

NEW LATEST CRETACEOUS MAMMALS FROM NORTHEASTERN COLORADO WITH BIOCHRONOLOGIC AND BIOGEOGRAPHIC IMPLICATIONS

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ABSTRACT—Few latest Cretaceous mammalian faunas are known from the central part of the Western Interior of North America. Here we report a collection of 28 mammalian fossils (23 isolated teeth, 5 dentulous jaw fragments) from five Upper Cretaceous localities in and around the Pawnee National Grassland (Weld County) in the Cheyenne Basin, northeastern Colorado. At least 10 taxa are represented, including two new multituberculates, a neoplagiaulacid *Parikimys carpenteri* and a ?cimolomyid *Paressonodon nelsoni*, which has greatest affinities to *Essonodon browni*. The new specimens combine with a previously reported sample for a total of 40 mammalian specimens from the area. Using a subsurface model based on geophysical log data, we stratigraphically arranged the fossil localities relative to the top of the Fox Hills Sandstone. Our stratigraphically lowest site is 95 m above the datum and likely near the top of the Laramie Formation. Presence of *Meniscoessus collomensis* at this site implies a late ‘Edmontonian’ or early Lancian age. The remaining sites are 220, 330, and 410 m above the datum and temporally equivalent to the Cretaceous part of the D1 sequence in the Denver Basin; the stratigraphically highest site is near the predicted Cretaceous–Tertiary boundary. The faunal samples from the latter sites include mostly typical Lancian taxa, except for two new taxa that suggest biogeographic differences with contemporaneous localities from farther north. This stratigraphic succession of fossil localities from northeastern Colorado may offer new perspectives on temporal and biogeographic changes of mammalian faunas leading up to the Cretaceous–Tertiary boundary.

INTRODUCTION

The fossil record of latest Cretaceous mammals from North America (Lancian land-mammal ‘age,’ NALMA) consists mostly of isolated teeth and fragmentary jaws; nevertheless, it includes more specimens and localities from this interval than any other major landmass (Kielan-Jaworowska et al., 2004). As such, it serves as a primary source of paleontological data for analyzing critical episodes in mammalian history, such as the Cretaceous–Tertiary (K–T) mass extinction and the rise of placental mammals (e.g., Alroy, 1999; Wilson, 2005), and for developing a Late Cretaceous biochronology of North America (Cifelli et al., 2004). Yet, despite more than 125 years of collecting (Van Valen, 1967) and relatively broad spatial and temporal coverage, this mammalian fossil database is limited by significant sampling deficiencies (Fig. 1).

In 2006, we initiated a paleontological survey of non-marine Late Cretaceous-aged exposures in the Cheyenne Basin of northeastern Colorado (Fig. 2). The aim was to improve the sampling of mammalian faunas south of the well-sampled northern Western Interior (e.g., Alberta, Montana, Wyoming) and those older than the well-sampled interval immediately before the K–T boundary (67.5–65.5 Ma). The survey occurred within the western part of Pawnee National Grassland (PNG) in Weld County and is supported by United States Forest Service. The history of paleontological exploration in the Cretaceous outcrops of Weld County dates back to at least the 1920s (see Carpenter, 1979); however, as the grassland designation might imply, exposures as well as vertebrate fossils are sparse. In 1977, Ken Carpenter, now of the Denver Museum of Nature & Science

(DMNS), was the first to discover mammal fossils in these outcrops as a graduate student at the University of Colorado under the guidance of Peter Robinson. Underwater screenwashing of a relatively small sediment sample (~300 kg) from University of Colorado Museum (UCM) locality 77062 led to the recovery of a vertebrate microfossil assemblage from the Laramie Formation that includes 12 mammalian specimens (Carpenter, 1979). On the basis of taxonomic composition and known stratigraphic relationships, the assemblage was considered contemporaneous with most Lancian faunas from the northern Western Interior (~67.5–65.5 Ma), including the Hell Creek (Montana) and type Lance (Wyoming) local faunas. More recent analyses have suggested that the assemblage might be older. Multituberculate specimens initially identified as *Meniscoessus* sp. were later referred to *M. collomensis* (Diem, 1999). This taxon, otherwise only known from the older Williams Fork Formation in northwestern Colorado, has been proposed as an indicator taxon for the poorly defined ‘Edmontonian’ NALMA, a temporal interval between the Judithian and Lancian NALMAs (Archibald, 1987; Lillegraven, 1987). Magneto- and biostratigraphic data from the Castle Pines Core and Kiowa Core in the nearby Denver Basin placed the Laramie Formation almost entirely within magnetostratigraphic C31n and the *Aquilapollenites striatus* pollen interval zone (Nichols and Fleming, 2002; Hicks et al., 2003; Reynolds and Johnson, 2003). If the deposition of the Laramie Formation in the Cheyenne Basin occurred at a similar time, the age of Carpenter’s small mammalian assemblage would be between 69 and 68 million years old (Reynolds and Johnson, 2003). This would make it older than most Lancian faunas, which typically occur within the Cretaceous part of magnetostratigraphic C29r or the younger part of C30n (e.g., Cifelli et al., 2004) and the *Wodehouseia spinata* pollen assemblage zone (Nichols and Sweet, 1993).

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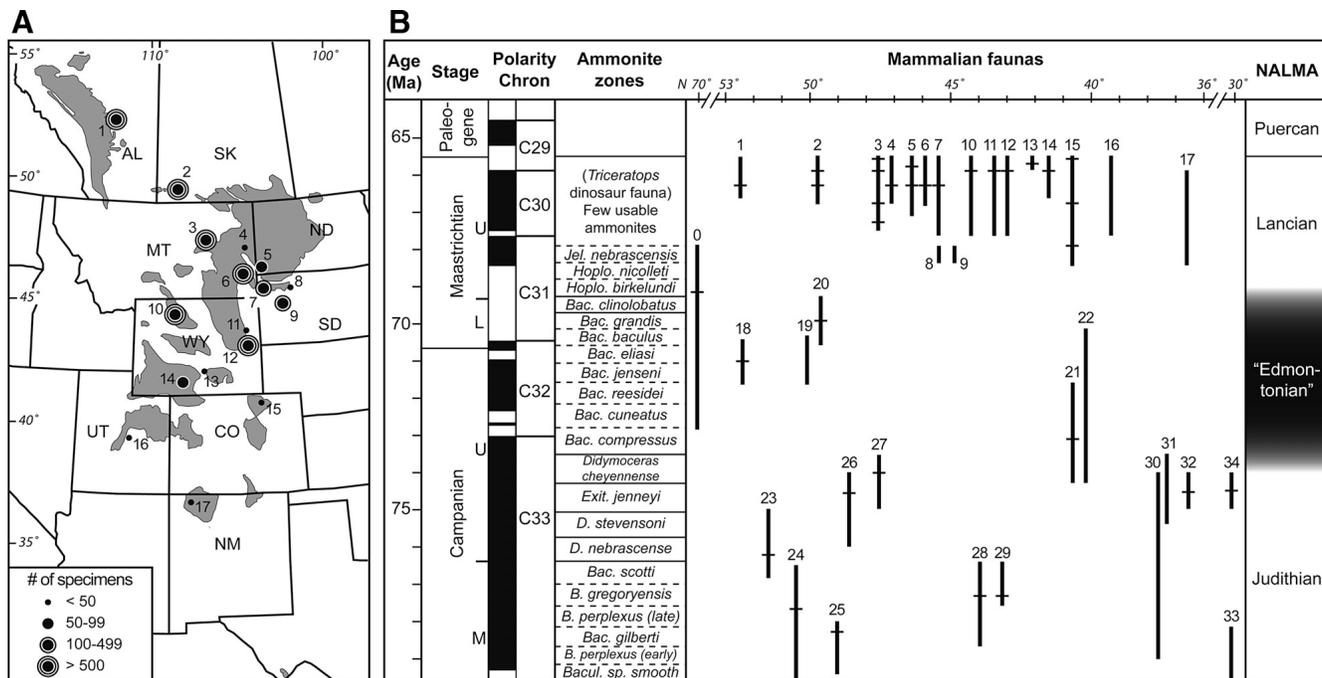


FIGURE 1. **A**, Map of western United States and Canada showing areas with notable Lancian mammal localities (modified from Higgins, 2003, and Lofgren et al., 2004). Sizes of dots correspond to the number of published specimens from each area. **B**, Estimated temporal correlations of major Late Cretaceous (Judithian, 'Edmontonian,' Lancian) mammal localities updated from Lillegraven and Ostresh (1990:fig. 5). For each locality, the vertical bar represents the range of estimated temporal correlation, and the horizontal bar represents the most likely temporal correlation. Multiple horizontal bars indicate estimates for multiple local faunas from a single area. Time scale follows Ogg et al. (2004). 0 = Pediomys Point local fauna, Prince Creek Fm., Alaska (not shown on map; Conrad et al., 1990; Clemens, 2003); 1 = Trochu local fauna, Scollard Fm., Alberta (Lillegraven, 1969; Russell, 1987); 2 = Wounded Knee and Gryde local faunas, Frenchman Fm., Saskatchewan (Johnston, 1980; Storer, 1991); 3 = Garfield and McCone Counties assorted local faunas, Hell Creek Fm., Montana (Archibald, 1982; Swisher et al., 1993; Lofgren, 1995; Wilson, 2005); 4 = Muddy Fork local fauna, Hell Creek Fm., Montana (Hunter et al., 1997); 5 = Little Missouri Badlands faunas, Hell Creek Fm., Montana (Hunter and Archibald, 2002; Pearson et al., 2002; Hicks et al., 2002); 6 = Ekalaka local faunas, Hell Creek Fm., Montana (Hunter and Archibald, 2002); 7 = Eureka Quarry local fauna, Hell Creek Fm., South Dakota (Wilson, 1983); 8 = Iron Lightning local fauna, Iron Lightning Member of the Fox Hills Fm., South Dakota (Waage, 1968); 9 = Red Owl Quarry local fauna, Fox Hills Fm., South Dakota (Wilson, 1987); 10 = Hewitt's Foresight One local fauna, Lance Fm., Wyoming (Webb, 2001); 11 = Mule Creek Junction assemblage, Lance Fm., Wyoming (Whitmore, 1985); 12 = Type Lance local fauna, Lance Fm., Wyoming (Clemens, 1964; Keating and Helsey, 1983; Lillegraven and McKenna, 1986); 13 = Hanna Basin, Ferris Fm., Wyoming (Eberle and Lillegraven, 1998a, 1998b); 14 = Black Butte Station local fauna, Lance Fm., Wyoming (Breithaupt, 1982); 15 = Cheyenne Basin assemblages, Laramie Fm. and D1 Sequence equivalents, Colorado (Carpenter, 1979; this paper); 16 = North Horn local fauna, North Horn Fm., Utah (Clemens, 1961; Cifelli, 1999); 17 = Alamo Wash local fauna, Naashoibito Member of the Kirtland Fm., New Mexico (Lehman, 1984; Flynn, 1986; Williamson and Weil, 2008); 18 = Drumheller local fauna, Horseshoe Canyon Fm., Alberta (Fox and Naylor, 1986; Eberth and Deino, 2005); 19 = Scabby Butte local fauna, lower part of St. Mary River Fm., Alberta (Russell, 1975); 20 = Lundbreck locality, upper part of St. Mary River Fm., Alberta (Russell, 1975; Clemens et al., 1979); 21 = Jubb Creek locality, Williams Fork Fm., Colorado (Lillegraven, 1987); 22 = Rio Blanco local fauna, Williams Fork Fm., Colorado (Archibald, 1987; Diem, 1999); 23 = Dinosaur Park local faunas, Dinosaur Park Fm., Alberta (Fox, 1981; Lillegraven and McKenna, 1986; Eberth and Deino, 2005; Braman and Brinkman, 2008); 24 = Foremost-Oldman local faunas, base of Oldman Fm., Alberta (Fox, 1976; Braman and Brinkman, 2008 and references therein); 25 = Hill County local faunas, Judith River Fm., Montana (Goodwin and Deino, 1989; Montellano, 1992); 26 = Egg Mountain locality, Two Medicine Fm., Montana (Montellano, 1992; Rogers et al., 1993; Horner et al., 2001); 27 = Type Judithian local fauna, Judith River Fm., Montana (Sahni, 1972; Lillegraven and McKenna, 1986; Rogers et al., 1993); 28 = Bighorn Basin local fauna, 'Mesaverde' Fm., Wyoming (Lillegraven and McKenna, 1986); 29 = Wind River Basin local fauna, 'Mesaverde' Fm., Wyoming (Lillegraven and McKenna, 1986); 30 = Kaiparowits local fauna, Kaiparowits Fm., Utah (Eaton, 1987; Eaton, 2002); 31 = Paunsaugut Plateau local fauna, Kaiparowits Fm., Utah (Eaton, 1993; Kielan-Jaworowska et al., 2004); 32 = Lower Hunter Wash local fauna, Fruitland and lower Kirtland Fms., New Mexico (Clemens, 1973; Flynn, 1986; Rigby and Wolberg, 1987; Lucas et al., 2006); 33 = Terlingua local fauna, Aguja Fm., Texas (Rowe et al., 1992; Weil, 1992; Cifelli, 1994); 34 = El Rosario local fauna, 'El Gallo' Fm., Baja California, Mexico (Lillegraven, 1972; Renne et al., 1991).

