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Fossil Mammals from the "Mesaverde" Formation (Late Cretaceous, Judithian) of the Bighorn and Wind River Basins, Wyoming, with Definitions of Late Cretaceous North American Land-Mammal "Ages"

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ABSTRACT

Mammalian faunas are documented for the first time from the "Mesaverde" Formation (Late Cretaceous) of Wyoming. Nonmarine fossils from the Bighorn and Wind River basins indicate a Judithian (revised definition) "age" for the assemblages through comparisons with approximately contemporaneous faunas of the Judith River (Montana) and Oldman (Alberta) formations. Three previously unknown genera are recognized, although not named herein, from the "Mesaverde" Formation (*Multituberculata*, new genus and species, unidentified; *Dryolestidae*, new genus and species, unidentified; and *Falepetrus barwini*). Three new species of previously described genera (*Alphadon sahnii*, *A. attaragos*, and *Paranyctoides megakeros*) are named. All species-level taxa (16 total) except *Alphadon lulli* are reported from Wy-

oming for the first time, and new records involve both geographic and geologic range extensions. The temporal record of the dryolestid appears relictual, being previously unknown from post-Jurassic strata in North America. Taxonomic comparisons suggest that the Judithian mammalian fauna of what was then coastal parts of the western interior was essentially homogeneous geographically, at least from southern Alberta to central Wyoming.

Nonmarine mammalian assemblages from the Oldman, Judith River, and "Mesaverde" formations correlate temporally with more easterly marine rock units that lie within (or within four zones above) the *Baculites gregoryensis* (cephalopod) Zone, part of the standard zonation of Upper Cretaceous rocks of the North American western interior. The upper part of the Red Bird Silty Mem-

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ber of the Pierre Shale at Redbird, Wyoming, holds the largely endemic invertebrate macrofaunal assemblage characteristic of the *B. gregoryensis* Zone as well as a newly described planktonic foraminiferal assemblage. The microfossils allow correlation to the upper Tylorian and/or lower Navarroan foraminiferal stages of the Gulf Coast. This, in turn, correlates approximately to the Campanian-Maastrichtian stage boundary at Gubbio, Italy, and European stratotypic sections. Judithian mammal faunas of the Rocky Mountains, therefore, must be younger in age (i.e., late Campanian and/or early Maastrichtian) in terms of the European stages than usually is considered on the basis of molluscan zonation within the North American western interior (e.g., well within the Campanian). Judithian mammals from the Rockies probably lived about 74–76 million years ago during the late part of geomagnetic Polarity Chron 33 or the early part of Polarity Chron 32, during the regressive phases of the Claggett cyclothem as recognized for the western shoreline of the Western Interior Seaway. They correlate stratigraphically with the lower part of the *Aquilapollenites quadrilobus* palynomorph Interval Zone of the northern Rockies.

Aquilian (oldest), Judithian, and Lancian (youngest) provincial North American land-mammal “ages” are redefined for the Late Cretaceous nonmarine sequence of the western interior from an older stage concept; the “ages,” based upon species-level mammalian assemblages, are modeled after the system used successfully for nonmarine Cenozoic faunas of North America. An Edmontonian “age” (previously used as a stage term, chronologically intermediate between the Judithian and Lancian) is probably identifiable as a discrete interval of geologic time, but is not yet defensible on the basis of mammalian assemblages. Therefore, it is not redefined as a land-mammal “age.”

We concur with the interpretation that the Djadokhta Formation of southern Mongolia and the Judith River and Oldman faunas of North America are essentially of the same age. This compresses the faunas of the Barun Goyot and Nemegt formations of southern Mongolia, plus that of the poorly known, nearby Bugeen Tsav locality, into an interval of time equivalent to the Judithian and/or Lancian North American land mammal “ages” and, most probably, to the Maastrichtian stage as typified in western Europe.

INTRODUCTION

This is the first systematic account of mammalian remains from the Late Cretaceous “Mesaverde” Formation of the North American western interior. As discussed below (see Geological Framework), the name Mesaverde Formation is used incorrectly in Wyoming; thus we consistently place the name within quotation marks to distinguish its use in Wyoming from its proper usage nearer the type section in southwestern Colorado.

The fossils described herein are of special biogeographical importance because they represent the most southerly, well-documented record of Judithian (revised definition, see under Biostratigraphy) mammals known from the continent. Although preliminary, we considered the development of this paper worthwhile because a new collecting effort in the “Mesaverde” Formation has been mounted by Lillegraven. It will be some time before the results of that could be made available in published form. Because of the limited number of specimens available, we are not considering elements of mammalian faunas of Late Cretaceous age from Utah (R. L.

Cifelli and J. G. Eaton, personal commun.), the Kirtland and Fruitland formations of New Mexico (Clemens et al., 1979; Flynn, in press), the El Gallo Formation (Clemens, 1980) of Baja California, Mexico, Eutaw Formation (Emry et al., 1981) of Mississippi, or Mount Laurel Formation (Krause and Baird, 1979) of New Jersey.

New faunas from two general areas (see figs. 1–3; Locality Data, below) within Wyoming are described. The first is from multiple localities in the north-central part of the state in the Bighorn Basin, with most sites being northeast of the town of Worland. The second is from two, closely adjacent localities at the center of the state in the Wind River Basin, in the area of the Rattlesnake Hills Anticline (Barwin, 1959, 1961a, 1961b; Ostrom, 1965; Shapurji, 1978). Virtually all of the reported specimens occur along with abundant nonmammalian remains within yellow channel sandstones, with considerable reworking of the fossils. Most mammalian specimens are represented by isolated teeth or edentulous jaw fragments as shown through

the various collecting techniques of surface-crawling, quarrying, underwater screen-washing, and dry-screening. No indication of the existence of articulated mammalian skeletal remains has yet been observed.

ABBREVIATIONS

INSTITUTIONAL

AMNH, Department of Vertebrate Paleontology, The American Museum of Natural History, New York

NMC, National Museum of Canada, Ottawa

PMAA-P, Provincial Museum and Archives of Alberta, Paleontological Collections, Drumheller

UA, Collection of Fossil Vertebrates, Department of Geology, The University of Alberta, Edmonton

UCMP, Museum of Paleontology, University of California, Berkeley

USGS, United States Geological Survey

UW, The Geological Museum, The University of Wyoming, Laramie

STANDARD DENTAL MEASUREMENTS

AP, Anteroposterior length

ANW, Anterior width (=width of trigonid of lower molariform teeth; =width of tooth on teeth in which only one width measurement was taken)

POW, Posterior width (=width of talonid of lower molariform teeth)

LTRI, Length of trigonid

MISCELLANEOUS

ACSN, American Commission on Stratigraphic Nomenclature

IUGS, International Union of Geological Sciences

MPR, Mongolian People's Republic

NACSN, North American Commission on Stratigraphic Nomenclature

NALMA, North American land-mammal "age"

P4, m1, Tooth designations: capital letters, upper jaw; lower case letters, lower jaw

HISTORY OF COLLECTING

WIND RIVER BASIN

Earlier successes in fossil recovery by screen-washing of large volumes of sediments in the type Lance Formation of eastern Wyoming prompted explorations by McKenna in 1961 to similar point bar and pond

deposits in older Cretaceous rocks of Wyoming and Utah, including the "Mesaverde" Formation (Barwin, 1959, 1961a, 1961b). Only one locality, however, the future site of Barwin Quarry (see fig. 2 and Locality Data, below), central Wyoming, was judged promising.

Prospecting at this site yielded the first fossil mammals from the "Mesaverde" Formation. Searches in nearby areas of outcrop west of the minimally productive Barwin Quarry were carried out in 1965 with the hope of finding new and better sites. Results were negative, however, and a decision was made to work Barwin Quarry. The richness of the site was minimal, yielding several teeth per ton of rock processed. A full-scale washing program was continued at Barwin Quarry in 1966.

After extensive overburden was removed by blasting and bulldozing, approximately 100 identifiable mammalian specimens and a large number of other vertebrate remains eventually were obtained from Barwin Quarry by screening about 80 tons of the fossiliferous sandstone. Unfortunately, total productivity was even less than the minimal value anticipated, so excavation was terminated at the end of the 1966 season. However, comparatively minor excavations were made by the AMNH crew in 1970. The collections made in 1965, 1966, and 1970 were catalogued by Thomas H. Rich, but no research was undertaken until Lillegraven rejuvenated the present project in 1981.

Surface collecting, including dry-screening, was done by J. Howard Hutchison and Michael T. Greenwald (University of California, Berkeley) at a newly discovered extension to the east of the fossil-bearing level represented at Barwin Quarry in August of 1976. Two days were spent at the site, resulting in the UCMP specimens used in the present study. The new locality (UCMP V-81101, Fales Rocks 1) is the same as UW V-81006, Fales Rocks.

Lillegraven visited UW V-81006 for one day in June of 1981, collecting a few teeth through dry-screening. He revisited the site in November of 1982, collecting about half a ton of rock for screen-washing. A sample of roughly 25 tons was taken by Lillegraven from the Fales Rocks locality in August of

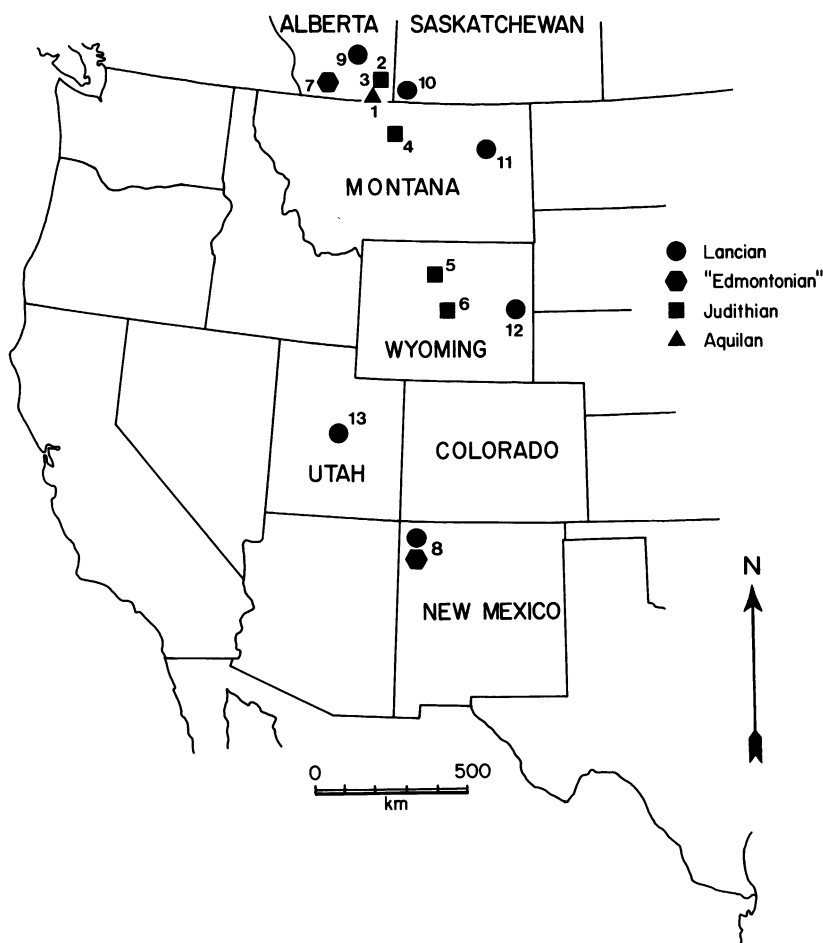


FIG. 1. Reference map of western North America showing general locations (numbers 5 and 6) of mammalian assemblages from "Mesaverde" Formation described in present paper (see fig. 2 for greater detail). Numbers refer to important Late Cretaceous mammal-bearing areas listed in table 10. See text concerning nature of "Edmontonian."

1983, but remains found there are not included in the present paper.

BIGHORN BASIN

The first mammals from the "Mesaverde" Formation of the Bighorn Basin were found in 1978 by Gerard R. Case. The specimens were recovered from many sites (see fig. 2 and Locality Data, below) to the northeast of Worland and were given to McKenna for study and inclusion within the AMNH collections; Case was searching primarily for remains of fossil sharks. Case returned to the area briefly in 1979.

Lillegraven and his party spent roughly two

weeks in the area discovered by Case in late July and early August of 1981. They prospected widely, searching with only modest success for new and richer mammal-bearing localities. Specimens recovered by surface prospecting, dry-screening, and test screen-washing are described in the present paper.

One site in the southwestern Bighorn Basin (UW V-81016, Late for Lunch locality, see fig. 2) was discovered by Kenneth E. Jackson of Lillegraven's field party in July of 1981; it was revisited briefly by Lillegraven's crew in August of 1982. The site appears highly promising for recovery of additional specimens of high quality, but the relative richness was not appreciated until the 1982 visit. A

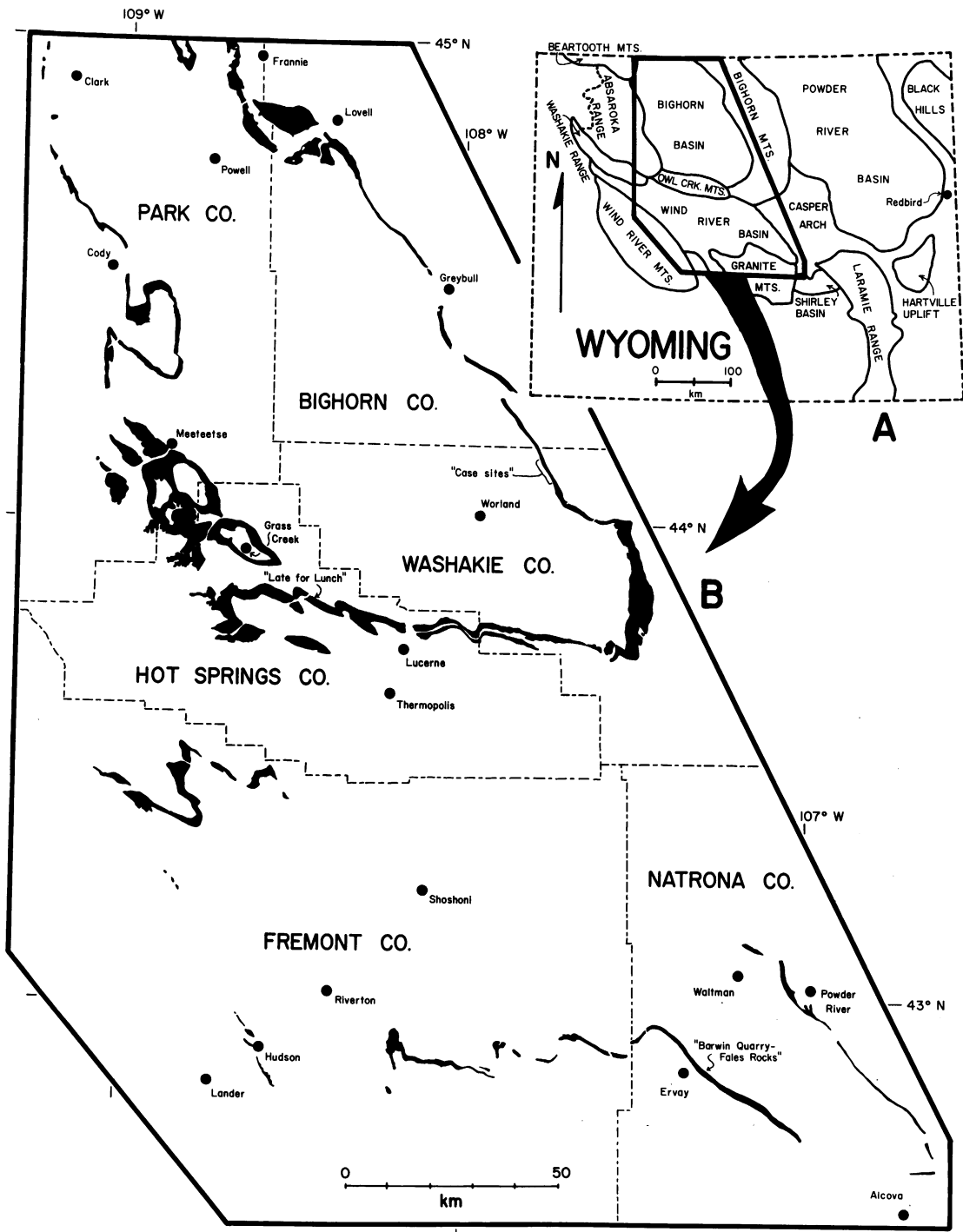


FIG. 2. Reference maps of Wyoming showing semi-detailed positions of mammalian assemblages from "Mesaverde" Formation. A, Inset, showing principal tectonic features surrounding Bighorn, Wind River, and Powder River basins. B, Outcrop pattern (solid black; traced from Love and Christiansen, 1983) of "Mesaverde" Formation of Bighorn and Wind River basins showing approximate areas for the Case sites, Late for Lunch locality, and Barwin Quarry-Fales Rocks (see section on locality data for more detail).

