	*Betonnia tsosia*	*Bomburodon priscus*	*Bubogonia bombadili*	*Bubogonia saskia*
5MiEKimbetoh	0	0	0	0	0	0	0	0	0	0	0	0	0
BetonnieTsosieWash	0	0	0	0	0	0	0	0	0	1	1	1	0
BigGulch	0	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitButte	0	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitSprings	0	0	0	0	0	0	0	0	0	0	0	0	0
BlackSpringCouleeChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
BlackToeMicrovertebrateLocality	0	0	0	0	0	0	0	0	0	1	0	0	0
BrownGreyChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
BugCreekAnthillsLocalFauna	0	0	0	0	0	0	0	0	1	0	0	0	0
CampsSkull	0	0	0	0	0	0	0	0	0	0	0	0	0
CarsonTradingPost	0	0	0	0	0	0	0	0	0	0	0	0	0
ChacoCanyon	0	0	0	0	0	0	0	0	0	0	0	0	0
DenazinWashEctoconusZone	0	0	0	0	0	0	0	0	0	0	0	0	0
DenazinWashTaeniolabisZone	0	0	0	0	0	0	0	0	0	0	1	0	0
EastFlankKimbetohWash	0	0	0	0	0	0	0	0	0	0	1	0	0
EngdahlRanch	0	0	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu1Fauna	0	0	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu2Fauna	0	0	1	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu3Fauna	0	0	0	0	0	0	0	0	0	0	0	0	0
GarbaniChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
GasTankHillLocalFauna	0	0	0	1	0	0	0	0	0	0	0	0	0
HarbichtHill	0	0	0	0	0	0	0	0	0	0	0	0	0
HellsHollowLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
HiattLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
KerrButte	0	0	0	0	0	0	0	0	0	0	0	0	0
LittleRoundtopChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
MalcomsExtension	0	0	0	0	0	0	0	0	0	0	0	0	0
McKeeverRanchLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
MHBTLongFallFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
MHBTRAVW1Fauna	0	0	0	0	0	1	0	0	0	0	0	0	1
PineCreePark	0	0	0	0	0	0	0	0	0	0	0	0	0
PurgatoryHill	0	0	0	0	0	0	0	0	0	0	0	0	0
SecondLevelChannelLocalFauna	0	0	0	0	0	0	0	0	1	0	0	0	0
ShiprockLocalFauna	0	0	0	0	0	0	0	0	1	0	0	0	0
SimpsonQuarry	0	0	0	0	0	1	0	0	0	0	0	0	0
SouthTableMountain LocalFauna	0	0	1	0	0	1	1	0	0	0	0	0	0
SplitLipFlatsLocalFauna	0	0	0	0	0	0	0	0	0	1	1	0	0
ThreeButtesLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
ThreeGulleysOver	0	0	0	0	0	0	0	0	0	0	0	0	0
UpUpTheCreekLocalFauna	0	0	0	0	0	0	0	0	1	0	0	0	0
WagonroadLocalFauna	0	0	0	1	1	0	0	0	0	0	0	0	0
WestBijouCreek	0	0	0	1	0	0	0	0	0	0	0	0	0
WestBijouGarsGalore	0	0	0	0	0	0	0	0	0	0	0	0	0
WestFlankKimbetohWash	0	0	0	0	0	0	0	0	0	0	0	0	0
WindyMudstoneFauna	1	1	0	0	0	0	0	1	0	0	0	0	0
WormCoulee	0	0	0	0	0	0	0	0	0	0	0	0	0
YellowSandHills	0	0	0	0	0	0	0	0	0	0	0	0	0

SITE	*Carcinodon antiquus*	*Carcinodon aquilonius*	*Carcinodon corax*	*Carcinodon olearyi*	*Carcinodon simplex*	*Carsioptychus coarctatus*	*Chacomylus sladei*	*Chacopterygus minutus*	*Choeroclaenus turgidunculus*	*Cimolestes incisus*	*Conacodon cophater*	*Conacodon delphae*	*Conacodon entoconus*
5MiEKimbetoh	0	0	0	0	0	0	0	0	1	0	1	0	0
BetonnieTsosieWash	1	0	0	1	1	1	0	0	1	0	1	0	1
BigGulch	0	0	0	0	0	1	0	0	0	0	0	0	0
BiscuitButte	0	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitSprings	0	0	0	0	0	0	0	0	0	0	0	0	0
BlackSpringCouleeChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
BlackToeMicrovertebrateLocality	0	0	0	0	1	0	0	1	1	0	1	0	1
BrownGreyChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
BugCreekAnthillsLocalFauna	0	0	0	0	0	0	0	0	0	1	0	0	0
CampsSkull	0	0	0	0	1	0	0	0	0	0	1	0	1
CarsonTradingPost	0	0	0	0	0	1	0	0	0	0	0	0	0
ChacoCanyon	0	0	0	0	0	1	0	0	0	0	1	0	1
DenazinWashEctoconusZone	1	0	0	1	1	1	0	0	1	0	1	0	1
DenazinWashTaeniolabisZone	1	0	0	1	1	1	0	0	1	0	1	0	1
EastFlankKimbetohWash	0	0	0	0	1	1	0	0	1	0	1	0	1
EngdahlRanch	0	0	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu1Fauna	0	0	0	0	0	0	0	0	0	0	0	1	0
FerrisMainSectionPu2Fauna	0	0	0	0	0	1	0	0	0	0	1	0	0
FerrisMainSectionPu3Fauna	0	0	0	0	0	1	0	0	0	0	1	0	0
GarbaniChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
GasTankHillLocalFauna	0	0	0	0	0	1	0	0	0	0	0	0	0
HarbichtHill	0	0	0	0	0	0	0	0	0	0	0	0	0
HellsHollowLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
HiattLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
KerrButte	0	0	0	0	0	0	0	0	0	0	0	0	0
LittleRoundtopChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
MalcomsExtension	0	0	0	0	0	0	0	0	0	0	1	0	1
McKeeverRanchLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
MHBTLongFallFauna	0	1	0	0	0	0	0	0	0	0	0	0	0
MHBTRAVW1Fauna	0	1	1	0	1	0	0	0	0	0	0	0	0
PineCreePark	0	1	0	0	0	0	0	0	0	0	0	0	0
PurgatoryHill	0	0	0	0	0	0	0	0	0	0	0	0	0
SecondLevelChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
ShiprockLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
SimpsonQuarry	0	1	1	0	0	0	0	0	0	0	0	0	0
SouthTableMountain LocalFauna	0	0	0	0	1	0	0	0	0	0	0	0	0
SplitLipFlatsLocalFauna	0	0	0	1	0	1	1	0	1	0	0	0	0
ThreeButtesLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
ThreeGulleysOver	0	0	0	1	0	1	0	0	0	0	0	0	0
UpUpTheCreekLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
WagonroadLocalFauna	0	0	0	0	0	1	0	0	0	0	0	0	1
WestBijouCreek	0	0	0	0	1	1	0	0	0	0	0	0	0
WestBijouGarsGalore	0	0	0	0	0	0	0	0	0	0	0	0	0
WestFlankKimbetohWash	0	0	0	0	1	1	0	0	1	0	1	0	1
WindyMudstoneFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
WormCoulee	0	0	0	0	0	0	0	0	0	0	0	0	0
YellowSandHills	0	0	0	0	0	0	0	0	0	0	0	0	0

<u>SITE</u>	*Conacodon harbourae*	*Conacodon kohlbergeri*	*Crustulus fontanus*	*Desmatoclaenus dianae*	*Desmatoclaenus hermaeus*	*Desmatoclaenus protogonioides*	*Ectoconus ditrigonus*	*Ectoconus symbolus*	*Eoconodon coryphaeus*	*Eoconodon gaudrianus*	*Eoconodon ginibitohia*	*Eoconodon hutchisoni*
5MiEKimbetoh	0	0	0	0	0	0	0	0	0	0	0	0
BetonnieTsosieWash	0	1	0	1	0	1	1	0	1	1	1	0
BigGulch	0	0	0	0	0	0	1	0	0	0	0	0
BiscuitButte	0	0	0	0	0	0	0	0	0	0	0	1
BiscuitSprings	0	0	1	0	0	0	0	0	0	0	0	0
BlackSpringCouleeChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
BlackToeMicrovertebrateLocality	0	0	0	0	0	0	1	0	0	1	0	0
BrownGreyChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
BugCreekAnthillsLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
CampsSkull	0	1	0	0	0	1	0	0	0	0	0	0
CarsonTradingPost	0	0	0	1	0	1	0	0	0	0	0	0
ChacoCanyon	0	0	0	0	0	0	1	0	0	1	0	0
DenazinWashEctoconusZone	0	0	0	0	0	1	1	0	1	1	0	0
DenazinWashTaeniolabisZone	0	0	0	0	0	0	1	0	1	1	0	0
EastFlankKimbetohWash	0	1	0	0	0	1	1	0	1	1	0	0
EngdahlRanch	0	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu1Fauna	1	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu2Fauna	0	0	0	0	0	0	1	0	0	0	0	0
FerrisMainSectionPu3Fauna	0	0	0	0	0	0	1	0	0	0	0	0
GarbaniChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	1
GasTankHillLocalFauna	0	1	0	0	1	0	1	1	0	0	0	0
HarbichtHill	0	0	0	0	0	0	0	0	0	0	0	0
HellsHollowLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
HiattLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
KerrButte	0	0	0	0	0	0	0	0	0	0	0	1
LittleRoundtopChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
MalcomsExtension	0	0	0	0	0	0	1	0	0	0	0	0
McKeeverRanchLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
MHBTLongFallFauna	0	0	0	0	0	0	0	0	0	0	0	0
MHBTRAVW1Fauna	0	0	0	0	0	0	0	0	0	0	0	0
PineCreePark	0	0	0	0	0	0	0	0	0	0	0	0
PurgatoryHill	0	0	0	0	0	0	0	0	0	0	0	0
SecondLevelChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
ShiprockLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
SimpsonQuarry	0	0	0	0	0	0	0	0	0	0	0	0
SouthTableMountain LocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
SplitLipFlatsLocalFauna	0	1	0	0	0	0	0	0	0	0	0	0
ThreeButtesLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
ThreeGulleysOver	0	0	0	0	0	0	0	0	1	0	0	0
UpUpTheCreekLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
WagonroadLocalFauna	0	1	0	0	1	0	1	1	0	0	0	0
WestBijouCreek	0	0	0	0	0	1	1	0	0	0	0	0
WestBijouGarsGalore	0	0	0	0	0	0	0	0	0	0	0	0
WestFlankKimbetohWash	0	0	0	0	0	1	1	0	1	1	0	0
WindyMudstoneFauna	0	0	0	0	0	0	0	1	0	0	0	0
WormCoulee	0	0	0	0	0	0	0	0	0	0	0	0
YellowSandHills	0	0	0	0	0	0	0	0	0	0	0	1

SITE	*Eoconodon nidhoggi*	*Escatepos campi*	*Fimbrethil agapetillus*	*Gillisonchus gillianus*	*Gillisonchus onostus*	*Goniacodon hiawathiae*	*Gypsonictops hypoconus*	*Gypsonictops illuminatus*	*Haplaletes andakupensi*	*Haploconus elachistus*	*Hemithlaeus kowalevskianu*	*Leptacodon proserpina*	*Litaletes gazinensis*
5MiEKimbetoh	0	0	0	0	0	0	0	0	0	0	1	0	0
BetonnieTsosieWash	0	1	1	1	0	0	0	0	0	0	1	0	0
BigGulch	0	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitButte	0	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitSprings	0	0	0	0	0	0	0	0	0	0	0	0	0
BlackSpringCouleeChannelLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
BlackToeMicrovertebrateLocality	0	0	1	1	0	0	0	0	0	0	1	0	0
BrownGreyChannelLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
BugCreekAnthillsLocalFauna	0	0	0	0	0	0	1	1	0	0	0	0	0
CampsSkull	0	0	0	0	0	0	0	0	0	0	1	0	0
CarsonTradingPost	0	0	0	1	0	0	0	0	0	0	0	0	0
ChacoCanyon	0	0	0	1	0	0	0	0	0	0	1	0	0
DenazinWashEctoconusZone	0	0	1	1	0	0	0	0	0	0	1	0	0
DenazinWashTaeniolabisZone	0	0	1	1	0	0	0	0	0	0	0	0	0
EastFlankKimbetohWash	0	0	1	1	0	0	0	0	0	0	1	0	0
EngdahlRanch	0	0	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu1Fauna	0	0	1	1	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu2Fauna	0	0	0	1	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu3Fauna	0	0	0	1	0	0	0	0	0	0	0	0	0
GarbaniChannelLocalFauna	1	0	0	0	0	0	0	0	0	0	0	0	0
GasTankHillLocalFauna	0	0	0	0	1	0	0	0	0	1	0	0	1
HarbichtHill	0	0	0	0	0	0	0	0	0	0	0	0	0
HellsHollowLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
HiattLocalFauna	1	0	0	0	0	0	0	0	0	0	0	0	0
KerrButte	0	0	0	0	0	0	0	0	0	0	0	0	0
LittleRoundtopChannelLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
MalcomsExtension	0	0	1	0	0	0	0	0	0	0	1	0	0
McKeeverRanchLocalFauna	1	0	0	0	0	0	0	0	0	0	0	0	0
MHBTLongFallFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
MHBTRAVW1Fauna	0	0	0	0	0	0	0	0	0	0	0	0	0
PineCreePark	0	0	0	0	0	0	0	0	0	0	0	0	0
PurgatoryHill	1	0	0	1	0	0	0	0	1	0	0	1	0
SecondLevelChannelLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
ShiprockLocalFauna	0	0	0	0	0	0	1	1	0	0	0	0	0
SimpsonQuarry	1	0	0	0	0	0	0	0	0	0	0	0	0
SouthTableMountain LocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
SplitLipFlatsLocalFauna	0	0	1	1	0	0	0	0	0	0	0	0	0
ThreeButtesLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
ThreeGulleysOver	0	0	0	0	0	0	0	0	0	0	0	0	0
UpUpTheCreekLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
WagonroadLocalFauna	0	0	0	0	0	1	0	0	0	1	0	0	0
WestBijouCreek	0	0	0	0	0	0	0	0	0	0	0	0	0
WestBijouGarsGalore	0	0	0	0	0	0	0	0	0	0	0	0	0
WestFlankKimbetohWash	0	0	0	1	0	0	0	0	0	0	1	0	0
WindyMudstoneFauna	0	0	1	1	0	0	0	0	0	0	0	0	0
WormCoulee	0	0	0	0	0	0	0	0	0	0	0	0	0
YellowSandHills	0	0	0	0	0	0	0	0	0	0	0	0	0