Over the past two years, we have undertaken paleontological and geological field work in exposures of Upper Cretaceous non-marine deposits in the PNG. This work has led to the discovery of 16 vertebrate fossil localities and the recovery of more than 500 vertebrate micro- and macrofossils through surface collection and underwater screenwashing of ~2000 kg of sediment. All fossils are housed at the DMNS and the University of Washington's Burke Museum of Natural History & Culture (UWBM). The taxonomically diverse vertebrate faunas represented by these fossil collections include at least 32 species of freshwater sharks and

rays, fish, amphibians, turtles, lizards, crocodiles, dinosaurs, and mammals. The 26 mammalian specimens (22 isolated teeth, three dentary fragments, one maxillary fragment) were recovered from three localities in the PNG and represent at least eight taxa. We also recovered a mammalian specimen from Carpenter's original locality (= Ken's Site; DMNH loc. 3426) and re-discovered a dentulous jaw fragment previously collected by Carpenter in 1978 at the Natural Fort locality (UCM loc. 78193). The fossil localities occur in stratigraphically limited and geographically isolated exposures. To develop an overarching stratigraphic framework, we

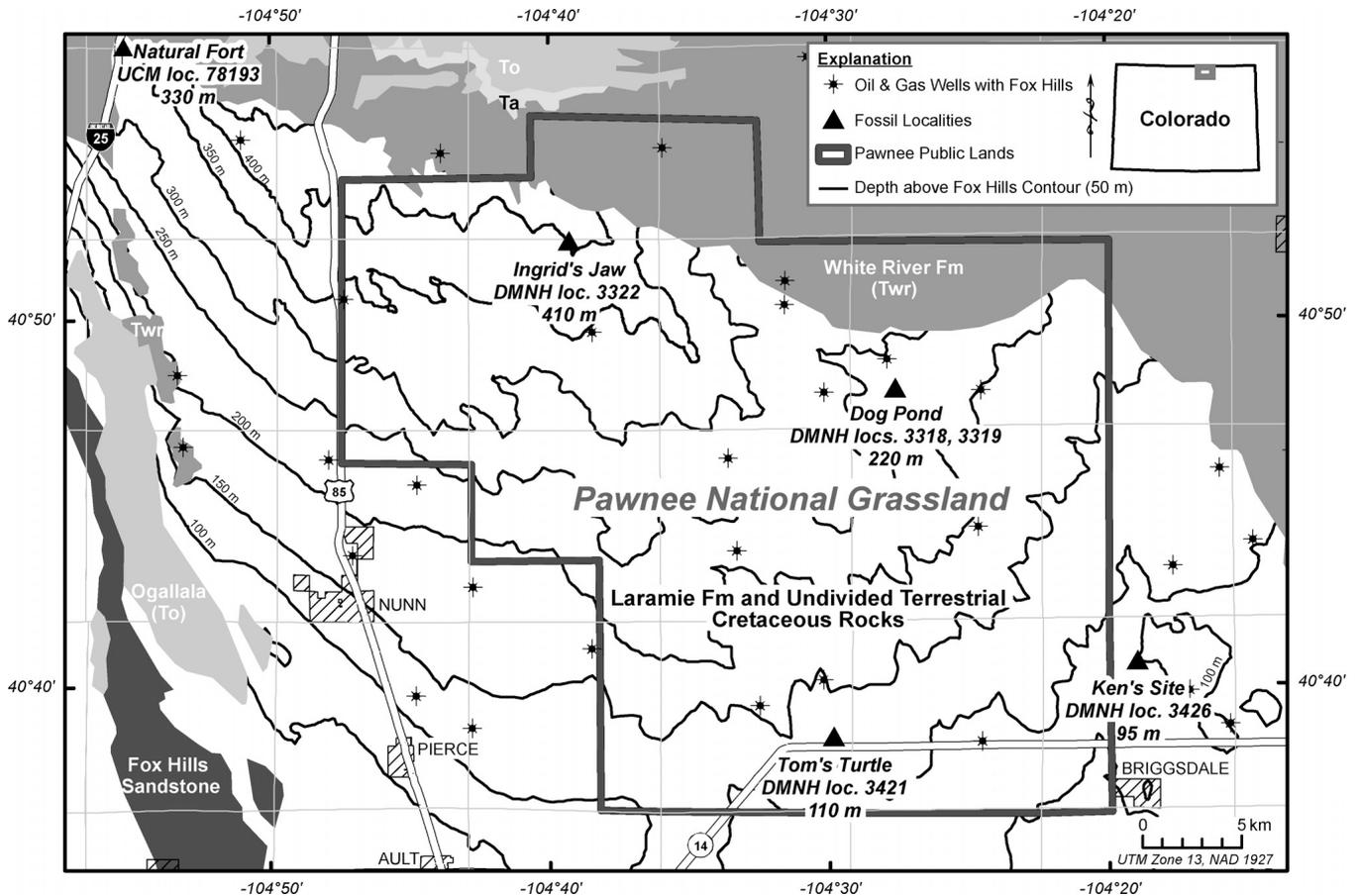


FIGURE 2. Map of the western part of the Pawnee National Grassland (outlined area) in Weld County, northeastern Colorado, with fossil localities (triangles) from this study. Contour lines indicate depth to the top of the Fox Hills Sandstone. Stars indicate location of geophysical well logs used to construct the subsurface map. Geologic formational boundaries are from Tweto (1979). The Cretaceous Fox Hills Sandstone is the base of the section and the Upper Eocene and Oligocene White River Group (Twr) and the Upper Oligocene and Miocene Arikaree (Ta) and Ogallala (To) Formations are capping units. The white area, traditionally been mapped as Laramie Formation (Tweto, 1979), is more likely temporally equivalent to the Cretaceous part of the D1 sequence in the Denver Basin (see Fig. 4 and text for details).

used subsurface data from geophysical well logs, and defined a reference horizon at the top of the Fox Hills Sandstone. Interpretation of these data indicates that our fossil localities sample a succession of upper Cretaceous strata 95, 220, 330, and 410 m above the Fox Hills Sandstone. Palynological and paleomagnetic studies are underway that will refine this framework and improve temporal correlations to other mammalian faunas in the Western Interior of North America. The long-term goal of the project is to develop a well-constrained stratigraphic succession of well-sampled mammalian assemblages leading up to the K–T boundary. Such a succession from the central Western Interior would complement those from the northern part (Pearson et al., 2002; Wilson, 2005) and allow us to address questions of latest Cretaceous biogeographic provincialism within the Western Interior and test the geographic variability of extinction patterns relating to the K–T impact event. Here, we describe the geologic context of the fossil localities and the new mammalian fossils from these localities, including two new multituberculate taxa.

Institutional Abbreviations—DMNH or DMNS, the Denver Museum of Nature & Science, Denver, Colorado, U.S.A.; MOR, the Museum of the Rockies, Montana State University, Bozeman, Montana, U.S.A.; PNG, the Pawnee National Grassland, Weld County, Colorado, U.S.A.; UCM, the University of Colorado Museum, Boulder, Colorado, U.S.A.; UCMP, the Uni-

versity of California Museum of Paleontology, Berkeley, California, U.S.A.; UMMP, the University of Michigan Museum of Paleontology, Ann Arbor, Michigan, U.S.A.; USFS, United States Forest Service; USNM, the Smithsonian Institution National Museum of Natural History, Washington, D.C., U.S.A.; UWBM, the University of Washington Burke Museum of Natural History and Culture, Seattle, Washington, U.S.A.

Dental Terminology, Conventions, and Measurements—The dental terminology used follows Simpson (1937) and Jepsen (1940) for multituberculates and Bown and Kraus (1979) and Kielan-Jaworowska et al. (2004) for therians. Cusp formulae for multituberculates are presented from the external row to the internal row (e.g., 7:8:6). Styler cusps on metatherian molars are labeled A–E as in Clemens (1966).

Multituberculate dental measurements (Fig. 3A–C) follow Clemens (1964), Novacek and Clemens (1977), Hunter et al. (1997), and Eaton (2002). Specimen orientation of isolated P4s/p4s follows Novacek and Clemens (1977) and Eaton (2002). Therian dental measurements (Fig. 3D–E) follow Lillegraven and Bieber (1986). Specimens were measured using a Leica MZ9.5 binocular dissecting microscope and custom measuring stage that has the capability of reading to 0.001 mm.

Measurement Abbreviations—L = length; ML = mesial length; DL = distal length; W = width; MW = mesial width; and

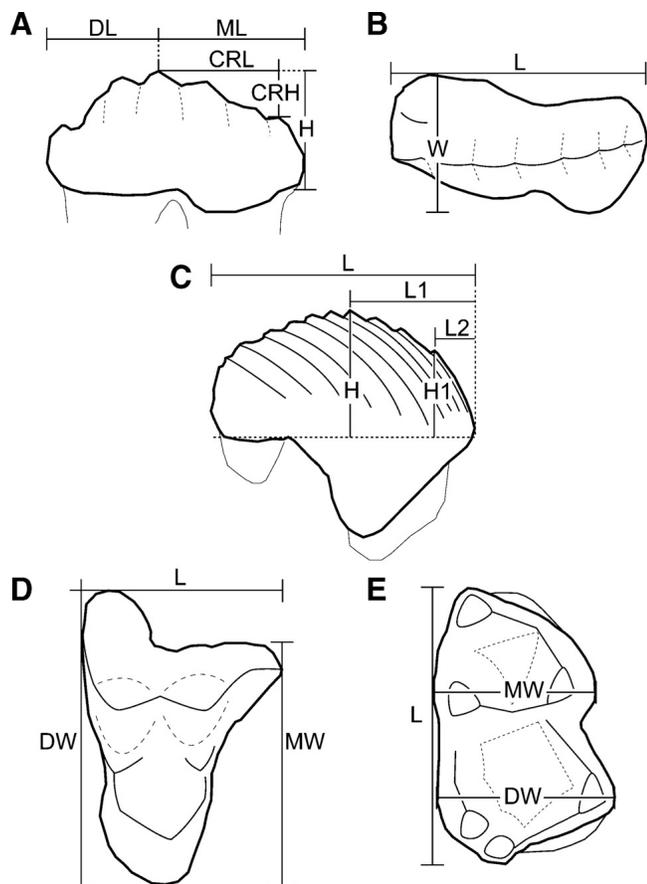


FIGURE 3. Schematic illustration of a multituberculate right P4 in buccal view, **A**, and in occlusal view, **B**, with measurement standards for length (L), width (W), distal length (DL), mesial length (ML), climbing ratio length (CRL), climbing ratio height (CRH), and height (H). Schematic illustration of a multituberculate right p4 in buccal view, **C**, with measurement standards for length (L), length to highest point in lateral profile (L1), length to first serration (L2), height (H), and height to first serration (H1). Schematic illustration of therian right upper molar in occlusal view, **D**, with measurement standards for length (L), distal width (DW), and mesial width (MW). Schematic illustration of a therian right lower molar in occlusal view, **E**, with measurement standards for length (L), mesial width (MW), and distal width (DW).

DW = distal width. For multituberculate p4s, **L1** = length 1 sensu Novacek and Clemens (1977); **L2** = length 2 sensu Hunter et al. (1997); **H** = height sensu Novacek and Clemens (1977); and **H1** = height 1 sensu Hunter et al. (1997). For multituberculate P4s, **CRL** = climbing ratio length and **CRH** = climbing ratio height sensu Eaton (2002). '≥' indicates a minimum measurement.

GEOLOGICAL SETTING

The PNG is located within the Cheyenne Basin (alternatively called the Julesburg Basin), the northern sub-basin of the larger Denver-Julesburg Basin (Weimer, 1996). Nomenclature is not always consistent and the Denver-Cheyenne (or Julesburg) Basin is oftentimes shortened to just 'the Denver Basin,' encompassing both the northern depression of the Cheyenne Basin and the southern depression, here called the Denver Basin. The Cheyenne Basin is bounded to the west by the Front Range and Laramie Range uplifts. To the south, it is separated from the Denver Basin by a structural high called the Greeley Arch, to

the northeast by the Chadron Arch, and to the northwest by the Hartville Uplift (Kirkham and Ladwig, 1979; Sonnenberg and Weimer, 1981; Weimer, 1996). Both the Denver and the Cheyenne Basins are asymmetric, with their axes close and parallel to the north-south-trending mountain front. They only became separated from each other after the formation of the Greeley Arch, which must have happened during or after the onset of the Laramide Orogeny, based on isopach and structure maps of the area.

The sedimentary strata that we focus on for this study consist of the Pierre Shale, Fox Hills Sandstone, and Laramie Formation (or Upper Cretaceous terrestrial rocks). In the Cheyenne Basin, these units are unconformably overlain by the Eocene and Oligocene White River Group (Fig. 4); in the Denver Basin, the Laramie Formation is unconformably overlain by the Cretaceous through Paleocene D1 sequence (Raynolds, 2002). Because at the time of deposition of the Pierre Shale, Fox Hills Sandstone, and Laramie Formation, the Cheyenne Basin was not yet separated from the Denver Basin, depositional patterns and setting are assumed to be comparable between these basins.

The Upper Cretaceous Pierre Shale consists of up to 2000 m of fine-grained marine deposits of the Western Interior Seaway. The Fox Hills Sandstone was deposited as beach and shoreface sandstones that can be up to 60 m thick, reflecting aggradational and mostly seaward stepping episodes of the Seaway retreat (Dechesne and Raynolds, 2005; Raynolds and Dechesne, 2007). The Fox Hills Sandstone is a coarsening-up, well-sorted, fine-grained sandstone that is often bleached to nearly white in the outcrops at the edges of the Cheyenne Basin. Its lower boundary with the Pierre Shale is transitional and mapped as the Upper Pierre Transition Zone (Tweto, 1979; Scott and Cobban, 1965; Kiteley, 1978). In contrast, its upper boundary is usually in sharp contact with the Laramie Formation. The Laramie Formation is both contemporaneous with and overlies the Fox Hills Sandstone. It consists of coals, carbonaceous shales, medium- to fine-grained isolated channel sandstones, and related overbank fine-grained sands and siltstones. These are interpreted as swamp, estuary, and fluvial-coastal plain deposits accumulated on the landward side of the Fox Hills Sandstone. The generally fine-grained deposits contrast distinctly from the coarsening up beach ridge deposits of the Fox Hills Sandstone on well logs and in the field. This sharp and recognizable boundary is key to correlation of outcrops and well logs and determination of the relative ages of fossil localities. Exposures in the PNG study area have traditionally been mapped as Laramie Formation (Tweto, 1979).

The Cretaceous strata are unconformably overlain by the fine-grained and tuffaceous upper Eocene and Oligocene White River Group, which in turn is capped by the somewhat coarser-grained, fluvially derived upper Oligocene to Miocene Arikaree—and the even coarser alluvial Ogallala Formations (O'Harra, 1920; Tweto, 1979; Prothero and Emry, 2004; Tedford et al., 2004). Based on well logs, this upper package can reach thicknesses of over 250 m in the northern part of the study area.