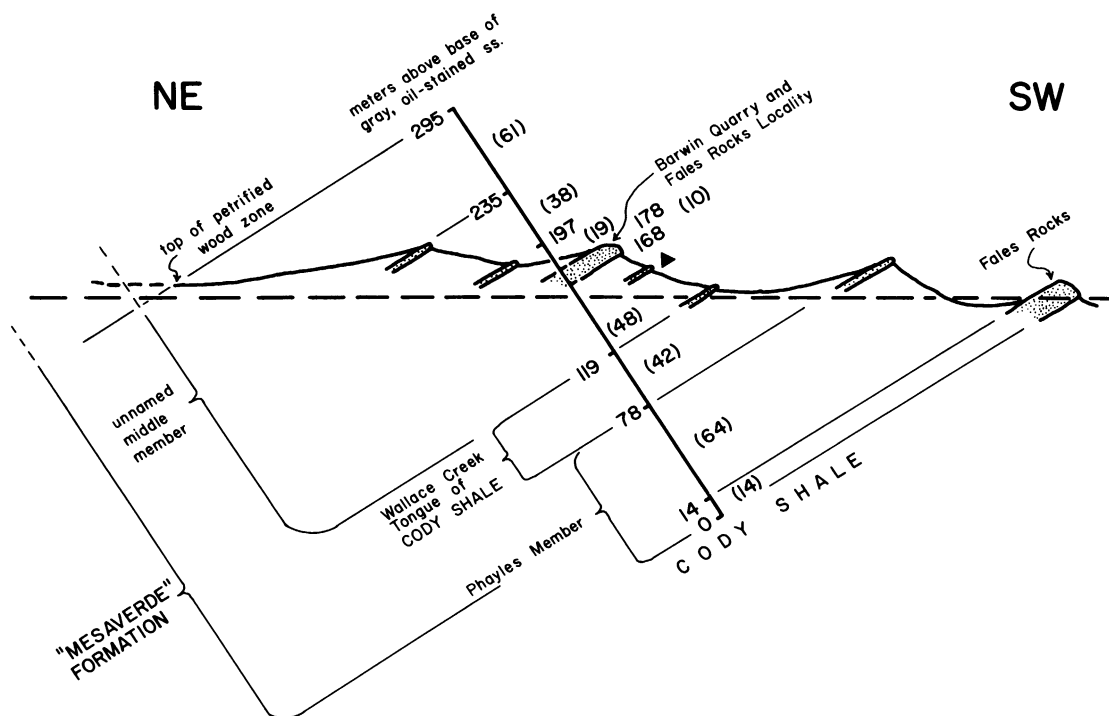


FIG. 3. Cross section of lower part of "Mesaverde" Formation in southeastern Wind River Basin in area of mammal-bearing localities (see fig. 2 and section on locality data). Stratigraphic terminology follows Barwin (1961a; see fig. 4). Section is presented normal to strike (strike 42–47°W, dip 31–33°N), and shows local topography relative to horizontal (heavy dashed line) and prominent sandstone outcrops (dotted pattern). Base of section is top of main body of Cody Shale. Top of section is unexposed and within "Mesaverde" Formation at top of level (best seen to NW of measured section) rich in petrified wood. Numbers in parentheses are thicknesses of individual rock units. Solid triangle indicates top of Wallace Creek Tongue of Cody Shale as delimited by Barwin (1961a); we place contact lower because of presence of nonmarine fossil vertebrates within contested part of section. Fales Rocks (spelling as used on USGS Garfield Park Quadrangle, 1959, 7.5 min topographic map) is a series of gray, oil-stained sandstones that serves as a prominent local landmark.

sample of about half a ton was secured in June of 1983, but fossils recovered then are not included in the present report.

GEOLOGIC AGE FRAMEWORK

BASED ON ZONATION BY MOLLUSCS

INTRODUCTION

Most comparisons made within the Systematic Paleontology section are made among fossils recovered from the upper part of the Oldman Formation (southern Alberta; Judith River Formation, Oldman beds of McLean, 1971), the Judith River Formation (north-central Montana), and the "Mesa-

verde" Formation (northwestern and central Wyoming). All fossils are from nonmarine strata, and a tacit assumption is that the various rock units are contemporaneous at a coarse level of resolution. Such an assumption is important, because it implies that most differences observed within species collected from the various areas are a result of individual or populational variation rather than evolutionary change expressed through a significant interval of geologic time. Is the assumption of contemporaneous existence justifiable?

The primary means for determining temporal correlation for strata of Late Cretaceous age in the North American western interior

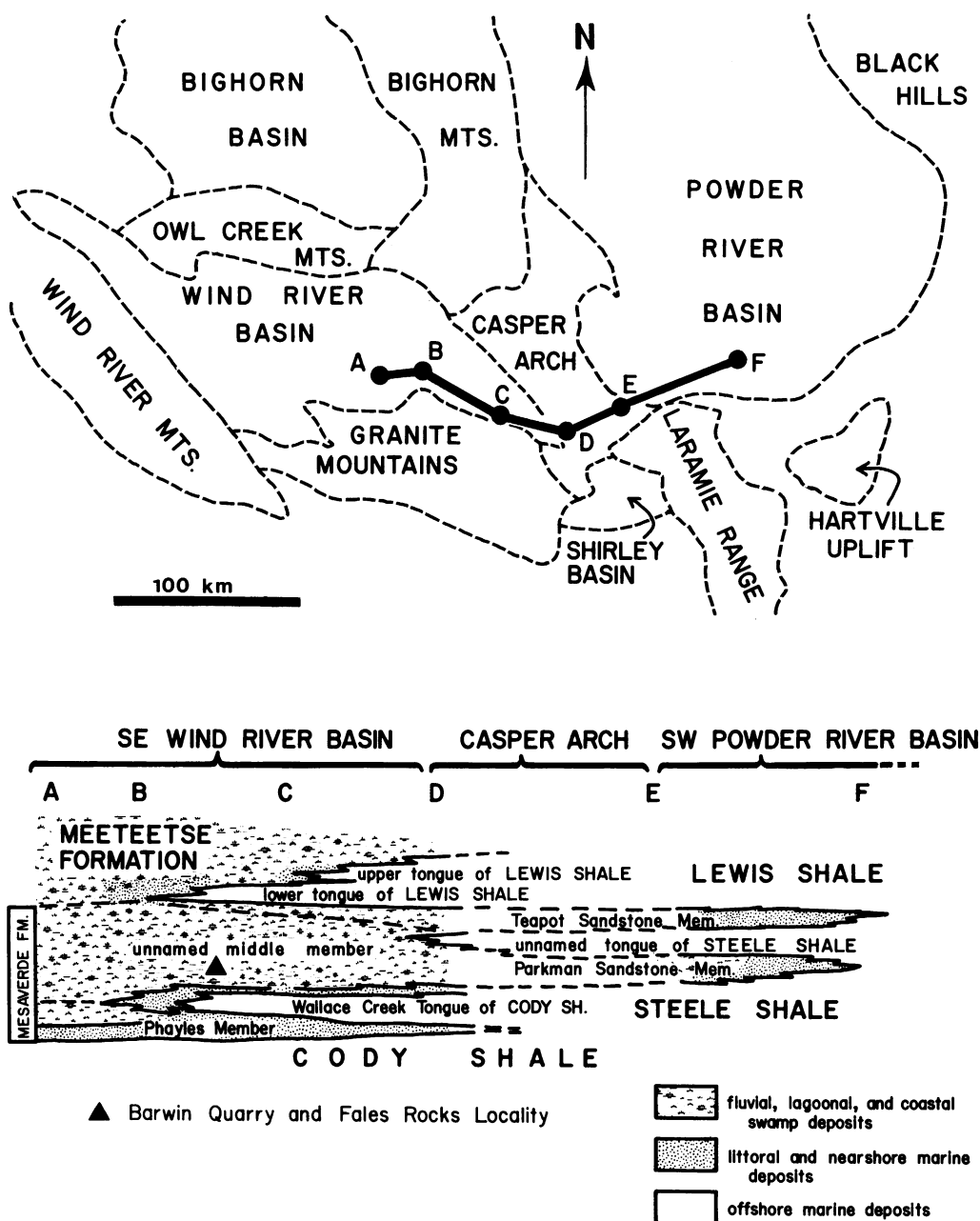


FIG. 4. Index map (above) of part of Wyoming (refer to fig. 2) and interpretive geologic cross section (below; modified from Barwin, 1961a, pl. IV, not drawn to scale) to show local relationships of important stratigraphic units. Approximate position of mammal-bearing localities (Barwin Quarry and Fales Rocks locality) is shown by solid triangle. Cretaceous strata above Cody Shale are lost to erosion across uplifted Casper Arch in chosen section.

is by the distribution of marine invertebrates. A history of how the basic framework of the Cretaceous System in the western interior was

developed has been presented by Waage (1975). We are concerned only with the Late Cretaceous (Senonian). Detailed zonations

exist, based primarily on marine molluscs, that are generally assumed to be contemporaneous geographically (see Kauffman, 1970, 1975; Obradovich and Cobban, 1975). The following section reviews specifically how the Oldman, Judith River, and "Mesaverde" formations relate to marine invertebrate zonation. The review is geographically based, progressing southward.

OLDMAN FORMATION

The Oldman Formation (Russell and Landes, 1940) overlies and partly interdigitates with the Foremost Formation (Oldman and Foremost members of the Belly River Formation as discussed by Williams and Burk, 1964, p. 175). McLean (1971) suggested extension of the name Judith River Formation (type section in Montana) into the plains of Canada, with relegation of the Oldman and Foremost formations to the status of beds. Although such terminology is now in general use among Canadian geologists (e.g., Forester et al., 1977), for purposes of convenience in designation of fossil beds we retain the older terms (the extensive need for qualification as "Judith River Formation of Alberta" is thereby obviated).

The Foremost Formation (Dowling, 1915) is composed of fine clastic sediments, occasional coals, and abundant strata bearing a brackish-water fauna. The Oldman and Foremost formations were considered by Jeletzky (1968, p. 46) to represent the *Baculites gregoryensis* (cephalopod) Zone of the United States (see Cobban and Reeside, 1952, chart 10b; Obradovich and Cobban, 1975, table 1). The upper reaches of the Oldman Formation in Alberta, however, probably involve lateral equivalents of as many as four cephalopod zones higher (approximately 2 million years younger) than the *B. gregoryensis* Zone (i.e., progressing upward, *B. scotti* through *B. rugosus* zones; see Forester et al., 1977, fig. 2). The principal assemblages of fossil mammals from Alberta's Oldman Formation occur high in the section. Dr. Dale A. Russell suggested to Lillegraven (letter dated November 19, 1984) that the mammalian assemblages of the upper Oldman Formation may be as young as the *B. rugosus* (= *Exiteloceras jenneyi*) Zone.

The Foremost Formation is underlain by the Pakowki Formation (Dowling, 1915; representing a westerly equivalent of the upper part of the marine Lea Shale); the Pakowki Formation bears the distinctive *Baculites obtusus* fauna, characterized by Jeletzky (1968, p. 45). The *B. obtusus* fauna of southern Alberta correlates in age in the United States with rocks of the Sharon Springs Member of the Pierre Shale and its more westerly equivalents such as the Claggett Shale (Hatcher and Stanton, 1903; Hatcher, 1904; Stanton and Hatcher, 1905; see also Gill and Cobban, 1965, fig. 3, 1966a, table 2, 1973, fig. 12).

The Oldman Formation is overlain by the Bearpaw Formation (Hatcher and Stanton, 1903; Stanton and Hatcher, 1905; Forester et al., 1977), bearing at its base (in Alberta) the *Baculites compressus* Zone, also recognized widely to the south (Cobban and Reeside, 1952; Obradovich and Cobban, 1975; Riccardi, 1983). Thus, the vertebrate assemblages of the Oldman Formation are reasonably constrained in terms of their positions within the North American western interior marine invertebrate zonation.

JUDITH RIVER FORMATION

The type Judith River Formation (Hayden, 1871; see also Stanton and Hatcher, 1903; Hatcher, 1904; Sahni, 1972; Gill and Cobban, 1973) is biostratigraphically bracketed in a similar fashion to the Oldman-Foremost complex of southern Alberta. That is, the nonmarine strata are underlain by the Claggett Shale, bearing the *Baculites asperiformis* Zone (of Cobban and Reeside, 1952, p. 1020; two zones higher than the *B. obtusus* Zone), and overlain by the Bearpaw Shale, bearing the *B. compressus* Zone (ibid.). The Judith River Formation grades eastward into the *B. gregoryensis* Zone within the Pierre Shale (ibid.). Thus the biostratigraphic correlation between nonmarine strata of the Oldman and Judith River formations is reasonably close and well controlled, in addition to corresponding to the same regression of the sea.

"MESAVERDE" FORMATION

GENERAL: As discussed by Reeside (1924), Weimer (1960), Fisher et al. (1960), and Molenaar (1983), the strata in Wyoming referred

to in current literature as the Mesaverde Formation or Group (Holmes, 1877: "Mesa Verde Group") and Lewis Shale (Cross et al., 1899) are significantly younger than the Mesaverde and Lewis Shale at their type sections in the San Juan Basin in southwestern Colorado. Not only are the more northerly rock units younger, they also represent clastic debris from quite different transgressive-regressive sequences of the Western Interior Seaway (see Weimer, 1960, fig. 7). Moreover, a widespread unconformity exists within the "Mesaverde" of Wyoming at the base of the Teapot Sandstone Member (Gill and Cobban, 1966b). Thus use of the names Mesaverde Formation and Lewis Shale for strata in Wyoming represents a long-standing, although generally understood, error.

BIGHORN BASIN: Nearly all mammalian specimens from the Bighorn Basin available for the present study come from the middle to upper parts of the "Mesaverde" Formation in the southeastern part of the basin. The localities are a few kilometers northeast of the No Water Creek section (number 5) of Gill and Cobban (1966b, fig. 1). According to their interpretation, the part of the section bearing the mammalian fossils would overlie the *Baculites perplexus* Zone (see Obradovich and Cobban, 1975, table 1) and would correlate to the east with: (1) the lower marine part of the Parkman Sandstone Member of the "Mesaverde" Formation; and (2) the *B. gregoryensis* Zone as seen in the Pierre Shale (see Gill and Cobban, 1966a). At least three species of *Baculites* that represent zones slightly lower than *B. gregoryensis* underlie the "Mesaverde" Formation in the southern Bighorn Basin within the Cody Shale. An erosional unconformity separates the upper part of the mammal-bearing section from the significantly younger Teapot Sandstone Member of the "Mesaverde" Formation (Gill and Cobban, 1966b, fig. 1).

WIND RIVER BASIN: All mammalian specimens known from the Wind River Basin come from the Barwin Quarry and Fales Rocks sites (see figs. 3 and 4; Locality Data below). These sites are within the lower part of the mainly nonmarine unnamed middle member of the "Mesaverde" Formation (Rich, 1958) as described by Barwin (1959, 1961a, p. 29, 1961b; Zapp and Cobban, 1962).

Although no marine fossils have been recovered from the unnamed middle member in the immediate vicinity of the mammal localities, the presence of *Inoceramus subcompressus* was reported by Keefer and Rich (1957, p. 73) from strata equivalent to the basal part of the member in the southeastern corner of the Wind River Basin (see Barwin, 1961a, p. 34). *Inoceramus subcompressus* occurs elsewhere in zones just below the *Baculites gregoryensis* Zone (see Kauffman, 1975, fig. 4).

Underlying the local unnamed middle member of the "Mesaverde" Formation is the Wallace Creek Tongue (of Barwin, 1961a, p. 14) of the Cody Shale. The Wallace Creek Tongue has yielded a variety of marine invertebrates (see Barwin, 1961a, pp. 17–19), including *Inoceramus subcompressus* and *Baculites* sp. aff. *B. haresi* (identifications by W. A. Cobban in written commun. to Barwin, 1957). Elsewhere, *Baculites haresi* is also characteristic of the zones just below the *B. gregoryensis* Zone (see Cobban and Reeside, 1952, chart 10B).

No marine invertebrates have yet been described from the upper part of the unnamed middle member of the "Mesaverde" Formation in the southeastern Wind River Basin. However, according to Barwin's (1961) interpretation of the correlation of the "Mesaverde" sections between the southeastern Wind River Basin and the southwestern Powder River Basin (see fig. 4), the mammal-bearing localities within the unnamed middle member correlate with the Parkman Member of the "Mesaverde" Formation. Cobban (1958, p. 116) reported the presence of *Baculites gregoryensis* within the Parkman Member in the southwestern Powder River Basin.

Following the above review, it seems reasonable to accept the assumption that the mammalian assemblages of the Oldman, Judith River, and "Mesaverde" formations do, indeed, represent essentially the same cephalopod-based biostratigraphic unit, correlating approximately with the marine *Baculites gregoryensis* Zone (of Cobban and Reeside, 1952); as discussed above, the material from the upper Oldman Formation may be as much as four zones younger. Because there is little evidence to suggest that the limits of the marine invertebrate zonation are significantly

time-transgressive from one geographic area to another, we can further assume that the mammalian faunas from Alberta, Montana, and Wyoming are essentially contemporaneous.

BASED ON ZONATION BY PLANKTONIC FORAMINIFERA

The Red Bird Silty Member of the Pierre Shale (see Gill and Cobban, 1966a) as seen in east-central Wyoming at Redbird is of particular importance because it provides a link between zonations based on ammonites and those based on planktonic foraminifera.

The Red Bird Silty Member contains a macrofauna characteristic of the *Baculites gregoryensis* (cephalopod) Zone (see Gill and Cobban, 1966a, table 2) which, as discussed above, is a principal correlative of the mammal-bearing strata of the nonmarine Oldman, Judith River, and "Mesaverde" formations. Unfortunately, the Late Cretaceous cephalopod zones of the North American western interior are represented by highly endemic species (see Kennedy and Cobban, 1976; Young, 1963) that have not proven useful for temporal correlation with warmer-water areas to the south. Moreover, the gastropods at Redbird are of little use in high-resolution correlation with areas outside the western interior (Sohl, 1967).

Bergstresser (1981, fig. 7) reported, among other taxa, the following species of planktonic foraminifera from the Red Bird Silty Member: *Archaeoglobigerina cretacea*, *A. sp. cf. A. blowi*, *Globigerinelloides multispina*, *G. prairiehillensis*, *G. volutus*, and *Heterohelix globulosa*. All of these widely distributed species constitute parts of the foraminiferal zonation of Upper Cretaceous rocks in the North American Gulf Coast (see Pessagno, 1967, 1969). Comparison of foraminiferal species' ranges between the two areas suggests correlation of the Red Bird Silty Member of the Pierre Shale with Pessagno's (1967, text-figs. 3-5) *Globotruncana fornicata*-*G. stuartiformis* Assemblage Zone of the Gulf Coast.

Species of planktonic foraminifera of the Pierre Shale are temporally long-ranging, and thus are of limited utility to detailed biostratigraphic zonation. Nevertheless, comparison of species' concurrent stratigraphic

ranges in conjunction with their known intervals of greatest abundance (Pessagno, 1967) suggests that the foraminiferal fauna of the Red Bird Silty Member represents the correlative of the *Globotruncana elevata* Subzone and/or the next higher *Rugotruncana subcircumnodifer* Subzone of the Gulf Coast (fig. 5). In the Gulf Coast, *Rugotruncana subcircumnodifer* first appears as a rare element of the upper half of the *G. elevata* Subzone, but becomes a common species only in the *R. subcircumnodifer* Subzone. Although unknown from the section of the Pierre Shale at Redbird, *R. subcircumnodifer* is well documented nearby in upper parts of the Niobrara Formation in rocks unquestionably older than the Red Bird Silty Member (Freerichs and Dring, 1981, p. 65; Bergstresser, 1981, p. 31). The planktonic foraminiferal fauna of the Red Bird Silty Member thus allows correlation with the upper Taylorian and/or lower Navarroan stages of the Gulf Coast (see Pessagno, 1969), with a Navarroan assignment being probable.