SITE	*Litomylus orthronepius*	*Loxolophus faulkneri*	*Loxolophus hyattianus*	*Loxolophus priscus*	*Loxolophus schizophrenus*	*Maiorana ferrisensis*	*Mimatuta minuial*	*Mimatuta morgoth*	*Mithrandir oligistus*	*Onychodectes tisonensis*	*Oxyacodon apiculatus*	*Oxyacodon archibaldi*	*Oxyacodon ferronensis*
5MiEKimbetoh	0	0	0	0	0	0	0	0	0	0	0	0	0
BetonnieTsosieWash	0	0	1	1	0	0	0	0	0	1	1	0	0
BigGulch	0	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitButte	0	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitSprings	0	0	0	0	0	0	0	0	0	0	0	0	0
BlackSpringCouleeChannelLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
BlackToeMicrovertebrateLocality	0	0	1	0	0	0	0	0	0	1	0	0	0
BrownGreyChannelLocalFauna	0	0	0	0	0	0	1	1	0	0	0	0	0
BugCreekAnthillsLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
CampsSkull	0	0	0	0	0	0	0	0	0	0	0	0	0
CarsonTradingPost	0	0	1	1	0	0	0	0	0	0	0	0	0
ChacoCanyon	0	0	0	0	0	0	0	0	0	0	0	0	0
DenazinWashEctoconusZone	0	0	1	0	0	0	0	0	0	1	0	0	0
DenazinWashTaeniolabisZone	0	0	1	1	0	0	0	0	0	1	1	0	0
EastFlankKimbetohWash	0	0	1	1	0	0	0	0	0	1	1	0	0
EngdahlRanch	0	0	0	0	0	0	0	0	0	0	0	0	1
FerrisMainSectionPu1Fauna	0	0	0	0	0	1	0	0	0	0	0	0	0
FerrisMainSectionPu2Fauna	0	1	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu3Fauna	0	0	1	1	0	0	0	0	0	0	1	0	0
GarbaniChannelLocalFauna	0	0	0	0	0	0	0	0	1	0	0	0	1
GasTankHillLocalFauna	0	0	0	1	0	0	0	0	0	0	0	0	1
HarbichtHill	0	0	0	0	0	0	0	1	0	0	0	0	0
HellsHollowLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
HiattLocalFauna	0	0	0	0	1	0	0	0	0	0	1	0	1
KerrButte	0	0	0	0	0	0	0	0	0	0	0	0	0
LittleRoundtopChannelLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
MalcomsExtension	0	0	0	0	0	0	0	0	0	0	0	0	0
McKeeverRanchLocalFauna	0	0	0	0	0	0	1	0	0	0	0	0	0
MHBTLongFallFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
MHBTRAVW1Fauna	1	0	0	0	1	0	0	0	1	0	0	0	0
PineCreePark	0	0	0	0	0	0	0	0	0	0	0	0	0
PurgatoryHill	0	0	0	0	0	0	0	0	1	0	0	0	0
SecondLevelChannelLocalFauna	0	0	0	0	0	0	1	1	0	0	0	0	0
ShiprockLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
SimpsonQuarry	1	0	0	0	1	0	0	0	0	0	0	1	0
SouthTableMountain LocalFauna	0	0	0	0	0	0	0	0	0	0	0	0	0
SplitLipFlatsLocalFauna	0	0	1	1	0	0	0	0	0	1	1	0	0
ThreeButtesLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0	0
ThreeGulleysOver	0	0	0	0	0	0	0	0	0	0	1	0	0
UpUpTheCreekLocalFauna	0	0	0	0	0	0	1	1	0	0	0	0	0
WagonroadLocalFauna	0	0	0	0	0	0	0	0	1	1	0	0	0
WestBijouCreek	0	0	1	0	0	0	0	0	0	0	0	0	0
WestBijouGarsGalore	0	0	0	0	0	0	0	0	0	0	0	0	0
WestFlankKimbetohWash	0	0	0	0	0	0	0	0	0	0	0	0	0
WindyMudstoneFauna	0	0	1	1	0	0	0	0	0	0	0	0	0
WormCoulee	0	0	0	0	0	0	1	1	0	0	0	0	0
YellowSandHills	0	0	0	0	0	0	0	0	0	0	0	0	1

SITE	*Oxyacodon marshater*	*Oxyacodon priscilla*	*Oxyprimus erikseni*	*Oxyprimus galadrielae*	*Pandemonium dis*	*Paradoxadonta ruetimeyeranus*	*Procerberus andesiticus*	*Procerberus formicarum*	*Procerberus grandis*	*Procerberus plutonis*	*Prodiacodon crustulum*	*Protogonodon kimbetovius*
5MiEKimbetoh	0	1	0	0	0	0	0	0	0	0	0	0
BetonnieTsosieWash	0	1	0	0	0	0	0	0	0	0	0	0
BigGulch	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitButte	0	0	0	0	0	0	0	0	0	0	1	0
BiscuitSprings	0	0	0	0	0	0	0	1	0	0	1	0
BlackSpringCouleeChannelLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0
BlackToeMicrovertebrateLocality	0	0	0	0	0	0	0	0	0	0	0	0
BrownGreyChannelLocalFauna	0	0	1	0	0	0	0	1	0	0	0	0
BugCreekAnthillsLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0
CampsSkull	0	0	0	0	0	0	0	0	0	0	0	0
CarsonTradingPost	0	0	0	0	0	0	0	0	0	0	0	0
ChacoCanyon	0	0	0	0	0	0	0	0	0	0	0	0
DenazinWashEctoconusZone	0	1	0	0	0	1	0	0	0	0	0	0
DenazinWashTaeniolabisZone	0	1	0	0	0	0	0	0	0	0	0	0
EastFlankKimbetohWash	0	1	0	0	0	0	0	0	0	0	0	1
EngdahlRanch	0	0	0	0	0	0	0	0	0	0	1	0
FerrisMainSectionPu1Fauna	0	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu2Fauna	0	1	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu3Fauna	0	1	0	0	0	0	0	0	0	0	0	0
GarbaniChannelLocalFauna	0	0	0	0	0	0	0	1	0	0	1	0
GasTankHillLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
HarbichtHill	0	0	1	0	0	0	0	1	0	0	0	0
HellsHollowLocalFauna	0	0	1	0	0	0	0	1	0	0	0	0
HiattLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
KerrButte	0	0	0	0	0	0	0	0	0	0	0	0
LittleRoundtopChannelLocalFauna	0	0	1	0	0	0	0	1	0	0	0	0
MalcomsExtension	0	0	0	0	0	0	0	0	0	0	0	0
McKeeverRanchLocalFauna	0	0	0	0	0	0	0	1	0	0	0	0
MHBTLongFallFauna	0	0	1	0	0	0	0	1	0	0	0	0
MHBTRAVW1Fauna	0	0	0	0	0	0	0	0	0	0	0	0
PineCreePark	0	0	0	0	0	0	0	0	0	0	0	0
PurgatoryHill	0	0	0	0	1	0	0	0	0	1	0	0
SecondLevelChannelLocalFauna	0	0	1	0	0	0	0	1	0	0	0	0
ShiprockLocalFauna	0	0	1	0	0	0	0	1	0	0	0	0
SimpsonQuarry	0	0	0	0	0	0	0	0	0	0	0	0
SouthTableMountain LocalFauna	0	0	0	0	0	0	1	0	1	0	0	0
SplitLipFlatsLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
ThreeButtesLocalFauna	0	0	1	0	0	0	0	0	0	0	0	0
ThreeGulleysOver	0	0	0	0	0	0	0	0	0	0	0	0
UpUpTheCreekLocalFauna	0	0	1	0	0	0	0	1	0	0	0	0
WagonroadLocalFauna	1	0	0	0	0	0	0	0	0	0	0	0
WestBijouCreek	0	0	0	0	0	0	0	0	0	0	0	0
WestBijouGarsGalore	0	0	0	0	0	0	0	0	0	0	0	0
WestFlankKimbetohWash	0	1	0	0	0	0	0	0	0	0	0	0
WindyMudstoneFauna	0	1	0	1	0	0	0	0	0	0	0	0
WormCoulee	0	0	1	0	0	0	0	1	0	0	0	0
YellowSandHills	0	0	0	0	0	0	0	1	0	0	1	0

SITE	*Protungulatum donnae*	*Protungulatum gorgun*	*Protungulatum sloani*	*Puercolestes simpsoni*	*Purgatorius ceratops*	*Purgatorius coracis*	*Purgatorius janisae*	*Purgatorius pinecreeensi*	*Purgatorius titusi*	*Purgatorius unio*	*Ragnarok nordicum*	*Ravenictis krausei*
5MiEKimbetoh	0	0	0	0	0	0	0	0	0	0	0	0
BetonnieTsosieWash	0	0	0	1	0	0	0	0	0	0	0	0
BigGulch	0	0	0	0	0	0	0	0	0	0	0	0
BiscuitButte	0	0	0	0	0	0	1	0	0	1	0	0
BiscuitSprings	0	0	0	0	0	0	1	0	0	1	0	0
BlackSpringCouleeChannelLocalFauna	1	1	0	0	0	0	0	0	0	0	1	0
BlackToeMicrovertebrateLocality	0	0	0	1	0	0	0	0	0	0	0	0
BrownGreyChannelLocalFauna	1	1	0	0	0	0	0	0	0	0	1	0
BugCreekAnthillsLocalFauna	1	1	0	0	0	0	0	0	0	0	0	0
CampsSkull	0	0	0	0	0	0	0	0	0	0	0	0
CarsonTradingPost	0	0	0	0	0	0	0	0	0	0	0	0
ChacoCanyon	0	0	0	0	0	0	0	0	0	0	0	0
DenazinWashEctoconusZone	0	0	0	0	0	0	0	0	0	0	0	0
DenazinWashTaeniolabisZone	0	0	0	1	0	0	0	0	0	0	0	0
EastFlankKimbetohWash	0	0	0	0	0	0	0	0	0	0	0	0
EngdahlRanch	0	0	0	0	0	0	0	0	0	1	0	0
FerrisMainSectionPu1Fauna	1	1	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu2Fauna	0	0	0	0	0	0	0	0	0	0	0	0
FerrisMainSectionPu3Fauna	1	0	0	0	0	0	0	0	0	0	0	0
GarbaniChannelLocalFauna	0	0	1	1	0	0	1	0	0	1	0	0
GasTankHillLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
HarbichtHill	1	1	0	0	1	0	0	0	0	0	1	0
HellsHollowLocalFauna	0	0	0	0	0	0	0	0	0	0	1	0
HiattLocalFauna	0	0	0	0	0	0	0	0	0	0	1	0
KerrButte	0	0	0	1	0	0	0	0	0	0	0	0
LittleRoundtopChannelLocalFauna	1	1	0	0	0	0	0	0	0	0	0	0
MalcomsExtension	0	0	0	0	0	0	0	0	0	0	0	0
McKeeverRanchLocalFauna	1	0	0	0	0	0	0	0	0	0	0	0
MHBTLongFallFauna	1	0	0	0	0	0	0	0	0	0	0	0
MHBTRAVW1Fauna	0	0	0	0	0	1	0	0	0	0	0	1
PineCreePark	0	0	0	0	0	0	0	1	0	0	0	0
PurgatoryHill	0	0	1	0	0	0	0	0	0	1	0	0
SecondLevelChannelLocalFauna	1	1	0	0	0	0	0	0	0	0	1	0
ShiprockLocalFauna	0	1	0	0	0	0	0	0	0	0	1	0
SimpsonQuarry	0	0	1	0	0	0	0	0	1	0	0	0
SouthTableMountain LocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
SplitLipFlatsLocalFauna	0	0	0	1	0	0	0	0	0	0	0	0
ThreeButtesLocalFauna	1	1	0	0	0	0	0	0	0	0	1	0
ThreeGulleysOver	0	0	0	0	0	0	0	0	0	0	0	0
UpUpTheCreekLocalFauna	1	1	0	0	0	0	0	0	0	0	1	0
WagonroadLocalFauna	0	0	0	0	0	0	0	0	0	0	0	0
WestBijouCreek	0	0	0	0	0	0	0	0	0	0	0	0
WestBijouGarsGalore	1	0	0	0	0	0	0	0	0	0	1	0
WestFlankKimbetohWash	0	0	0	0	0	0	0	0	0	0	0	0
WindyMudstoneFauna	1	0	1	0	0	0	0	0	0	0	0	0
WormCoulee	1	0	0	0	0	0	0	0	0	0	1	0
YellowSandHills	0	0	0	0	0	0	1	0	0	1	0	0