The study area is situated in the northeastern high plains of Colorado. The physical appearance of the study area is relatively flat, with several small drainages creating limited and widely scattered outcrops. Stratigraphy based on field correlations is thus extremely difficult. Relative positioning of fossil localities within the Upper Cretaceous strata of the PNG depended on a subsurface model developed from over 300 geophysical logs from the Colorado part of the Cheyenne Basin that were obtained from the Colorado Oil and Gas Commission. The relative stratigraphic position of each locality is measured in distance above the top of the Fox Hills Sandstone, a contact that is easily recognized both in the field and on geophysical well logs (Fig. 2). Because the Fox Hills Sandstone was deposited before the onset of the Laramide Orogeny and therefore before the current Cheyenne and Denver sub-basins took their shapes, the current basin geometry did not

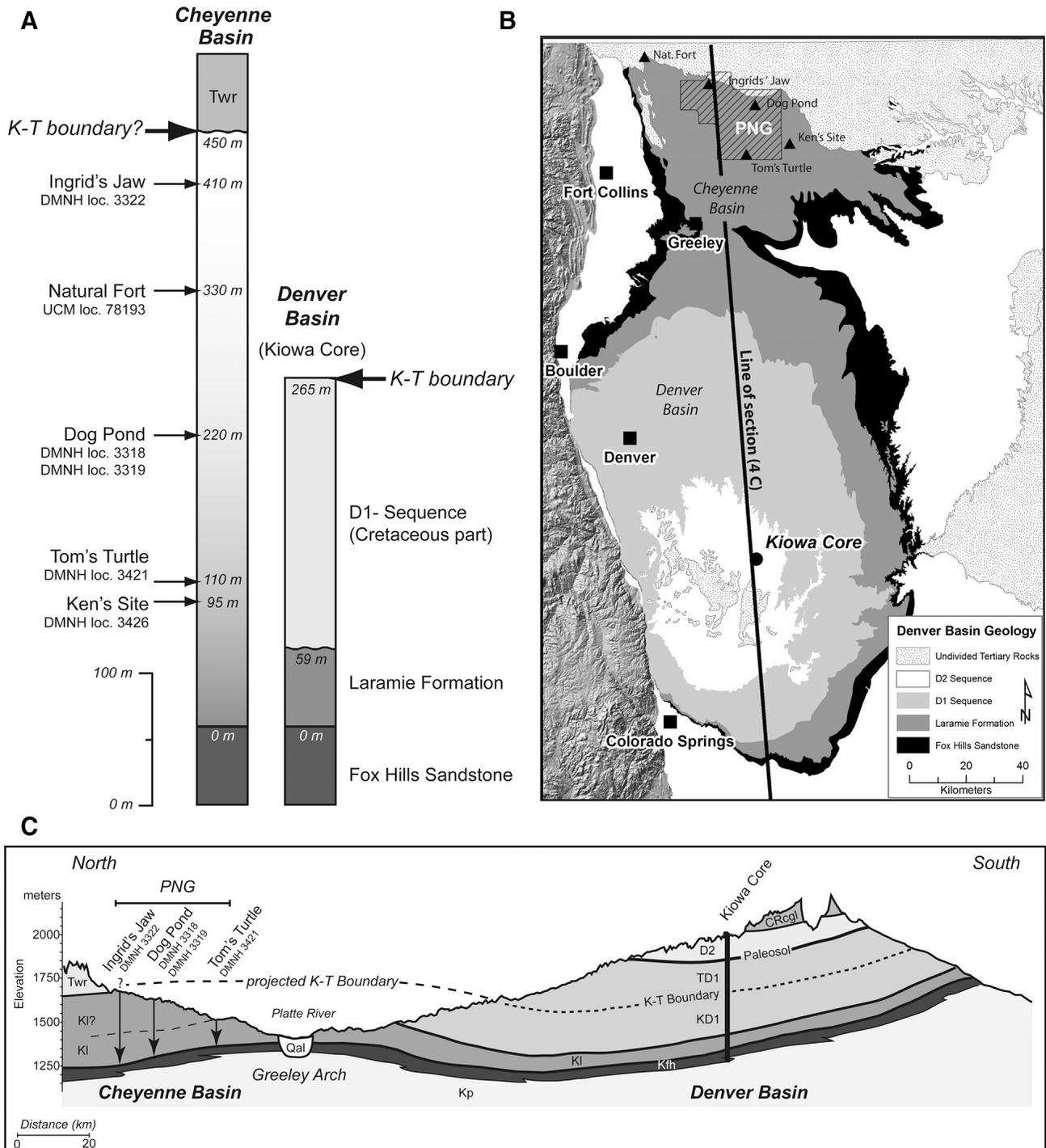


FIGURE 4. **A**, Stratigraphic diagram of the Upper Cretaceous and Cenozoic units of the Cheyenne Basin. Thicknesses are compared to the uppermost Cretaceous units in the Denver Basin at the Kiowa Core, which is at a similar distal geographic position from the mountain front as the fossil localities in this study. Stratigraphic positions of fossil localities are based on the subsurface model described in the text. Note that the 450 m of strata above the Fox Hills Sandstone and below the White River Formation of the Cheyenne Basin have traditionally been mapped as the Laramie Formation. The Laramie Formation–D1 sequence unconformity has not been recognized in the Cheyenne Basin, but Tom's Turtle and Ken's Site are likely temporally equivalent to the top of the Laramie Formation and the Dog Pond Area and Ingrid's Jaw are likely temporally equivalent to strata of the Cretaceous D1 sequence, both of the Denver Basin. **B**, Map with bold line showing the line of section for part C, and triangles showing the Cheyenne Basin fossil localities. **C**, Cross-section through both the Denver and Cheyenne Basins to illustrate the discrepancy in the thickness of the mapped Laramie Formation north and south of the Greeley Arch. This cross-section is based on ~3500 well logs in both the Denver and Cheyenne Basins. Arrows indicate how the relative stratigraphy of the DMNS localities was determined by measuring depth from the surface to the top of the Fox Hills Sandstone. The diagram also illustrates the suggested projection of the K–T Boundary to slightly above Ingrid's Jaw site, based on thicknesses from the Denver Basin and the Cretaceous fossils at this site. Kp = Pierre Shale; Kfh = Fox Hills Sandstone; KI = Laramie Formation; KI? = traditionally mapped Laramie Formation, but based on thickness comparisons this interval is probably time equivalent to the D1 sequence in the Denver Basin. KD1 = Cretaceous part of the D1 sequence in the Denver Basin; TD1 = Tertiary part of the D1 sequence in the Denver Basin; D2 = D2 sequence in the Denver Basin (Raynolds, 2002); Twr = White River Formation; CRcgl = Castle Rock Conglomerate.

influence the depositional geometry of the Fox Hills Sandstone or Laramie Formation. As an approximation for the relative stratigraphic position between each fossil locality on the surface, a continuous grid was interpolated using well log data points to determine the depth of the top of the Fox Hills Sandstone below the surface. Thus, even if the locality on the surface is geographically far from an existing well, the stratigraphic distance to the top of the Fox Hills Sandstone surface can be measured. Localities in this study are stratigraphically far enough apart from each other that there is no ambiguity about their relative age (Figs. 2, 4).

Description of Fossil Localities

Ken's Site—DMNH loc. 3426 (= UWBM loc. C1099 = UCM loc. 77062) is situated on the west side of an eroded ridge, just east of Highway 77 (Carpenter, 1979) and spans an area of about 100 m². The strata are characterized by upper very fine to lower fine sandstone beds alternating with grey mudstone and siltstone beds with ripple marks, indicating an off-channel and overbank depositional environment. There are abundant iron oxide concretions and weathered layers, especially near the top of the section, which is about 5 m high. Most fossils (including turtles and dinosaurs) are found at the base of the exposures in a dark grey mudstone layer. The locality is ~95 m above the top of the Fox Hills Sandstone, which makes Ken's Site the stratigraphically lowest and oldest site described in this paper.

The Dog Pond Area—This area includes Lar 5 (DMNH loc. 3318) and Lar 6 (DMNH loc. 3319). The outcrop is approximately 500 m² and about 8 m in relief, consisting of light orange, weathered sandstone beds. These beds have large-scale, lateral accretion planes (up to 3 m high), and extensive soft-sediment deformation near the axis and thickest parts of the multi-storey channel. Planar- and trough cross-stratification are present at the base of this channel body where the bedding is not distorted by soft-sediment deformation. Grain size fines up from coarse to fine sand and the sorting is moderate. Both bedforms and lateral accretion planes indicate an east to southeast flow direction (130°) for this channel belt. There is a 50 cm silty sand and mudstone bed, with current ripples about 4 m above the base that separates the channel into two storeys. Lar 5 is situated in the coarse-grained basal lag of the oldest channel, and Lar 6 is at the storey break. A tyrannosaurid phalanx, hadrosaurid metatarsal, turtle shell pieces, and microvertebrate fossils have been recovered from the Dog Pond Area. It is ~220 m above the top of the Fox Hills Sandstone and thus younger than Ken's Site.

The Natural Fort—UCM loc. 78193 is located among a large outcrop of ~0.4 km² and up to 12 m in relief that lies immediately east of Interstate 25 near northbound exit 293, where there was once a rest area. The sediments show extensive soft-sediment deformation within a sandy channel fill. Microvertebrate fossils have been found in situ and as float at the base of the outcrop; screenwashing has not yet been attempted. The Natural Fort is ~330 m above the top of the Fox Hills Sandstone and thus younger than Ken's Site and the Dog Pond Area.

Ingrid's Jaw—DMNH loc. 3322 (= UWBM loc. C1098) is an irregular, weathered isolated outcrop of ~30 m² immediately south of Weld County Road 122. The sediments are distinctly orange-colored, and are made up of upper fine-grained, moderately well-sorted sandstone. Although the internal bedding geometry is distorted by extensive, meter-scale, soft-sediment deformation, 20–30 cm long distorted trough cross-bedding can still be recognized. Mud rip-up clasts of up to 15 cm in diameter are found just above some of the preserved bed breaks. These sediments were deposited in a fluvial channel. Because of the limited outcrop extent and distorted cross bedding, channel orientation is difficult to determine in the field. From aerial photography, a NNW-SSE linear trend is interpreted from the gentle sandy ridgeline that this outcrop forms. Microvertebrate

fossils have been surface collected and found within sediments screenwashed from this locality. Ingrid's Jaw is ~410 m above the top of the Fox Hills Sandstone and is the stratigraphically highest and youngest of our localities.

Depositional and Stratigraphic Context of Fossil Localities

All localities are located in terrestrial sediments in or near paleo-channels or overbank deposits. The localities in channels show extensive soft-sediment deformation (up to meter scale). At both Tom's Turtle (DMNH loc. 3421; no mammals recovered) and the Dog Pond Area, the fresh water algae *Pediastrum* was found in the fine-grained mudstone layers just below the channel, indicating that quiet water was present on the landscape. This combined with soft-sediment deformation implies rapid deposition in wetland environments. The isolated nature of the channels and the lateral accretion implies deposition on low-gradient slopes. Abundant turtle, crocodile, and fish fossils support this interpretation of a wetland to swampy environment. The extensive soft-sediment deformation throughout the 450 m thick Upper Cretaceous non-marine strata suggests that the depositional environment might not have changed significantly through time.

Based on geophysical well logs, the total thickness of the Laramie Formation to the south in the Denver Basin is on average 110 m, though it varies considerably from 240 m near the mountains to 90 m in the distal parts of the basin. Because the Greeley Arch had not developed by the time of deposition of the Laramie Formation, we expect the thickness of the Laramie Formation in the Cheyenne Basin to be similar. Yet, in the Cheyenne Basin, the thickness is up to 450 m, also based on well logs, for the interval that is traditionally mapped as Laramie Formation and measured between the top of the Fox Hills Sandstone and the base of the White River Formation. The apparent discrepancy likely exists because the basal conglomerate of the overlying D1 sequence in the Denver Basin (Arapahoe Conglomerate; Reynolds, 2002) has not been identified in the Cheyenne Basin and changes in depositional environment throughout the stratigraphic column are subtle (from coals and soft sediment deformation in isolated channels to soft sediment deformation in isolated channels without coals at the top of the Laramie interval), both of which make it challenging to identify the top of the Laramie Formation in the Cheyenne Basin on well logs or in the field. Thus, we suggest that the interval between the top of the Fox Hills Sandstone and the White River Formation encompasses the equivalent of both the Laramie Formation and the Cretaceous part of the D1 sequence from the Denver Basin (Fig. 4).

At 95 m above the top of the Fox Hills Sandstone, Ken's Site is likely near the top of the Laramie Formation, as is Tom's Turtle site at 110 m. The distinct coal beds and carbonaceous shales in the lower part of the Laramie section (and at Tom's Turtle) up to about 110 m above the top of the Fox Hills would suggest a correlation to the coal rich intervals that are typical (but not exclusive) to the Laramie Formation in the Denver Basin (Kirkham and Ladwig, 1979). In contrast, the higher stratigraphic positions of the Dog Pond Area (220 m), Natural Fort (330 m), and Ingrid's Jaw (410 m) are estimated to be temporally equivalent to the Cretaceous part of the D1 sequence in the Denver Basin. Comparing with the strata in Denver Basin, the stratigraphic thicknesses suggest that our youngest locality, Ingrid's Jaw, might be close to the K–T boundary, though we have not yet recovered evidence for the K–T boundary event in the study area.

SYSTEMATIC PALEONTOLOGY

- MAMMALIA Linnaeus, 1758
 ALLOTHERIA Marsh, 1880
 MULTITUBERCULATA Cope, 1884
 CIMOLODONTA McKenna, 1975
 PTILODONTOIDEA Sloan and Van Valen, 1965

NEOPLAGIAULACIDAE Ameghino, 1890
MESODMA Jepsen, 1940
MESODMA cf. *M. FORMOSA* (Marsh, 1889a)
 (Fig. 5A)

Referred Specimen—DMNH 52512, right p4 from DMNH loc. 3318.

Description and Discussion—DMNH 52512 is a poorly preserved right p4, with most enamel worn away postmortem and breakage on the mesioventral part of the tooth. The specimen has at least 10 serrations, and in profile, the mesial aspect of the crown is nearly vertical; both features support its referral to *Mesodma*. In size, it is most similar to *M. formosa*, but due to the state of preservation, we only tentatively refer it to this species. Measurements: $L \geq 3.55$ mm, $W \geq 1.07$ mm.

PARIKIMYS CARPENTERI, gen. et sp. nov.
 (Fig. 5B–E)

Etymology—*Pariki* (Caddoan) means ‘horn’ and is the likely derivation of the name of the Native American Pawnee Nation, referring to the upright and curved scalplock hairstyle of Pawnee men; we use it to honor the tribe as well as the National Grassland. *Mys* (Latin) means mouse or small gnawing mammal, a common suffix for generic names of multituberculates; *Carpenter*, in honor of the DMNS vertebrate paleontologist, Ken Carpenter, whose initial field work in the sparse, non-marine Cretaceous exposures of Weld County inspired this project.

Holotype—DMNH 52224, left dentary fragment with p4–m2 and p3 alveolus.

Type Locality—Ingrid’s Jaw (DMNH loc. 3322 = UWBM loc. C1098) is in strata temporally equivalent to the top of the Cretaceous D1 sequence in the PNG of Weld County, Colorado (see Fig. 2 and Description of Fossil Localities above for details).

Diagnosis—Differing from *Mesodma* in: p4 with more arcuate and more symmetrical profile (ventrodistally sloping distal half), taller first serration (greater H1:H ratio), dorsodistally sloping mesial aspect (not vertical or mesially convex; greater L2:L ratio) that forms a sharp angle with the mesio buccal lobe, as in *Neoplagiaulax* and *Cimolodon*; m1 waisted with pyramidal not crescentic internal cusps and crescentic not subcrescentic external cusps. Differing from *Neoplagiaulax* and *Cimolodon* in: p4 with less arcuate, shorter (smaller H:L ratio) and less symmetrical profile, and fewer serrations (10 rather than 11–12 or 12–14, respectively). Differing from *Cimolodon nitidus* in: smaller dental dimensions, p4 with fewer lateral ridges (8 rather than 9–12 for *C. nitidus*), m1 with a distally open central valley, internal and external cusp rows of m2 not connected mesially.

Description and Discussion—DMNH 52224 is a well-preserved, left dentary fragment with p4–m2 and the distal margin of the p3 alveolus. The specimen is missing the horizontal ramus mesial to the p3 alveolus, the ventral margin of the horizontal ramus, and the dorsal end of the coronoid process. The coronoid process originates just ventral to the level of the p4 mesio buccal lobe and level with the mesial aspect of the m1 (Fig. 5C). It ascends at an angle of 54° with the horizontal and blocks the buccal view of m2. A mental foramen is ventral and mesial to the mesial root of the p4. The teeth of DMNH 52224 overlap in size with those of small Late Cretaceous taxa, such as *Neoplagiaulax burgessi*, *Mesodma formosa*, *M. thompsoni*, *Paractypodus foxi*, *Paracimexomys priscus*, and *Cimexomys minor*. In morphology, they are most comparable to teeth of *N. burgessi*, *Mesodma*, and the larger *Cimolodon nitidus*.