BASED ON ZONATION BY BENTHONIC FORAMINIFERA

As discussed by Caldwell and North (1984), assemblages of benthonic foraminifera may be diachronous, and species usually have extensive stratigraphic ranges that span several cephalopod zones. Nevertheless, a zonation of marine Cretaceous strata of the North American western interior has been established on the basis of benthonic species (Caldwell et al., 1978). The *Eoeponidella linki* Zone (ibid., p. 551; same as "Zone XI" of Caldwell and North, 1975, p. 323) encompasses the lowest part of the Bearpaw Formation plus underlying marine strata laterally equivalent to the Judith River Formation. The *E. linki* Zone involves the *Baculites gregoryensis* through *Didymoceras stevensoni* cephalopod zones (see Caldwell et al., 1978, table 1, p. 503).

Benthonic foraminifera from the Red Bird Silty Member of the Pierre Shale at Redbird, Wyoming, were listed by Bergstresser (1981, p. 86); this member is represented by the *Baculites gregoryensis* (cephalopod) Zone. Although Bergstresser (1981) did not discuss the section at Redbird in terms of Caldwell

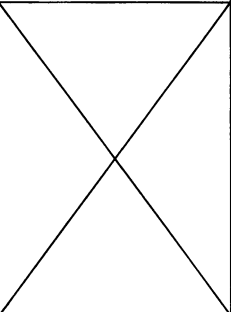
STANDARD NORTH AMERICAN STAGES	ASSEMBLAGE ZONES	SUBZONES	ZONULES
NAVARROAN	<i>Globotruncana confusa – stuartiformis</i>	<i>Abathomphalus mayaroensis</i>	
		<i>Globotruncana gansseri</i>	
	<i>Globotruncana fornicata – stuartiformis</i>	<i>Rugotruncana subcircumnodifer</i>	<i>Rugotruncana subpennyi</i>
			<i>Globotruncana lapparenti s.s.</i>
<i>Globotruncana elevata</i>		<i>Globotruncana calcarata</i>	
		<i>Pseudotextularia elegans</i>	
TAYLORIAN	<i>Archaeoglobigerina blowi</i>	<i>Planoglobulina glabrata</i>	
		<i>Dictyomitra multicostata</i>	

FIG. 5. Correlation chart for Upper Cretaceous sequences of western Gulf Coastal Plain and Caribbean Basin (abbreviated from Pessagno, 1969, pl. 2).

et al.'s (1978) zonation, the Red Bird Silty Member is a temporal equivalent of part of the *Eoepionidella linki* zone, originally defined in Saskatchewan.

We compared lists of species of benthonic foraminiferans from Upper Cretaceous strata in Canada (Caldwell et al., 1978), the Pierre Shale at Redbird (Bergstresser, 1981), and at the Gulf Coast (Cushman, 1946, pp. 9-13). Although the percentage of species endemic to the western interior is high, many were in common with the Gulf Coast.

Of the species shared between the *Eoepionidella linki* Zone of Canada and the Gulf Coast, most in the latter area are found both in Taylorian and Navarroan foraminiferal stages (see Pessagno, 1969). Only one species

from the *E. linki* Zone (*Nodosaria proboscidea*) is reputed unique to the Taylorian, and it is a rare form in the Gulf Coast, originally described from Europe (Cushman, 1946, p. 72). Another species (*Glomospira gordialis*) is restricted to sub-Navarroan strata in the Gulf Coast, but is identified from rocks in Canada known to be above the *E. linki* Zone (Caldwell et al., 1978, pp. 557-558). As pointed out by Cushman (1946, p. 18), however, identification of *G. gordialis* from the Gulf Coast is in doubt, and the species is very similar to Recent forms. Thus, the presumed restriction of *Nodosaria proboscidea* or *Glomospira gordialis* to sub-Navarroan strata in the North American Gulf Coast inspires little confidence.

Contrariwise, two species occur in the *Eoeponidella linki* Zone that, in the Gulf Coast, are linked specifically with the Navarroan Stage; *Reophax texanus* is an index fossil for the Navarroan (Cushman, 1946, p. 16) and *Spiroplectammina semicomplanata*, though also known in the upper Taylorian, is characteristic of the Navarroan Stage (ibid., p. 28).

Data from comparative stratigraphic ranges of benthonic foraminiferans of the *Eoeponidella linki* Zone cannot be used with total confidence in correlation to the Upper Cretaceous sequence of the Gulf Coast. Nevertheless, the most parsimonious interpretation is consistent with that derived from planktonic species, as discussed above. Using terminology from the Gulf, correlation is most probable with upper Taylorian and/or lower Navarroan stages, with correlation to the Navarroan being probable.

BASED ON RADIOISOTOPIC DATING TECHNIQUES

Radioisotopic dates are not yet directly available for mammal-bearing strata of the Oldman, Judith River, or "Mesaverde" formations nor for marine equivalents close to the *Baculites gregoryensis* (cephalopod) Zone in the North American western interior. However, Obradovich and Cobban (1975) summarized data from potassium-argon techniques applied to bentonite deposits found associated with bracketing cephalopod zones. The weighted mean for several sites was 72.2 Ma (74.0 using corrected constants of Steiger and Jager, 1977; see Dalrymple, 1979) as determined from the *Didymoceras nebrascense* Zone, two zones higher than the *Baculites gregoryensis* Zone. Obradovich and Cobban (1975) reported a weighted mean of 77.9 Ma (79.9 using new IUGS constants) for the *Baculites obtusus* Zone, some seven zones below the *B. gregoryensis* Zone. Following the questionable procedure of assigning equal durations to each of the nine cephalopod zones intervening between the two available K-Ar age assemblages, we calculated an age of 76.6 Ma (using new IUGS constants) for the *Baculites gregoryensis* Zone. If the same assumption is made for the entire suite of zones in Obradovich and Cobban's table 1,

the *Baculites gregoryensis* Zone occurs at 76.1 Ma. Large potential error, however, should be anticipated for these crude and admittedly oversimplified calculations. Kennedy and Odin (1982, p. 590) estimated the Campanian-Maastrichtian boundary to be about 72 Ma. Harland et al. (1982) placed it at 73 Ma. Both of these estimates, however, are based on rocks occurring higher in the section than the *B. gregoryensis* Zone.

BASED ON EUROPEAN STAGES

GENERAL INFORMATION

Attempts to correlate the nonmarine mammal-bearing Oldman, Judith River, and "Mesaverde" formations to the stages used for the Late Cretaceous of Europe presently depends most importantly on planktonic foraminifera collected in laterally equivalent marine strata. As stated above, the cephalopod zonation of the North American temperate western interior is too endemic to allow satisfactory links with the more tropical Tethyan realm. At the species level, gastropods give similar results (Sohl, 1967, p. 9), although genera from the Pierre Shale are common to the Campanian and Maastrichtian of the Gulf Coast. Stratigraphic range data for the species of marine bivalves from the western interior discussed by Kauffman (especially 1970, 1973, 1975, 1979) are summarized by a method that does not allow detailed interbasinal correlation. Furthermore, Kauffman (1968) based zonations for Caribbean inoceramids on European stages as determined through ammonites for the North American western interior.

Assemblages of radiolarians, marine diatoms, and calcareous nannoplankton are not sufficiently known from the Late Cretaceous sequence of the western interior to inspire confidence in long-distance correlations. Palynomorphs, because of marked biotic provincialism within the western interior, cannot be used for purposes of correlation beyond that area. The mammals, of course, cannot be linked directly to the European stratotypes, all of which are represented by marine rocks. Finally, the greatly scattered radioisotopic ages available from the western interior are difficult to tie with confidence to

stratigraphic sections in other parts of the world.

Despite the above-cited practical restrictions to correlation with the Old World stratotypes, the Oldman, Judith River, and "Mesaverde" formations have been correlated, with seeming confidence, to the Campanian stage in commonly used reference sources (see, for example, McGookey et al., 1972; Williams and Burk, 1964; Kauffman, 1977, 1979); the basis for all of these is cephalopod and/or bivalve zonation.

Rawson et al. (1978; also see Harland et al., 1982) summarized the histories of the concepts of the type Campanian (district of Charente, west-central France) and Maastrichtian (near the town of Maastricht in the Netherlands on the Belgian border; see Kennedy, 1984) and the way these stages are recognized in practice today. The base of the Campanian is presently drawn at the base of the *Placenticer* (*Diplamoceras*) *bidorsatum* (cephalopod) Zone (see Van Hinte, 1976, fig. 2; Kennedy and Odin, 1982, table 6). The Campanian-Maastrichtian boundary is usually recognized (see Birkelund et al., 1984; Schulz et al., 1984; Surlyk, 1984) at the base of the *Belemnella lanceolata* (temperate belemnite) Zone (*Acanthoscaphites tridens* Tethyan Zone; Van Hinte, 1976, fig. 2).

As summarized by Alvarez et al. (1977), the Late Cretaceous marine section in the Umbrian Apennines of east-central peninsular Italy exposed at Gubbio holds a key to worldwide correlation of biological/geological events of that interval of time. Abundant planktonic foraminifera and well-defined magnetic polarity zones developed through a roughly 300 m thick Late Cretaceous section allow close temporal comparisons with marine rock units in distant oceanic basins.

Premoli Silva (1977) used the Tethyan version of the cephalopod zonation scheme discussed above to define the base of the Campanian and the Campanian-Maastrichtian boundary at Gubbio. She recognized that the Gubbio section was well within the warm-water Tethyan realm during Late Cretaceous time, thus allowing direct comparisons of planktonic foraminiferal zonations with the Caribbean Basin and North American Gulf Coast (see Kauffman, 1977 for reconstruction of distribution of marine climatic zones).

In terms of Tethyan planktonic foraminifera, Premoli Silva (1977, fig. 2) recognized the base of the *Globotruncana elevata* Zone as the base of the Campanian (note that Van Hinte, 1976 carried the *G. elevata* Zone into the late Santonian, below the *Placenticer* *bidorsatum* Zone) and the top of the *G. calcarata* Zone as the Campanian-Maastrichtian boundary (Kennedy and Odin, 1982, table 7; see Marks, 1984). Comparison of species lists from Premoli Silva (1977, fig. 1) and Pessagno (1969, pls. 3-5) shows that both defined the base of the *G. elevata* Zone (a Subzone in Pessagno's usage) using essentially the same range zone criteria. Pessagno, however, considered the base of the *Archaeoglobigerina blowi* Zone (next below the *G. elevata* Zone) of the Gulf Coast to be the base of the Campanian; this appears to be late Santonian in the usual European sense (Van Hinte, 1976, fig. 2) and as applied to the Gubbio section by Premoli Silva. Although the Santonian-Campanian boundary problem as recognized in North America is of interest (see Frerichs, 1980 for discussion), it is of less importance than the position of the Campanian-Maastrichtian boundary in reference to the mammalian faunas that constitute the basis for the present paper.

As summarized by Lanphere and Jones (1978), general disagreement exists on the placement of the Campanian-Maastrichtian boundary within the fossil-rich marine sequence of the North American western interior. Because of the proven utility of range zones of planktonic foraminifera to distant correlation, we emphasize that procedure in the discussion that follows.

Comparison of species range zones from Premoli Silva (1977) for the Gubbio section and Pessagno (1969) for the Gulf Coast shows that they used identical criteria for recognition of the Campanian-Maastrichtian boundary. Both recognized the top of the *Globotruncana calcarata* Zone as the boundary (fig. 5). The *G. calcarata* Zone is a total-range zone for that species and contains the first appearance of *G. subcircumnodifer*. The same sequence was described by Olsson (1964) for the North American Atlantic seaboard in New Jersey and Delaware, and he too considered the top of the *G. calcarata* Zone as the Campanian-Maastrichtian boundary. The same

system was used by Sissingh (1977, 1978) for calcareous nannoplankton zonation and by Barrier (1980) for specific application to the Gulf Coast.

As discussed in previous sections, foraminiferans from the Red Bird Silty Member of the Pierre Shale (representing the *Baculites gregoryensis* (cephalopod) Zone and the lateral equivalent of the mammalian assemblages in question) probably correlate with the late Taylorian and/or early Navarroan stages of the North American Gulf Coast. The Taylorian-Navarroan boundary is set at the top of the *Globotruncana calcarata* (foraminiferal) Zone, recognized at Gubbio, the North American Atlantic seaboard, and the Gulf Coast as the Campanian-Maastrichtian boundary. Thus, because of a downward relocation of the boundary, the mammal-bearing strata of the Oldman, Judith River, and "Mesaverde" formations that have so confidently been considered Campanian in age (see Clemens et al., 1979) lie precariously close to the relocated Campanian-Maastrichtian boundary, and possibly within limits of the early Maastrichtian since that stage has now been expanded.

Such a conclusion is incompatible with the concept of the Campanian-Maastrichtian boundary as it generally has been identified within the western interior on the basis of molluscan faunas; the boundary on the basis of planktonic foraminifera would be roughly nine or ten cephalopod zones lower than the level selected, for example, by Jeletzky (in Cobban and Reeside, 1952) and by McGookey et al. (1972, fig. 9) and six or seven cephalopod zones below the level suggested by Obradovich and Cobban (1975). The radioisotopic dates (mean of 74.0 Ma, corrected) determined by Obradovich and Cobban (1975) for the *Didymoceras nebrascense* (cephalopod) Zone of the western interior (near the Campanian-Maastrichtian boundary as determined by Pessagno, 1969, and Olsson, 1964) are somewhat earlier than the date recognized for the Campanian-Maastrichtian boundary (72 Ma) by Lowrie and Alvarez (1977, fig. 3) in their revised magnetic-polarity time scale for the Late Cretaceous. Radioisotopic age estimates are close, however, between the Obradovich and Cobban (1975) date and the estimate of 74.5 Ma recently

suggested for the Campanian-Maastrichtian boundary by Berggren et al. (in press, fig. 1 and appendix III).

CAVEAT

In terms of application of the above information to mammalian faunas discussed in the present paper, one important lesson is learned. Because of the proximity of the various Oldman, Judith River, and "Mesaverde" mammalian assemblages to the Campanian-Maastrichtian boundary as now recognized, we can no longer blithely consider them to be Campanian in age. They could represent the late Campanian, early Maastrichtian, or both.

A provincial zonation is therefore needed for the nonmarine faunas of the North American Late Cretaceous to avoid the use of dubiously applicable interpretive names such as Campanian or Maastrichtian. Such a need was recognized decades ago by Professor Loris S. Russell (1964, 1975), who developed a local system of terminology. The provincial terms Aquilan, Judithian, and Lancian will be used within the Systematic Paleontology section below, but in somewhat different interpretations from those originally intended by Russell. The differences are specified in the section below entitled Biostratigraphy.

BASED ON MAGNETOSTRATIGRAPHY

If we assume that the correlations discussed above are correct, the *Baculites gregoryensis* Zone and mammal-bearing Oldman, Judith River, and "Mesaverde" formations should be close to the late part of geomagnetic Polarity Chron 33 or the early part of Polarity Chron 32 (see Palmer, 1983). Unfortunately, however, this part of the Upper Cretaceous section of the western interior lacks a magnetostratigraphic zonation.

IN RELATION TO PULSES OF SEA LEVEL CHANGE

Vail et al. (1977) summarized the importance of global cycles of changes in sea level (recognized in three orders of magnitude) to interpretations of earth history, though they did not release data specific for Cretaceous time. Ryer (1983) recognized a still smaller,

fourth-order, transgressive-regressive cycle as pertaining specifically to the Cretaceous sequence of Utah. Matsumoto (1980) discussed sea level changes during Cretaceous time from a global perspective.

Weimer (1960) recognized four important transgressive-regressive sequences of the strandline of the Western Interior Seaway within Upper Cretaceous rocks of the Rocky Mountains; these correspond in a general sense to third-order cycles of Vail et al. (1977). The mammalian faunas of the Oldman, Judith River, and "Mesaverde" formations are found within Weimer's third regressive (R3) pulse.

Kauffman (1977) and Hancock and Kauffman (1979) recognized a sequence similar to Weimer's for the Upper Cretaceous of the western interior, but began their numbering system with the base of the Cretaceous. The mammalian faunas described in the present paper relate to the regressive phase of the Claggett cyclothem (R8) of Hancock and Kauffman (1979, table 3).

BASED ON PALYNOMORPH BIOZONES

Nichols et al. (1982) devised a zonation for the Upper Cretaceous of the northern and central Rocky Mountains of the United States on the basis of pollen and spores. Their biozones have the unique advantages of stratigraphic utility within nonmarine rocks in subsurface exploration and, to some extent, in recognizability within contemporary marine strata. The Judithian mammalian faunas discussed herein fall within the *Aquilapollenites quadrilobus* Interval Zone, the base of which is below the upper part of the type Judith River Formation of north-central Montana, the part yielding the mammalian fauna described by Sahni (1972). Further, the mammals are within Nichols et al.'s (1982) informally recognized *Siberiapollis montanensis* Subzone, the lower of the two subzones of the *A. quadrilobus* Interval Zone.

The *Aquilapollenites quadrilobus* Interval Zone is extensive temporally, involving the early form of *Baculites perplexus* (below) through *B. grandis* (above) cephalopod zones for the western interior (see Obradovich and Cobban, 1975); this includes roughly 16 cephalopod zones. Nichols et al. (1982) sug-

gested that because of biotic provincialism, this palynomorph interval zone may be difficult to recognize in Canada.

SUMMARY OF GEOLOGIC SETTING

The mammalian fossils from the Oldman, Judith River, and "Mesaverde" formations were deposited essentially contemporaneously in nonmarine sediments near the western shoreline of the Western Interior Seaway during the regressive phase of the Claggett cyclothem. The mammal-bearing sedimentary sequences were essentially contemporaneous in deposition with more easterly, marine sediments bearing the *Baculites gregoryensis* (cephalopod) Zone (or as many as four zones younger) of the North American western interior. We correlate the *B. gregoryensis* Zone, on the basis of stratigraphically associated foraminiferans, with the upper Tylorian and/or lower Navarroan foraminiferal stages of the North American Gulf Coast; an early Navarroan assignment is slightly favored. When linked by planktonic foraminifera to equivalents of the European stratotypes, the correlation suggests time of deposition of the mammalian assemblages near the end of the Campanian and/or the beginning of the Maastrichtian, with possible overlap. The mammals in question probably lived about 74 to 76 million years ago, near the end of geomagnetic Polarity Chron 33 or the beginning of Polarity Chron 32 and occur stratigraphically within the lower part of the *Aquilapollenites quadrilobus* palynomorph Interval Zone of the northern Rockies.