SITE	*Thangorodrim thalion*	*Tinuviel eurydice*	*Tiznatzinia vanderhoof*	*Tricentes calenancus*	*Ursolestes perpetior*	*Valenia wilsoni*	*Wortmania otariidens*
5MiEKimbetoh	0	0	0	0	0	0	0
BetonnieTsosieWash	0	0	1	0	0	1	0
BigGulch	0	0	0	0	0	0	0
BiscuitButte	0	0	0	0	0	0	0
BiscuitSprings	0	0	0	0	0	0	0
BlackSpringCouleeChannelLocalFauna	0	0	0	0	0	0	0
BlackToeMicrovertebrateLocality	0	0	1	0	0	0	0
BrownGreyChannelLocalFauna	0	0	0	0	0	0	0
BugCreekAnthillsLocalFauna	0	0	0	0	0	0	0
CampsSkull	0	0	0	0	0	0	0
CarsonTradingPost	0	0	0	0	0	0	0
ChacoCanyon	0	0	0	0	0	0	0
DenazinWashEctoconusZone	0	0	0	0	0	0	0
DenazinWashTaeniolabisZone	0	0	1	0	0	0	1
EastFlankKimbetohWash	0	0	0	0	0	0	1
EngdahlRanch	0	0	0	0	0	0	0
FerrisMainSectionPu1Fauna	0	0	0	0	0	0	0
FerrisMainSectionPu2Fauna	0	0	0	0	0	1	0
FerrisMainSectionPu3Fauna	0	0	0	0	0	0	0
GarbaniChannelLocalFauna	1	0	0	0	0	0	0
GasTankHillLocalFauna	0	0	0	0	0	1	0
HarbichtHill	0	0	0	0	0	0	0
HellsHollowLocalFauna	0	0	0	0	0	0	0
HiattLocalFauna	0	1	0	0	0	0	0
KerrButte	0	0	0	0	0	0	0
LittleRoundtopChannelLocalFauna	0	0	0	0	0	0	0
MalcomsExtension	0	0	0	0	0	0	0
McKeeverRanchLocalFauna	0	0	0	0	0	0	0
MHBTLongFallFauna	0	0	0	0	0	0	0
MHBTRAVW1Fauna	0	0	0	1	0	0	0
PineCreePark	0	0	0	0	0	0	0
PurgatoryHill	1	1	0	1	0	0	0
SecondLevelChannelLocalFauna	0	0	0	0	0	0	0
ShiprockLocalFauna	0	0	0	0	0	0	0
SimpsonQuarry	0	0	0	1	1	0	0
SouthTableMountain LocalFauna	0	0	0	0	0	0	0
SplitLipFlatsLocalFauna	0	0	0	0	0	0	0
ThreeButtesLocalFauna	0	0	0	0	0	0	0
ThreeGulleysOver	0	0	0	0	0	0	0
UpUpTheCreekLocalFauna	0	0	0	0	0	0	0
WagonroadLocalFauna	0	0	0	0	0	0	0
WestBijouCreek	0	0	0	0	0	0	0
WestBijouGarsGalore	0	0	0	0	0	0	0
WestFlankKimbetohWash	0	0	0	0	0	0	0
WindyMudstoneFauna	0	0	0	0	0	0	0
WormCoulee	0	0	0	0	0	0	0
YellowSandHills	0	0	0	0	0	0	0

Table S1.3. Locality sorting information in final occurrence datasets.

Site	Basin	Interval	Lithology	Collecting method
5MiEKimbetoh	San Juan	Pu2	Unknown	Surface
BetonnieTsosieWash	San Juan	Pu2	Mudstone	Screen-wash
BigGulch	Denver	Pu2/Pu3	Sandstone	Surface
BiscuitButte	Williston	Pu3	Sandstone	Screen-wash
BiscuitSprings	Williston	Pu3	Sandstone	Screen-wash
BlackSpringCouleeChannelLocalFauna	Williston	Pu1	Sandstone	Screen-wash
BlackToeMicrovertebrateLocality	San Juan	Pu2	Mudstone	Screen-wash
BrownGreyChannelLocalFauna	Williston	Pu1	Sandstone	Screen-wash
BugCreekAnthillsLocalFauna	Williston	Pu1	Sandstone	Screen-wash
CampsSkull	San Juan	Pu2	Unknown	Surface
CarsonTradingPost	San Juan	Pu3	Mudstone	Surface
ChacoCanyon	San Juan	Pu2	Unknown	Surface
DenazinWashEctoconusZone	San Juan	Pu2	Siltstone	Surface
DenazinWashTaeniolabisZone	San Juan	Pu3	Mudstone	Surface
EastFlankKimbetohWash	San Juan	Pu2	Mudstone	Surface
EngdahlRanch	Williston	Pu3	Sandstone	Screen-wash
FerrisMainSectionPu1Fauna	Hanna	Pu1	Sandstone	Surface
FerrisMainSectionPu2Fauna	Hanna	Pu2	Sandstone	Surface
FerrisMainSectionPu3Fauna	Hanna	Pu3	Mudstone	Surface
GarbaniChannelLocalFauna	Williston	Pu3	Sandstone	Screen-wash
GasTankHillLocalFauna	Castle Valley/Wasatch	Pu2	Mudstone	Surface
HarbichtHill	Williston	Pu1	Sandstone	Surface
HellsHollowLocalFauna	Williston	Pu1	Sandstone	Screen-wash
HiattLocalFauna	Williston	Pu2	Sandstone	Surface
KerrButte	Williston	Pu3	Sandstone	Screen-wash
LittleRoundtopChannelLocalFauna	Williston	Pu1	Sandstone	Screen-wash
MalcomsExtension	San Juan	Pu2	unknown	Surface
McKeeverRanchLocalFauna	Williston	Pu1	Sandstone	Screen-wash
MHBTLongFallFauna	Williston	Pu1	Siltstone	Screen-wash
MHBTRAVW1Fauna	Williston	Pu2	Siltstone	Screen-wash
PineCreePark	Williston	Pu2	Sandstone	Surface

Table S1.3. cont.

Site	Basin	Interval	Lithology	Collecting method
PurgatoryHill	Williston	Pu3	Sandstone	Screen-wash
SecondLevelChannelLocalFauna	Williston	Pu1	Sandstone	Screen-wash
ShiprockLocalFauna	Williston	Pu1	Mudstone	Screen-wash
SimpsonQuarry	Crazy Mountain	Pu2	Mudstone	Screen-wash
SouthTableMountain LocalFauna	Denver	Pu1	Siltstone	Surface
SplitLipFlatsLocalFauna	San Juan	Pu3	Sandstone	Screen-wash
ThreeButtesLocalFauna	Williston	Pu1	Sandstone	Screen-wash
ThreeGulleysOver	San Juan	Pu3	Unknown	Surface
UpUpTheCreekLocalFauna	Williston	Pu1	Sandstone	Screen-wash
WagonroadLocalFauna	Castle Valley/Wasatch	Pu3	Mudstone	Surface
WestBijouCreek	Denver	Pu2/Pu3	Claystone	Surface
WestBijouGarsGalore	Denver	Pu1	Sandstone	Screen-wash
WestFlankKimbetohWash	San Juan	Pu2	Mudstone	Surface
WindyMudstoneFauna	Hanna	Pu1	Mudstone	Screen-wash
WormCoulee	Williston	Pu1	Unknown	Screen-wash
YellowSandHills	Williston	Pu3	Sandstone	Screen-wash

Table S1.4. Species sorting information in final occurrence datasets.

Species	Body mass class	Diet
AmpliconusBrowni	1-2.5 kg	herbivore
AnisonchusAthelas	1-2.5 kg	herbivore
AnisonchusSectorius	2.5-5 kg	herbivore
BaioconodonDenverensis	5-10 kg	herbivore
BaioconodonJeffersonensis	1-2.5 kg	herbivore
BatodonTenuis	<100 g	insectivore
BetonniaTsosia	100-500 g	insectivore
BomburodonPriscus	500 g-1 kg	herbivore
BubogoniaBombadili	500 g-1 kg	omnivore
BubogoniaSaskia	500 g-1 kg	omnivore
CarcinodonAntiquus	5-10 kg	carnivore
CarcinodonAquilonius	1-2.5 kg	carnivore
CarcinodonCorax	1-2.5 kg	carnivore
CarcinodonOlearyi	2.5-5 kg	carnivore
CarcinodonSimplex	2.5-5 kg	carnivore
CarsioptychusCoarctatus	>30 kg	herbivore
ChacomylusSladei	100-500 g	insectivore
ChacopterygusMinutus	<100 g	insectivore
ChoeroclaenusTurgidunculus	1-2.5 kg	herbivore
CimolestesIncisus	100-500 g	insectivore
ConacodonCophater	100-500 g	herbivore
ConacodonDelphae	5-10 kg	herbivore
ConacodonEntoconus	5-10 kg	herbivore
ConacodonHarbourae	1-2.5 kg	herbivore
ConacodonKohlbergeri	1-2.5 kg	herbivore
CrustulumFontanus	1-2.5 kg	herbivore
DesmatoclaenusDianae	5-10 kg	herbivore
DesmatoclaenusHermaeus	10-20 kg	herbivore
DesmatoclaenusProtogonioides	2.5-5 kg	herbivore
EctoconusDitrigonus	>30 kg	herbivore
EctoconusSymbolus	20-30 kg	herbivore
EoconodonCoryphaeus	>30 kg	carnivore
EoconodonGaudrianus	5-10 kg	carnivore

Table S1.4. cont.

Species	Body mass class	Diet
EoconodonGinibitohia	2.5-5 kg	omnivore
EoconodonHutchisoni	10-20 kg	carnivore
EoconodonNidhoggi	5-10 kg	omnivore
EscateposCampi	500 g-1 kg	herbivore
FimbrethilAgapetillus	100-500 g	herbivore
GillisonchusGillianus	1-2.5 kg	herbivore
GillisonchusOnostus	1-2.5 kg	herbivore
GoniacodonHiawathiae	10-20 kg	carnivore
GypsonictopsHypoconus	100-500 g	insectivore
GypsonictopsIlluminatus	100-500 g	insectivore
HaplaletesAndakupensis	100-500 g	insectivore
HaploconusElachistus	500 g-1 kg	herbivore
HemithlaeusKowalevskianus	2.5-5 kg	herbivore
LeptacodonProserpinae	<100 g	insectivore
LitaletesGazinensis	100-500 g	insectivore
LitomylusOrthronepius	100-500 g	insectivore
LoxolophusFaulkneri	20-30 kg	herbivore
LoxolophusHyattianus	2.5-5 kg	omnivore
LoxolophusPriscus	5-10 kg	omnivore
LoxolophusSchizophrenus	1-2.5 kg	omnivore
MaioranaFerrisensis	500 g-1 kg	herbivore
MimatutaMinuial	500 g-1 kg	herbivore
MimatutaMorgoth	1-2.5 kg	herbivore
MithrandirOligistus	500 g-1 kg	herbivore
OnychodectesTisonensis	10-20 kg	omnivore
OxyacodonApiculatus	500 g-1 kg	herbivore
OxyacodonArchibaldi	1-2.5 kg	herbivore
OxyacodonFerronensis	100-500 g	herbivore
OxyacodonMarshater	500 g-1 kg	herbivore
OxyacodonPriscilla	100-500 g	herbivore
OxyprimusErikseni	100-500 g	omnivore
PandemoniumDis	100-500 g	insectivore
ParadoxadontaRuetimeyeranus	10-20 kg	omnivore

Table S1.4. cont.

Species	Body mass class	Diet
ProcerberusAndesiticus	100-500 g	insectivore
ProcerberusFormicarum	100-500 g	insectivore
ProcerberusGrandis	2.5-5 kg	insectivore
ProcerberusPlutonis	500 g-1 kg	insectivore
ProdiacodonCrustulum	100-500 g	insectivore
ProtogonodonKimbetovius	20-30 kg	herbivore
ProtogonodonPentacus	20-30 kg	herbivore
ProtungulatumDonnae	1-2.5 kg	omnivore
ProtungulatumGorgun	1-2.5 kg	omnivore
ProtungulatumSloani	500 g-1 kg	omnivore
PuercolestesSimpsoni	500 g-1 kg	insectivore
PurgatoriusCeratops	<100 g	insectivore
PurgatoriusCoracis	<100 g	insectivore
PurgatoriusJanisae	<100 g	insectivore
PurgatoriusPinecreeensis	<100 g	insectivore
PurgatoriusTitusi	<100 g	insectivore
PurgatoriusUnio	100-500 g	insectivore
RagnarokNordicum	2.5-5 kg	herbivore
RavenictisKrausei	500 g-1 kg	carnivore
ThangorodrimThalion	5-10 kg	omnivore
TinuvielEurydice	5-10 kg	herbivore
TiznatziniaVanderhoofi	500 g-1 kg	herbivore
TricentesCalenancus	2.5-5 kg	herbivore
UrsolestesPerpetior	1-2.5 kg	insectivore
ValeniaWilsoni	500 g-1 kg	herbivore
WortmaniaOtariidens	20-30 kg	omnivore

Table S1.5. Richness, evenness, average body mass, and average dietary mode values for localities in final occurrence datasets.