The p4 of DMNH 52224 is well preserved, except buccally where much of the enamel below the serrations has been lost postmortem. The mesial root is much larger than the distal root. The crown has ten serrations, eight lingual ridges, and remnants of at least seven buccal ridges; the counts compare well to p4s of *Mesodma* but are less than in p4s of *Neoplagiaulax* and

Cimolodon. Among the well-preserved lingual ridges, the first follows the mesial aspect of the crown and is not parallel to the other lingual ridges; the second is short and does not extend ventrally to the same level as the others; the third nearly intersects the first and second; and the others are somewhat mesially convex and well-separated from each other (Fig. 5D). The buccal aspect of the crown slopes ventrobuccally, whereas the lingual aspect is nearly vertical. In profile (Fig. 5C, E), the mesial face of the p4 crown slopes dorsodistally at an angle of 59° with the horizontal, such that the first serration is distal to the mesial edge (L2:L = 0.15). This is similar to the condition in p4s of *Neoplagiaulax* (0.22 for UCMP 116896) and *Cimolodon nitidus* (0.20 for UCMP 52062) and contrasts with the lower, more convex to flat mesial face in p4s of *Mesodma* (0.07 for *M. thompsoni*, UMMP 81650). The height of the first p4 serration of DMNH 52224 (H1:H = 0.69) is slightly greater than on p4s of *Mesodma* (0.63 for *M. thompsoni*, UMMP 81650) and less than on p4s of *Cimolodon nitidus* (0.81 for UCMP 52062) and *Neoplagiaulax* (0.81 for UCMP 116896). Overall, the p4 of DMNH 52224 is moderately tall and has a H:L ratio (0.46) that is similar to those of *Mesodma* (0.42–0.59; Eaton, 2002:table 1) and *Neoplagiaulax* (0.47–0.50; Archibald, 1982:table 7) but less than in the very tall p4s of *Cimolodon* (0.55–0.64; Eaton, 2002:table 1). The p4 arc reaches its maximum height at the fifth serration. The midpoint length to total length ratio is 0.47, which is comparable to p4s of *Mesodma* (0.43–0.53), *Neoplagiaulax* (0.52–0.55; Archibald, 1982:table 7), and *Cimolodon* (0.40–0.57; Eaton, 2002:table 1). Distally, the p4 gently slopes ventrally to form a profile that is more arcuate and symmetrical than in *Mesodma* and less so than in *Neoplagiaulax* and *Cimolodon*. The p4 mesio buccal lobe is pendulous and forms a sharp angle with the mesial face that resembles that in *Neoplagiaulax* and *Cimolodon*; the resulting mesio basal overhang is deep and supports the presence of a peg-like p3. The distobuccal wear facet is small on this relatively unworn tooth. Measurements: $L = 3.96$ mm, $W = 1.46$ mm, $L1 = 1.88$ mm, $L2 = 0.60$ mm, $H = 1.83$ mm, $H1 = 1.26$ mm.

The m1 was slightly dislodged postmortem from the dentary (Fig. 5C, D); in life, it stood below the level of the p4, as in neoplagiaulacids and cimolodontids. The m1 is considerably shorter in length than the p4 (p4:m1 L = 1.58), which is also the case in *Mesodma* (1.47–1.67) and *Cimolodon nitidus* (1.4–1.8; Clemens, 1964); molars of *Neoplagiaulax burgessi* have not yet been identified. The m1 cusp formula of DMNH 52224 (6:4) is consistent with the range of values in m1s of both *Mesodma* (5–7:4–6) and *Cimolodon nitidus* (5–8:4–7; Clemens, 1964). In occlusal view, there is slight waisting between the third and fourth cusps on the internal row and between the third and fourth cusps on the external row (Fig. 5B), a condition also found in some m1s of *Cimolodon nitidus*. The mesial aspect of the crown is narrow and forms a V-shaped concavity that presumably received the distal end of the p4. The cusps of the internal row are distinctly taller than and mesiodistally offset from the cusps of the external row. The m1 cusp morphology is for the most part similar to that of *Cimolodon* and more primitive than that in *Mesodma*. The first internal cusp is small and conical; the other internal cusps are pyramidal, with the last cusp being mesiodistally elongate. The medial aspect of the last two cusps of the internal row are somewhat fluted. Minor wear is evident on the medial aspect of the internal cusp apices; whereas a greater degree of wear is evident on the external cusp apices, particularly their buccal aspects; in both rows, the degree of wear is relatively even from the mesial to distal ends. The first two cusps of the external row are small and conical to pyramidal whereas the remaining cusps are distinctly crescentic; a shallow transverse valley separates the last two cusps. The external row extends distally beyond the internal row. Although the central valley is open distally in contrast to m1s of *Cimolodon*, a very low ridge connects the last cusps of the internal and external rows. Minor wear is evident in the central

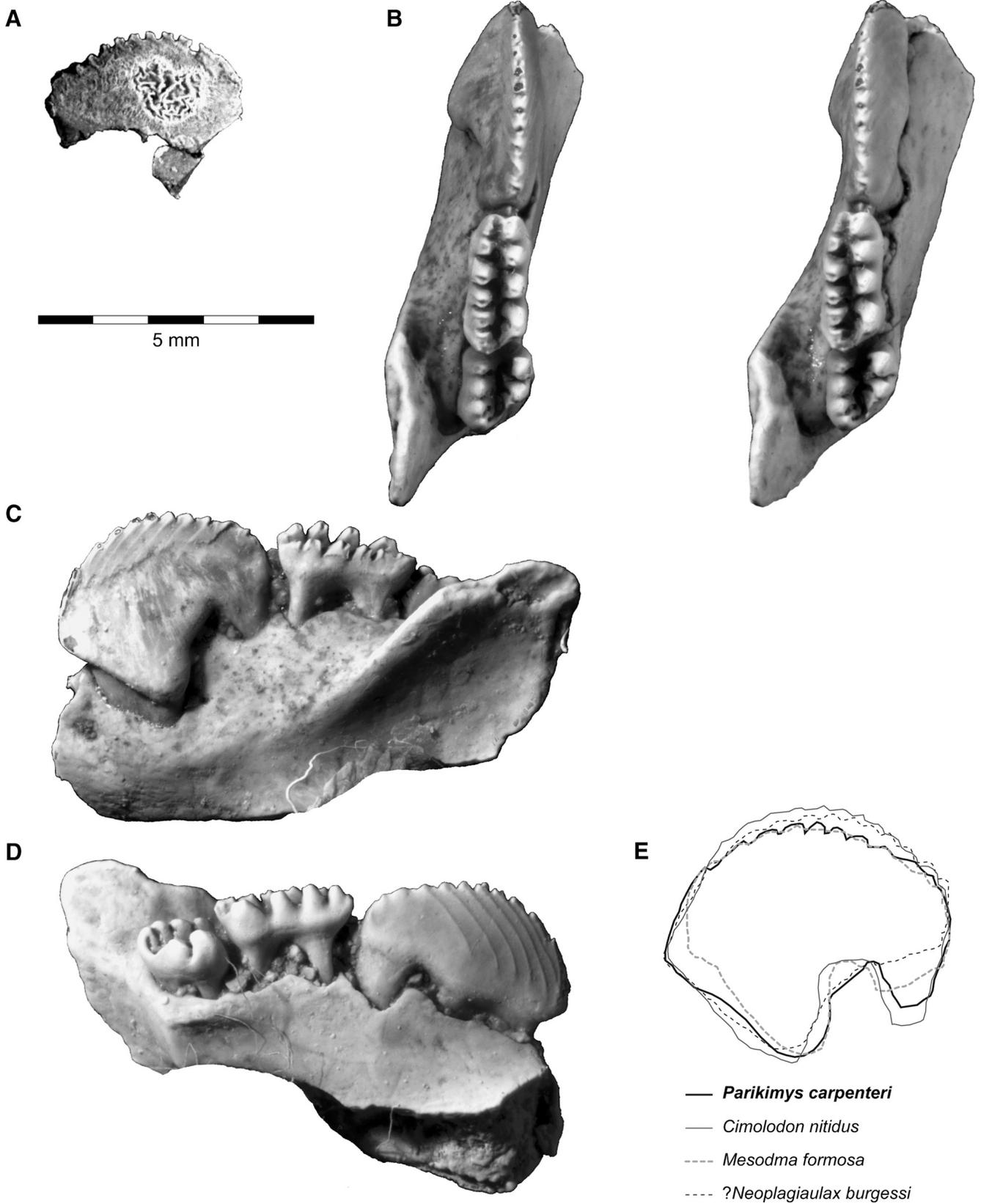


FIGURE 5. *Mesodma* cf. *M. formosa* (DMNH 52512), right p4, **A**, in buccal view. Type specimen of *Parikimys carpenteri* (DMNH 52224), left dentary fragment with p4–m2: in **B**, stereo occlusal, **C**, buccal, and **D**, lingual views. Scale bar equals 5 mm. Superimposed buccal outlines of p4s, **E**, *Parikimys carpenteri*, DMNH 52224 (black); *Cimolodon nitidus*, UCMP 185873 (thin dark gray); *Mesodma formosa*, UCMP 46407 (bold dashed gray); and *?Neoplagiaulax burgessi*, UCMP 116895 (dashed black).

valley on the lingual sides of all but the first two external cusps and on the buccal side of all internal cusps. Measurements: L = 2.51 mm, W = 1.15 mm.

The m2 cusp formula is 4:2, compared to 3:2 in *Mesodma* and 4–6:2 in *Cimolodon nitidus*. In occlusal view (Fig. 5B), the mesial margin of the crown is slightly oblique and the distal margin is strongly oblique to the mesiodistal line of orientation, as the external row extends distally beyond the internal row. The cusps of the internal row are larger than those of the external row. The first internal cusp is sub-crescentic to crescentic; the second internal cusp is larger than the first cusp; a low ridge gently slopes from the distal aspect of this cusp down to the central valley and up to the fourth external cusp. Both internal cusps are medially fluted. In buccal view (Fig. 5D), the cusps of the external row are poorly separated; in lingual view, they are sub-crescentic to crescentic and separated medially by fluting. The fourth external cusp is the smallest and is positioned slightly lingually relative to the other cusps in the row. The central valley of m2 is broader than that of m1 and shows evidence of wear, whereas the cusp apices show little to no evidence of wear. Measurements: L = 1.61 mm, W = 1.25 mm.

Overall, DMNH 52224 bears some resemblance to *Cimolodon nitidus*, but many of these features are primitive (e.g., m1 conical and pyramidal cusps). The p4 of DMNH 52224 is most similar to that of *?Neoplagiaulax burgessi*. Molars of *?N. burgessi* are unfortunately unknown, but some similarities exist between the molars of DMNH 52224 and the slightly more derived molars of another neoplagiaulacid, *Mesodma*. Differences with these and other latest Cretaceous multituberculates warrant the erection of a new genus and species for the specimen, whereas similarities to *Mesodma* and *?N. burgessi* support placement within Neoplagiaulacidae.

CIMOLOMYIDAE Marsh, 1889b
MENISCOESSUS Cope, 1882

Comments—Clemens (1964), Archibald (1982), and Lillegraven (1987) provided summaries of the complicated systematic history of *Meniscoessus*. In brief, we follow previous authors who restricted *M. conquistus* to the type material (Simpson, 1929; Clemens, 1964; Lillegraven, 1987) and included *M. borealis* and *M. greeni* as junior synonyms of *M. robustus* (Archibald, 1982; Eberle and Lillegraven, 1998). We recognize a third Lancian species, *M. seminoensis*, from the lower Ferris Formation of the western Hanna Basin, Wyoming (Eberle and Lillegraven, 1998). *M. collomensis* is a species known from the lower part of the Williams Fork Formation of northwestern Colorado and considered ‘Edmontonian’ in age (Archibald, 1987; Lillegraven, 1987; Diem, 1999). The type specimen is a dentary with m1–2 (UCM 48613) that is in most respects similar to *M. robustus* (e.g., fully crescentic cusps), except for its smaller size (Lillegraven, 1987:appendix 2). In our study area, four multituberculate specimens from Ken’s Site (UCM loc. 77062) were initially referred to *Meniscoessus* sp. (Carpenter, 1979), but some were later referred to *M. collomensis* by Diem (1999). Our measurements of the m2 (UCM 38785: L = 5.03 mm, W = 3.76 mm) fall significantly below the reported range for *M. robustus* (L = 6.8–8.8 mm, W = 3.9–5.5 mm; Lillegraven, 1987:appendix 2) and the expected m2 size of *M. conquistus* and *M. seminoensis* based on other tooth positions. Thus, we agree with Diem’s (1999) referral of at least the m2 (UCM 38785) and tentatively the considerably worn M1 (UCM 38784) to *M. collomensis*.

MENISCOESSUS cf. *M. ROBUSTUS* Marsh, 1889b
(Fig. 6)

Referred Specimens—DMNH 52225, right upper incisor; DMNH 52226, right dentary fragment with p4; DMNH 52229,

right p4 mesial fragment; DMNH 52395, right M1 fragment; and DMNH 52525, left m1, all from DMNH loc. 3322.

Description and Discussion—p4: DMNH 52226 is a small portion of dentary and a well-preserved p4 (Fig. 6A, B). The p4 has 10 distinct serrations and two small swellings distal to the serrations. This contrasts with the eight or nine serrations typically found in p4s of *M. robustus*, although the only known p4 of *M. greeni* (now junior synonym of *M. robustus*) has 10 serrations (Lillegraven, 1987; Wilson, 1987). There is a notch distal to the first serration that does not cut ventrally. The second serration is well separated from the first serration. The profile of the arc is nearly symmetrical, reaching its greatest height between the third and fifth serrations; the tip of the fourth serration is broken. Distal to the fifth serration the height of the arc decreases steeply. There are nine external ridges and nine or possibly 10 internal ridges. The second external ridge terminates mesioventrally near the base of the first external ridge. The mesiodistal separation between ridges (external and internal) increases distally. A depression at the distolingual end of the crown bears a swelling that might be a distolingual cuspule (Fig. 6B). Likewise, a ridge delineates a depression at the distobuccal end of the crown (Fig. 6A). The mesio-buccal lobe is mesiodistally long and its distal margin is nearly vertical. Direct comparisons with p4s of *M. robustus* from the Lance (UCMP 46875) and Hell Creek (UCMP 107405) local faunas reveal that in DMNH 52226, the first serration is lower (H1:H = 0.61 compared to ~0.82 and 0.72, respectively), the H:L ratio is lower (0.43 compared to 0.62 and 0.67, respectively), the mesial aspect of the arc profile is less vertical, the distal portion of the arc profile descends more steeply, and overall the crown is less robust. Measurements of this and the other p4 also fall on the low end of the size ranges for p4s of *M. robustus* reported by Clemens (1964) and below those reported by Archibald (1982). Measurements: L = 5.67 mm, W = 2.21 mm, L1 = 2.71 mm, L2 = 0.67 mm, H = 2.46 mm, H1 = 1.50 mm. One of the reviewers suggested that this specimen might be referable to another cimolomyid genus, perhaps the new *Paessonodon*; this possibility cannot be ruled out at this time.