LOCALITY DATA

GENERAL INFORMATION

Locality data presented below are of several degrees of reliability (see also fig. 2). Positions of both localities in the Wind River Basin and all UW localities in the Bighorn Basin were plotted in the field with pertinent topographic maps in hand. Written communication from Dr. Donald Baird (November 4 and December 29, 1981) to Lillegraven, on the other hand, suggested that positions of the various Case Sites were not plotted in the field, but rather from memory some time after the collections were made. With one

exception, geographic coordinates of the Case Sites in all probability should not be considered accurate to less than a quarter-section. The exception is Case Site 5, which is essentially the same as UW V-81032, as documented by photographs.

Also included below are listings of all available mammalian specimen numbers from each locality. Many of the specimens, however, were unidentifiable (edentulous jaw fragments, fragmented teeth, isolated incisors and canines, etc.) and do not appear in the species discussions in the Systematic Paleontology sections.

Topographic quadrangle maps involved are: *Bighorn Basin*—Blue Mesa (1914, 15 min; Late for Lunch locality); and, for the remainder, Broom Draw, McDermotts Butte, and Worland SE (all 1967, 7.5 min); *Wind River Basin*—Garfield Peak (1959, 7.5 min; Barwin Quarry and Fales Rocks).

Bighorn Basin (Washakie County,
except UW V-81016)

The following localities, with the exception of UW V-81016, have similar lithologies of friable, yellow channel sandstones with occasional stringers of clay galls and clay clasts. The sandstones show local cementations that weather into hoodoos and large cannonball concretions.

Case Site 1 (unnumbered AMNH locality; Gerard R. Case field number MV500). NW¼ of sec 35, T. 48 N, R. 91 W. Collected by G. R. Case in 1978.

AMNH 109415

Case Site 2 (unnumbered AMNH locality; Gerard R. Case field numbers MV497, 501–505, 507–509). SE¼ of sec 27, T. 48 N, R. 91 W. Collected by G. R. Case in 1978.

AMNH 109414, 109416–109417, 109424, 109452, 109461, 109464–109466, 109468, 109475, 109479, 109481–109482, 109484, 109486

Case Site 3 (unnumbered AMNH locality; Gerard R. Case field numbers MV511–515). Eastern center of sec 27, T. 48 N, R. 91 W. Collected by G. R. Case in 1978.

AMNH 109421–109423, 109478, 109480

Case Site 4 (unnumbered AMNH locality; Gerard R. Case field numbers MV498,

506). NE¼ of sec 27, T. 48 N, R. 91 W. Collected by G. R. Case in 1978.

AMNH 109413, 109425, 109483

Jerry Case Five (UW V-81032 = AMNH unnumbered locality, Case Site 5; Gerard R. Case field numbers MV496, 499, 516–517). NE corner of NW¼ of NW¼ of sec 27 plus SE corner of SW¼ of SW¼ of sec 22, T. 48 N, R. 91 W. Collected by G. R. Case in 1978 and J. A. Lillegraven in 1981.

AMNH 109418–109419, 109426–109435, 109437–109446, 109448–109450, 109462, 109476, 109485, 109487–109489; UW 17071–17073

Case Site 6 (unnumbered AMNH locality; Gerard R. Case field number MV521). NW¼ of SW¼ of sec 22, T. 48 N, R. 91 W. Collected by G. R. Case in 1978.

AMNH 109477

Case Site 8 (unnumbered AMNH locality; Gerard R. Case field number MV510). Presumably south-center of sec 16, T. 48 N, R. 91 W. Collected by G. R. Case in 1978.

AMNH 109420

Case Site 8:30 (unnumbered AMNH locality; no field number). Presumably center of sec 16, T. 48 N, R. 91 W. Collected by G. R. Case in 1979.

AMNH 109453–109455

No locality name (unnumbered AMNH locality; no field number), “12 mi NE of Worland.” Collected by G. R. Case and R. Steiner in 1978.

AMNH 109456–109460

Late for Lunch Locality (UW V-81016). South-central part of SW¼ of NW¼ of NW¼ of sec 25, T. 45 N, R. 97 W, Hot Springs County. On basal flanks of SE part of tallest local hill below massive bands of white sandstone that make up the hill. Fossils come from a moderately cemented, plant-rich channel sandstone set between low-grade lignite layers. The fossiliferous layer is only 10–15 cm thick and extends laterally less than 10 m. Collected by J. A. Lillegraven in 1981 and 1982.

UW 17068–17070, 17087

Old Number One (UW V-81036). Near NE corner of NE¼ of SE¼ of NE¼ of SW¼ of sec 16, T. 48 N, R. 91 W. Collected by J. A. Lillegraven in 1981.

UW 17084

Old Number Four (UW V-81038). Center of

N $\frac{1}{2}$ of NW $\frac{1}{4}$ of NW $\frac{1}{4}$ of NE $\frac{1}{4}$ of sec 21, T. 48 N, R. 91 W. Collected by J. A. Lillegraven in 1981.

UW 15529–15530, 17099–17101

Old Number Five (UW V-81040). SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of SE $\frac{1}{4}$ of NE $\frac{1}{4}$ of sec 21, T. 48 N, R. 91 W. Collected by J. A. Lillegraven in 1981.

UW 15531

Meteors (UW V-81066). Center of W $\frac{1}{2}$ of NE $\frac{1}{4}$ of SE $\frac{1}{4}$ of NW $\frac{1}{4}$ of sec 27, T. 48 N, R. 91 W. Collected by J. A. Lillegraven in 1981.

UW 15532–15533, 17095

No Wind (UW V-81073). South-central part of NW $\frac{1}{4}$ of NE $\frac{1}{4}$ of SE $\frac{1}{4}$ of sec 27, T. 48 N, R. 91 W. Collected by J. A. Lillegraven in 1981.

UW 17096

Sunset to Dawn Two (UW V-81076). NE $\frac{1}{4}$ of SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of sec 27, T. 48 N, R. 91 W. Middle of outcrop area. Collected by J. A. Lillegraven in 1981.

UW 15522–15528, 17075–17083

Sunset to Dawn Three (UW V-81077). NE $\frac{1}{4}$ of SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of sec 27, T. 48 N, R. 91 W. Low on outcrop area. Collected by J. A. Lillegraven in 1981.

UW 17097–17098

Wind River Basin (Natrona County)

Fales Rocks (UW V-81006 = UCMP V-81101 and within general area of UCMP V-5833). Below top of southwestern slope of hill 6450 (on Garfield Peak Quadrangle, 1959, 7.5 min topographic map) in NE $\frac{1}{4}$ of SW $\frac{1}{4}$ of SW $\frac{1}{4}$ of SE $\frac{1}{4}$ of SW $\frac{1}{4}$ of sec 4, T. 33 N, R. 87 W. Vertebrate fossils occur at multiple levels through at least 10 m of yellowish to golden channel sandstone (see figs. 3 and 4). The richest fossil-bearing level is within a basal ironstone-cemented pebble conglomerate and throughout the overlying 2 m of more friable, yellowish sandstone. Fossils are seen both as isolated occurrences in massively cross-bedded sandstones and within concentrations of clay-gall stringers along thin bedding planes. A few thin lignite beds occur within sandstone bedding planes. Collected by J. H. Hutchison and M. T. Greenwald in 1976 and J. A. Lillegraven in 1981.

UCMP 125336–125343, 125346–125350; UW 15515–15518, 15520, 15535, 15538–15540, 15581, 17041–17062

Barwin Quarry (unnamed AMNH locality; no field numbers). 37 m northwest of Fales Rocks (UW V-81006) locality, at same stratigraphic horizon. Fossils occur in an identical geologic situation between the two named localities and fossils are present in abundance between the two sites. Collected by M. C. McKenna and party in 1961, 1966, and 1970.

AMNH 59695, 59697–59699, 80001–80006, 80009–80022, 86301–86302, 86304–86319, 86321–86326, 86328–86337, 86339–86343, 86345–86346, 86348–86354, 86356–86365, 88482–88495, 88497–88499, 108676, 108678–108688

SYSTEMATIC PALEONTOLOGY

CLASS MAMMALIA LINNAEUS, 1758

SUBCLASS ALLOTHERIA (MARSH, 1880)

ORDER MULTITUBERCULATA COPE, 1884

SUBORDER PTILODONTOIDEA
SLOAN AND VAN VALEN, 1965

FAMILY NEOPLAGIAULACIDAE
AMEGHINO, 1890

GENUS *MESODMA* JEPSEN, 1940

Mesodma primaeva (Lambe, 1902)
Figure 6A–E; table 1

HOLOTYPE: NMC 1890, right mandible with p4m1.

TYPE LOCALITY: Oldman Formation in valley of Red Deer River near Steeveville, Alberta.

LOCALITIES REPRESENTED IN PRESENT STUDY AND REFERRED SPECIMENS: WIND RIVER BASIN: p4, AMNH 86305, 86323, UW 15539 (fig. 6A, B); P4, AMNH 59697, 86304 (fig. 6C–E), 86356.

KNOWN DISTRIBUTION: Oldman Formation (Judithian), Alberta; Judith River Formation (Judithian), Montana; and "Mesa-verde" Formation (Judithian), Wind River Basin, Wyoming.

DESCRIPTION AND COMPARISONS: p4. The three p4s referred to *Mesodma primaeva* agree closely in structure with the holotype (Lambe,

TABLE 1
Measurements of Teeth Referable to
Mesodma primaeva

	AP	ANW
p4 AMNH 86305	3.74	1.71
UW 15539 ^a	3.48	1.34
P4 AMNH 59697	3.39	1.77
86304	3.60	1.89

^a From Fales Rocks; unmarked teeth from Barwin Quarry.

1902, pl. 15, figs. 13, 14) and with AMNH 77121, referred by Sahni (1972, p. 367) to this species. Anteroposterior lengths of specimens from the Wind River Basin (see table 1) are below the range of variation reported by Novacek and Clemens (1977, table 1, p. 704) for specimens of *M. primaeva* from the Judith River Formation. Both complete specimens from the Wind River Basin (AMNH 86305 and UW 15539) have 11 serrations.

P4. Three teeth from the Wind River Basin are referable to P4s of *Mesodma primaeva* on the basis of size and general morphology. However, several differences from the Montana specimens are noted (Sahni, 1972, p. 369). First, the teeth from Wyoming are roughly a half millimeter shorter (table 1), though they match well in length with teeth from the same locality identified as p4s of this species. Secondly, the cusp count of the medial row in both complete specimens from Wyoming is seven, rather than six as seen in Montana. In both cases, however, the extra cusp is weakly developed and the main crest effectively has only five cusps; AMNH 59697 has a minuscule first (anterior) cusp and AMNH 86304 has the tallest and last cusp of the main crest incompletely bifurcated. Finally the anterolabial and posterolingual rows have only single, strong cusps in contrast to the two seen in each case in specimens from the Judith River Formation.

Mesodma sp.

Figure 6F; table 2

INCLUDED SPECIMENS: BIGHORN BASIN: m1, UW 17044; M1, UW 17083; M2, UW 15528. WIND RIVER BASIN: M1, UW

TABLE 2
Measurements of Teeth Referable to
Mesodma sp.

	AP	ANW
m1 Wind River Basin UW 17044 ^a	2.11	1.01
M1 Bighorn Basin UW 17083	2.36	1.41
Wind River Basin UW 15538 ^a	2.43	1.44
M2 Bighorn Basin UW 15528	1.61	1.41
Wind River Basin AMNH 80003	2.24	1.96
86364	1.42	1.59
108683	1.97	1.61

^a From Fales Rocks; unmarked teeth from Wind River Basin are from Barwin Quarry.

15538 (fig. 6F); M2, AMNH 80003, 86364, 108683.

DESCRIPTION AND COMPARISONS: Seven isolated molars referable to the genus *Mesodma* but of uncertain species have been recovered. The largest among them (AMNH 80003) may represent *M. primaeva*, but the remainder probably belong to one or more undescribed smaller species. Measurements are provided in table 2.

A possibility exists as well that some of these teeth are referable to a species of *Kimbetohia*. Clemens (1963, p. 43) identified two p4s from the type Lance Formation as ?*Mesodma* sp. Clemens later (1973a, p. 79) identified these teeth as *Kimbetohia campi* Simpson, 1936 on the basis of a suggestion (personal commun.) from Robert E. Sloan. Sloan (1981, p. 150) defended that assertion by pointing out that the two isolated p4s from Wyoming are, as is true in P4s from New Mexico presumed to be from *K. campi*, "... intermediate in morphology between *Mesodma thompsoni* and those of various species of *Ptilodus*." The identification as *K. campi* of isolated p4s from the Lance Formation of Wyoming is based on: (1) presumed intermediacy in p4 morphology (i.e., size, orientation of labial wrinkles, lateral profile, bifurcation of labial striations) between *Mesodma* and *Ptilodus* (the holotype of *K. campi* is an upper jaw); and (2) the interpretation

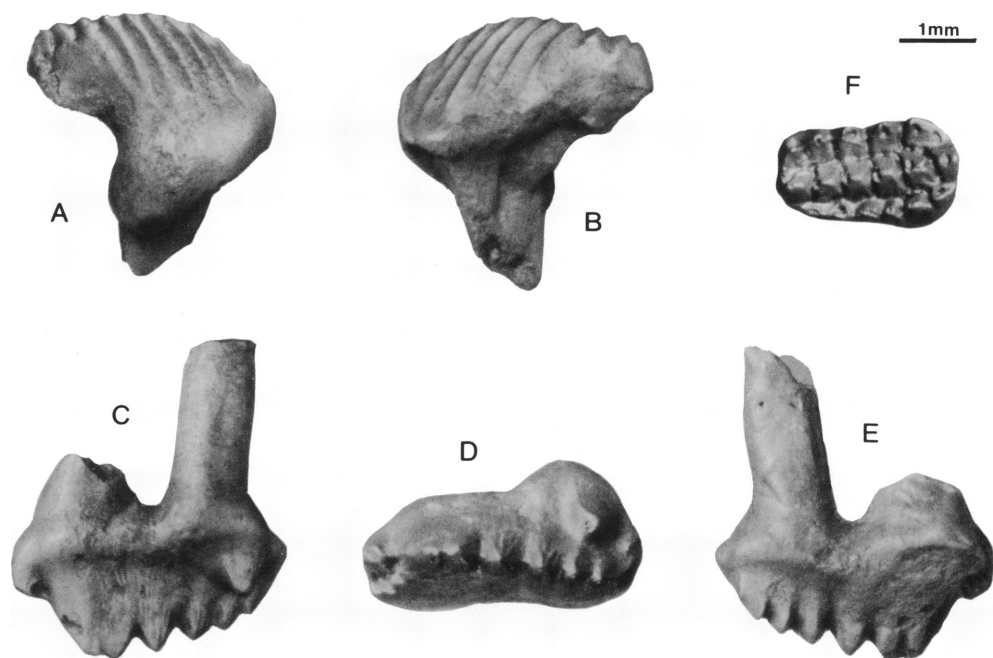


FIG. 6. Judithian *Mesodma* teeth from the "Mesaverde" Formation, Wyoming. A, UW 15539, right p4, *Mesodma primaeva*, labial view. B, Same, lingual view. C, AMNH 86304, right P4, *Mesodma primaeva*, labial view. D, Same, occlusal view. E, Same, lingual view. F, UW 15538, left M1, *Mesodma* sp., occlusal view. All $\times 10$.

that *Kimbetohia* was a phylogenetic intermediate between *Mesodma* and *Ptilodus*. Until physical evidence becomes more convincing, we do not consider documentation adequate for the former existence of *K. campi* in Wyoming.

m1. UW 17044 follows in all respects the description provided by Clemens (1963, p. 45) for *Mesodma* sp. from the type Lance Formation.

M1. UW 15538 and 17083 follow most aspects of Clemens' (1963, p. 47) description of M1s of *Mesodma*, but have a lower cusp count (as also noted by Fox, 1971a, p. 920, for a specimen of Campanian age from the upper part of the Milk River Formation). Cusp counts in the "Mesaverde" specimens are 5:6:3-6. The internal cusp row of UW 15538 differs from the usual situation in *Mesodma* by continuing all the way to the base of the first cusp on the middle row. The anteriormost cusp on the internal row is minuscule and anteroposteriorly elongated, but the last five cusps are all well formed and conical.

M2. The four available M2s follow Clemens' (1963, p. 48) description of M2s of *Mesodma*, but show the lesser cusp formula variation of 1:3:3-4; only one specimen (AMNH 86364) has four internal cusps.

SUBORDER INCERTAE SEDIS

FAMILY CIMOLOMYIDAE (MARSH, 1888)
SLOAN AND VAN VALEN, 1965

GENUS *CIMOLOMYS* MARSH, 1889

Cimolomys clarki Sahni, 1972

Figure 7A-G; tables 3, 4

HOLOTYPE: AMNH 77179, isolated right p4.

TYPE LOCALITY: Clayball Hill locality, Judith River Formation, Montana.