Site	*MS* rounded	*J*	Average mass (kg)	Average diet
5MiEKimbetoh	2	1.000	1.11	herbivore
BetonnieTsosieWash	25	0.728	7.99	herbivore
BigGulch	2	0.918	25.8	herbivore
BiscuitButte	4	0.959	5.48	insectivore
BiscuitSprings	2	0.118	0.34	insectivore
BlackSpringCouleeChannelLocalFauna	5	0.804	1.26	omnivore
BlackToeMicrovertebrateLocality	15	0.873	5.64	herbivore
BrownGreyChannelLocalFauna	8	0.745	1.01	omnivore
BugCreekAnthillsLocalFauna	6	0.471	0.56	insectivore
CampsSkull	6	0.936	7.19	herbivore
CarsonTradingPost	7	0.980	11.27	herbivore
ChacoCanyon	7	0.948	13.99	herbivore
DenazinWashEctoconusZone	18	0.770	13.23	herbivore
DenazinWashTaeniolabisZone	20	0.862	8.90	herbivore
EastFlankKimbetohWash	20	0.833	10.62	herbivore
EngdahlRanch	3	0.946	1.68	insectivore
FerrisMainSectionPu1Fauna	7	0.892	4.33	herbivore
FerrisMainSectionPu2Fauna	8	0.894	10.20	herbivore
FerrisMainSectionPu3Fauna	8	0.937	10.08	herbivore
GarbaniChannelLocalFauna	10	0.550	4.54	insectivore
GasTankHillLocalFauna	13	0.89	12.51	herbivore
HarbichtHill	7	0.874	1.02	omnivore
HellsHollowLocalFauna	4	0.746	1.11	herbivore
HiattLocalFauna	6	0.735	3.26	herbivore
KerrButte	2	1.000	0.51	insectivore
LittleRoundtopChannelLocalFauna	6	0.913	0.75	omnivore
MalcomsExtension	5	0.963	9.94	herbivore
McKeeverRanchLocalFauna	4	0.845	1.23	omnivore
MHBTLongFallFauna	5	0.879	1.83	omnivore
MHBTRAVW1Fauna	10	0.861	2.94	carnivore
PineCreePark	1	0.592	0.54	insectivore

Table S1.5. cont.

Site	*MS* rounded	*J*	Average mass (kg)	Average diet
PurgatoryHill	12	0.824	2.27	insectivore
SecondLevelChannelLocalFauna	8	0.826	0.92	omnivore
ShiprockLocalFauna	7	0.673	0.83	insectivore
SimpsonQuarry	12	0.754	3.07	insectivore
SouthTableMountain LocalFauna	3	0.717	3.70	herbivore
SplitLipFlatsLocalFauna	15	0.900	6.18	herbivore
ThreeButtesLocalFauna	5	0.720	1.30	omnivore
ThreeGulleysOver	4	0.961	13.72	herbivore
UpUpTheCreekLocalFauna	9	0.760	0.93	omnivore
WagonroadLocalFauna	13	0.911	12.12	herbivore
WestBijouCreek	6	0.789	15.18	herbivore
WestBijouGarsGalore	2	0.811	1.27	herbivore
WestFlankKimbetohWash	12	0.803	13.90	herbivore
WindyMudstoneFauna	8	0.848	3.96	omnivore
WormCoulee	5	0.456	0.98	herbivore
YellowSandHills	6	0.373	2.09	insectivore

S1.2. References

Abbuhl, B., Peppe, D. J., & Flynn, A. (2015). Lateral floral variability in the early Paleocene Nacimiento Formation San Juan Basin NM. Paper presented at the 2015 GSA Annual Meeting, Baltimore, Maryland.

Archibald, J. D. (1981). The earliest known Palaeocene mammal fauna and its implications for the Cretaceous–Tertiary transition, *Nature*, *291*(5817), 650-652.

Archibald, J. D. (1982). A study of Mammalia and geology across the Cretaceous-Tertiary boundary in Garfield County Montana. *University of California Publications in Geological Sciences*, *122*, 1-286.

Archibald J. D. Butler R. F. Lindsay E. H. Clemens W. A. & Dingus L. (1982). Upper Cretaceous–Paleocene biostratigraphy and magnetostratigraphy Hell Creek and Tullock Formations northeastern Montana, *Geology*, *10*(3), 153-159.

Archibald, J. D., & Clemens W. A. (1984). Mammal evolution near the Cretaceous-Tertiary boundary. In Berggren, W. A., & Van Couvering, J. A. (eds.), *Catastrophes and Earth History: The New Uniformitarianism* (pp. 339-71). Princeton, NJ; Princeton University Press.

Atteberry, M., & Eberle, J., (2018). Phylogeny of new earliest Paleocene (Puercan) periptychid 'condylarths' from the Great Divide Basin. Poster presented at the Joint 70th Annual Rocky Mountain GSA Section/114th Annual Cordilleran GSA Section Meeting, Flagstaff, Arizona.

Ayers Jr., W. B. (1986). Lacustrine and fluvial-deltaic depositional systems Fort Union Formation (Paleocene) Powder River Basin, Wyoming and Montana. *AAPG Bulletin*, *70*(11), 1651-1673.

Barclay, R. S., Johnson, K. R., Betterton, W. J., & Dilcher, D. L. (2003). Stratigraphy and megaflora of a KT boundary section in the eastern Denver Basin, Colorado. *Rocky Mountain. Geology*, *38*(1), 45-71.

Beaumont, E. A. (1979). Depositional environments of Fort Union sediments (Tertiary, Northwest Colorado) and their relation to coal. *AAPG Bulletin*, *63*(2), 194-217.

Bown, T. M. (1980). Summary of latest Cretaceous and Cenozoic sedimentary tectonic and erosional events Bighorn Basin, Wyoming. In Gingerich, P. D. (ed.), *Early Cenozoic Paleontology and Stratigraphy of the Bighorn Basin Wyoming: Commemorating the 100th Anniversary of J. L. Wortman's Discovery of Fossil Mammals in the Bighorn Basin*. *University of Michigan Papers on Paleontology*, *24*, 25-32.

Buckley, G. A. (1994). *Paleontology geology and chronostratigraphy of Simpson Quarry (early Paleocene) Bear Formation, Crazy Mountains Basin, South-central Montana* (Doctoral dissertation, Rutgers University New Brunswick).

Buckley, G. A. (1995). The multituberculate *Catopsalis* from the early Paleocene of the Crazy Mountains Basin in Montana. *Acta Palaeontologica Polonica*, *40*(4), 389-398.

Buckley G. A. (1997). A new species of *Purgatorius* (Mammalia; Primatomorpha) from the lower Paleocene Bear Formation, Crazy Mountains basin south-central Montana. *Journal of Paleontology*, *71*(1), 149-155.

Buckley G. A. (2018). Magnetostratigraphy of Upper Cretaceous (Lancian) to Middle Paleocene (Tiffanian) strata in the northeastern Crazy Mountains Basin, Montana, USA. *Rocky Mountain Geology, 53*(2), 59-74.

Cather S. M. Heizler M. T. & Williamson T. E. (2018). Detrital sanidine and paleocurrent constraints on deposition of the Paleocene Nacimiento and Animas Formations, San Juan Basin, New Mexico. Abstract presented at the Joint 70th Annual Rocky Mountain GSA Section/114th Annual Cordilleran GSA Section Meeting, Flagstaff, Arizona.

Chester, S. G., Bloch, J. I., Boyer, D. M., & Clemens, W. A. (2015). Oldest known euarchontan tarsals and affinities of Paleocene *Purgatorius* to Primates. *Proceedings of the National Academy of Sciences*, *112*(5), 1487-1492.

Cifelli, R. L., Czaplewski, N. J., & Rose, K. D. (1995). Additions to knowledge of Paleocene mammals from the North Horn Formation, central Utah. *Great Basin Naturalist*, *55*(4), 304-314.

Clemens, W. A. (1974). *Purgatorius*, an early paromomyid primate (Mammalia). *Science*, *184*(4139), 903-905.

Clemens, W. A. (2002). Evolution of the mammalian fauna across the Cretaceous-Tertiary boundary in northeastern Montana and other areas of the Western Interior. In Hartman J. H., Johnson K.R., & Nichols, D. J. (eds.), *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*. *Geological Society of America Special Paper*, *361*, 217-245.

Clemens W. A. (2004). *Purgatorius* (Plesiadapiformes Primates? Mammalia,) a Paleocene immigrant into northeastern Montana: Stratigraphic occurrences and incisor proportions. In Dawson, M. R., & Lillegraven, J. A. (eds.) *Fanfare for an Uncommon paleontologist: Papers in honor of Malcolm McKenna*. *Bulletin of Carnegie Museum of Natural History*, *36*, 3-13.

Clemens W. A. & Wilson G. P. (2009). Early Torrejonian mammalian local faunas from northeastern Montana, USA. In Albright III, L. B. (ed.), *Papers on Geology Vertebrate Paleontology and Biostratigraphy in Honor of Michael O. Woodburne*. *Museum of Northern Arizona Bulletin*, *65*, 111-158.

Clemens W. A. (2017). *Procerberus* (Cimolestidae Mammalia) from the latest Cretaceous and earliest Paleocene of the northern Western Interior, USA. *PaleoBios*, *34*, 1-26.

Crystal V. (2017). A new earliest Paleocene mountain proximal mature forest floor fossil leaf site in the Denver Basin Colorado USA: Implications for the origins of rainforests. Paper presented at the 2017 GSA Annual Meeting, Seattle, Washington.

Dahlberg E. L. Eberle J. J. Sertich J. J. & Miller I. M. (2016). A new earliest Paleocene (Puercan) mammalian fauna from Colorado's Denver Basin, USA. *Rocky Mountain Geology*, *51*(1), 1-22.

Dane C. H. (1946). Stratigraphic relations of Eocene Paleocene and latest Cretaceous formations of eastern side of San Juan Basin, New Mexico. *United States Geological Survey Oil and Gas Investigation Charts*, *24*.

Davis, A. J., Peppe, D. J., Atchley, S. C., Williamson, T. E., & Flynn, A. G. (2016). Climate and landscape reconstruction of the Arroyo Chijuillita Member of the Nacimiento Formation, San Juan Basin, New Mexico: Providing environmental context to early Paleocene mammal evolution. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *463*, 27-44.

Dewar, E. W. (1996). *Mammalian paleoecology of the Early Paleocene Littleton Local Fauna (Denver Formation, Colorado)* (Master's thesis, University of Colorado Boulder).

Dewar, E. W. (2003). Functional diversity within the Littleton fauna (early Paleocene), Colorado: Evidence from body mass tooth structure and tooth wear. *PaleoBios*, *23*(1), 1-19.

Eberle, J. J., & Lillegraven, J. A. (1998a). A new important record of earliest Cenozoic mammalian history: Geologic setting Multituberculata and Peradectia. *Rocky Mountain Geology*, *33*(1), 3-47.

Eberle, J. J., & Lillegraven, J. A. (1998b). A new important record of earliest Cenozoic mammalian history: Eutheria and paleogeographic/biostratigraphic summaries. *Rocky Mountain Geology*, *33*(1), 49-117.

Eberle, J. J. (1999). Bridging the transition between didelphodonts and taeniodonts. *Journal of Paleontology*, *73*(5), 936-944.

Eberle, J. J. (2003). Puercan mammalian systematics and biostratigraphy in the Denver Formation, Denver Basin, Colorado. *Rocky Mountain Geology*, *38*(1), 143-169.

Fastovsky, D. E. (1987). Paleoenvironments of vertebrate-bearing strata during the Cretaceous-Paleogene transition, eastern Montana and western North Dakota. *Palaios*, *2*(3), 282-295.

Fastovsky, D. E. & Dott Jr., R. H. (1986). Sedimentology stratigraphy and extinctions during the Cretaceous-Paleogene transition at Bug Creek, Montana. *Geology*, *14*(4), 279-282.

Flynn, A., Peppe, D. J., Abbuhl, B., & Williamson, T. E. (2016). Early Paleocene plant communities from the lower Nacimiento Formation (San Juan Basin, New Mexico, USA) document relatively long-term ecosystem instability following the Cretaceous-Paleogene extinction event. Abstract presented at the GSA Annual Meeting, Denver, Colorado.

Fox, R. C. (1968). A new Paleocene mammal (Condylarthra: Arctocyonidae) from a well in Alberta, Canada. *Journal of Mammalogy*, *49*(4), 661-664.

Fox, R. C. (1990). The succession of Paleocene mammals in western Canada. In Bown, T. M., & Rose, K. D. (eds.), *Dawn of the Age of Mammals in the Northern Part of the Rocky Mountain Interior, North America*. *Geological Society of America Special Paper*, *243*, 516-524.

Fox, R. C., Rankin, B. D., Scott, C. S., & Sweet, A. R. (2014). Second known occurrence of the early Paleocene plesiadapiform *Pandemonium* (Mammalia: Primates), with description of a new species. *Canadian Journal of Earth Sciences*, *51*(12), 1059-1066.

Fox, R. C., & Scott, C. S. (2011). A new early Puercan (earliest Paleocene) species of *Purgatorius* (Plesiadapiformes, Primates) from Saskatchewan Canada. *Journal of Paleontology*, *85*(3), 537-548.

Fox, R. C., Scott, C. S., & Buckley, G. A. (2015). A 'giant' purgatoriid (Plesiadapiformes) from the Paleocene of Montana USA: mosaic evolution in the earliest primates. *Palaeontology*, *58*(2), 277-291.

Fox, R. C., & Youzwyshyn, G. P. (1994). New primitive carnivorans (Mammalia) from the Paleocene of western Canada, and their bearing on relationships of the order. *Journal of Vertebrate Paleontology*, *14*(3), 382-404.

Gazin, C. L. (1941a). Paleocene mammals from the Denver Basin, Colorado. *Journal of the Washington Academy of Sciences*, *31*(7), 289-295.

Gazin, C. L. (1938). A Paleocene mammalian fauna from central Utah. *Journal of the Washington Academy of Sciences*, *28*(6), 271-277.

Gazin, C. L. (1941b). The mammalian faunas of the Paleocene of central Utah with notes on the geology. *Proceedings of the United States National Museum*, *91*(3121), 1-53.