DMNH 52229 is a mesial fragment of a right p4 (Fig. 6C, D). Three serrations, five buccal ridges, and six lingual ridges are preserved. The preserved morphology corresponds to the mesial aspect of DMNH 52226, except that the first serration is somewhat lower than that in DMNH 52226. Measurement: W = 2.18 mm.

m1: DMNH 52525 is a nearly complete left m1 (Fig. 6G–I). The mesial aspect of the crown is concave to receive the distal end of p4. The first buccal cusp is smaller than all other cusps and is subcrescentic. The remaining buccal cusps are crescentic and show slight apical wear. The distalmost cusp of the buccal row is missing; in life, the cusp formula was likely 5:4. The cusps of the lingual row are distally offset from those of the buccal row. The first two lingual cusps suffered postmortem apical damage; nevertheless, the cusps of the lingual row appear to have been taller than those of the buccal row. The lingual cusps are crescentic with their apices deflected distally. The opposing faces of the buccal and lingual cusps display some vertical ribbing. DMNH 52525 is on the low end of the size range for published specimens of *M. robustus*, but we do not recognize any morphological differences with comparative specimens of this taxon. Measurements: L = 7.41 mm (slight breakage), W = 4.03 mm.

M1: DMNH 52395 is a poorly preserved right M1 (Fig. 6J). The mesial and distal ends of the crown are missing, and the enamel of the preserved portion is worn. Four buccal cusps, two medial cusps, and the edge of the lingual row are preserved on the crown. The size of the specimen and its interpreted morphology suggest its referral to *Meniscoessus robustus*. Measurements: L ≥ 5.25 mm, W ≥ 4.11 mm.

Upper incisor: DMNH 52225 is a right I2 (Fig. 6E, F). The root and crown have a mesially convex curvature. A vertical groove extends along most of the height of the buccal side giving the

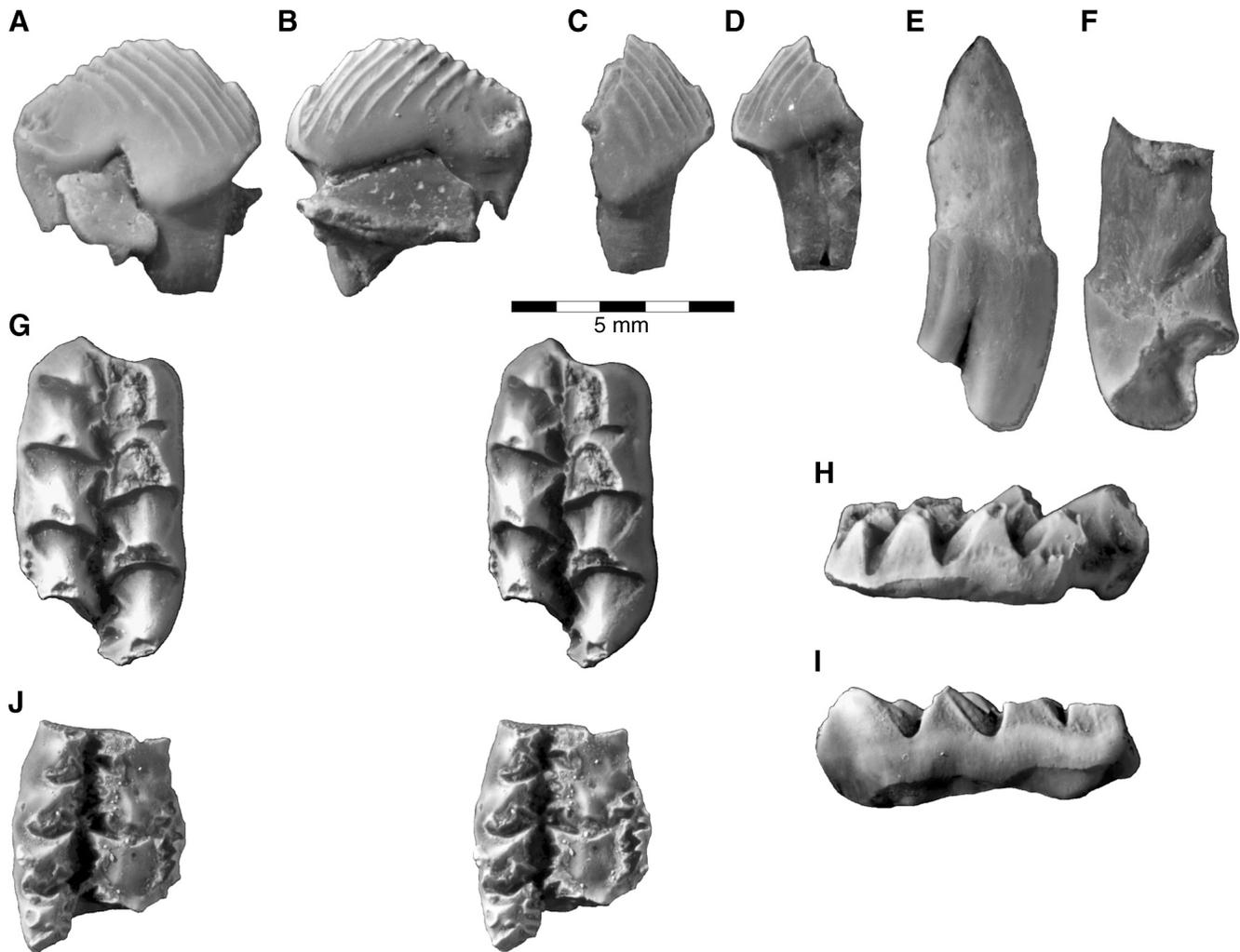


FIGURE 6. *Meniscoessus* cf. *M. robustus*, right dentary fragment (DMNH 52226): in **A**, buccal and **B**, lingual views; mesial fragment of a right p4 (DMNH 52229): in **C**, buccal and **D**, lingual views; right upper incisor (DMNH 52225): in **E**, lateral and **F**, medial views; left m1 (DMNH 52525): in **G**, stereo occlusal, **H**, buccal, and **I**, lingual views; and fragment of right M1 (DMNH 52395), **J**, in stereo occlusal view. Scale bar equals 5 mm.

crown a mitten-like appearance. Heavy apical wear has produced a slightly convex basin within an enamel ring. Measurements: L (base of enamel to crown apex) = 4.25 mm, W (maximum) = 3.50 mm.

Because of minor differences with the published and comparative material, we tentatively refer the new specimens to *M. robustus* until further discoveries better characterize *Meniscoessus* from the PNG. *M. robustus* is otherwise only known from as far south as Black Butte Station locality in southern Wyoming (Breithaupt, 1982).

?*CIMOLOMYS* Marsh, 1889b
(Fig. 7)

Referred Specimen—DMNH 52524, right P4 from DMNH loc. 3319.

Description and Discussion—DMNH 52524 is a relatively well-preserved right P4 with a cusp formula of 0:5. The mesioexternal platform, which is missing some enamel, is laterally pronounced but does not bear any cusps (Fig. 7A); P4s of *Mesodma*, *Cimexomys*, *Parectypodus*, *Cimolodon*, and some species of *Cimolomys* have one or more mesioexternal cusps. The medial row of DMNH 52524 consists of five cusps with minor apical wear that

vary in size, are not appressed to each other, lack striated enamel, and lack lateral grooves between them. These features differ from those in P4s of *Mesodma*, *Cimexomys*, *Parectypodus*, and *Cimolodon* but are consistent with those in P4s of *Cimolomys*. The profile of the medial row increases in height sharply from the first to the third cusp, and, as sometimes is the case in P4s of *Cimolomys*, the penultimate cusp is the tallest but only slightly taller than the third and fifth cusps. In P4s of *Mesodma*, *Cimexomys*, and *Parectypodus*, the distalmost cusp is the tallest cusp and the crown area distal to the tallest cusp is small (DL:L = 0.29 for *M. hensleighi* USNM 215119 and 0.39 for *C. judithae* MOR 302) compared to DMNH 52524 (0.45). The climbing ratio of DMNH 52524 (CR = 0.45) is also greater than in P4s of *Mesodma hensleighi* (0.20, USNM 215119) and *Cimexomys judithae* (0.23, MOR 302). A low basal cusp and a small distolingual cusp form a small distal basin on DMNH 52524 that is comparable to those in P4s of *Cimolomys*. The distolingual cusp is connected to the fifth cusp of the medial row by a faint ridge. Measurements: L = 2.75 mm, W = 1.34 mm, ML = 1.52 mm, DL = 1.24, CRL = 1.25 mm, H = 1.21 mm, CRH = 0.56 mm. The occlusal outline of DMNH 52524 is less rectangular than P4s of *Cimolomys*, but other features suggest that it is referable to this taxon. In

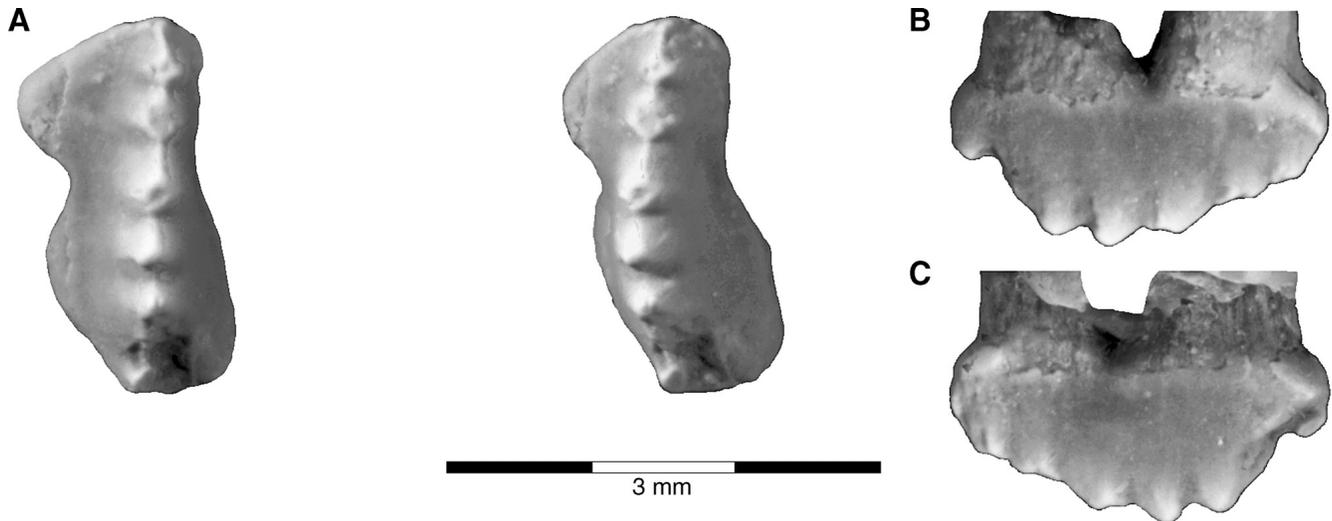


FIGURE 7. ?*Cimolomys*, right P4 (DMNH 52524), in **A**, stereo occlusal, **B**, buccal, and **C**, lingual views. Scale bar equals 3 mm.

particular, DMNH 52524 compares well in size and morphology to P4s of ?*C. butleria* from the Kaiparowits Formation of southern Utah (Judithian; Eaton, 2002), though the latter has a smaller mesioexternal platform. Until more specimens are discovered, we tentatively refer the Pawnee specimen to *Cimolomys*.

?CIMOLOMYIDAE Marsh, 1889b
PARESSONODON NELSONI, gen. et sp. nov.
 (Fig. 8A–C)

Etymology—*Para* (Greek), near, referring to morphological similarity and close phylogenetic relationship to *Essonodon*. *Nelson*, in honor of DMNS volunteer, Charles Nelson, who found the holotype and has contributed substantial energy to the project.

Holotype—UWBM 89450, right maxillary fragment with M1–M2.

Type Locality—Ingrid’s Jaw (DMNH loc. 3322 = UWBM loc. C1098) is in strata temporally equivalent to the top of the Cretaceous D1 sequence in the PNG of Weld County, Colorado (see Fig. 2 and Description of Fossil Localities above for details).

Diagnosis—Differing from *Essonodon* in: smaller absolute size (M1 length is about 35% shorter); larger M2 to M1 length ratio (M2:M1 L = 0.44 versus 0.30–0.36 in *E. browni*; Archibald, 1982); molars with less developed ridges of latticework; M1 with lower cusp formula (6:7:6–7 versus 8:7:7 in *E. browni*, Archibald, 1982), mesial width narrower than distal width (MW:DW = 0.77 versus 0.85 in *E. browni*, Archibald, 1982), mesial cusps of internal row smaller than distal cusps (subequal in *E. browni*, Archibald, 1982), in occlusal view, the mesial half of the crown curves buccally, internal cusps lack buccal ridges, cusp rows not as well separated; M2 with external cusp and crown length subequal to width (L:W = 1.00 vs. 0.90–0.95 in *E. browni*, Archibald, 1982). Differing from *Cimolodon* in: molars with latticework of ridges that cross cusp row valleys; smaller M2 to M1 ratio (M2:M1 L = 0.69 in *C. niidus*; Clemens, 1964); M1 with multiple accessory roots, strong ‘torsion’ along its mesiodistal axis, ‘stairstep’ arrangement of cusp rows, internal row of cusps extends full length of crown, and medial row with mesiodistal ridgeline separating cusp row valleys; M2 with only two medial row cusps.

Description and Discussion—UWBM 89450 is a right maxillary fragment with a well-preserved M1 and M2. The anterior end of the maxilla is broken near the mesial end of M1 (Fig. 8A, B); the zygomatic process is not preserved. The posterior margin of the fragment is broken near the distal end of M2. The jagged dor-

sal margin of the maxillary fragment indicates breakage, except for a smooth, ventrally concave groove that is level with the midpoint of M1 (Fig. 8A); it is interpreted as the ventral margin of the sphenopalatine foramen (Fig. 8A, spf). Immediately dorsal to the M1 on the external surface in the anterior part of the orbit, the maxilla forms a thickened shelf that broadens posteriorly above the M2. Dorsal to this shelf, the bone forms a thin flange that is part of the lateral wall of the orbit. On the internal surface, the medial margin of the palatine process of the maxilla is a broken surface from M1 to M2 (Fig. 8B, C); there is no evidence of a palatal vacuity, though the breakage may have occurred lateral to the bony margin of a palatal vacuity. This may contrast with an interpretation of a maxillary fragment of *Essonodon browni* (UCMP 120397). The internal surface of the maxillary of UCMP 120397 led Archibald (1982:94) to raise the hypothesis that a palatal vacuity may have been present medial to the posterior two-thirds of M1 and M2 or alternatively that the bony secondary palate did not extend beyond the first one-third of M1.