LOCALITIES REPRESENTED IN PRESENT STUDY AND REFERRED SPECIMENS: BIG-HORN BASIN: m1, AMNH 109422, 109423, 109466, 109485; m2, AMNH 109444, 109457 (fig. 7B); P4, AMNH 109419, UW 17071 (fig. 7E-G); M1, AMNH 109424, 109425, 109438, 109456, 109464, 109479,

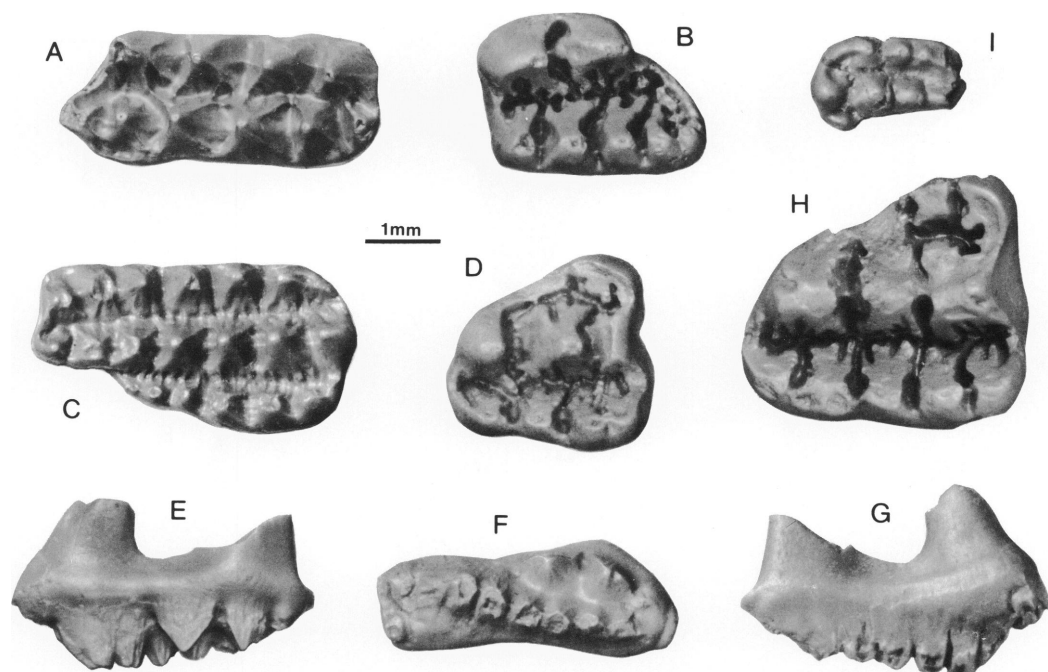


FIG. 7. Judithian *Cimolomys*, *Meniscoessus*, and *Paracimexomys* teeth from the "Mesaverde" Formation, Wyoming. A, UW 15535, right m1, *Cimolomys clarki*, occlusal view. B, AMNH 109457, left m2, *Cimolomys clarki*, occlusal view. C, AMNH 88485, left M1, *Cimolomys clarki*, occlusal view. D, UCMP 125336, right M2, *Cimolomys clarki*, occlusal view. E, UW 17071, right P4, *Cimolomys clarki*, labial view. F, Same, occlusal view. G, Same, lingual view. H, AMNH 86346, right M2, *Meniscoessus intermedius*, occlusal view. I, AMNH 88484, right M1, *Paracimexomys priscus*, occlusal view. All $\times 10$.

UW 15532, 17072. WIND RIVER BASIN: m1, AMNH 86363, UW 15535 (fig. 7A); P4, AMNH 108679; M1, AMNH 59695, 59698, 59699, 80002, 86306, 88485 (fig. 7C); M2, AMNH 86307, 88482, 108678, UCMP 125336 (fig. 7D).

KNOWN DISTRIBUTION: Judith River Formation (Judithian), Montana; and "Mesaverde" Formation (Judithian), Bighorn and Wind River basins, Wyoming.

DESCRIPTION, COMPARISONS, AND DISCUSSION: Identification of isolated teeth of *Cimolomys* from the "Mesaverde" Formation to the level of species is most difficult because of the scanty pre-Lancian record of the genus available for comparative purposes. Diagnostic features useful in differentiating the various named species are few. Measurements are provided in table 3.

The largest existing samples of teeth from *Cimolomys* were described by Clemens (1963) from the type Lance Formation (for *C. gracilis*), with measurements provided by him

in table 9 (p. 93). Roughly one-third of the dental measurements presented in table 3 of the present paper fall below the range of variation documented by Clemens (*lengths*: m1, 4.3–5.5; m2, 3.2–4.2; P4, 2.9–3.1; M1, 4.3–6.0; and M2, 3.1–3.8; *widths*: m1, 1.8–2.5; m2, 2.1–2.9; P4, 1.3–1.4; M1, 2.1–3.1; and M2, 2.7–3.0). The diagnosis provided by Sahni (1972, p. 371) for *C. clarki* reads: "*Cimolomys clarki* is smaller than, but similar to, its Maestrichtian descendant, *C. gracilis*." Unfortunately, Sahni did not present full measurement data, but estimates of dental size from his illustrated specimens suggest that the type material of *C. clarki* corresponds to or is slightly smaller than specimens reported in table 3 of the present paper.

?*Cimolomys* sp. B from the Milk River Formation (Fox, 1971a, p. 932) has teeth significantly smaller than those from the "Mesaverde" Formation, and *Cimolomys* sp. A, also from the Milk River Formation (Fox, 1971a, p. 930), has morphological differences

TABLE 3
Measurements of Teeth Referable to
Cimolomys clarki

		AP	ANW
m1	Bighorn Basin		
	AMNH 109422	4.28	2.22
	109423	—	1.91
	109466	—	1.88
	109485	4.35	2.06
	Wind River Basin		
	UW 15535 ^a	4.24	1.76
m2	Bighorn Basin		
	AMNH 109457	2.92	2.11
P4	Bighorn Basin		
	UW 17071	3.99	1.56
M1	Bighorn Basin		
	AMNH 109424	4.20	2.51
	109438	—	2.52
	109456	4.25	2.46
	109479	—	2.37 est.
	Wind River Basin		
	AMNH 59698	—	2.57
	59699	—	2.53
	86306	—	2.73
	88485	4.36	2.34
M2	Wind River Basin		
	AMNH 86307	3.00	2.88
	108678	3.30	2.90
	125336 ^a	2.74	2.60

^a From Fales Rocks; unmarked teeth from Wind River Basin are from Barwin Quarry.

(discussed below) from the specimens presently under study. Thus, from the criterion of size, the "Mesaverde" fossils probably are best identified as *C. clarki*.

Unfortunately, cusp counts of the cheek teeth provide little immediate help in identification, as can be seen by study of table 4. Specimens from the "Mesaverde" Formation have m1s that are intermediate in external row number between *Cimolomys gracilis* and *C. clarki* or ?*C. sp. A*, but more like *C. clarki* and ?*C. sp. A* in internal row number. m2s from the "Mesaverde" Formation are more advanced in external row count than *C. clarki*, and more like *C. gracilis*. P4s show basic similarity of counts between *C. gracilis* and *C. clarki*. M1s from the "Mesaverde" Formation are closer in cusp counts to *C. gracilis* than to *C. clarki*. Finally, cusp counts of M2s from the "Mesaverde" Formation appear lower than either *C. gracilis* or *C. clarki*. Thus, although little weight can be placed on the interpretation of cusp counts at present, the specimens from the "Mesaverde" Formation are basically in agreement with those of *C. gracilis*, with certain lower (more primitive?) numbers of cusps.

Almost all other morphological features of the teeth from the "Mesaverde" Formation fit the descriptions by Clemens (1963) for *Cimolomys gracilis*; because few differences

TABLE 4
Cusp Counts (Not Including Tiny Cuspules) of Cheek Teeth of Various Species of *Cimolomys*
See text for discussion.

	<i>C. clarki</i>	<i>C. gracilis</i>	<i>C. clarki</i>	? <i>C. sp. A</i>
	Present paper, "Mesaverde" Fm.	Clemens, 1963, type Lance Fm.; Archibald, 1982, Hell Creek Fm.	Sahni, 1972, Judith River Fm.	Fox, 1971a, Milk River Fm.
m1	6-7:4	7-8 : 5-7 mode 7 mode 5	5-6:4	6:4
m2	5:2	4-6 : 2-3 mode 5 mode 2	4:2	?
P4	2:6:1	1-2 : 5-6 : 1-3 mode 1 mode 5	2:5-6:2	1:5
M1	6-7:7:4-5	5-8 : 7-10 : 4-6 mode 7 mode 8	5:6:6	?
M2	1:3:3-4	2-3 : 3-4 : 4-7 mode 2 mode 3 mode 4	2:3:4	?

were noted between *C. clarki* and *C. gracilis* by Sahni (1972), however, the descriptions also hold well for *C. clarki*. Nevertheless, a few minor dental differences from *C. gracilis* were noted during the course of the present study. For example, cusps on m1 and cusps on the medial row of M1 on specimens from the "Mesaverde" Formation are slightly less crescentic than the usual condition of *C. gracilis*; the more pyramidal shape is presumed the more primitive condition. Secondly, AMNH 109457, an m2 from the "Mesaverde" Formation, has a ridge, though not a strong one, that connects the anterior internal and external cusps; such a ridge is lacking in *C. gracilis* (see Clemens, 1963, p. 78) and usually present in *C. clarki* (see Sahni, 1972, p. 371). Thirdly, adequately complete specimens from the "Mesaverde" Formation have small accessory roots on M1 on either side of the interradicular crest as described for *C. clarki* by Sahni (1972, p. 373); this is in contrast to the condition in *C. gracilis* (see Clemens, 1963, p. 79) in which usually it is only the lingual accessory root that is developed.

Differences also exist in structure of P4 between specimens from the "Mesaverde" Formation and *Cimolomys gracilis*. As illustrated by Sahni (1972, fig. 11I, p. 372), the P4 is proportionately longer and narrower than in the more rectangular tooth in *C. gracilis* illustrated by Clemens (1963, fig. 35, p. 78). UW 17071 (fig. 7E-G), a long, narrow tooth, is more similar in proportions to that of *C. clarki* than to *C. gracilis*. The relative length of the shearing blade to total tooth length (as measured to the apical crest of the blade) is comparable in *C. gracilis* (blade length 61% of total length; measured from Clemens, 1963, fig. 36, p. 78), *C. clarki* (59%; Sahni, 1972, fig. 11I, p. 372), and UW 17071 from the "Mesaverde" Formation (67%; from specimen).

Specimens of m1 from the "Mesaverde" Formation (e.g., UW 15535) possess a short posterolabial cingulum in common with *Cimolomys gracilis* (see Clemens, 1963, p. 77); no mention of such a structure in *C. clarki* was made by Sahni (1972), and the structure does not appear in the described specimens of ?*C. sp. A* from the Milk River

Formation (see Fox, 1971a, fig. 6D, p. 931). ?*Cimolomys sp. A* also has an anterolingual lobe on the crown (Fox, 1971a, p. 931) that has not been observed on *C. gracilis*, *C. clarki*, or specimens from the "Mesaverde" Formation. Thus, by a process of elimination and with great equivocation, we suggest that the specimens referred to *Cimolomys* from the "Mesaverde" Formation show overall greater similarity to *C. clarki* than they do to *C. gracilis*, and we thereby use the former name for these temporally roughly equivalent fossil remains. However, we do not feel that the differences from *C. gracilis* are constant enough to justify the development of a revised diagnosis for *C. clarki*.

GENUS *MENISCOESSUS* COPE, 1882

Meniscoessus intermedius Fox, 1976b

Figure 7H

HOLOTYPE: UA 12081, right mandible with m1-2.

TYPE LOCALITY: Lowermost Oldman Formation along South Saskatchewan River, about 48.3 km north of Medicine Hat and 24.1 km west of Hilda, Alberta.

REFERRED SPECIMEN FROM PRESENT STUDY: Isolated right M2, AMNH 86346 (fig. 7H) from Barwin Quarry, Wind River Basin.

KNOWN DISTRIBUTION: Lowermost Oldman Formation (Judithian) and possibly Foremost Formation (Judithian; see Fox, 1976b, p. 1217), Alberta; and "Mesaverde" Formation (Judithian), Wind River Basin, Wyoming.

DESCRIPTION: AMNH 86346 has a cusp formula of 2:3:5 and, except for its large size (AP, 3.79; W, 3.41) and higher cusp count, differs little from M2s referred to *Cimolomys clarki*. Complex flutings adorn both sides of the cusps of the middle row, the lingual sides of the external cusps, and the labial sides of the internal cusps; the labial and lingual surfaces of the crown are smooth. All cusps in each row are sharply separated from one another by precipitous valleys, and the rows are even more severely separated by deep, straight valleys. The anterior cusp of the middle row is connected by a strong, anteriorly convex crest to the anterior cusp of the external row. A similarly oriented but much

lower and weaker crest joins the anterior cusps of the middle and internal rows. A strong and precipitously sloping crest joins the posterior cusp of the middle row to the labial base of the external row's last cusp. The valley between the middle and internal rows is virtually open posteriorly, being closed by only a low and delicate ridge. Cusp wear renders apical shape difficult to interpret, but the following appears correct: *internal row*—cusp 1 conical, cusps 2–5 subcrescentic; *middle row*—all subcrescentic; and *external row*—cusp 1 conical, cusp 2 pyramidal.

A strong appression facet from contact with M1 covers the dorsal half of the enamel including all of the anterior surface of the anterior cusp of the middle row and adjacent bases of the anterior cusps of the external and internal rows. The forward root, as viewed anteriorly, forms a low isosceles triangle with its base at the edge of the enamel; in side view it is only slightly greater in anteroposterior girth than the posterior root. The back root, as viewed posteriorly, is more columnar in shape, has its origin dorsal to overhanging enamel, and is much narrower than the forward root. No accessory roots are present.

COMPARISONS AND DISCUSSION: Identification of AMNH 86346 as *Meniscoessus intermedius* is based in large part upon comparisons with the holotype (m1–2) and PMAA-P72.14.1, an isolated M1 referred to *M. intermedius* by Fox (1976b, see fig. 3, p. 1220 of that paper). The morphology described above for AMNH 86346 would be expected for an M2 (as yet unknown) of the type material; all are remarkably *Cimolomys*-like, presumably primitive for the family. The size of AMNH 86346 also agrees well with that of the type material, since Fox (1976b, table 1, p. 1220) reported the length of m2 in the holotype as 4.1 mm (roughly 0.3 mm longer than the M2 described here).

Although the existence of an M2 of *Meniscoessus ferox* from the somewhat older Milk River Formation was mentioned by Fox (1976b, p. 1220), the specimen remains undescribed. Direct comparison of AMNH 86346 with *M. ferox* (see Fox, 1971a, p. 933; known in published form only by P4) is impossible.

The cusp formula of M2 for *Meniscoessus major* (see Sahni, 1972, p. 376 and fig. 12G)

appears to exceed that of AMNH 86346, and probably should be written as 2–3?:4:5–6?, with the queries reflecting uncertainty due to heavy cusp wear. The approximate measurements of AMNH 77261 (M2 illustrated by Sahni, 1972, fig. 12G, p. 375) are AP, 4.4 mm and W, 4.2 mm, significantly larger than for the specimen from the "Mesaverde" Formation. Measurements of m2 of the holotype of *M. major* (see L. S. Russell, 1937, p. 76) are AP, 4.7 mm and W, 3.2 mm, again representing a significantly larger tooth.

Identification of AMNH 86346 as *Meniscoessus conquistus* (see Sloan and Russell, 1974, p. 6) or *M. robustus* (see Clemens, 1963, table 10, p. 93 and Archibald, 1982, table 13, p. 86) can be eliminated on the basis of size alone, although numerous morphological differences exist as well.

SUBORDER AND FAMILY INCERTAE SEDIS

GENUS *PARACIMEXOMYS* ARCHIBALD, 1982

Paracimexomys priscus (Lillegraven, 1969)

Figure 7I

HOLOTYPE: UA 3231, isolated right M1.

TYPE LOCALITY: University of Kansas locality KUA-1, Scollard Formation, Alberta.

REFERRED SPECIMEN FROM PRESENT STUDY: Isolated M1, AMNH 88484 from Barwin Quarry, Wind River Basin.

KNOWN DISTRIBUTION: Trochu local fauna, Scollard Formation (Lancian), Alberta; Hell Creek Formation, Montana (Lancian); and "Mesaverde" Formation (Judithian), Wind River Basin, Wyoming.

DESCRIPTION, COMPARISONS, AND DISCUSSION: AMNH 88484 (fig. 7I) differs in four respects from the holotype of "*Cimexomys*" *priscus* (transferred to *Paracimexomys* by Archibald, 1982, p. 111). The specimen from Wyoming: (1) shows less "waisting" of the crown as seen in occlusal view; (2) has but a single cusp (rather than two) on the internal cusp row; (3) has its internal cusp row terminating at the middle (rather than at the anterior end) of the third cusp of the middle row; and (4) is smaller (AP, 2.24 estimated; W, 1.40).

Fox (1971a, p. 922) defined a new species,

Cimexomys magister, from the upper part of the Milk River Formation. Archibald's defining criteria for *Paracimexomys* include features seen in "*Cimexomys*" *magister*, thus requiring use of the name *P. magister*. Diagnostic differences cited by Fox that are useful in distinguishing teeth from those of "*C.*" *priscus* were few, and the greater age of the enclosing rocks probably weighed in the establishment of the trivial name. As might be expected in a fauna of intermediate age, a dilemma is seen in attempting to identify AMNH 88484 to the species level; the specimen shares features with *Paracimexomys magister* (single cusp in the internal row) on one hand and with *P. priscus* (four well-defined cusps in the external row) on the other. The cusp count on the external row requires more elaboration. Lillegraven, in his original definition of "*C.*" *priscus*, interpreted the worn holotype as having four cusps in the external row. Fox (1971a, p. 922), upon reexamining the specimen, suggested that wear had probably obliterated a small posterior-most external cusp, thereby indicating a five-cusp row. Fox's prime evidence for the existence of the fifth cusp in the holotype was the presence of a transverse lingual valley that terminates at the wear facet; a discrete fifth cusp does occur on specimens from the Milk River Formation.

Whether the worn holotype of *Paracimexomys priscus* had a fifth cusp or not probably never will be known certainly, but new specimens of *P. priscus* collected and described by Archibald (1982) provide pertinent information. UCMP 117033 (Archibald, 1982, fig. 39a) and AMNH 88484 show identical structure on the posteroexternal-most cusp. In both, the anterior part of the cusp is a low cone that constricts posteriorly to a broad ridge that curves posteromedial to terminate at the labial base of the last cusp of the middle row. Admittedly, there is a hint of a transverse valley that partly separates the cone from the ridge-like parts of the cusp, but neither Archibald nor we consider the separation great enough to warrant recognition of two cusps; there is no significant break in the cusp height when seen in side view. Thus, in contrast to the situation in *P. magister*, we consider AMNH 88484 and the usual con-

dition in *P. priscus* to involve a fundamentally four-cusped external row.