Gingerich, P. D. (1980). History of early Cenozoic vertebrate paleontology in the Bighorn Basin. In Gingerich, P. D. (ed.), *Early Cenozoic Paleontology and Stratigraphy of the Bighorn Basin, Wyoming: Commemorating the 100th Anniversary of J. L. Wortman's Discovery of Fossil Mammals in the Bighorn Basin*. *University of Michigan Papers on Paleontology*, *24*, 7-24.

Gingerich, P. D. (2016). Paleocene faunal evolution at Polecat Bench in the northern Bighorn Basin of Wyoming, USA. *Vertebrata PalAsiatica*, *54*(3), 212-234.

Gingerich, P. D., Rose, K. D., & Krause, D. W. (1980). Early Cenozoic mammalian faunas of the Clark's Fork Basin-Polecat Bench Area, northwestern Wyoming. In Gingerich, P. D. (ed.), *Early Cenozoic Paleontology and Stratigraphy of the Bighorn Basin, Wyoming: Commemorating the 100th Anniversary of J. L. Wortman's Discovery of Fossil Mammals in the Bighorn Basin*. *University of Michigan Papers on Paleontology*, *24*, 51-68.

Halverson E. K. & Eberle J. J. (2018). A new middle Paleocene (early Tiffanian) mammalian fauna from the Overland Member of the Fort Union Formation, Great Divide Basin, Wyoming, USA. *Rocky Mountain Geology*, *53*(2), 75-111.

Hartman, J. E. (1986). Paleontology and biostratigraphy of lower part of Polecat Bench Formation, southern Bighorn Basin, Wyoming. *Rocky Mountain Geology*, *24*(1), 11-63.

Hartman, J. H., Butler, R. D., Weiler, M. W., Schumaker, K. K., Wilson, G. P., Clemens, W. A., & Horner, J. R. (2014). Context naming and formal designation of the Cretaceous Hell Creek Formation lectostratotype, Garfield County, Montana. In Wilson, G. P., Clemens, W. A., Horner, J. R., & Hartman, J. H. (eds.) *Through the End of the Cretaceous in the Type Locality of the Hell Creek Formation in Montana and Adjacent Areas*. *Geological Society of America Special Papers*, *503*, 89-121.

Hartman, J. H., Buckley, G. A., Krause, D. W., & Kroeger, T. J. (1989). Paleontology stratigraphy and sedimentology of Simpson Quarry (early Paleocene), Crazy Mountains Basin, South-central Montana. In French, D. E., & Grabb, R. F. (eds.), *1989 Field Conference Guidebook Montana Centennial Edition – Geologic Resources of Montana Volume II: Road Logs, August-September 1989* (pp. 173-185). Billings MT: Montana Geological Society.

Hartman, J. H., & Krause, D. W. (1993). Cretaceous and Paleocene stratigraphy and paleontology of the Shawmut Anticline and the Crazy Mountains Basin, Montana: Road log and overview of recent investigations. In French, D. E.m & Grabb, R. F. (eds.), *1993 Montana Geological Society Field Conference Guidebook: Energy and Mineral Resources of Central Montana – Old Timers' Rendezvous Edition*. Billings MT: Montana Geological Society.

Heizler M. T., Mason, A., Williamson, T. E., Peppe, D. J., & Ramezani, J. (2013) 40Ar/39Ar Chronostratigraphy of Cretaceous and Paleocene strata in the San Juan Basin, New Mexico: Accuracy limitations of high precision measurements. Abstract presented at 2013 Geological Society of America Annual Meeting, Denver, Colorado.

Hicks, J. F., Johnson, K. R., Obradovich, J. D., Tauxe, L., & Clark, D. (2002). Magnetostratigraphy and geochronology of the Hell Creek and basal Fort Union Formations of southwestern North Dakota, and a recalibration of the age of the Cretaceous-Tertiary boundary. In Hartman, J. H., Johnson, K. R., & Nichols, D. J. (eds.), *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*. *Geological Society of America Special Paper*, *361*, 35-55.

Hicks, J. F., Johnson, K. R., Obradovich, J. D., Tauxe, L., & Clark, D. (2002). Magnetostratigraphy and geochronology of the Hell Creek and basal Fort Union Formations of southwestern North Dakota and a recalibration of the age of the Cretaceous-Tertiary boundary. Hartman, J. H., Johnson, K. R., & Nichols, D. J. (eds.), *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*. *Geological Society of America Special Paper*, *361*, 35-55.

Hicks J. F., Johnson, K. R., Obradovich, J. D., Miggins, D. P., & Tauxe, L. (2003). Magnetostratigraphy of upper Cretaceous (Maastrichtian) to lower Eocene strata of the Denver Basin Colorado. *Rocky Mountain Geology*, *38*(1), 1-27.

Hunter J. P. Pearson D. & Hartman J. (2003). Additions to the Puercan mammals of North Dakota and a framework for study of post- K/T vertebrate recovery. *Journal of Vertebrate Paleontology*, *23*(S3), 64A.

Hunter, J. P., & Archibald, J. D. (2002). Mammals from the end of the age of dinosaurs in North Dakota and southeastern Montana with a reappraisal of geographic differentiation among Lancian mammals. Hartman, J. H., Johnson, K. R., & Nichols, D. J. (eds.), *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*. *Geological Society of America Special Paper*, *361*, 191-216.

Hunter, J. P. (1999). The radiation of Paleocene mammals with the demise of the dinosaurs: Evidence from southwestern North Dakota. *Proceedings of the North Dakota Academy of Science*, *53*, 141-144.

Hunter, J. P., Pearson, D., & Hartman, J. (2003). Additions to the Puercan mammals of North Dakota and a framework for study of post- K/T vertebrate recovery. *Journal of Vertebrate Paleontology*, *23*(S3), 64A.

Hunter, J. P., & Archibald, J. D. (2002). Mammals from the end of the age of dinosaurs in North Dakota and southeastern Montana, with a reappraisal of geographic differentiation among Lancian mammals. In Hartman, J. H., Johnson, K. R., & Nichols, D. J. (eds.), *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*. *Geological Society of America Special Paper*, *361*, 191-216.

Jepsen, G. L. (1930). New vertebrate fossils from the Lower Eocene of the Bighorn Basin, Wyoming. *Proceedings of the American Philosophical Society*, *69*(1), 117-131.

Jepsen, G. L. (1940). Paleocene faunas of the Polecat Bench Formation, Park County, Wyoming: Part I. *Proceedings of the American Philosophical Society*, *83*(2), 217-340.

Jepsen, G. L., & Van Houten, F. B. (1947). Early Tertiary stratigraphy and correlations. In Blackstone Jr., D. L., & Sternberg, C. W. (eds.) *Field Conference in the Bighorn Basin Guidebook: August 5-8 1947* (pp. 142-149). Casper, WY: Wyoming Geological Association.

Johnson, K. R., Reynolds, M. L., Werth, K. W., & Thomasson, J. R. (2003). Overview of the Late Cretaceous early Paleocene and early Eocene megafloras of the Denver Basin Colorado. *Rocky Mountain Geology*, *38*(1), 101-120.

Johnston P. A. & Fox R. C. (1984). Paleocene and Late Cretaceous mammals from Saskatchewan, Canada. *Palaeontographica Abteilung A*, *186*, 163–222.

Kelly, T. S. (2014). Preliminary report on the mammals from Lane's Little Jaw Site Quarry: A latest Cretaceous (earliest Puercan?) local fauna, Hell Creek Formation, southeastern Montana. *Paludicola*, *10*(1), 50-91.

Kondrashov, P., & Lucas, S. G. (2006). Early Paleocene (Puercan and Torrejonian) archaic ungulates (Condylarthra, Procreodi, and Acreodi) of the San Juan Basin, New Mexico. Lucas, S.G., Spielmann, J. A., Hester, P. M., Kenworthy, J. P., & Santucci, V. L. (eds.), *America's Antiquities: 100 Years of Managing Fossils on Federal Lands*. *New Mexico Museum of Natural History & Science Bulletin*, *34*, 84-97.

Kroeger, T. J. (1996). *The paleoecologic significance of Paleocene palynomorph assemblages from the Ludlow Slope and Cannonball Formations, southwestern North Dakota* (Doctoral dissertation University of North Dakota, Grand Forks).

LeCain, R., Clyde, W. C., Wilson, G. P., & Riedel, J. (2014). Magnetostratigraphy of the Hell Creek and lower Fort Union formations in northeastern Montana. In Wilson, G. P., Clemens, W. A., Horner, J. R., & Hartman, J. H. (eds.), *Through the End of the Cretaceous in the Type Locality of the Hell Creek Formation in Montana and Adjacent Areas*. *Geological Society of America Special Papers*, *503*, 137-147.

Lerbekmo, J. F., Sweet, A. R., & Braman, D. R. (1995). Magnetobiostratigraphy of late Maastrichtian to early Paleocene strata of the Hand Hills, south central Alberta, Canada. *Bulletin of Canadian Petroleum Geology*, *43*(1), 35-43.

Leslie, C. E., Peppe, D. J., Williamson, T. E., Heizler, M., Jackson, M., Atchley, S. C., Nordt, L., & Standhardt, B. (2018). Revised age constraints for Late Cretaceous to early Paleocene terrestrial strata from the Dawson Creek section, Big Bend National Park, west Texas. *Geological Society of America Bulletin*, *130*(7-8), 1143-1163.

Lillegraven, J. A., Snoke, A. W., & McKenna, M. C. (2004). Tectonic and paleogeographic implications of late Laramide geologic history in the northeastern corner of Wyoming's Hanna Basin. *Rocky Mountain Geology*, *39*(1), 7-64.

Lindsay, E. H., Jacobs, L. L., & Butler, R. F., (1978). Biostratigraphy and magnetostratigraphy of Paleocene terrestrial deposits, San Juan Basin, New Mexico. *Geology*, *6*(7), 425-429.

Lofgren D. L. (1995). The Bug Creek Problem and the Cretaceous-Tertiary transition at McGuire Creek, Montana. *University of California Publications in Geological Sciences*, *140*, 1-200.

Lucas, S. G., & Estep, J. W. (2000). Field notes of Walter Granger's 1912, 1913, and 1916 expeditions to the San Juan Basin, New Mexico. In Lucas, S. G. (ed.), New Mexico's Fossil Record 2. *New Mexico Museum of Natural History & Science Bulletin*, *16*, 169-186.

Lucas, S. G., & Williamson, T. E. (1993). Late Cretaceous to early Eocene vertebrate biostratigraphy and biochronology of the San Juan basin, New Mexico. In Lucas, S. G., & Zidek, J. (eds.), *Vertebrate Paleontology in New Mexico*. *New Mexico Museum of Natural History & Science Bulletin*, *2*, 105-136.

Lyson, T. R., Bercovici, A., Chester, S. G., Sargis, E. J., Pearson, D., & Joyce, W. G. (2011). Dinosaur extinction: closing the '3 m gap'. *Biology Letters*, *7*(6), 925-928.

Matthew, W. D. (1937). Paleocene faunas of the San Juan Basin, New Mexico. *Transactions of the American Philosophical Society*, *30*, 1-510.

McComas K. M. & Eberle J. J. (2016). A new earliest Paleocene (Puercan) arctocyonid mammal from the Fort Union Formation Great Divide Basin Wyoming and its phylogenetic position among early 'condylarths'. *Journal of Systematic Palaeontology*, *14*(6), 445-459.

McGrew, P. O., & Roehler, H. W. (1960). Correlation of Tertiary units in southwestern Wyoming. In McGookey, D. P. & Miller Jr., D. N. (eds.), *Overthrust Belt of Southwestern Wyoming and Adjacent Areas: 15th Annual Field Conference Guidebook* (pp. 156-158). Casper, WY: Wyoming Geological Association.

McKenna, M. C. (1960). Fossil Mammalia from the early Wasatchian Four Mile fauna, Eocene of northwest Colorado. *University of California Publications in Geological Sciences*, *37*, 1-130.

Middleton, M. D. (1982). A new species and additional material of *Catopsalis* (Mammalia Multituberculata) from the Western Interior of North America. *Journal of Paleontology*, 56(5), 1197-1206.

Middleton, M. D. (1983). *Early Paleocene vertebrates of the Denver Basin, Colorado* (Doctoral dissertation, University of Colorado Boulder).

Middleton, M. D. & Dewar, E. W. (2004). New mammals from the early Paleocene Littleton fauna (Denver Formation, Colorado). In Lucas, S. G., Zeigler, K. E., & Kondrashov, P. (eds.), *Paleogene Mammals. New Mexico Museum of Natural History & Science Bulletin*, *26*, 59-80.

Moore, W. L. (1976). Stratigraphy and environments of deposition of the Cretaceous, Hell Creek Formation (reconnaissance) and the Paleocene Ludlow Formation (detailed), southwestern North Dakota. *North Dakota Geological Survey Report of Investigations*, *56*, 1-40.

Murphy, E. C., Hoganson, J. W., & Johnson, K. R. (2002). Lithostratigraphy of the Hell Creek Formation in North Dakota. In Hartman, J. H., Johnson, K. R., & Nichols, D. J. (eds.), *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*. *Geological Society of America Special Paper*, *361*, 9-34.

Nichols, D. J., & Fleming, R. F. (2002). Palynology and palynostratigraphy of Maastrichtian Paleocene and Eocene strata in the Denver Basin, Colorado. *Rocky Mountain Geology*, 37(2), 135-163.

Obradovich, J. D. (2002). Geochronology of Laramide synorogenic strata in the Denver Basin, Colorado. *Rocky Mountain Geology*, *37*(2), 165-171.

Peppe, D. J., Evans, D. A., & Smirnov, A. V. (2009). Magnetostratigraphy of the Ludlow Member of the Fort Union Formation (Lower Paleocene) in the Williston Basin, North Dakota. *Geological Society of America Bulletin*, *121*(1-2), 65-79.