The tooth crowns of UWBM 89450 exhibit only minor wear (Fig. 8C). The exposed mesial root of M1 is buccolingually broad and extends dorsobuccally along its length. Its mesial aspect is slightly concave. Other roots are not visible, but lateral undulations at the cervix indicate the presence of up to three accessory roots and the distal root. The M1 cusp formula is 6:7:7. Several small cusps or cuspids on the mesial and distal ends of the cusp rows were included in the count, though they may not be visible in more worn specimens (M1 cusp formula without small cusps is 5:6:6). This differs from the cusp formula for M1s of *Essonodon* (8:7:7). In occlusal view, the lingual margin of the M1 curves buccally, whereas the buccal margin curves only slightly buccally. All three of the cusp rows extend the full length of the crown. In *Essonodon*, the mesial cusps of the internal row are more fully developed and subequal in size to the distal cusps. The crown exhibits the ‘torsion’ of the cusp rows along the mesiodistal axis and, mesially, the ‘stairstep’ arrangement of cusp rows that Archibald (1982:94) described in M1s of *Essonodon browni*. The ‘stairstep’ arrangement is most evident in lingual view (Fig. 8B), where one sees that the internal row cusp apices are level with or lower than the troughs between successive cusps in the medial row and a similar relationship exists for medial row cusps relative to external row cusps. The first external cusp is very small and mesiolingual to the second external cusp. At the mesial margin of the crown, a narrow, slightly mesially concave ridge extends

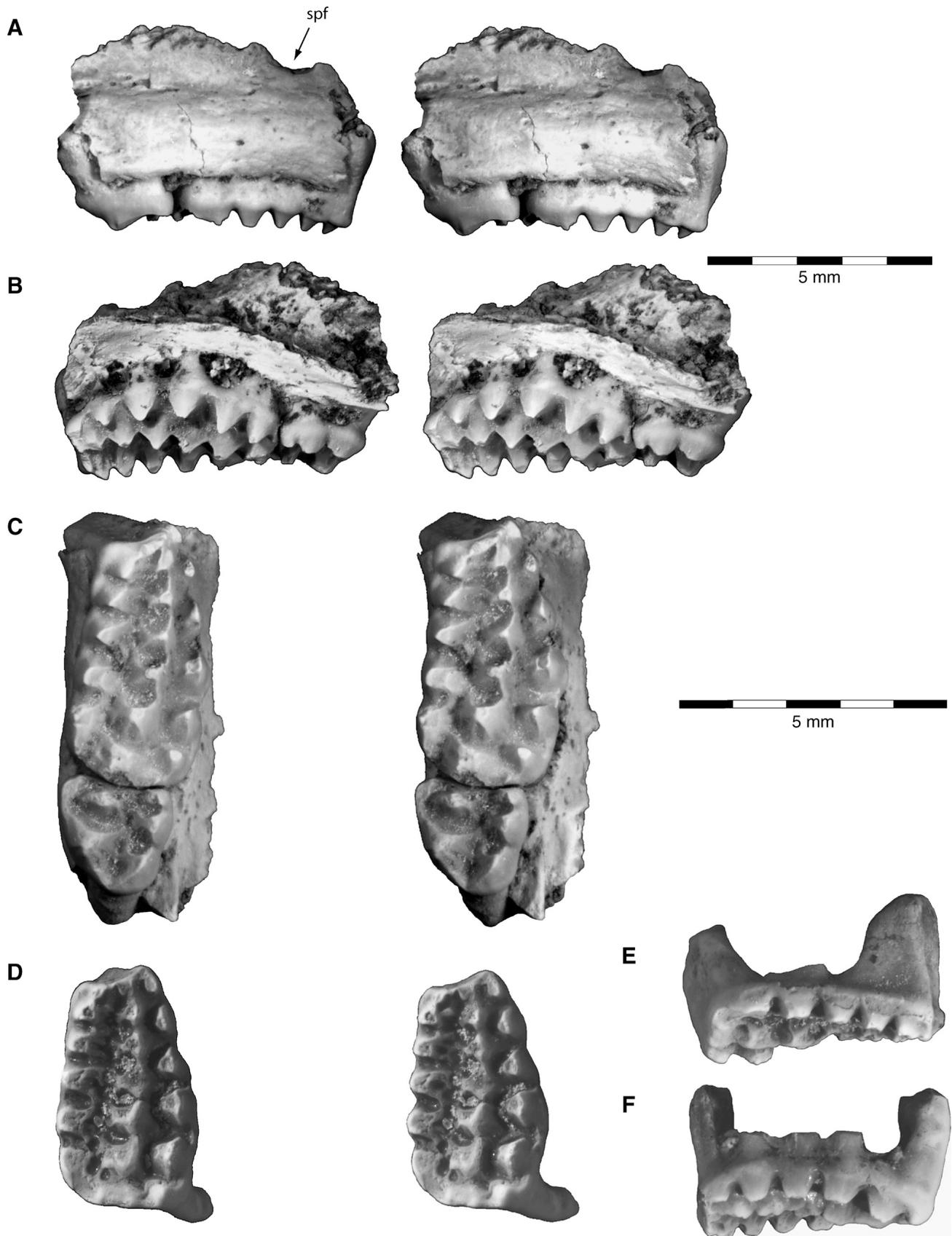


FIGURE 8. Type specimen of *Paressonodon nelsoni*, right maxillary fragment with M1–2 (UWBM 89450): in **A**, stereo buccal (spf = sphenopalatine foramen) and **B**, stereo lingual views; scale bar equals 5 mm; **C**, stereo occlusal view of same; *Paressonodon* cf. *P. nelsoni*, right M1 (DMNH 54571): in **D**, stereo occlusal, **E**, buccal, and **F**, lingual views. Scale bar for **C–F** equals 5 mm.

from the first external cusp to the first cusps of the medial and internal rows. Abrasion on the mesial aspect of this obliquely transverse ridge is likely from contact with the distal aspect of the P4. The other five external cusps are low and pyramidal. They decrease in height distally, but the cusp bases increase in size distally. Likewise, wear along the medial cusp faces increases distally, whereas the angle of the wear facets becomes lower with respect to the horizontal. From each cusp in the external row several ridges emanate. Faint ridges extend mesiodistally to connect the bases of neighboring external row cusps; these low ridges are strongest in the three distal cusps. More prominent ridges extend dorsolingually from external cusp apices along the mesial and distal edges of medial wear facets into the valley between the external and medial rows. The near-continuous ridgeline appears as a series of U-shaped undulations in occlusal or occlusolingual view. The first cusp of the medial row is small and just above the height of the transverse ridge at the mesial margin of the crown. The next three cusps of the medial row are pyramidal, whereas the last three are subcrescentic to crescentic. The cusps of the medial row increase in height and size distally, although the last cusp is worn. From each cusp apex, mesial and distal ridges extend buccally into the valley between the medial and external rows. The mesial ridge in each pair is more prominent, whereas the distal ridge is most evident near the base of the cusp. These ridges form a latticework in the valley between the medial and external rows by extending mesially to anastomose with ridges from neighboring medial cusps or by connecting with the U-shaped ridges of the external row. This latticework is less pronounced than it is in *Essonodon browni* (Archibald, 1982:figs. 32, 33). Lingual ridges also connect successive cusps in the medial row. This ridgeline, like that in the external row, forms a series of U-shaped undulations that extend from the second cusp to the second to last cusp. The trough of each U-shape is well above the base of the cusps and the valley between the medial and internal rows. This high ridgeline effectively separates the external-medial valley from the medial-internal valley; the only connection between these valleys occurs between second to last and last cusps of the medial row. The internal row of cusps takes a curvilinear path. The cusps are conical in shape and increase in size and height distally from the first to second to last cusp. The last cusp is very small and distolingual to the second to last cusp. Ridges extend mesially and distally from each cusp apex, except on the first and last cusps, but do not reach the base of the cusp. Successive cusps of the internal row are well separated from each other. Measurements: L = 4.86 mm, W = 2.64 mm.

The M2 is very small relative to the M1 (M2:M1 L = 0.44), though the ratio is even smaller in *Essonodon* (M2:M1 L = 0.36 for UCMP 120397; Archibald, 1982:table 14). The exposed distal root is distally convex and extends dorsodistally (Fig. 8A). A mesial root is indicated by the visible lateral undulation at the cervix. The crown has a mesially concave mesial margin that receives the distally convex distal margin of M1 (Fig. 8C). The M2 cusp formula is 1:2:3. The length to width ratio of the crown is one, which is slightly greater than it is in M2s of *Essonodon* (0.95 for UCMP 120397; Archibald, 1982:table 14). The apex of the external cusp is worn, but the enamel outline of a small cusp is evident. A transverse ridge at the mesial margin of the crown connects this cusp with the first cusp of the medial and internal rows. The first cusp of the medial row is medium-sized, mesiodistally compressed, and conical. A buccal and a lingual ridge emanate from this cusp. The buccal ridge extends to the external cusp. The main lingual ridge splits into three secondary ridges. Of the secondary ridges, the mesial one extends to the first cusp of the internal row, the intermediate one extends to the second cusp of the internal row, and the distal one terminates in the valley between the medial and internal cusp rows. The second cusp of the medial row is crescentic and the largest cusp on the crown.

A ridge extends mesiobuccally from its apex to the first cusp of the external row. Two main ridges also emanate from the lingual aspect of the cusp. The mesial main ridge splits into two secondary ridges: the mesial one extends to the second cusp of the internal row and the distal one extends to the third cusp of the internal row. The distal main ridge also splits into two secondary ridges: the mesial one terminates in the valley between the medial and internal rows and the distal one extends to the distal ridge coming off the third cusp of the internal row. The first cusp of the internal row is small and at the mesial margin of the crown. The second cusp of the internal row is medium-sized and pyramidal. The third cusp is mesiodistally elongate and subcrescentic. Ridges extend buccally from apices of the internal cusps to connect with other ridges and form a latticework in the valley between the medial and internal rows. Mesiodistal ridges also connect successive cusps of the internal row. The ridgeline, like those in M1, forms a series of U-shaped undulations that extend from the first to last cusp. The trough of each U-shape is well above the base of the cusps and the valley between the medial and internal rows. This high ridgeline closes off the valley from the lingual margin of the crown. Measurements: L = 2.13 mm, W = 2.14 mm.

Paressonodon nelsoni shares several derived features with *Essonodon*, such as a low M2:M1 length ratio, L:W of M2 \leq 1, an M1 with a full internal row, latticework between cusp rows, and a 'stairstep' arrangement of cusp rows. However, the state of development of these features in *Paressonodon* is clearly more primitive than in *Essonodon* (e.g., M1 with a less fully developed internal row, less developed latticework, lower cusp formula, and larger M2:M1 length ratio; Weil, 1999). Because the type locality (Ingrid's Jaw, DMNH loc. 3322) is considered contemporaneous with Lancian localities that have yielded *Essonodon*, *P. nelsoni* is not ancestral to *Essonodon*, but the two taxa may form a clade within Cimolomyidae.

PARASSONODON cf. *P. NELSONI*
(Fig. 8D–F)

Referred Specimen—DMNH 54571, right M1, from DMNH loc. 3322.

Description and Discussion—DMNH 54571 is an isolated right M1 (Fig. 8D) that was initially referred to *Cimolodon nitidus* on the basis of size and cusp formula. With the discovery of UWBM 89450, we tentatively refer the specimen to *Paressonodon nelsoni*. The mesial root structure is identical to that of the M1 on the holotype. There is one buccal accessory root and three lingual accessory roots. The distal root is broader than the mesial root and is dorsolingually oriented along its length. The crown shows a greater degree of wear than in the holotype. The cusps on the distobuccal edge of the crown are worn nearly flat (Fig. 8D). In occlusal view, the lingual margin curves buccally and the buccal margin is nearly straight. All three of the cusp rows extend the full length of the crown. The crown exhibits the same 'torsion' of the cusp rows along the mesiodistal axis and the 'stairstep' arrangement of cusp rows that is observed in the holotype (Fig. 8E). The 'stairstep' arrangement is less pronounced than in the holotype perhaps due to the degree of apical cusp wear. The cusp formula is 6:7:6. In the holotype, the last cusp or cuspid of the internal row is very small; in DMNH 54571, it could easily have been obliterated by wear. The cusp morphologies and ridges are identical to those in the M1 of the holotype, except for perhaps the last cusp of the medial row, which is nearly flat due to wear. As in the holotype, the ridgeline that mesiodistally connects cusps of the medial row closes the passage between the two longitudinal valleys, except for between the last two cusps. The dimensions of DMNH 54571 are smaller than the M1 of the holotype and thus, we only tentatively refer this specimen to *Paressonodon nelsoni*. Measurements: L = 4.35 mm, W = 2.52 mm.

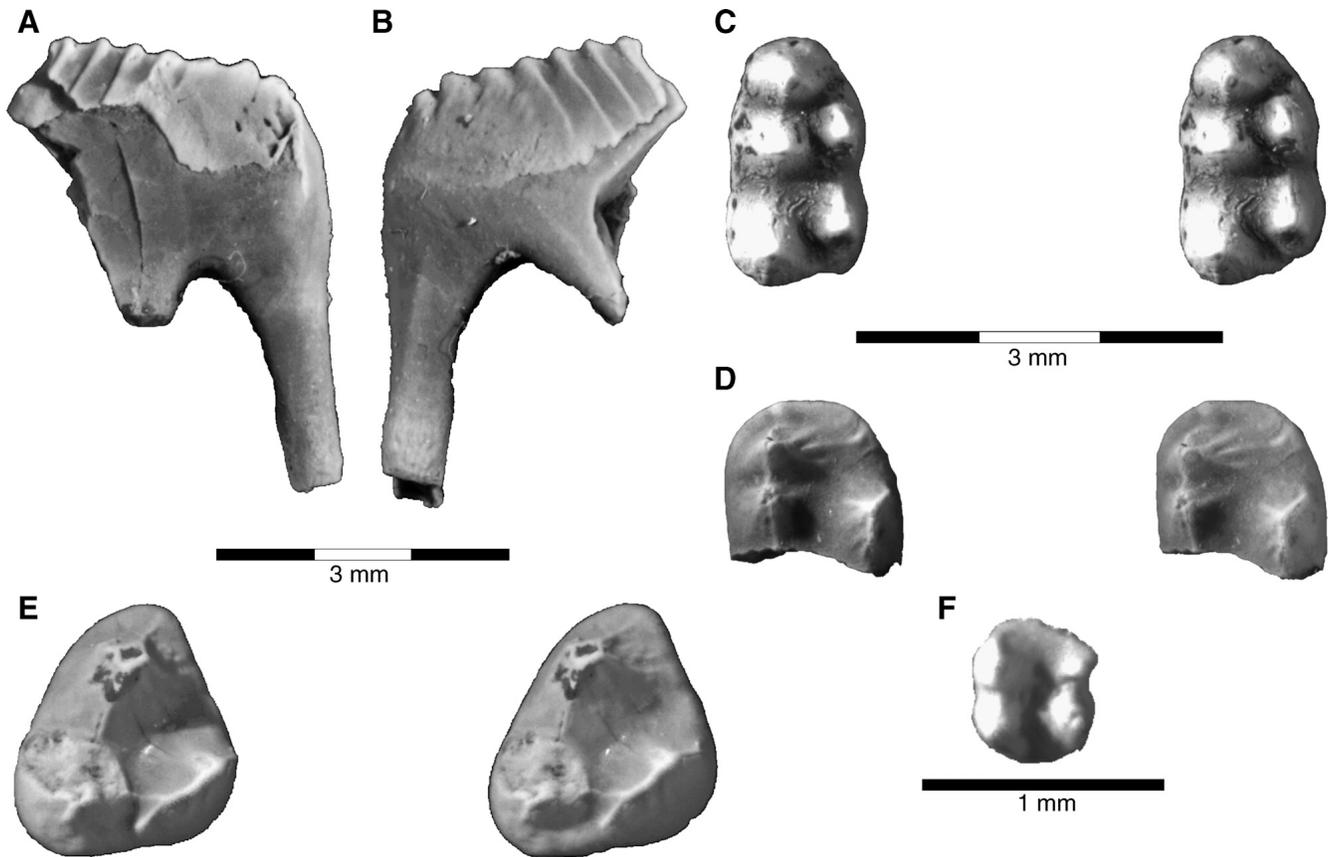


FIGURE 9. cf. *Cimolodon*, distal fragment of left p4 (UWBM 89403): in **A**, buccal and **B**, lingual views. Scale bar equals 3 mm. Multituberculata indeterminate: mesial upper premolar (DMNH 52227), **C**, in stereo occlusal view; fragment of mesial upper premolar (UWBM 89400), **D**, in stereo occlusal view; mesial upper premolar (UWBM 89401), **E**, in stereo occlusal view; scale bar equals 3 mm; and mesial upper premolar (DMNH 55271), **F**, in occlusal view. Scale bar equals 1 mm.