Although AMNH 88484 is nearly a millimeter shorter than the holotype of *Paracimexomys priscus* (and of *P. magister*), the specimen does fall within the smaller end of the range documented by Archibald (1982, table 17, p. 114) for *P. priscus* from UCMP locality V-73087 in the Hell Creek Formation of Montana. Thus the only significant difference observed between AMNH 88484 and *P. priscus* is the presence of but a single cusp in the internal row, presumably a primitive feature shared with *P. magister*. For that reason, and until better evidence to the contrary is forthcoming, we favor identification of AMNH 88484 as *P. priscus*, thereby extending the geologic range of that morphospecies from the Lancian into the Judithian.

Multituberculata, new genus and species, unnamed

SPECIMENS: p4 fragments, AMNH 86301, 86302.

LOCALITY: Wind River Basin, "Mesa-verde" Formation (Judithian), Barwin Quarry.

DESCRIPTION AND DISCUSSION: The two p4s (AMNH 86301, anterior half of tooth but lacking labial lobe; AMNH 86302, fragment of mid-dorsal part of blade) are too fragmentary for adequate description or even tentative identification, but stand out nevertheless because of their enormous size relative to other known Late Cretaceous multituberculates. We estimate that the total tooth length of AMNH 86301 prior to breakage would have been at least 11 mm, much larger than any previously described Mesozoic multituberculate. The tooth is a fully developed ptilodontoid structure (see Clemens and Kielan-Jaworowska, 1979, p. 142), not showing trends toward reduction (or plesiomorphically small size) typical of *Meniscoessus robustus* (see Clemens, 1963, p. 88).

AMNH 86301 has a minimum of 11 striations, both on the lingual and labial sides. At least the first three striations on both sides of the tooth run to the apices of serrations. The first six striations on both sides begin separately from one another, run completely par-

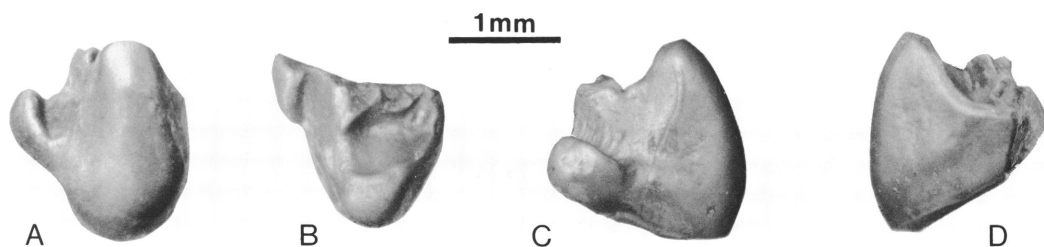


FIG. 8. Judithian dryolestid, genus and species unidentified, AMNH 109462, fragmentary right lower molar, from the "Mesaverde" Formation, Wyoming. A, Labial view. B, Occlusal view. C, Posterior view. D, Anterior view. All $\times 15$.

allel, and do not branch. From the seventh striation posteriorly, their ventral ends progressively diverge more ventrally and terminate well away from the edge of the enamel. AMNH 86302 provides little information other than the presence of well-developed, though not unusually strong, serrations at midblade, with a one-to-one relationship of striation (gently convex anteriorly) to serration.

Unidentified Specimens of Multituberculates

In addition to the specimens discussed above, a number of isolated teeth remain unidentified and are listed below. Though most are fragmentary or heavily worn, some are excellently preserved and should be identifiable once larger samples and better comparative series become available.

Isolated incisors, lower and upper

AMNH 86318, 86325, 86345, 86351,
86352, 108677, 109468, 109470, 109475
UCMP 125344, 125345
UW 15523, 17100

p4

AMNH 86324, 86342, 88483
UCMP 125335

m1

AMNH 109429

Anterior upper premolars

AMNH 88491, 108684, 108687
UW 17041, 17070

P4

UW 17042, 17043

M1

AMNH 80013, 86360, 108676, 109437,
109446

M2

AMNH 109465

UW 17045

Unidentifiable molar fragments

AMNH 80001, 80004, 88486

Edentulous mandible

UW 17087

SUBCLASS THERIA

PARKER AND HASWELL, 1897

SUBLEGION DRYOLESTOIDEA (BUTLER, 1939)

FAMILY DRYOLESTIDAE MARSH, 1879

Dryolestidae, genus and species unidentified Figure 8A-D

SPECIMEN: AMNH 109462 (fig. 8A-D), fragmentary right lower molar.

LOCALITY: Case Site 5, Bighorn Basin, "Mesaverde" Formation (Judithian).

DESCRIPTION, COMPARISONS, AND DISCUSSION: AMNH 109462 is roughly the labial two-thirds of a right lower molar, split anteroposteriorly. Present are the entire protoconid, labial half of the talonid, and fractured base of the metaconid; no parts of the paraconid or roots are preserved. The fragment follows in most respects the description of lower molars of *Dryolestes priscus* by Simpson (1929, p. 60), and is not greatly dissimilar from the illustration of teeth of the same species by Prothero (1981, fig. 5, p. 294). The size of AMNH 109462 is comparable to known specimens of *D. priscus*.

The tooth is moderately worn, with obvious wear on the apex of the broadly basined protoconid, on the pre- and postprotocristids, and on a postvallid facet (extending from

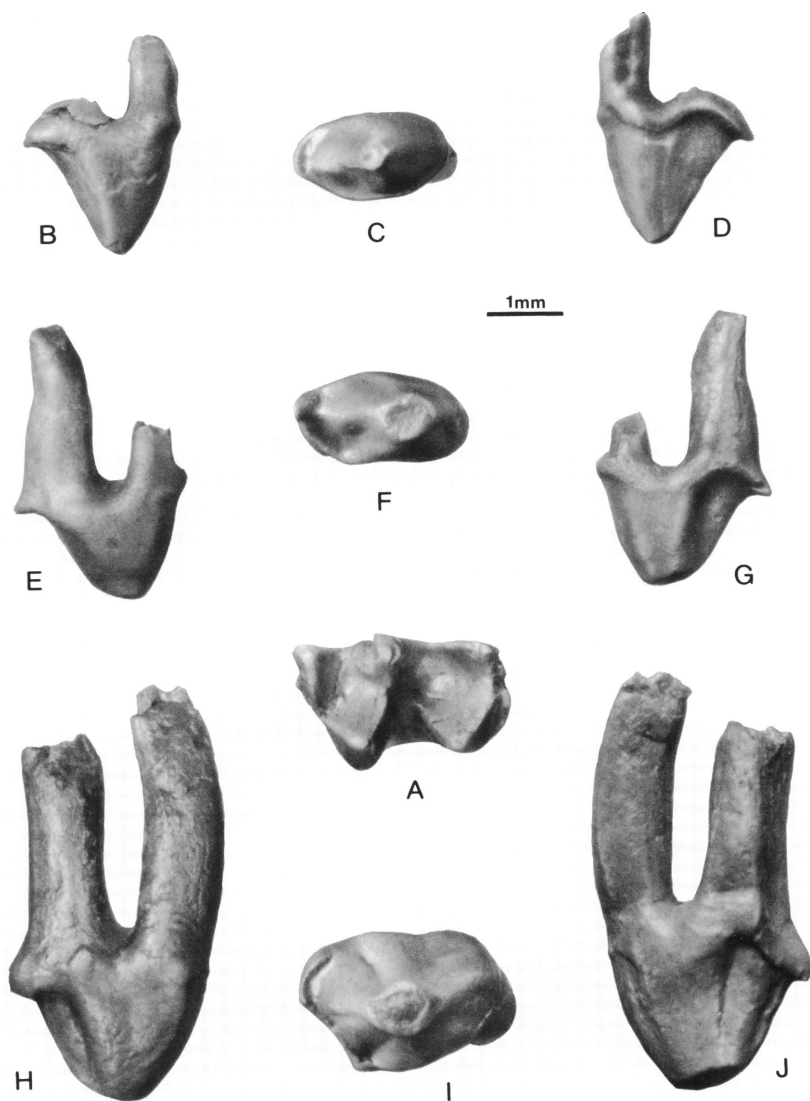


FIG. 9. Judithian *Alphadon russelli* from the "Mesaverde" Formation, Wyoming. A, AMNH 80022, left m3, occlusal view. B, UW 17098, right P1, labial view. C, Same, occlusal view. D, Same, lingual view. E, AMNH 109483, right P2, labial view. F, Same, occlusal view. G, Same, lingual view. H, AMNH 86359, right P3, labial view. I, Same, occlusal view. J, Same, lingual view. All $\times 10$.

the posterior surface of the apex of the protoconid ventrolingually to just above the top of the talonid, then dorsolingually up the posterior wall of the metaconid). Oval appression facets are present just ventral to the protoconid-paraconid notch and on the posterior surface of the talonid. Light, dorsoventrally aligned rugosities of the enamel are present on the basal postvallid surface; the enamel is otherwise essentially smooth. No cusps are

preserved on the transversely ridged talonid. A weak, transversely aligned swelling (with a spot worn through to the dentine) is seen on the lingual termination of the preprotocristid. The protoconid shows no sign of a labial cingulum.

Identification of AMNH 109462 as a dryolestid is based on similarities with teeth of *Dryolestes* and *Laolestes* (see Prothero, 1981, pp. 293–296). Identification to a lower taxo-

onomic level is impossible until more complete materials are discovered. The specimen is exciting, however, in suggesting that dryolestoids, until now thought extinct in North America since the Late Jurassic (see Kraus, 1979), survived as rare animals until nearly the end of the Mesozoic. Thus they join the triconodonts and symmetrodonts as rare Late Cretaceous relicts (see Fox, 1976a, 1984b) from earlier times of greater diversity.

INFRAClass, ORDER, AND FAMILY
INCERTAE SEDIS

Falepetrus barwini

Clemens and Lillegraven, in press

HOLOTYPE: AMNH 86316, isolated right upper molariform tooth.

TYPE LOCALITY: Barwin Quarry, "Mesaverde" Formation, Wind River Basin, Wyoming.

REFERRED SPECIMEN: Isolated left upper molariform tooth, UCMP 118602, UCMP locality V-77083, Judith River Formation, Montana.

KNOWN DISTRIBUTION: Judith River Formation (Judithian), Montana; and "Mesaverde" Formation (Judithian), Wind River Basin, Wyoming.

COMMENTS: *Falepetrus barwini* is described elsewhere by Clemens and Lillegraven (in press), and is included here only to complete the listing of mammalian taxa known from the "Mesaverde" Formation of Wyoming. The two teeth represent an advanced (i.e., protocone-bearing) therian mammal that shares specializations with neither the marsupials nor eutherians. The species can be added to the peculiar, and clearly paraphyletic, assemblage discussed by Kielan-Jaworowska and others (1979) as "therians of metatherian-eutherian grade."

INFRAClass METATHERIA HUXLEY, 1880

ORDER MARSUPIALIA ILLIGER, 1811

FAMILY DIDELPHIDAE GRAY, 1821

GENUS *ALPHADON* SIMPSON, 1927b

Alphadon russelli Fox, 1979a

Figures 9A-J, 10A-D; table 5

HOLOTYPE: UA 14805, right maxillary fragment with P3M1-4.

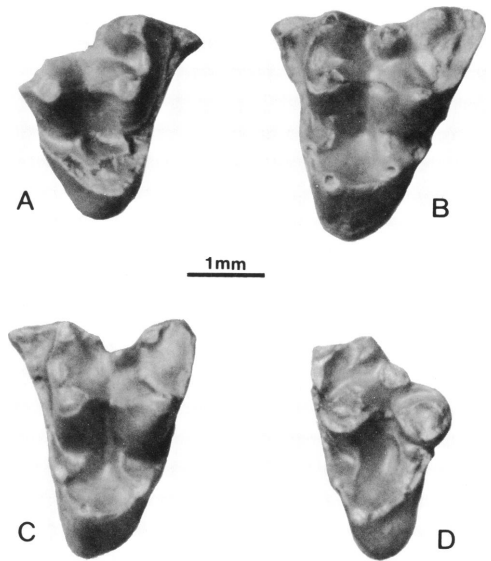


FIG. 10. Judithian *Alphadon russelli* from the "Mesaverde" Formation, Wyoming (continued). A, UW 17073, right M1. B, UW 15516, right M2 (reversed to appear as a left M2). C, UW 17053, left M3. D, AMNH 108680, left M4. All occlusal views, $\times 10$.

TYPE LOCALITY: Uppermost part of Oldman Formation, near Irvine, Alberta.

LOCALITIES REPRESENTED IN PRESENT STUDY AND REFERRED SPECIMENS: BIGHORN BASIN: mx, AMNH 109430, 109435, 109452, 109474, 109480; right P1, UW 17098 (fig. 9B-D); right P2, AMNH 109483 (fig. 9E-G); P3, AMNH 109427, 109432, 109441, 109473, 109489, UW 17080; right M1, UW 17073 (fig. 10A); M2, AMNH 109461. WIND RIVER BASIN: m3, AMNH 80022 (fig. 9A); P1, AMNH 108688; P2, AMNH 80011; right P3, AMNH 86359 (fig. 9H-J), UCMP 125338, UW 17049; M2, AMNH 80012, 86308, UW 15516 (fig. 10B), 17054; M3, UW 17049; M2, AMNH 80012, 86308, UW 15516, 17054; left M3, UW 17053 (fig. 10C); left M4, AMNH 108680 (fig. 10D); Mx, AMNH 80017, 86336.

KNOWN DISTRIBUTION: Oldman Formation (Judithian), Alberta; and "Mesaverde" Formation (Judithian), Bighorn and Wind River basins, Wyoming.

DESCRIPTION, COMPARISONS, AND DISCUSSION: Lower premolars. Because of the difficulty of differentiating isolated lower premolars of *Alphadon russelli* from those of

TABLE 5
Measurements of Teeth Referable to *Alphadon russelli*

	AP	LTRI	ANW	POW
m3 Wind River Basin AMNH 80022	2.96	1.26	1.81	1.53
P1 Bighorn Basin UW 17098	2.09		1.17	
Wind River Basin AMNH 108688	—		1.12	
P2 Bighorn Basin AMNH 109483	2.41		1.21	
Wind River Basin AMNH 80011	—		1.24	
P3 Bighorn Basin AMNH 109427	2.48		1.47	
109432	2.62		1.67	
109441	2.48		1.73	
109473	2.61		1.76	
109489	—		1.75	
UW 17080	2.52		1.74	
Wind River Basin AMNH 86359	2.67		1.89	
UCMP 125338 ^a	2.41		1.53	
UW 17049 ^a	2.74		1.74	
M1 Bighorn Basin UW 17073	—		2.72	—
M2 Bighorn Basin AMNH 109461	2.70		2.94	3.08
Wind River Basin AMNH 80012	2.41		2.83	2.96
86308	2.77		2.84	3.00
UW 15516 ^a	2.87		2.92	3.18
17054 ^a	2.48		3.01	3.09
M3 Wind River Basin UW 17053 ^a	2.41		3.05	3.17
M4 Wind River Basin AMNH 108680	1.92 est.		—	2.37

^a From Fales Rocks; unmarked teeth from Wind River Basin are from Barwin Quarry.

other species of *Alphadon*, none here is identified. Almost certainly, however, lower premolars of this species are represented within the following list of teeth identified as “*Alphadon* sp. px.”

m3. AMNH 80022 (fig. 9A; table 5) is of the appropriate size and follows the descriptions of m3s of *Alphadon russelli* by Fox (1979a, table 2, p. 96 and p. 99) from Alberta. Further description is deemed unnecessary.

mx. All teeth identified as “mx” of *Alphadon russelli* are fragmentary, and provide no

new information on lower molar structure for the species.

P1–3. The P1–3s here referred to *Alphadon russelli* follow in most respects descriptions for P3 provided by Fox (1979a) for that species (p. 98) and for its close relative, *A. praesagus* (p. 93); the P1 (fig. 9B–D) and P2 (fig. 9E–G), previously unknown, are recognized on the basis of their small size (table 5), narrowness, and more delicate features.

Fox (1979a, p. 98) stressed the basic morphological similarity of upper premolars be-

tween *Alphadon praesagus* and *A. russelli*; those from the latter species are smaller and proportionately narrower, but Fox noted no differences in the Alberta material in regard to cingula or furrows in the crown. A few minor differences are observable in P3 between specimens of *A. russelli* from the Oldman and "Mesaverde" formations. For example, the lingual cingulum in three of the nine available specimens from Wyoming continues weakly (though uninterrupted) forward across the anterior half of the crown to be continuous with the anterior cingulum; the lingual cingulum in the Alberta specimens stops short of the anterior root. Secondly, the anterior cingulum of the specimens from Alberta are "... more prominent lingually than labially ..." (Fox, 1979a, p. 93). No such consistency is noted in the specimens from the "Mesaverde" Formation; the anterior cingulum is either equally developed on both sides (the most common situation), or is stronger on the labial or lingual side in equal proportions. A third difference is the vertical anterolingual furrow of enamel on the main cusp. As with P3s from the Oldman Formation, the furrow is usually present in the Wyoming specimens (5 of 8); in two, however, the furrow is double.

Orthal shear facets are observable on several specimens on the anterior and posterior crests and on the labial and lingual sides of the main cusp. These are in addition to the dominant, horizontally oriented grinding wear surfaces.

M1. Remaining parts of UW 17073 (fig. 10A) agree in morphology with M1s described for *Alphadon russelli* from Alberta by Fox (1979a, p. 98). No further description is necessary.

M2. The M2s referred to *Alphadon russelli* from the "Mesaverde" Formation (fig. 10B) follow the descriptions by Fox (1979a, p. 98) in all but trivial aspects. The Wyoming specimens, however, show no development of protoconal cingula.

M3. Only one specimen (UW 17053; fig. 10C) of M3 referable to *Alphadon russelli* has been recovered from the "Mesaverde" Formation. It differs in two respects from comparable teeth of that species from Alberta. First, the Wyoming specimen lacks protoconal cingula, variably developed in M3s from

the Oldman Formation. Secondly, stylar cusps C and D in UW 17053 are approximately equal in size. This is of modest interest because one of the diagnostic features of *A. russelli* from *A. praesagus* cited by Fox (1979a, p. 98) is that the former usually has stylar cusp C larger than D on M3.