Peppe, D. J., Heizler, M. T., Williamson, T. E., Masson, I. P., Brusatte, S., Weil, A., & Secord, R. (2013). New age constraints on the Late Cretaceous through early Paleocene rocks in the San Juan Basin, New Mexico. Abstract presented at 2013 Geological Society of America Annual Meeting, Denver, Colorado.

Pocknall, D. T., & Flores, R. M. (1987). Coal palynology and sedimentology in the Tongue River Member, Fort Union Formation, Powder River Basin, Wyoming. *Palaios*, *2*(2), 133-145.

Redman, C. M., Gardner, J. D., Scott, C. S., & Braman, D. R. (2015). Geological setting of vertebrate microfossil localities across the Cretaceous–Paleogene boundary in southwestern Saskatchewan, Canada. *Canadian Journal of Earth Sciences*, *52*(10), 846-862.

Rigby, J. K., & Rigby Jr., J. K. (1990). Geology of the Sand Arroyo and Bug Creek Quadrangles, McCone County, Montana. *Brigham Young University Geology Studies*, *36*, 69-134.

Rigby Jr, J. K., Newman, K. R., Van Der Kaars, J. S. S., Sloan, R. E., & Rigby, J. K. (1987). Dinosaurs from the Paleocene part of the Hell Creek Formation, McCone County, Montana. *Palaios*, *2*(3), 296-302.

Roberts, A. E. (1965). Correlation of Cretaceous and lower Tertiary rocks near Livingston, Montana, with those in other areas of Montana and Wyoming. *US Geological Survey Professional Paper*, *525B*(5), B54-B63.

Robinson, P. (1971). The Tertiary deposits of the Rocky Mountains: A summary and discussion of unsolved problems. *Rocky Mountain Geology*, *9*(2), 86-96.

Robinson S. G. (1986). Paleocene (Puercan-Torrejonian) mammalian faunas of the North Horn Formation, central Utah. *Brigham Young University Geology Studies*, *33*(1), 87-133.

Rook, D. L., Hunter, J. P., Pearson, D. A., & Bercovici, A. (2010). Lower jaw of the early Paleocene mammal *Alveugena* and its interpretation as a transitional fossil. *Journal of Paleontology*, 84(6), 1217-1225.

Russell, L. S. (1974). Fauna and correlation on the Ravenscrag Formation (Paleocene) of southwestern Saskatchewan. *Royal Ontario Museum Life Sciences Contribution*, *102*, 1–52.

Scott, C. S., Fox, R. C., & Redman, C. M. (2016). A new species of the basal plesiadapiform Purgatorius (Mammalia Primates) from the early Paleocene Ravenscrag Formation, Cypress Hills, southwest Saskatchewan, Canada: Further taxonomic and dietary diversity in the earliest primates. *Canadian Journal of Earth Sciences*, *53*(4), 343-354.

Shearer, J. C., Moore, T. A., & Demchuk, T. D. (1995). Delineation of the distinctive nature of Tertiary coal beds. *International Journal of Coal Geology*, *28*(2-4), 71-98.

Simmons, N. B. (1987). A revision of *Taeniolabis* (Mammalia: Multituberculata) with a new species from the Puercan of eastern Montana. *Journal of Paleontology*, *61*(4), 794-808.

Simpson, G. G. (1951). Hayden, Cope, and the Eocene of New Mexico. *Proceedings of the Academy of Natural Sciences of Philadelphia*, *103*, 1-21.

Simpson, G. G. (1981). History of vertebrate paleontology in the San Juan Basin. In Lucas, S. G., Rigby, J. K., & Kues, B. S. (eds.), *Advances in San Juan Basin Paleontology* (pp. 3-28). Albuquerque: University of New Mexico Press.

Sinclair, W. J., & Granger, W. (1914). Paleocene deposits of the San Juan Basin, New Mexico. *Bulletin of the American Museum of Natural History*, *33*(22), 297-316.

Sloan, R. E., Rigby, J. K., Van Valen, L. M., & Gabriel D. (1986). Gradual dinosaur extinction and simultaneous ungulate radiation in the Hell Creek Formation. *Science*, *232*(4750), 629-633.

Sloan, R. E., & Van Valen, L. (1965). Cretaceous mammals from Montana. *Science*, *148*(3667), 220-227.

Sloan, R. E. (1987). Paleocene and latest Cretaceous mammal ages biozones magneto zones rates of sedimentation and evolution. In Fassett, J. E., & Rigby Jr, J. K. (eds.) *The Cretaceous–Tertiary boundary in the San Juan and Raton basins, New Mexico and Colorado*. *Geological Society of America Special Papers*, *209*, 165-200.

Sprain, C. J., Renne, P. R., Wilson, G. P., & Clemens, W. A. (2015). High-resolution chronostratigraphy of the terrestrial Cretaceous-Paleogene transition and recovery interval in the Hell Creek region, Montana. *Geological Society of America Bulletin*, *127*(3-4), 393-409.

Sprain, C. J., Renne, P. R., Clemens, W. A., & Wilson, G. P. (2018). Calibration of chron C29r: New high-precision geochronologic and paleomagnetic constraints from the Hell Creek region, Montana. *Geological Society of America Bulletin*, *130*(9-10), 1615-1644.

Standhardt, B. R. (1986). *Vertebrate paleontology of the Cretaceous/Tertiary transition of Big Bend National Park, Texas* (Doctoral dissertation, Louisiana State University, Baton Rouge).

Standhardt, B. R. (1995). Early Paleocene (Puercan) verterbrates of the Dogie locality, Big Bend National Park, Texas. In Santucci, V., & McClelland, L. (eds.), *National Park Services Paleontological Research* (pp. 46-48). Lakewood, CO: National Park Service Geological Resource Division.

Swisher III, C. C., Dingus, L., & Butler, R. F. (1993). 40Ar/39Ar dating and magnetostratigraphic correlation of the terrestrial Cretaceous–Paleogene boundary and Puercan Mammal Age, Hell Creek–Tullock formations, eastern Montana. *Canadian Journal of Earth Sciences*, *30*(9), 1981-1996.

Templeman, T. (2018). *New earliest Paleocene (Puercan) multituberculate fauna from the China Butte Member of the Fort Union Formation, Great Divide Basin, Wyoming* (Master's thesis, University of Colorado Boulder).

Tomida, Y., & Butler, R. F. (1980). Dragonian mammals and Paleocene magnetic polarity stratigraphy North Horn Formation, central Utah. *American Journal of Science*, *280*(8), 787-811.

Van Valen, L., & Sloan, R. E., (1965). The earliest primates. *Science*, *150*(3697), 743-745.

Williamson, T. E., Weil, A., & Standhardt, B. (2011). Cimolestids (Mammalia) from the early Paleocene (Puercan) of New Mexico. *Journal of Vertebrate Paleontology*, *31*(1), 162-180.

Williamson, T. E., & Lucas, S. G. (1992). Stratigraphy and mammalian biostratigraphy of the Paleocene Nacimiento Formation, southern San Juan Basin, New Mexico. In Lucas, S.G., Kues, B. S., Williamson, T. E., & Hunt, A. P. (eds.), *San Juan Basin IV*. *New Mexico Geological Society Guidebook*, *43*, 265-296.

Williamson, T. E. (1996). The beginning of the Age of Mammals in the San Juan Basin, New Mexico: Biostratigraphy and evolution of Paleocene mammals of the Nacimiento Formation. *New Mexico Museum of Natural History & Science Bulletin*, *8*, 1- 142.

Williamson, T. E., Nichols, D. J., & Weil, A. (2008). Paleocene palynomorph assemblages from the Nacimiento Formation, San Juan Basin, New Mexico, and their biostratigraphic significance. *New Mexico Geology*, *30*(1), 3-11.

Williamson, T. E., Brusatte, S. L., Peppe, D. J., Secord, R. S., & Weil, A. (2012). No evidence for conformable contact between the Ojo Alamo Sandstone and the Nacimiento Formation. Abstract presented at the New Mexico Geological Society Annual Spring Meeting, Socorro, New Mexico.

Williamson, T. E., & Brusatte, S. L. (2014). Small theropod teeth from the Late Cretaceous of the San Juan Basin, northwestern New Mexico, and their implications for understanding latest Cretaceous dinosaur evolution. *PLOS ONE*, *9*(4), e93190.

Williamson, T. E., & Weil, A. (2008) Metatherian mammals from the Naashoibito Member, Kirtland Formation, San Juan Basin, New Mexico, and their biochronologic and paleobiogeographic significance. *Journal of Vertebrate Paleontology*, *28*, 803–815.

Wilson, G. P. (2005). Mammalian faunal dynamics during the last 1.8 million years of the Cretaceous in Garfield County, Montana. *Journal of Mammalian Evolution*, *12*(1-2), 53-76.

Wilson, G. P. (2013). Mammals across the K/Pg boundary in northeastern Montana, USA: Dental morphology and body-size patterns reveal extinction selectivity and immigrant-fueled ecospace filling. *Paleobiology*, *39*(3) 429-469.

Wilson, G. P. (2014). Mammalian extinction survival and recovery dynamics across the Cretaceous-Paleogene boundary in northeastern Montana, USA. In Wilson, G. P., Clemens, W. A., Horner, J. R., & Hartman, J. H., (eds.), *Through the End of the Cretaceous in the Type Locality of the Hell Creek Formation in Montana and Adjacent Areas*. *Geological Society of America Special Papers*, *503*, 365-392.

Winterfeld, G. F. (1982). Mammalian paleontology of the Fort Union Formation (Paleocene) eastern Rock Springs Uplift, Sweetwater County, Wyoming. *Rocky Mountain Geology*, *21*(1), 73-111.

APPENDIX 2:

STATISTICAL RESULTS

Table S2.1. Chi-square contingency test results.

Dataset	Variable 1	Variable 2	χ^2	*v*	*p*
Pu1 sites	Basin	Lithology	11.958	12	0.449
	Basin	Collecting	21.669	8	0.006
	Region	Lithology	9.464	6	0.149
	Region	Collecting	7.892	4	0.096
	Lithology	Collecting	7.958	6	0.241
Pu2/Pu3 sites	Basin	Lithology	24.903	15	0.051
	Basin	Collecting	19.516	10	0.034
	Region	Lithology	8.5513	6	0.200
	Region	Collecting	13.276	4	0.01
	Lithology	Collecting	4.0519	6	0.670

Table S2.2. Shapiro-Wilks results for richness and evenness.

Data subset	W_{MS}	p_{MS}	W_J	p_J
Pu1 sites, screen-wash	0.974	0.925	0.851	0.023
Pu1 sites, surface	0.765	0.033	0.826	0.177
Pu2/Pu3 sites, screen-wash	0.902	0.170	0.840	0.028
Pu2/Pu3 sites, surface	0.900	0.058	0.899	0.057

Table S2.3. Shapiro-Wilks results for body size and diet.

Data subset	W_{size}	p_{size}	W_{diet}	p_{diet}
Pu1 screenwash	0.636	8.66E-05	0.726	6.953E-04
Pu1 surface	0.887	0.344	0.750	2.2E-16
Pu2/Pu3 screenwash	0.953	0.677	0.624	1.706E-04
Pu2/Pu3 surface	0.907	0.075	0.253	1.057E-08

Table S2.4. Kruskal-Wallis results.

		MS			***J***		
Dataset	**Variable**	χ^2	*v*	*p*	χ^2	*v*	*p*
Pu1 sites, screen-wash	Region	3.157	2	0.206	1.457	2	0.483
	Basin	3.157	2	0.206	1.457	2	0.483
	Lithology	1.56	2	0.458	1.701	2	0.427
Pu1 sites, surface	Region	2	2	0.368	2	2	0.368
	Basin	2	2	0.368	2	2	0.368
	Lithology	1.5	1	0.221	1.5	1	0.221
Pu2/Pu3 sites, screen-wash	Region	5.727	1	0.017	0.117	1	0.732
	Basin	6.873	2	0.032	0.327	2	0.849
	Lithology	3.818	2	0.148	0.327	2	0.849
Pu2/Pu3 sites, surface	Region	2.125	2	0.346	5.073	2	0.079
	Basin	5.298	4	0.258	6.084	4	0.193
	Lithology	7.938	3	0.047	3.417	3	0.332

Table S2.4. cont.

Dataset	Variable	Body mass χ^2	v	p	Diet χ^2	v	p
Pu1 screenwash	Region	3.591	2	0.166	2.567	2	0.277
	Basin	3.591	2	0.166	2.567	2	0.277
	Lithology	2.073	2	0.355	1.620	2	0.445
Pu1 surface	Region	7.938	2	0.368	12.6	2	0.002
	Basin	8.638	2	0.368	12.6	4	0.013
	Lithology	0	1	1	0.5	1	0.480
Pu2/Pu3 screenwash	Region	6.231	1	0.013	9	1	0.003
	Basin	6.577	2	0.037	9.031	2	0.011
	Lithology	1.884	2	0.390	1.889	2	0.389
Pu2/Pu3 surface	Region	5.133	2	0.077	8	2	0.018
	Basin	9.004	4	0.061	8	4	0.092
	Lithology	3.209	4	0.524	3.5	4	0.478

Table S2.5. ANOSIM results.