CIMOLODONTIDAE McKenna, 1975
 CIMOLODON Marsh, 1889b
 cf. *CIMOLODON*
 (Fig. 9A, B)

Referred Specimen—UWBM 89403, distal fragment of a left p4 from DMNH loc. 3426 (= UWBM loc. C1099).

Description and Discussion—UWBM 89403 is a fragment of a left p4 that preserves the distal root and the distal portion of the crown. A considerable amount of enamel on the ventrobuccal side of the crown has been lost (Fig. 9A) and distal to the last buccal ridge, evidence of attritional wear remains. We infer that it differed from p4s of cimolomyids in having a greater number of serrations; it preserves seven serrations, four lingual ridges, and four buccal ridges (Fig. 9A, B). In size and morphology, UWBM 89403 is most similar to p4s of *Cimolodon*. However, due to the fragmentary nature of the specimen, we only tentatively refer it to *Cimolodon*. Measurements: $L \gg 3.36$ mm, $W \geq 1.63$ mm.

MULTITUBERCULATA, indet.
 (Fig. 9C–F)

Referred Specimens—DMNH 52227, mesial upper premolar; DMNH 52230, tooth fragment; UWBM 89400, mesial upper premolar; and UWBM 89401, fragment of a mesial upper premolar, all from DMNH loc. 3322 (= UWBM loc. C1098); and DMNH 55271, mesial upper premolar from DMNH loc. 3318.

Description and Discussion—DMNH 52227 is a small, well-preserved mesial upper premolar with an ovoid occlusal outline (Fig. 9C). The crown has a longitudinal row with three cusps and a second row with two cusps. Measurements: $L = 2.00$ mm, $W = 1.18$ mm.

DMNH 52230 is a small fragment of a medium-sized crown preserving three cusps that appear to be part of two rows. UWBM 89400 is a fragment of a small, mesial upper premolar with three low cusps (Fig. 9D). The cusps are arranged in two mesiodistal rows. Measurements: $L \gg 1.48$ mm, $W \geq 1.49$ mm.

UWBM 89401 is a medium-sized, well-preserved mesial upper premolar (Fig. 9E). It has two roots, and the crown has three cusps that form a triangle with the base on the distal end and the apex on the mesial end of the crown (orientation based on more complete specimens, e.g., USNM 6076 *Ptilodus montanus*). Ridges from the apices of the distal cusps extend to the apex of the mesial cusp. The base of the mesial cusp is mesially expanded. Measurements: $L = 2.09$ mm, $W = 1.98$ mm.

DMNH 55271 is a very small, mesial upper premolar (Fig. 9F). Two roots are preserved. The crown, which is moderately preserved, consists of four low cusps arranged in two longitudinal rows. Measurements: $L = 0.66$ mm, $W = 0.55$ mm.

DMNH 52227, DMNH 55271, and UWBM 89400 show differences in size and morphology that may be due to a combination of tooth position and interspecific differences. They could be referable to *Mesodma*, *Parikimys*, possibly *Cimexomys* (not yet recognized in the Pawnee local fauna), or some combination. Based on

size and general morphology, UWBM 89401 may be referable to *Cimolodon*.

THERIA Parker and Haswell, 1897
 METATHERIA Huxley, 1880
 MARSUPIALIA Illiger, 1811
 "DIDELPHIMORPHIA" Gill, 1872
 PEDIOMYIDAE Simpson, 1927
 Genus and species indet.
 (Fig. 10A)

Referred Specimen—DMNH 52394, left dentary fragment with an erupting m4 from DMNH loc. 3322 (= UWBM loc. C1098).

Description and Discussion—DMNH 52394 is a fragment of a left dentary that includes the mesial margins of the coronoid process and masseteric fossa and the distal end of the horizontal ramus, which has a maximum depth of 2.62 mm (Fig. 10A). The mandibular canal is visible at the ends of the fragment. The distal alveolus of the m3 and the distal margin of the mesial alveolus of the m3 are preserved. The m4 crypt contains an unerupted crown. The tooth is dipped mesioventrally and rotated lingually within the crypt. The protoconid is significantly taller than the metaconid. The buccal aspect of the protoconid is strongly convex and its medial aspect is flat. The well-separated apices of the two cusps are connected by a sharp and deep protocristid. The morphology of the unerupted m4 is indicative of a pediomyid, and size comparisons suggest that DMNH 52394 is probably referable to *?Leptalestes cooki*.

PROTOLAMBDA Osborn, 1898
PROTOLAMBDA HATCHERI Osborn, 1898
 (Fig. 10B–E)

Referred Specimens—DMNH 52228, lingual fragment of a left M2 from DMNH loc. 3322 (= UWBM loc. C1098); and UCM 40589, left dentary fragment with p3 from UCM loc. 78193.

Description and Discussion—DMNH 52228 is a worn fragment of a left M2 that preserves the lingual root, the posmetacrista, and the remainder of the crown lingual to the apices of the paracone and metacone (Fig. 10B). Among Lancian pediomyids, it is most consistent with the size and morphology of *Protolambda hatcheri*. The metacone was taller than the slightly more buccal paracone. The protocone is tall with a broad distally expanded base. The conules are largely worn away. Measurements: $L \geq 2.65$ mm, $MW \geq 3.62$ mm, $DW \geq 3.24$ mm.

UCM 40589 is a left dentary fragment with a well-preserved p3 and a distal alveolus for p2 (Fig. 10C–E). We refer it to *P. hatcheri* on the basis of size, robustness, and general agreement with specimens in Clemens (1966). The p3 is double-rooted tooth with a robust crown. The mesial half is dominated by a cusp with a somewhat blunted apex. A weak cingulid extends one-third the length of the crown from the mesial aspect along the lingual base (Fig. 10E). A distinct cristid that exhibits minor wear descends steeply from the apex to the talonid (Fig. 10C). It forms a notch at the base of the talonid and then ascends to the dominant talonid cusp (hypoconid). A second, minor talonid cusp is mesiolingual to the hypoconid. A small cristid extends mesially from this cusp forming a small basin (Fig. 10C, E). A postcingulid descends from the distal aspect of the hypoconid and extends mesially along the buccal base of the talonid. Measurements of p3: $L = 3.80$ mm, $W = 1.57$ mm. *P. hatcheri* was previously known from as far south as the North Horn Formation of central Utah.

LEPTALESTES Davis, 2007
?LEPTALESTES COOKI (Clemens, 1966)
 (Fig. 10F–K)

Comments—We follow Davis (2007) in only tentatively referring this species to *Leptalestes*. In his morphological and cladistic

analysis, he found that this species possessed few synapomorphies of the genus relative to *L. krejci* and *L. prokrejci*.

Referred Specimens—DMNH 52511, left M3; and UWBM 89435, left m4, both from DMNH loc. 3322 (= UWBM loc. C1098).

Description—DMNH 52511 is well preserved, except that the apex of the metacone has been sheared off and the protocristae are worn (Fig. 10F). The morphology of the specimen is consistent with the descriptions for M3s of *?Leptalestes cooki* (i.e., *Pediomys cooki* of Clemens, 1966). Styler cusps A, B, and a reduced D are present. Styler cusp C is absent. The ectoflexus is fairly deep. The postmetacrista extends buccally, whereas the preparacrista extends more mesio buccally (Fig. 10G, H). The conules are small and just lingual to the buccal cusps. The postmetaconule crista nearly extends to the buccal margin of the crown (Fig. 10G). The protocone is fairly narrow with a slight distal expansion of its base. Measurements: $L = 2.15$ mm, $MW = 2.51$ mm, $DW = 3.13$ mm.

UWBM 89435 is a well-preserved left m4 (Fig. 10I–K). Apices of the metaconid and hypoconulid have been damaged, and other cusps show minor apical wear. Size and morphology of the specimen match those in Clemens (1966). The relatively narrow talonid is indicative of the m4 position. Measurements: $L = 2.35$ mm, $AW = 1.55$ mm, $DW = 1.33$ mm. These specimens are the southern-most occurrences of the species.

"ALPHADONTIDAE" Marshall, Case, and Woodburne, 1990
PROTALPHADON Cifelli, 1990
 Species indet.
 (Fig. 10L)

Referred Specimen—DMNH 52526, right m1 from DMNH loc. 3318.

Description and Discussion—DMNH 52526 is a well-worn right m1 (Fig. 10L) that has features characteristic of 'alphadontids.' Its size and the path of its cristid obliqua (meets the distal wall of the trigonid lingual to the protocristid notch) allow us to refer it to *Protalphadon*, rather than *Alphadon*, in which the cristid obliqua meets the distal wall of the trigonid below the protocristid notch. Measurements: $L = 1.99$ mm, $MW = 0.86$ mm, $DW = 0.97$ mm. We do not refer the specimen to *P. lulli* or *P. foxi* because these Lancian species have not yet been distinguished on the basis of lower molars. This occurrence extends the range for the genus south from the Hanna Basin, where Eberle and Lillegraven (1998a) reported *A. lulli* (placed in *Protalphadon* by Cifelli, 1990).

ALPHADON Simpson, 1927
ALPHADON JASONI Storer, 1991
 (Fig. 10M–O)

Referred Specimen—UWBM 89434, right m1 or m2 from UWBM loc. C1098 (= DMNH loc. 3322).

Description and Discussion—UWBM 89434 is a right m1 or m2 in pristine condition, except for slight wear on the protoconid and breakage to the mesial root (Fig. 10M–O). The systematic revision of *Alphadon* by Johanson (1996) distinguished *A. jasoni* from *A. marshi* only on the basis of upper molar features; however, the size and more delicate features of UWBM 89434 agree with lower molar specimens from Storer (1991) and Wilson (2004) that were referred to *A. jasoni* rather than the more robust *A. marshi*. The protoconid and the cristids emanating from it are tall (Fig. 10M); a carnassial notch is present on the paracristid. The paraconid is slightly taller than the metaconid (Fig. 10O). The cristid obliqua meets the distal aspect of the trigonid below the apex of the protocristid. The hypoconulid is large and is positioned buccally to form a deep hypoflexid (Fig. 10M). The crown possesses faint mesial cingulid and a postcingulid (Fig. 10N). The relatively broad angle formed by the trigonid cusps and the relatively wide talonid indicate the tooth is from the beginning of the

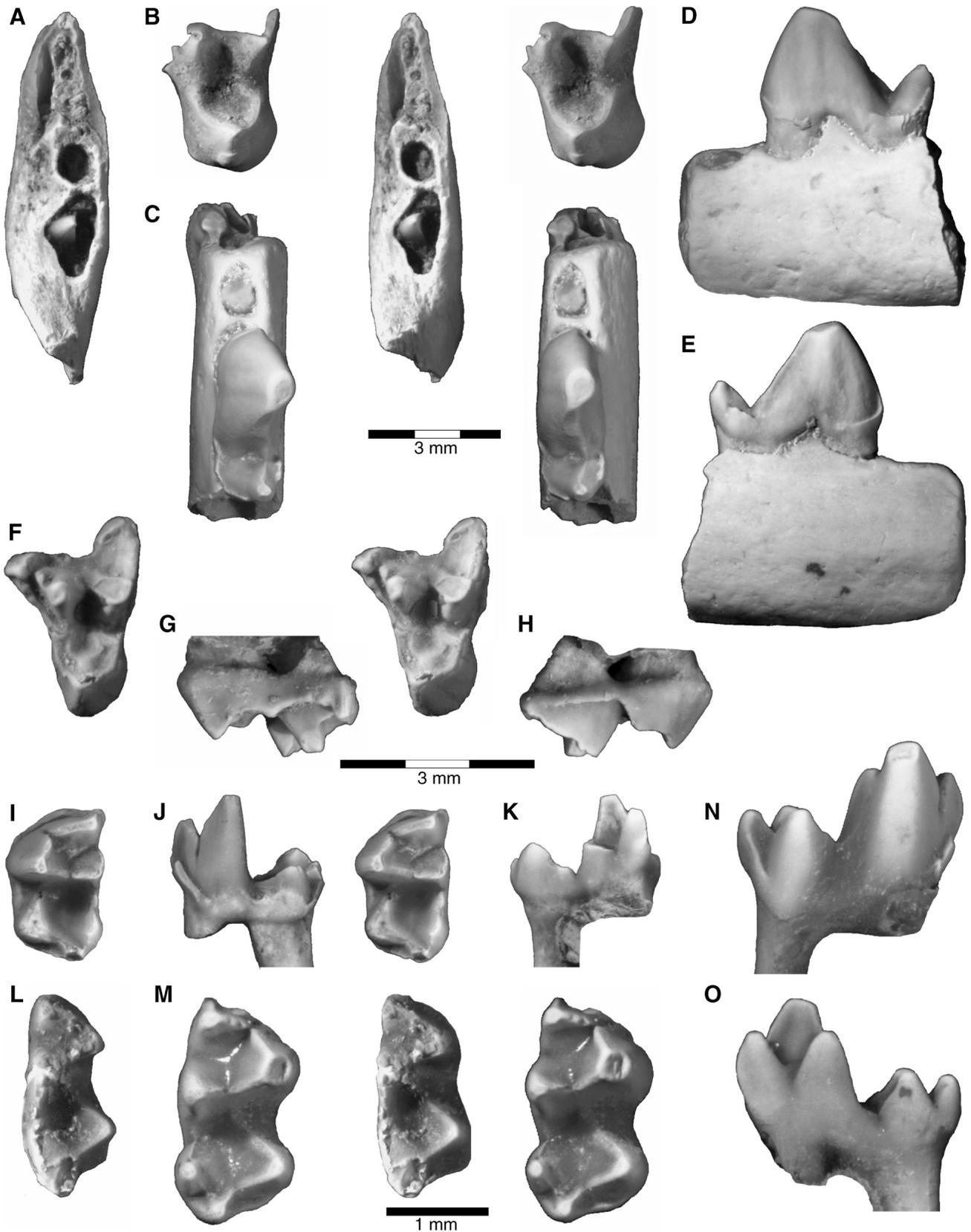


FIGURE 10. Pedomyidae indeterminate, left dentary fragment with erupting m4 (DMNH 52394): **A**, in stereo occlusal view; *Protolambda hatcheri*, lingual fragment of left M2 (DMNH 52228): **B**, in stereo occlusal view; and left dentary fragment with p3 (UCM 40589): in **C**, stereo occlusal, **D**, buccal, and **E**, lingual views. Scale bar for **A–E** equals 3 mm. *?Leptalestes cooki*, left M3 (DMNH 52511): in **F**, stereo occlusal, **G**, mesial, and **H**, distal views; and left m4 (UWBM 89435): in **I**, stereo occlusal, **J**, buccal, and **K**, lingual views. Scale bar for **F–K** equals 3 mm. *Protalphadon* sp., right m1 (DMNH 52526): **L**, in stereo occlusal view. *Alphadon jasoni*, right m1 or m2 (UWBM 89434): in **M**, stereo occlusal, **N**, buccal, and **O**, lingual views. Scale bar for **L–O** equals 1 mm.