M4. AMNH 108680 (fig. 10D), here referred to *Alphadon russelli*, is a nearly complete M4, lacking only the roots and the labial part of the anterolabial expansion of the stylar shelf. We provide detail on the tooth in addition to that given for specimens from the Oldman Formation by Fox (1979a, p. 98). The protocone is intermediate in height between the para- and metacones and is sharply recumbent anteriorly. A weak anterior lingual cingulum is present on the base of the protocone dorsal to the protoconule. No hint of a posterior lingual cingulum exists. The protoconule is strong, forming a broad preprotoconular shelf that continues labiad, apparently to the (broken away) stylar cusp A. The postprotoconular wing, however, is weak, terminating at the rounded base of the paracone. The metaconule is strong, with the premetaconular wing terminating just dorsal to the paracone-metacone notch; the postmetaconular wing ends immediately posterior to the lingual rounded base of the metacone. The protocone is markedly basined between the conules.

The metacone is a round cone, apparently lacking a postmetacrista. It has a weak premetacrista that narrows to a shallow notch at the base of the postprotocrista. Only a narrow stylar shelf exists opposite the metacone, ending at the posterior base of the strong, rounded stylar cusp C (cusp "D" of Fox, 1979a, p. 98). The towering paracone has a strong, posteriorly directed postparacrista and an even stronger preparacrista. The latter projects straight labiad toward the (broken away) styloconal area. Just anterolabial to stylar cusp C is a minuscule teardrop-shaped cusp (cusp "C" of Fox, 1979a, p. 98) with a tapered crest that projects a short distance anterolingually. Despite Fox's (1979a, p. 98) assertions, we see no didactic or functional reason to assume that the cusp seen at the depth of the ectoflexus, set between the bases of the paracone and metacone, should not be referred to as cusp "C." Fox's cusp "C" seems

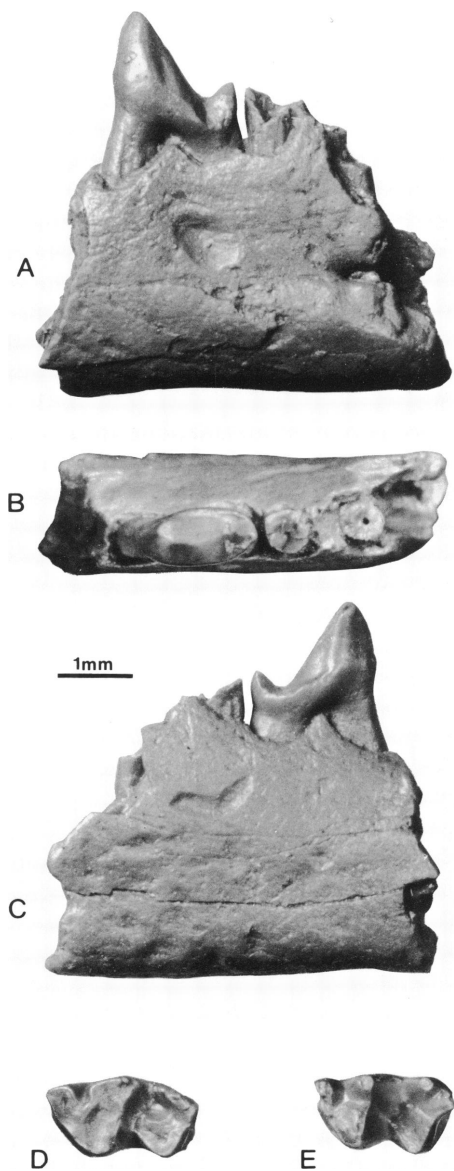


FIG. 11. Judithian *Alphadon halleyi* from the "Mesaverde" Formation, Wyoming. A-C, AMNH 86343, left lower jaw with p3 and roots of m1: labial, occlusal, and lingual views, respectively. D, AMNH 109428, left m1, occlusal view. E, UCMP 125347, left m2, occlusal view. All $\times 10$.

to be nothing more than a supernumerary cusp, of variable development, on an expanded region of the anterior styler shelf. In any case, identification of styler cusps as "A," "B," "C," and so forth is based entirely on topographic position and, without additional

justification, should not be interpreted as carrying an implication of homology.

Wear is difficult to interpret on AMNH 108680 because of surface breakages, but it is heavy on the apex of the metaconule while being nonexistent on the apex of the protoconule. Wear is also heavy on the pre- and postparacrista and on the anterior surface of the preprotoconular wing. Wear elsewhere is either light or impossible to determine.

Alphadon halleyi Sahni, 1972

Figure 11A-E; table 6

HOLOTYPE: AMNH 77367, isolated left m1.

TYPE LOCALITY: Clambank Hollow locality, Judith River Formation, Montana.

LOCALITIES REPRESENTED IN PRESENT STUDY AND REFERRED SPECIMENS: BIGHORN BASIN: m1, AMNH 109428 (fig. 11D), UW 17081; m4, UW 15524. WIND RIVER BASIN: p3, AMNH 86343 (fig. 11A-C); m2, AMNH 80021, UCMP 125347 (fig. 11E).

KNOWN DISTRIBUTION: Oldman Formation (Judithian), Alberta; Judith River Formation (Judithian), Montana; and "Mesaverde" Formation (Judithian), Bighorn and Wind River basins, Wyoming.

DESCRIPTION, COMPARISONS, AND DISCUSSION: *Alphadon halleyi* represents the middle-size version of four small species of *Alphadon* (all smaller than *A. russelli*) known from the "Mesaverde" Formation of Wyoming. Slightly larger forms are *A. sahnii* and *A. lulli* and a tiny form is *A. attaragos*. As discussed below, samples of *A. halleyi* identified by Fox (1979a) from the Oldman Formation and Sahni (1972) from the Judith River Formation both appear to contain teeth referable to *A. sahnii*.

p3. AMNH 86343 (fig. 11A-C) is identified as *Alphadon halleyi* on the basis of size; the structure of p3 of this species was previously undescribed. It is a strongly double-rooted tooth that lacks an anterior accessory cusp, an anterior keel on the main cusp, and basal cingula. The main cusp is strongly keeled posteriorly, with a simple, anteriorly keeled posterior accessory (taloid) cusp. A moderately developed ridge runs anterolingually, then straight anteriorly from the apex of the taloid cusp to terminate on the posterolingual

surface of the main cusp, about halfway up its height. Obvious wear on the tooth is seen only on the posterior keel of the main cusp, anterior ridge of the talonid cusp, and as a sharply troughed vertical groove on the lateral side of the tooth at the junction between the main and talonid cusps. As is usual for *Alphadon*, the posterior mental foramen is placed below the posterior root of m1.

m1. AMNH 109428 (fig. 11D) and UW 17081 match the size and morphology of the holotype almost perfectly, and although more heavily worn than the type, follow in all recognizable features the description provided by Sahni (1972, p. 381). No further description is necessary. Measurements of the holotype taken by Lillegraven (table 6), however, differ significantly from those reported by Sahni (p. 381). AMNH 77368 (m1) and 77369 (m2) from the Judith River Formation were identified by Sahni as *A. halleyi*, but not specifically cited in his text; they are referable to *A. sahnii*. Similarly, UA 1736 and UA 6987, respectively identified by Fox (1979a, p. 100, fig. 3a, c) as m3 and M1 of *A. halleyi*, are also identifiable as *A. sahnii*.

m2. UCMP 125347 (fig. 11E) and AMNH 80021 (labial half of tooth only) have features characteristic of m2s of *Alphadon* and agree in size and all other morphological features with the holotype of *A. halleyi*.

m4. The crown of UW 15524 is heavily damaged, but it has the greatly narrowed talonid and posteriorly elongated hypoconulid area characteristic of m4. Although the size is appropriate for reference to *Alphadon halleyi*, no other diagnostic features are recognizable.

The few scattered isolated teeth here identified as *Alphadon halleyi* provide no phylogenetic information beyond that discussed by Fox (1979a, p. 101) in terms of possible ancestry to *A. lulli*.

***Alphadon sahnii*, new species**

Figures 12A–J, 13A–D; table 7

HOLOTYPE: UCMP 125337 (fig. 13A), isolated right M1.

TYPE LOCALITY: Fales Rocks locality, UCMP V-81101, "Mesaverde" Formation, Wind River Basin, Wyoming.

LOCALITIES REPRESENTED IN PRESENT

TABLE 6
Measurements of Teeth Referable to
Alphadon halleyi, New Species

	AP	LTRI	ANW	POW
p3 Bighorn Basin AMNH 86343	1.60		0.79	
m1 Bighorn Basin AMNH 109428	1.98	1.00	1.02	0.98
UW 17081	2.03	0.89	1.04	1.06
m2 Wind River Basin AMNH 80021	1.91	0.82	—	—
UCMP 125347 ^a	1.86	0.74	1.00	1.02
m4 Bighorn Basin UW 15524	1.74	—	—	—
m1 cast of holotype AMNH 77367	1.98	0.93	0.97	1.06

^a From Fales Rocks; unmarked teeth from Wind River Basin are from Barwin Quarry.

STUDY AND REFERRED SPECIMENS: BIGHORN BASIN: m1, AMNH 109414, 109421, UW 17075 (fig. 12A); m2, AMNH 109426, 109431, 109442, 109482, 109484 (fig. 12B), UW 15530, 15531; m3, AMNH 109478, 109481; P2, UW 15522, 15526 (fig. 12E–G); P3, AMNH 109445, UW 17082 (fig. 12H–J); M1, AMNH 109439; M2, AMNH 109417; M4, AMNH 109443. WIND RIVER BASIN: m1, UCMP 125350; m2, AMNH 86310, 86330, 86362, 88488, UW 17057, 17059; m3, AMNH 86309, 86328, 86331, UW 15520 (fig. 12C), 17056, 17061; m4, AMNH 86332 (fig. 12D), UW 15540, 17055; mx, AMNH 80016, 86329; P3, AMNH 86341, 86357; M1, AMNH 86337; M2, AMNH 86312, 86313, 86321, 86333, 108686 (fig. 13B); M3, UW 17052 (fig. 13C); left M4, AMNH 86311, UW 17050 (fig. 13D).

KNOWN DISTRIBUTION: Probably Oldman Formation (Judithian), Alberta; probably Judith River Formation (Judithian), Montana; and "Mesaverde" Formation (Judithian), Bighorn and Wind River basins, Wyoming.

ETYMOLOGY: Species named in honor of Dr. Ashok Sahni for his primary research on the vertebrate fauna of the Judith River Formation.

DIAGNOSIS: Small species of *Alphadon*, intermediate in size between *A. wilsoni* and *A. marshi*; molar cusps slightly inflated; P2–3

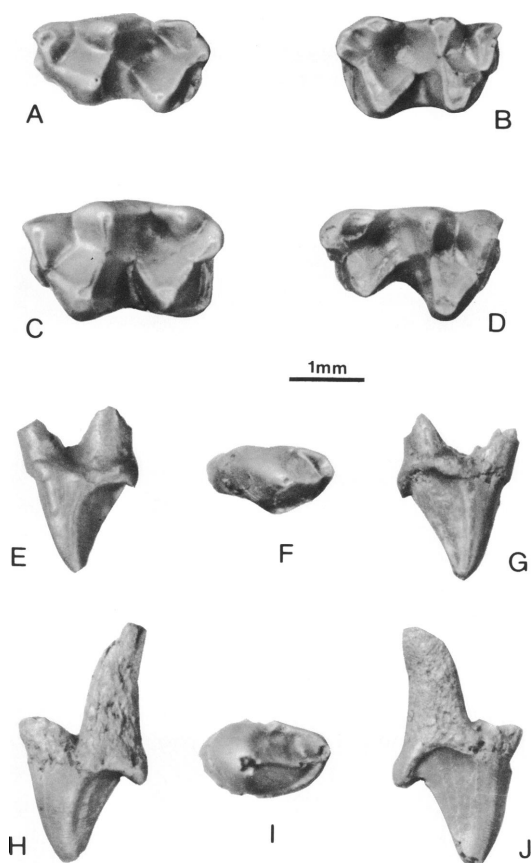


FIG. 12. Judithian *Alphadon sahnii*, new species, from the "Mesaverde" Formation, Wyoming. A, UW 17075, left m1, occlusal view. B, AMNH 109484, right m2, occlusal view. C, UW 15520, left m3, occlusal view. D, AMNH 86332, right m4, occlusal view. E–G, UW 15526, left P2, labial, occlusal, and lingual views, respectively. H–J, UW 17082, left P3, labial, occlusal, and lingual views, respectively. All $\times 10$.

usually lacking anterolingual parts of basal cingulum; P2–3 with anterior border of main cusp unkeeled and with strong wear on posterior crest of main cusp.

DESCRIPTION: Lower premolars. Because of the difficulty of differentiating isolated lower premolars of *Alphadon sahnii* from those of other species of *Alphadon*, none is identified here. Almost certainly, however, lower premolars of this species are represented below under List of Unidentified Specimens of Therians, px.

m1–4. All molars of this species, upper and

lower (fig. 12A–D), are slightly inflated in general construction; the cusps lack the delicacy characteristic of *Alphadon marshi* and *A. wilsoni*.

The protoconid is markedly the tallest cusp, with the paraconid slightly lower than the metaconid. The metaconid is set posterior to the protoconid, but not distantly so. The anterior cingulid begins labial to the apex of the paraconid and terminates on the anterolabial surface of the protoconid. The posterior cingulid begins just below the apex of the hypoconulid and terminates on the posterolabial surface of the hypoconid; a labial basal cingulid is lacking. The paraconid is usually vertically keeled anteriorly. The posterior face of the paraconid and the anterior face of the metaconid are usually rounded, but sometimes each is lightly ridged vertically. The metaconid usually has a vertical posterior keel that runs posteriorly to a slight notch at the junction with an anterior cristid from the entoconid.

The hypoconid is the tallest of the talonid cusps and the hypoconulid the lowest. The entoconid is set slightly posterior to the level of the hypoconid and, on m4, markedly so. The entoconid is laterally compressed and, although usually having a rounded posterior edge, sometimes is posteriorly keeled. Anteriorly, the entoconid has a sharply descending cristid, occasionally with an accessory cuspule. The entoconid is set anterolingually from the hypoconulid. The talonid is deeply basined, with the deepest part just labial to the notch between the posterior metaconid ridge and the anterior entoconid cristid. The cristid obliqua is either straight or slightly convex labially, and commonly has a short, vertical anterior continuation that climbs high up the posterior wall of the talonid.

The hypoconulid is compressed, posteriorly recumbent, and with the long axis running posterolingually to anterolabially. The hypoconulid and hypoconid are connected by a continuous crest, but the posthypoconid cristid courses more directly labiad. Although usually absent, occasionally a weak, posterolingually convex cristid at the extreme posterolingual corner of the crown connects the bases of the hypoconulid and entoconid.

Wear is heaviest across all main crests of the trigonid, the length of the cristid obliqua,

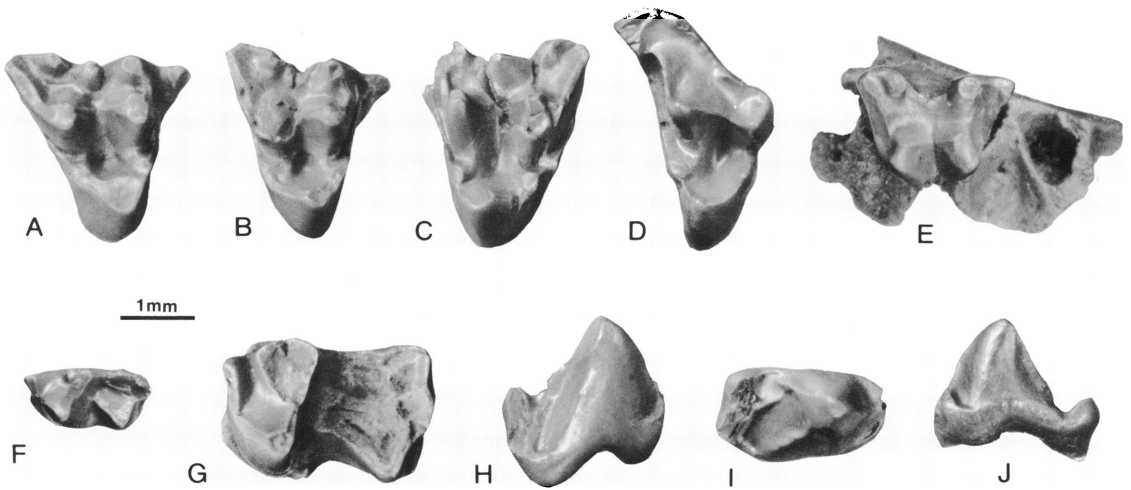


FIG. 13. Judithian *Alphadon sahnii*, new species (continued), *Alphadon lulli*, *Alphadon attaragos*, new species, *Paranyctoides megakeros*, new species, and *Gypsonictops lewisi* from the "Mesaverde" Formation, Wyoming. A, UCMP 125337, *Alphadon sahnii*, new species, holotype, right M1, occlusal view. B, AMNH 108686, *Alphadon sahnii*, right M2, occlusal view. C, UW 17052, *Alphadon sahnii*, left M3, occlusal view. D, UW 17050, *Alphadon sahnii*, left M4, occlusal view. E, UCMP 125349, *Alphadon lulli*, labial half of right M3 in fragment of maxilla, occlusal view. F, UW 17079, *Alphadon attaragos*, new species, holotype, left m1, occlusal view. G, AMNH 109420, *Paranyctoides megakeros*, new species, holotype, left m1, occlusal view. H–J, UW 17047, *Gypsonictops lewisi*, right p4 (p3 of traditional designation), labial, occlusal, and lingual views, respectively. All $\times 10$.

the apex of the entoconid, and the crests that join the apices of the hypoconid and hypoconulid. Lighter wear is also observed on the anterior and posterior cingulids, on the pre- and postvallid shear surface of the trigonid, and on the posterior shear surface of the hypoflexid. The central parts of the trigonid and talonid basins remain unworn even into advanced stages of wear. Similarly, the apices of the entoconid and hypoconulid retain their distinctness even into heavy stages of wear.

P2. UW 15522 and 15526 (fig. 12E–G), clearly referable to *Alphadon*, are identified as P2s of *A. sahnii* on the basis of size. The teeth have strong, double, divergent roots. The main cusp is only weakly keeled anteriorly, but has a sharply developed posterior crest. There is no anterior accessory cusp per se, but a sharply constructed cingulum begins at the anterolabial corner of the crown, wraps around the anterior edge of the main cusp, and continues in an undulating course along the lingual base of the tooth to the apex of the moderately developed posterior accessory cusp. A small basin between the postero-labial base of the main cusp and the posterior

accessory cusp is enclosed by a cingulum that runs from the apex of the posterior accessory cusp to the labial midbase of the main cusp. The widest part of the tooth is just posterior to the level of the apex of the main cusp and the lingual cingulum is strongest at that point. Wear is strong on the posterior crest of the main cusp and on the conjoined lingual surface of the main cusp–posterior accessory cusp. Obvious abrasion facets do not exist elsewhere, even under conditions of heavy wear.