Dataset	Variable	*R*	*P*
Pu1 sites, screen-wash	Basin	0.587	0.017
	Region	0.434	0.019
	Lithology	0.333	0.122
	Body Size	-0.013	0.573
	Diet	0.227	0.002
Pu1 sites, surface	Basin	0.403	0.055
	Region	0.403	0.054
	Lithology	0.152	0.263
	Body Size	-0.117	0.865
	Diet	0.379	0.001
Pu2/Pu3 sites, screen-wash	Basin	0.445	0.006
	Region	0.499	0.005
	Lithology	0.206	0.138
	Body Size	-0.001	0.492
	Diet	0.101	0.002
Pu2/Pu3 sites, surface	Basin	0.494	0.008
	Region	0.151	0.182
	Lithology	0.720	0.002
	Body Size	0.119	0.248
	Diet	-0.070	0.922

APPENDIX 3:

AGNES DENDROGRAMS

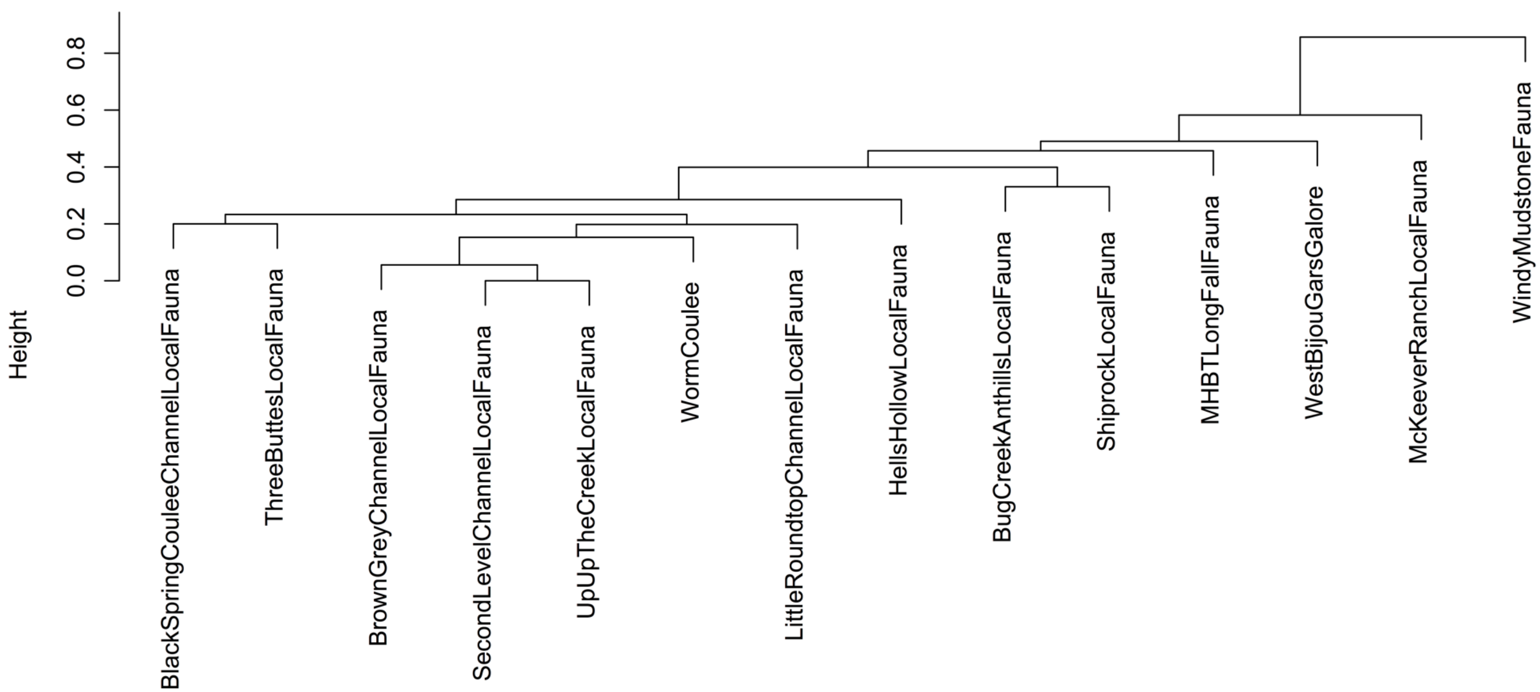


Figure S3.1. Dendrogram of Pu1 screen-washing sites. AC = 0.65.

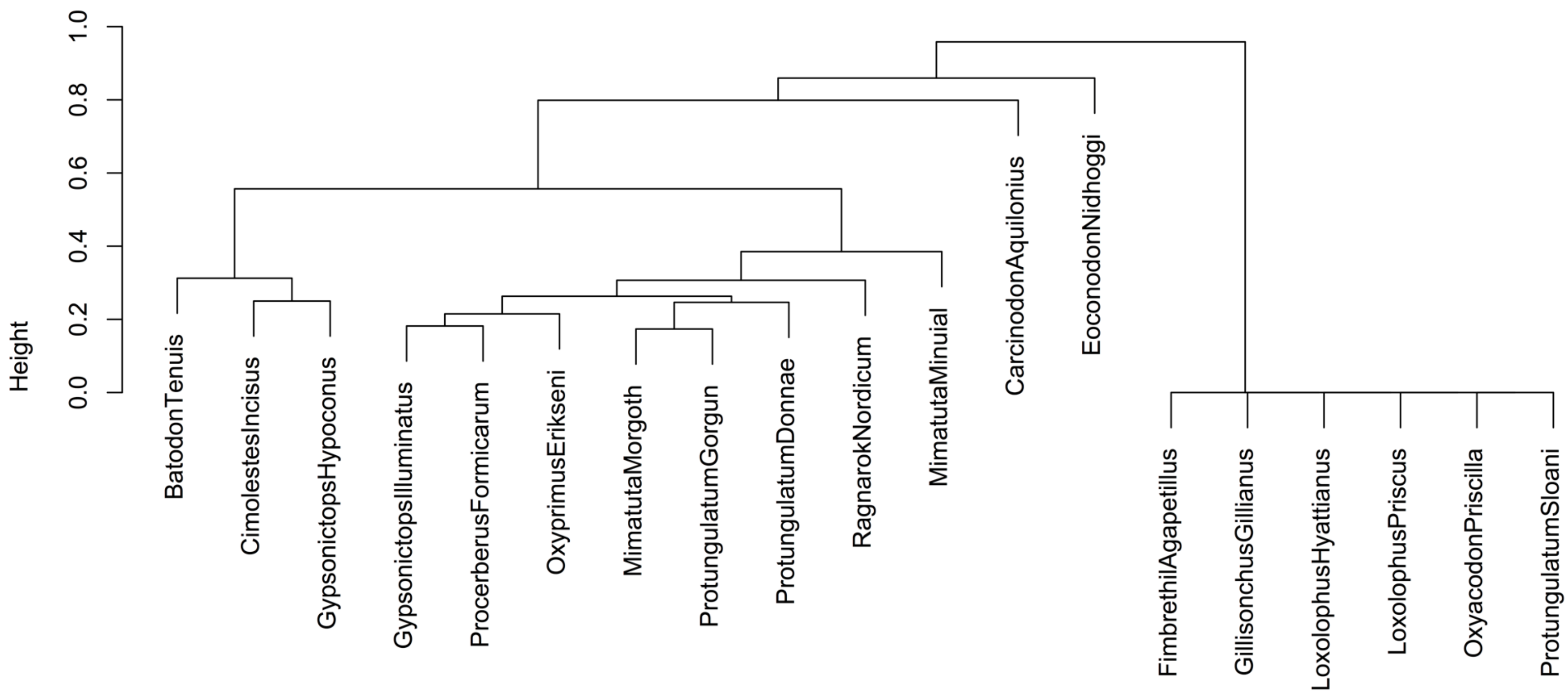


Figure S3.2. Dendrogram of taxa at Pu1 screen-washing sites. AC = 0.76.

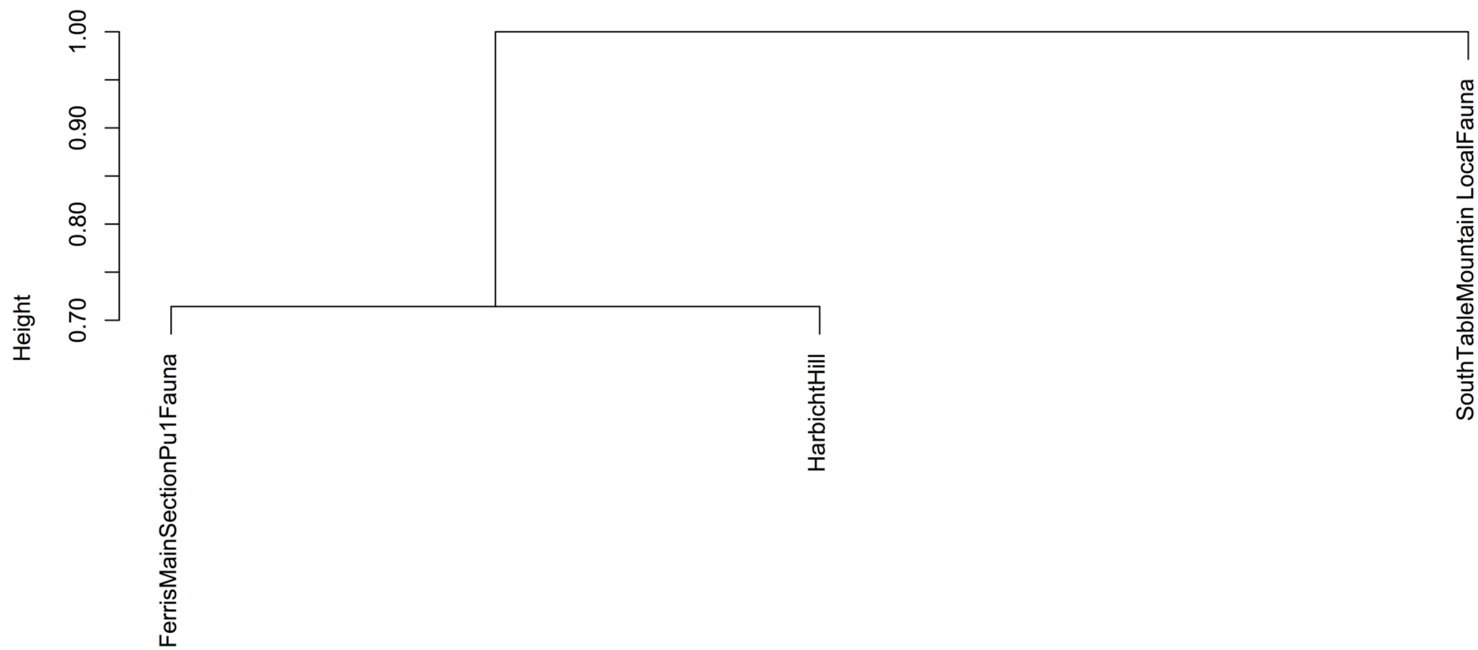
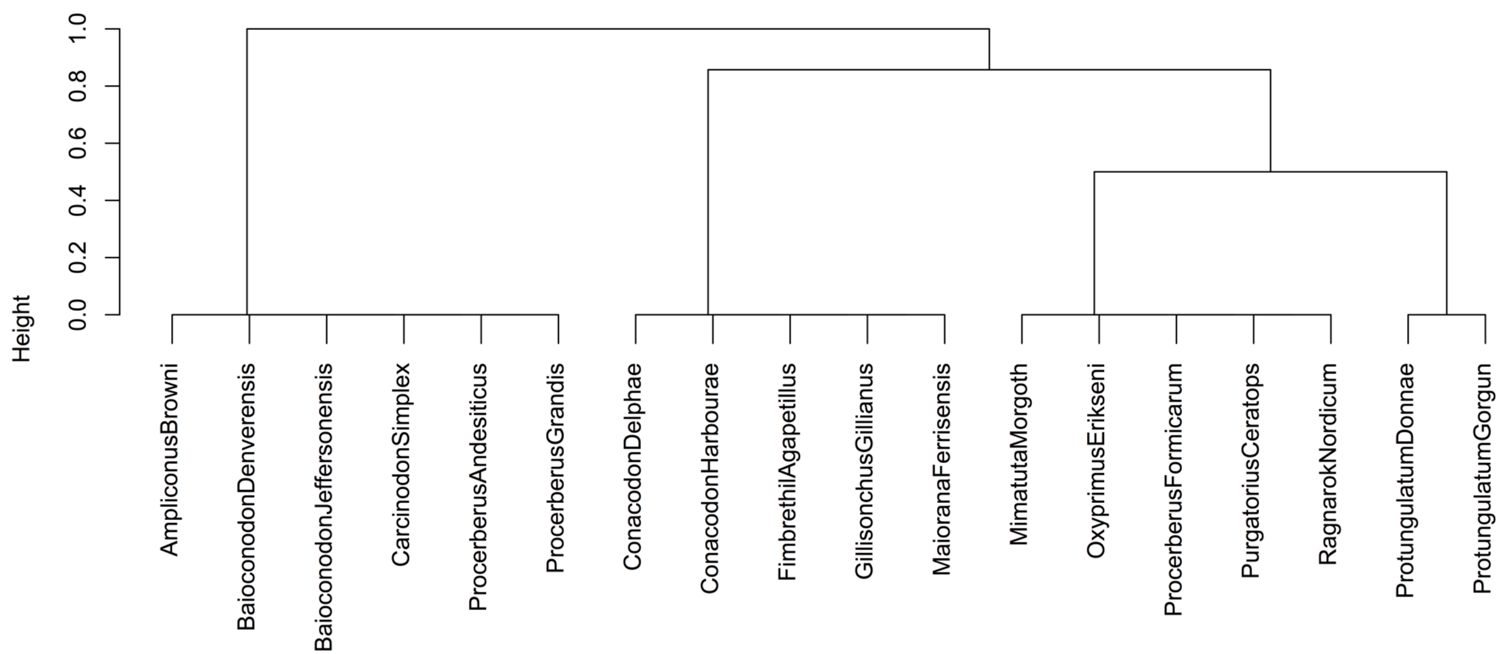


Figure S3.3. Dendrogram of Pu1 surface sites. AC = 0.19.