TABLE 1. Faunal list and number of specimens for each mammal-bearing locality in the Cheyenne Basin.

	Ken's Site (DMNH 3426)	Dog Pond Area (DMNH 3318, 3319)	The Natural Fort (UCM 78193)	Ingrid's Jaw (DMNH 3322)
Depth to Fox Hills Sandstone	95 m	220 m	330 m	410 m
<i>Meniscoessus collomensis</i>	2			
<i>Meniscoessus</i> cf. <i>M. robustus</i>				
<i>Meniscoessus</i> sp.	2			
<i>Paessonodon nelsoni</i>				1
<i>Paessonodon</i> cf. <i>P. nelsoni</i>				1
? <i>Cimolomys</i>		1		
Cimolomyidae indet.	1			
cf. <i>Cimolodon</i>	1			
<i>Mesodma</i> cf. <i>M. formosa</i>		1		
<i>Parikimys carpenteri</i>				1
Multituberculata indet.	5	1		4
<i>Protalphadon</i> sp.		1		
<i>Alphadon jasoni</i>				1
<i>Protolambda hatcheri</i>			1	1
? <i>Leptalestes cooki</i>				2
Pediomyidae indet.				1
Metatheria indet.		1		1
Eutheria indet.	1			
Theria indet.				1
Mammalia indet.	1	1		
No. of specimens	13	7	1	19

Stratigraphic depth to the top of the Fox Hills Sandstone is based on geophysical well log data. Data for Ken's Site is from this paper and Carpenter (1979).

molar series (Fig. 10M). Measurements: L = 2.19 mm, MW = 1.16 mm, DW = 1.22 mm. This occurrence extends the geographic range for *A. jasoni* south from the Bighorn Basin, Wyoming.

METATHERIA, indet.

Referred Specimens—DMNH 52527, mesial fragment of right lower molar from DMNH loc. 3318; and UWBM 89436, mesial fragment of left lower molar from UWBM loc. C1098 (= DMNH loc. 3322).

Description—DMNH 52527 preserves the protoconid and metaconid of a right lower molar. The protoconid is significantly taller than the metaconid. The protoconid forms a carnassial notch. Its presence and the size of the fragment suggest referral to *Pediomyidae*; however, the specimen is too fragmentary to identify beyond *Metatheria*.

THERIA, indet.

Referred Specimen—UWBM 89402, right upper canine from DMNH loc. 3322 (= UWBM loc. C1098).

Description—UWBM 89402 is a well-preserved right upper canine that is laterally compressed and has a gentle curvature. Slight wear on the apex of the crown forms a shallow groove along the mesiolateral aspect of the crown. L (from enamel to tip) = 3.71 mm, L (from base of root to tip) = 7.71 mm, W (maximum) = 1.60 mm.

MAMMALIA, indet.

Referred Specimens—DMNH 55275, incisor; and DMNH 55216, incisor, both from DMNH loc. 3318.

DISCUSSION

Forty mammalian specimens (12 in Carpenter, 1979; 28 in this paper) are now known from the Upper Cretaceous non-marine deposits of the Cheyenne Basin in northeastern Colorado. The five mammal-bearing localities sample four distinct stratigraphic horizons that span 315 m of section, from what we interpret as temporally equivalent to the top of the Laramie Formation to

near the top of the Cretaceous part of the D1 sequence in the Denver Basin (~68–65.5 Ma). Faunal lists are in Table 1.

Biochronologic Implications

The Lancian age, the youngest of the latest Cretaceous land-mammal 'ages,' is preceded by the informally recognized 'Edmontonian' age and succeeded by the Paleocene Puercan age (but see Cifelli et al., 2004, for a discussion of Puercan localities of possible latest Cretaceous age). It is characterized by the well-sampled mammalian local fauna from the type Lance Formation of eastern Wyoming and faunal correlatives from, for example, the Hell Creek Formation of northeastern Montana (Lillegraven and McKenna, 1986; Cifelli et al., 2004). The end of the Lancian or, more precisely, the beginning of the ensuing Puercan is defined by the first appearance of the archaic ungulate *Protungulatum* (Archibald and Lofgren, 1990; Lofgren et al., 2004). The beginning of the Lancian, however, is poorly defined because, perhaps most critically, the older 'Edmontonian' has not been paleontologically characterized. It is regarded as a temporal interval intermediate in age to Judithian and Lancian local faunas (Fig. 1B), but vertebrate fossils from this interval are sparse. This is in part due to a marine transgressive phase that limited the extent of continental deposition (T9 of Kauffman, 1977; Lillegraven and Ostresh, 1990), but even among the known 'Edmontonian' mammalian assemblages, few index fossils exist; most taxa also occur in older Judithian faunas and/or younger Lancian faunas (Cifelli et al., 2004). Also, with collecting efforts focused higher in section at the Lancian–Puercan transition and the K–T boundary (Clemens, 2002; Wilson, 2005), most well-sampled Lancian local faunas with independent age control sample a small slice of the latest Cretaceous (~67.5–65.5 Ma; Cifelli et al., 2004). Moreover, with so few 'Edmontonian' or Lancian localities in documented stratigraphic superposition, discriminating between temporal and biogeographic differences among geographically separated local faunas remains problematic (e.g., Lillegraven and McKenna, 1986; Fox, 1989; Hunter et al., 1997). The study area in Garfield County, northeastern Montana is an exception. In a stratigraphic succession of well-sampled mammalian assemblages

through the Hell Creek Formation, Wilson (2005) has demonstrated with statistical confidence that (i) two taxa that were previously mentioned as possible Lancian index taxa, *Glasbius* and *Essonodon*, are locally restricted to the upper part of the Hell Creek Formation (~67–65.6 Ma); (ii) *Batodon*, another possible Lancian index taxon, is rare but present in both the upper and lower parts of the formation; and (iii) the taxonomic composition from the lower part of the formation (~67.6–67 Ma) is in most respects Lancian in character. To further clarify the faunal transition from ‘Edmontonian’ to Lancian time, it will be critical to extend these biochronologic and biostratigraphic patterns deeper in time. The stratigraphic model and ongoing palynological and paleomagnetic studies in the Cheyenne Basin offer such an opportunity. The mammal localities, which have thus far yielded only small samples, represent the beginnings of a faunal succession that could shed light on the ‘Edmontonian’–Lancian transition.

Ken’s Site (UCM loc. 77062 = DMNH loc. 3426 = UWBM loc. C1099) is our stratigraphically lowest locality at 95 m above the top of the Fox Hills Sandstone. If we assume, based on its coal occurrences and on stratigraphic thicknesses (Fig. 2B), that it is temporally close to the top of the Laramie Formation of the nearby Denver Basin, Ken’s Site would be ~68 Ma in age (near the C31n–C30r boundary; Hicks et al., 2003; Raynolds and Johnson, 2003). The site has yielded 13 mammalian specimens (12 in Carpenter, 1979, and one in this paper). The two that are identifiable to the species-level were referred to the multituberculate *Meniscoessus collomensis* (Diem, 1999; this paper), a species considered morphologically intermediate to the Judithian and Lancian species of *Meniscoessus* (Lillegraven, 1987) and otherwise only known from the ‘Edmontonian’ Williams Fork Formation of northwestern Colorado (Fig. 1B; Lillegraven, 1987; Diem, 1999; Diem and Archibald, 2005). Although some have regarded *M. collomensis* as potentially diagnostic for the ‘Edmontonian’ (Lillegraven, 1987; Cifelli et al., 2004), we opt to consider Ken’s Site to be late ‘Edmontonian’ or early Lancian in age until the boundary between these intervals is better resolved.

Ken’s Site might be at least two million years younger than the Williams Fork Formation localities (~74–70 Ma; Fig. 1B) and other ‘Edmontonian’ localities, and perhaps one million years older than most Lancian faunas. The *Pedimys* Point local fauna from the Prince Creek Formation of North Slope, Alaska (Clemens, 2003), the Iron Lightning and Red Owl Quarry assemblages from the Fox Hills Formation in South Dakota (Cifelli et al., 2004), and the Alamo Wash local fauna from the Naashoibito Member of the Kirtland Formation in New Mexico (Flynn, 1986; Williamson and Weil, 2008) may all be similar in age to Ken’s Site. None has been shown to have significant faunal differences with typical Lancian faunas, but they are either represented by relatively few specimens or have yet to be fully described (Waage, 1968; Wilson, 1983, 1987; Clemens, 2003; Williamson and Weil, 2008). Continued sampling at these localities and systematic study of available fossils will be crucial to characterizing the ‘Edmontonian’–Lancian transition. For now, we note that *Meniscoessus collomensis* occurs in ‘Edmontonian’ localities of northwestern Colorado and the oldest locality from our section (Ken’s Site), but not from our younger sites; rather, all five *Meniscoessus* specimens from Ingrid’s Jaw (DMNH loc. 3322) are tentatively referred to the Lancian *M. robustus*.

Among our younger localities, the Dog Pond Area (DMNH locs. 3318, 3319), is 220 m above the top of the Fox Hills Sandstone. We estimate, based on the lack of coals and on stratigraphic thicknesses (Fig. 2B), that it is temporally equivalent to the middle part of the Cretaceous part of the D1 sequence of the Denver Basin, which correlates to C30n and is between ~67 and 66 Ma in age (Hicks et al., 2003; Raynolds and Johnson, 2003). As such, these localities would be slightly older than most well-sampled Lancian local faunas (e.g., Trochu and Lance local faunas; Cifelli et al., 2004), and, like Ken’s Site, would bridge

the temporal gap between ‘Edmontonian’ and latest Lancian local faunas. Of the seven mammalian specimens currently known, one was referred to *?Cimolomys*, and might be referable to either *?C. butleria*, a species previously reported from the Judithian Kaiparowits Formation of southern Utah (Eaton, 2002), or alternatively, to a new genus or species. The other specimens are referable to *Mesodma* cf. *M. formosa* and *Protalphadon*, taxa typical of Lancian faunas and possibly Judithian faunas. The Natural Fort (UCM 78193) is stratigraphically above the Dog Pond Area (330 m) and is likely temporally equivalent to the upper part of the Cretaceous D1 sequence of the Denver Basin, near the C30n/C29r boundary. The only specimen, a lower jaw of *Protolambda hatcheri*, is a typical member of Lancian faunas.

The youngest locality in our section, Ingrid’s Jaw (DMNH loc. 3322), is 410 m above the top of the Fox Hills Sandstone. Stratigraphic thicknesses and the presence of dinosaurs suggest that it is temporally equivalent to the upper third of the Cretaceous part of the D1 sequence in the Denver Basin and probably close to the K–T boundary (~65.5 Ma, C29r; Hicks et al., 2003; Raynolds and Johnson, 2003). Most other Lancian faunas are from C29r and near the K–T boundary (Fig. 1B), and thus it is not surprising that of the 19 mammalian specimens from Ingrid’s Jaw, most are common Lancian taxa. The two exceptions, *Parikimys carpenteri* and *Paressonodon nelsoni*, are new taxa that probably reflect latitudinal or paleoenvironmental differences rather than temporal differences with other latest Lancian local faunas (see below).

Paleobiogeographic Implications

Lancian mammal localities are broadly distributed along a north-south transect of the Western Interior, from western Canada to southern Texas; however, as shown in Figure 1A, large representative samples are restricted to the north (Cifelli et al., 2004). Lancian localities in the central and southern parts of the Western Interior (e.g., Colorado, Utah, New Mexico, Texas) have mostly yielded isolated specimens, small samples, or mammalian assemblages that remain unpublished. This geographic bias is cause for thought in light of hypotheses of latitudinal differentiation among Late Cretaceous and early Paleocene terrestrial biotas of the Western Interior (e.g., Wolf and Upchurch, 1987; Anthony and Maas, 1990; Rowe et al., 1992; Nichols and Sweet, 1993; Weil, 1999; Lehman 2001).

Fossil localities in the Cheyenne Basin of northeastern Colorado represent a step toward addressing this geographic gap in our record of Lancian mammals. The only significant Lancian assemblages from farther south are from the North Horn Formation, central Utah (Cifelli et al., 1999), and the Naashoibito Member of the Kirtland Formation, San Juan Basin (Clemens, 1973; Williamson and Weil, 2008). Thus far, mammalian fossils from the Cheyenne Basin support a level of taxonomic continuity among faunas from the northern and central Western Interior. Occurrences of *Meniscoessus robustus*, *Protolambda hatcheri*, *?Leptalestes cooki*, *Alphadon jasoni*, and *Protalphadon* all represent southern range extensions of common Lancian taxa. By contrast, there is tempting evidence of latitudinal differences among the faunas of the northern and central Western Interior. Ingrid’s Jaw (DMNH loc. 3322), which is likely contemporaneous with well-sampled local faunas from the northern Western Interior, has thus far yielded a small sample of 19 specimens, of which seven are identifiable to the species level. Among these specimens, there are two taxa, *Parikimys carpenteri* and *Paressonodon nelsoni*, that have never been reported from the thousands of specimens from the Lancian localities to the north.

CONCLUSIONS

The Upper Cretaceous non-marine deposits of the Cheyenne Basin, though not highly fossiliferous, hold significant promise.

We have documented a sequence of mammalian fossil samples within a stratigraphic model and have shown the potential of this study area to help refine the biochronologic boundary between 'Edmontonian' and Lancian time and expand our view of latest Cretaceous mammalian evolution in the central Western Interior. In addition to the 12 mammalian specimens previously described (Carpenter, 1979), we reported 28 specimens, including two new taxa, *Parikimys carpenteri* and *Paessonodon nelsoni*. These new taxa and those recently uncovered in western Canada and eastern Wyoming (*Schowalteria*, *Nanocuris*; Fox and Naylor, 2003; Fox et al., 2007; Riedel and Wilson, 2008) emphasize how much is left to learn about Lancian mammalian faunas, from well- and poorly sampled areas, alike. Studies of terrestrial vertebrate faunas leading up to and across the K–T boundary have until now focused on a single region of the globe, the northern Western Interior of North America (Archibald, 1996; Fox, 1997; Pearson et al., 2002; Wilson, 2005). We hope that continued fossil collecting in the Cheyenne Basin may in the future provide a stratigraphic succession of vertebrate faunas leading up to the K–T boundary that will broaden our spatial understanding of this pivotal event in Earth's history.

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