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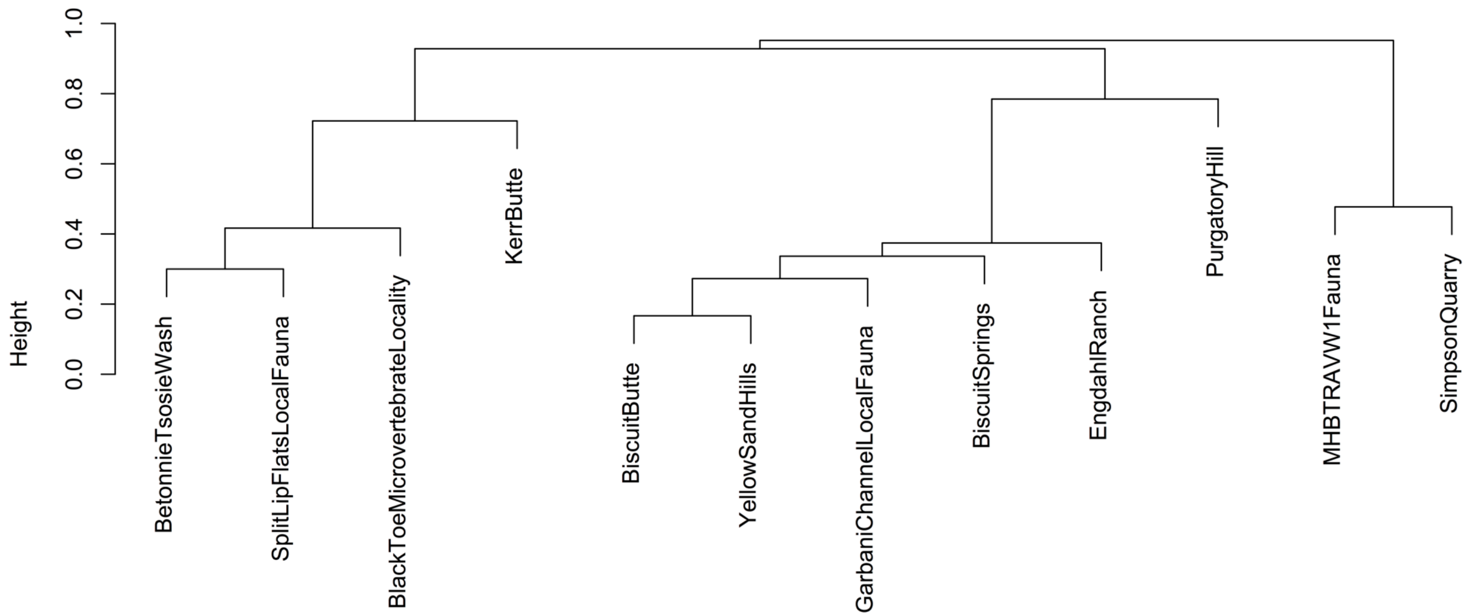

Figure S3.5. Dendrogram of Pu2/Pu3 screen-washing sites. AC = 0.58.

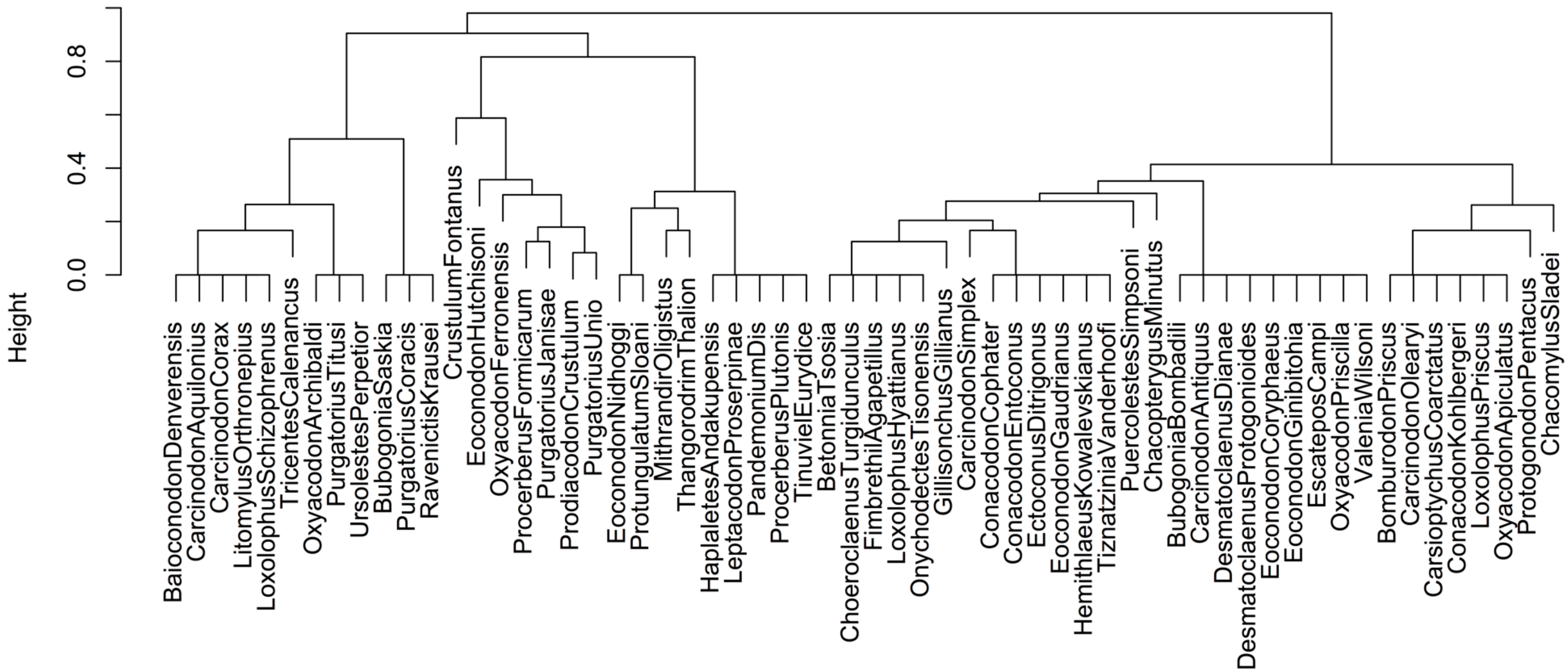

Figure S3.6. Dendrogram of taxa at Pu2/Pu3 screen-washing sites. AC = 0.94.

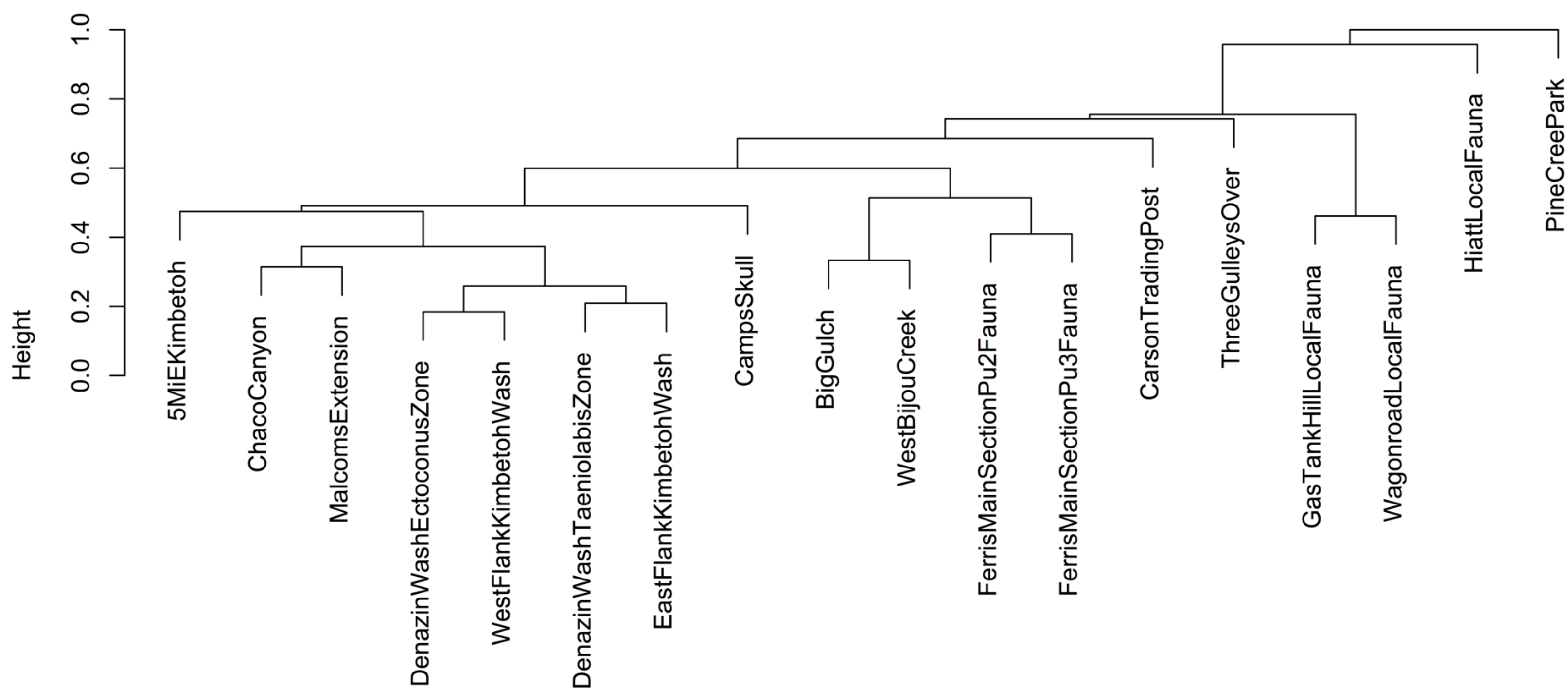

Figure S3.7. Dendrogram of Pu2/Pu3 surface sites. AC = 0.55.

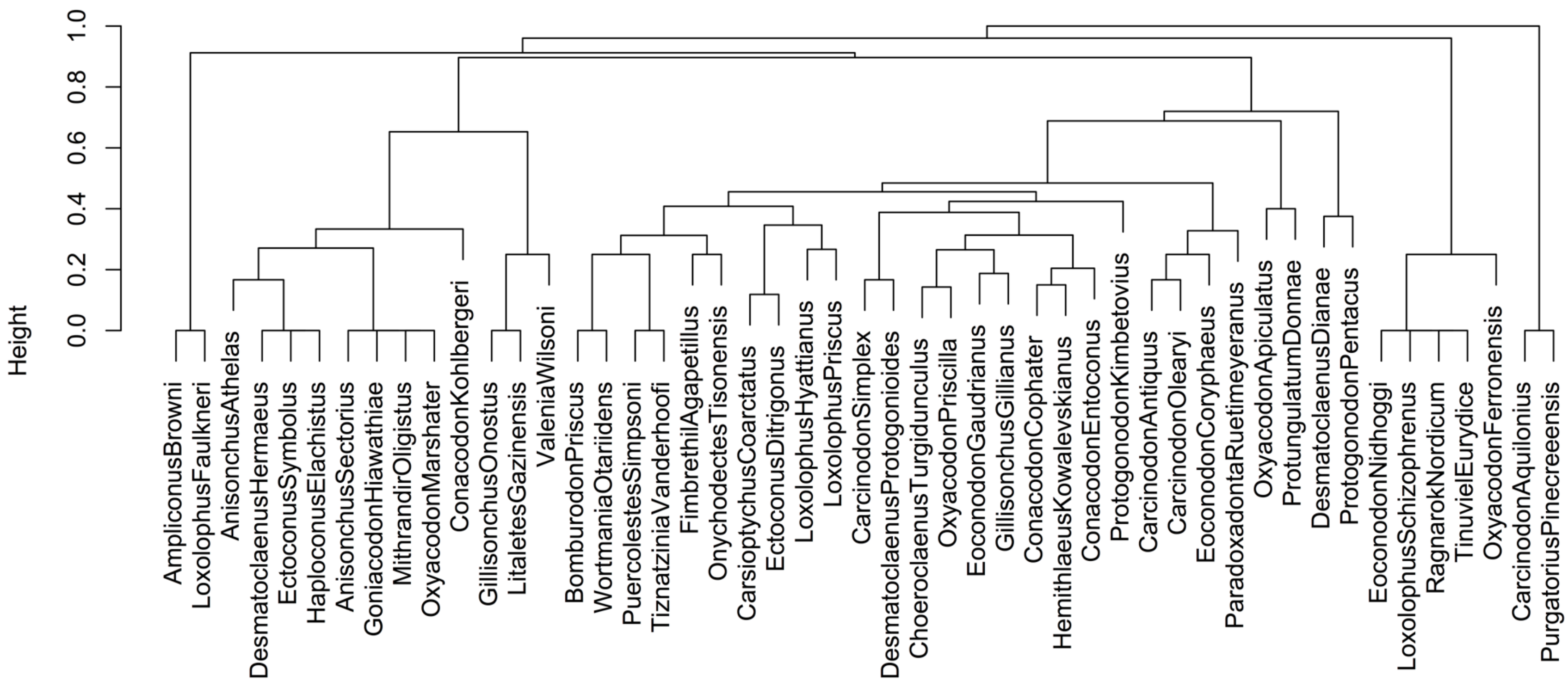

Figure S3.8. Dendrogram of taxa at Pu2/Pu3 surface sites. AC = 0.86.