P3. The P3 (fig. 12H–J) is merely a larger variation on the structure of P2, with a proportionately larger posterior accessory cusp and taller main cusp. There is some tendency for the cingulum across the anterolabial quarter of the main cusp to approach weak completion. The wear pattern is identical to that of P2.

M1. Styler cusps A, B, C, and D (fig. 13A) are well separated from one another and strongly developed on M1; A is the lowest. Styler cusp B is the largest and is conical except for a short, forwardly projecting spur originating at the anterolabial corner of the

cuspsule's apex. Cusp C is a sharply pointed cone, intermediate in height between stylar cusps B and D. Stylar cusp D is anteroposteriorly elongated. The paracone and metacone are roughly equal in height and general development; the lingual surfaces of both are broadly rounded. The preparacrista makes an anteriorly convex arc between the apices of the paracone and stylar cusp B. The postparacrista is straight, joining directly with an equally straight premetacrista. The postmetacrista makes a gentle posteriorly convex arc to terminate at the posterolabial extreme of the stylar shelf.

The protoconule and metaconule are moderately scaled and about equal in development. The preprotoconule crista continues as a cingulum along the base of the crown to the apex of stylar cusp A. The postprotoconule crista is a short, rounded crest that terminates at the lingual base of the paracone. The premetaconule crista is a short, rounded crest terminating at the anterolingual base of the metacone. The postmetaconule crista terminates at a level posterior to the apex of the metacone at the base of the vertical wall formed by the postmetacrista. The protocone is broadly based and lacks all but hints of lingual cingula.

Heaviest wear is seen on the apices of stylar cusps A–C, para- and metaconal crests, protoconal and conular crests, and in the general vicinity of the anterior faces of the paracone-preparacrista and adjacent cingulum plus stylar cusp A.

M2. Except for the usual differences in coronal proportions, the M2 (fig. 13B) differs in only a few ways from the description given above for M1. Prime among these are: (1) stylar cusps C and D in M2 are either subequally developed (the usual case) or D slightly exceeds the height of C; and (2) the internal crests of the conules tend to be sharp-edged rather than rounded. AMNH 109417 shows weak lingual cingula on the protocone, but the usual case (as in M1) is to lack such cingula. The wear pattern is as in M1 except that stylar cusp D comes into active wear sooner.

M3. UW 17052 (fig. 13C), heavily damaged, is the only tooth referable to M3 of *Alphadon sahnii*. Stylar cusp C is nearly as strong as stylar cusp B; it is unknown whether

this was the usual situation in M3s of this species.

M4. The paracone of M4 (fig. 13D) is by far the tallest cusp, with the metacone and protocone of the same height and the conules the lowest. The preparacrista is a sharp, thin, bladelike crest that runs anterolabially but terminates abruptly well short of the anterolabial extreme of the stylar shelf. The labial end of the preparacrista hooks forward with a weak connection to the anterior cingulum, a continuation of the preprotoconule crista. The lingual surface of the paracone is rounded. The labial surface is flattened, and almost concave as the sharp paraconal apex curves ventrolingually. The postparacrista is short, straight, and sharply keeled, connecting with the base of a still shorter and sharper premetacrista.

The posterior wall of the metacone is flat, with a crest running from its apex in a posteriorly convex arc to become continuous with the labial margin of the stylar shelf. Stylar cusp C is weakly developed and anteroposteriorly elongated. Minor undulations of the edge of the stylar shelf are seen between stylar cusps C and B. The latter is low and placed just posterolabial to the termination of the preparacrista. A weak notch separates stylar cusp B from A, the tallest of the stylar shelf.

The protoconule has a strong anterior crista that continues labially as a basal cingulum to the apex of stylar cusp A. The postprotoconule crista is short, terminating at the lingual base of the paracone. The metaconule lacks an anterior crista. The postmetaconule crista is strong, terminating at the lingual base of the metacone. A pronounced indentation, as seen in occlusal view, exists on the posterior wall of the tooth between the metacone and metaconule.

The protocone is anteroposteriorly compressed with strong pre- and postprotoconular crests that terminate at the central bases of the protoconule and metaconule, respectively. There are no hints of lingual cingula.

Specimens adequately worn to provide information on wear patterns are unknown.

RELATIONSHIPS: The teeth of *Alphadon sahnii* are most closely comparable to those of *A. wilsoni* and *A. marshi*, species known from rocks of Lancian age. *Alphadon sahnii*

is intermediate in size between those two species (compare data in table 7 of the present paper with figs. 16 and 17 of Lillegraven, 1969), however, and differs as well in the minor features cited above in the diagnosis. It is possible, though certainly not proven, that *A. sahnii* was ancestral either to *A. wilsoni* or *A. marshi*, or to both.

As discussed in the section dealing with *Alphadon halleyi*, it is highly probable that AMNH 77368 (m1) and 77369 (m2) from the Judith River Formation and UA 1736 (m3) and 6987 (M1) from the Oldman Formation also represent teeth of *A. sahnii*.

Alphadon lulli Clemens, 1966

Figure 13E

HOLOTYPE: UCMP 47047, fragmentary left maxilla with M1-2, alveoli of M3, and parts of alveoli of P3 and M4.

TYPE LOCALITY: Lull 2 quarry, UCMP V-5620, Lance Formation, Powder River Basin, Wyoming.

LOCALITIES REPRESENTED IN PRESENT STUDY AND REFERRED SPECIMENS: BIGHORN BASIN: M3, UW 17078. WIND RIVER BASIN: fragmentary right M3, UCMP 125349 (fig. 13E).

KNOWN DISTRIBUTION: "Mesaverde" Formation (Judithian), Bighorn and Wind River basins, Wyoming; Hell Creek Formation (Lancian), Montana; and Lance Formation (Lancian), Wyoming.

DESCRIPTION AND COMPARISONS: The two fragmentary M3s from the "Mesaverde" Formation agree well in size and general morphology with homologous teeth of *Alphadon lulli* from the younger Hell Creek Formation (Archibald, 1982, p. 128) and Lance Formation (Clemens, 1966, p. 8). Available dental measurements of the Wyoming specimens are: UCMP 125349, AP, 2.06; and UW 17078, POW, 2.70. Styler cusp C is lacking in UCMP 125349 and apparently weak (enamel abraded away from labial edge of styler shelf) on UW 17078. The ectoflexus is rather broadly developed on both specimens. UCMP 125349 shows styler cusp B to be tall and conical, A much lower, and D weak and anterolingually elongated along the posterior rim of the ectoflexus; there is no styler cusp

E per se, only the posterolabial extension of a rather low postmetacrista. The wear pattern on UCMP 125349 is as described by Clemens (1966, p. 10). UW 17078 shows the conules to be strongly developed and fully winged. There is no hint of protoconal cingula.

If properly identified, these two specimens could be the first known pre-Lancian representatives of *Alphadon lulli*. They provide no new information concerning phylogenetic relationships of the species.

Alphadon attaragos, new species

Figure 13F

HOLOTYPE AND ONLY KNOWN SPECIMEN: UW 17079 (fig. 13F), isolated left m1.

TYPE AND ONLY KNOWN LOCALITY: Sunset to Dawn Two locality, UW V-81076, "Mesaverde" Formation, Bighorn Basin, Wyoming.

KNOWN DISTRIBUTION: "Mesaverde" Formation (Judithian), Bighorn Basin, Wyoming.

ETYMOLOGY: Gr. *attaragos*, meaning morsel or bit, in reference to minuscule size.

DIAGNOSIS: Minuscule size; metaconid of m1 set far posterior to protoconid; hypoconulid essentially conical; molar construction uninflated.

DESCRIPTION: UW 17079 (fig. 13F) is a left m1 of minuscule size (AP, 1.68; LTRI, 0.74; ANW, 0.76; POW, 0.79) and uninflated construction. The metaconid is set far posterior to the protoconid, giving the trigonid the appearance of an equilateral triangle (base at lingual side) in occlusal view. Although somewhat damaged, the hypoconulid appears to have been conical, rather than ridge-like as in *Alphadon sahnii*. The tooth otherwise follows the basic construction typical of *A. sahnii*.

RELATIONSHIPS: The hypodigm of a single isolated lower molar does not allow adequate interpretation of phylogenetic relationships. The basic construction of m1, however, is close to that of *Alphadon sahnii*, and *A. attaragos* may represent a counterpart of tiny body size. *Alphadon attaragos* is the smallest species of the genus yet described; continued collecting with fine-meshed washing screens

TABLE 7
Measurements of Teeth Referable to *Alphadon sahnii*, New Species

	AP	LTRI	ANW	POW
m1 Bighorn Basin				
AMNH 109414	2.32	1.06	1.18	1.21
109421	2.22	1.03	1.15	1.17
UW 17075	2.32	1.08	1.23	1.24
Wind River Basin				
UCMP 125350 ^a	2.14	0.96	0.94	1.00
m2 Bighorn Basin				
AMNH 109431	2.41	1.00	1.45	1.37
109442	2.49	1.05	1.42	1.50
109482	2.38	1.00	1.37	1.42
109484	2.16	0.87	1.29	1.30
UW 15530	2.27	0.96	1.40	1.34
15531	2.16	0.88	1.33	1.31
Wind River Basin				
AMNH 86310	2.33	0.95	1.46	1.41
86330	2.14	0.94	1.37	1.40
86362	2.28	0.91	1.31 est.	1.31
88488	2.32	0.99	1.44	1.38
UW 17057 ^a	2.04	0.81	1.36	1.34
17059 ^a	2.42	0.99	1.32	1.32
m3 Bighorn Basin				
AMNH 109481	2.42	1.06	1.62	1.44
Wind River Basin				
AMNH 86309	2.53	1.08	1.69	1.45
86328	—	0.98	1.47	—
86331	2.66	0.99	1.68	1.41
UW 15520 ^a	2.60	1.07	1.58	1.43
17056 ^a	2.19	0.91	1.44	1.24
17061 ^a	2.15	0.84	1.37	1.26
m4 Wind River Basin				
AMNH 86332	2.41	0.94	1.52	1.17
UW 15540 ^a	2.50	1.00	1.51	1.35
17055 ^a	2.77	1.14	1.73	1.41
P2 Bighorn Basin				
UW 15522	1.57		0.91	
15526	1.52		0.95	
P3 Bighorn Basin				
AMNH 109445	—		1.03	
UW 17082	1.73		1.05	
Wind River Basin				
AMNH 86341	—		1.09	
86357	—		1.08	
M1 Bighorn Basin				
AMNH 109439	2.31		2.47	2.62
Wind River Basin				
UCMP 125337 ^a	2.40		2.25	2.43
M2 Bighorn Basin				
AMNH 109417	—		2.39	—
Wind River Basin				
AMNH 86312	2.22		2.31	2.48
86313	2.49		2.57	2.84

TABLE 7—(Continued)

	AP	LTRI	ANW	POW
86321	2.01		2.21	2.34
86333	2.32 est.		—	—
108686	2.14		2.23	2.48
M3 Wind River Basin				
UW 17052 ^a	2.03 est.		2.55	2.75 est.
M4 Wind River Basin				
UW 17050 ^a	2.06		3.11	2.08

^a From Fales Rocks; unmarked teeth from Wind River Basin are from Barwin Quarry.

will be necessary for improving knowledge of these interesting animals.

FAMILY PEDIOMYIDAE (SIMPSON, 1927b)

Pedionmys sp.

INCLUDED SPECIMEN: UW 15533, isolated right trigonid of m2 or m3.

LOCALITY: Meteors locality, UW V-81066, "Mesaverde" Formation, Bighorn Basin, Wyoming.

COMMENTS: The single specimen (probably m2 or m3) is identified as *Pedionmys* sp. on the basis of placement of the anterior termination of the cristid obliqua, well labial to the notch between the crests of the protoconid and metaconid. Identification to the level of species is impossible, though it is probable that the specimen (LTRI, 1.24; ANW, 1.24) would fall within the range of variation of *P. clemensi* (see Fox, 1979b, table 1, p. 106 for mean values).

The rarity of specimens of *Pedionmys* in the "Mesaverde" Formation comes as somewhat of a surprise; it is a fairly common member of more northerly faunas, and is known from Late Cretaceous faunas as far south as New Mexico and Baja California, Mexico (see Clemens, 1979, table 11-2, p. 194). Whether this represents an artifact of collecting bias or a real ecological differentiation is unknown. Clemens (1973b, p. 163), however, also noted a comparative rarity of pedionmyids within the Hunter Wash local fauna ("Edmontonian") of the Kirtland and Fruitland formations of New Mexico.

INFRAClass EUTHERIA GILL, 1872

ORDER INSECTIVORA CUVIER, 1817;
BOWDICH, 1821

SUPERFAMILY ERINACEOIDEA
(FISCHER DE WALDHEIM, 1817)

FAMILY CF. NYCTITHERIIDAE
SIMPSON, 1928

GENUS *PARANYCTOIDES* FOX, 1979c

Paranyctoides megakeros, new species
Figure 13G; table 8

HOLOTYPE: AMNH 109420 (fig. 13G), isolated left m1.

TYPE LOCALITY: Case Site 8, "Mesaverde" Formation, Bighorn Basin, Wyoming.

REFERRED SPECIMEN: AMNH 109469, isolated trigonid of mx (Case Site 2, Bighorn Basin).

KNOWN DISTRIBUTION: "Mesaverde" Formation (Judithian), Bighorn Basin, Wyoming.

ETYMOLOGY: Gr. *megas*, large, plus Gr. *keros*, horn; after discovery in the Bighorn Basin.

DIAGNOSIS: Lower molar morphology as in *Paranyctoides sternbergi*, but size of new species about 56 percent greater.

DESCRIPTION, COMPARISONS, AND DISCUSSION: AMNH 109420 (fig. 13G) and 109469 follow without exception the description of lower molars of *Paranyctoides sternbergi* by Fox (1979c, pp. 119–121); molar construction seems to be more delicate than in *P.*

TABLE 8
Measurements of Teeth Referable to
Paranyctoides megakeros, New Species

		AP	LTRI	ANW	POW
m1	AMNH 109420	2.71	1.05	1.73	1.75
mx	AMNH 109469	—	0.99	1.63	—

maleficus (see Fox, 1984, pp. 12–13). The teeth from Wyoming (table 8), however, are more than half again as large as those from Alberta (Fox, 1979c, table 1, p. 116; Fox, 1984, table 1), and it seems highly unlikely that the same species are represented.

The only descriptive details that can be added beyond those by Fox (1979c, 1984) have to do with tooth wear. AMNH 109420 shows that the talonid (at least of m1) wears much more heavily than the trigonid and that wear is principally horizontal on the crests that rim the talonid basin, not on the more vertical shearing surfaces. Postvallid wear on the trigonid greatly exceeds prevallid wear, but the cristids receive the heaviest wear of the trigonid.

The new specimens from Wyoming provide no additional information on the phylogenetic affinities of *Paranyctoides*. Although we use the higher-category systematic hierarchy suggested by Fox (1979c, p. 119, 1984, p. 9), we neither defend nor challenge the existence of true nyctitheres in Late Cretaceous time. The new specimens do, however, serve to document further the extent of diversification of eutherian mammals during Late Cretaceous time in North America (see discussions by Fox, 1979c, p. 124, 1984, p. 16).

SUPERFAMILY INCERTAE SEDIS

GENUS *GYPSONICTOPS* SIMPSON, 1927a

Gypsonictops lewisi Sahni, 1972

Figure 13H–J

HOLOTYPE: AMNH 77429, isolated p4.

TYPE LOCALITY: Clambank Hollow locality, Judith River Formation, Montana.

LOCALITIES REPRESENTED IN PRESENT STUDY AND REFERRED SPECIMENS: Wind River Basin, right p4 (p3 of traditional designation), UW 17047 (fig. 13H–J), UW locality V-81006 and lingual fragment of Mx, AMNH 108682, "Barwin Quarry."

KNOWN DISTRIBUTION: Oldman Formation (Judithian), Alberta; Judith River Formation (Judithian), Montana; and "Mesa-verde" Formation (Judithian), Wind River Basin, Wyoming.

DESCRIPTION AND COMPARISONS: The two specimens of *Gypsonictops* from the Wind

River Basin are identified as *G. lewisi* on the basis of stratigraphic occurrence (Judithian), comparable size of teeth, and lack of morphological differences from other specimens referred to the species.

p4. UW 17047 (fig. 13H–J) agrees in size (AP, 2.24; W, 1.25) and major features of construction with AMNH 77428, a tooth from the Judith River Formation identified by Sahni (1972, fig. 15D–F, p. 392) as the penultimate premolar of *Gypsonictops lewisi*. Fox (1979c, p. 117) suggested that because known species of *Gypsonictops* have five lower premolars, the designation of p1–2–3–4–5 should replace Clemens' (1973a, p. 6) recommended use of pa–b–c–3–4; Fox's terminology is applied here. Clemens (1973a, pp. 7–8 and fig. 5, p. 11) documented the high degree of individual variation in p4 structure in the Lancian species of *Gypsonictops hypoconus*; marked variation thus may also be expected in p4s of *G. lewisi*. Species identification at this point, however, is tentative.

UW 17047, of robust construction, has a small anterior basal cusp set well above the enamel-dentine boundary immediately lingual to the anterior ridge of the tooth's main cusp. A short but strongly developed cingulum descends ventrad and curves posterolabial from the basal cusp to terminate on the anterolabial base of the main cusp. The main cusp has a sharp vertical ridge that is slightly convex labially and runs from the apex to the labial base of the anterior basal cusp. There is no hint of a metaconid. A strong posterolingual ridge runs ventrad from the apex of the main cusp to terminate at the talonid. Immediately lingual to that point of termination, an equally strong anteroposterior talonid ridge forms the lingual edge of a small and narrow but distinctly basined talonid. A second vertical ridge, less pronounced and more undulating in course, runs from the apex of the main cusp down its posterolabial corner to terminate at the base of the cusp.

The posterior edge of the talonid has enamel broken away and its morphology is thereby impossible to determine fully. It appears, however, that the posterior edge of the talonid basin was closed by a transverse ridge that continued ventrolabially, then anteriorly, to terminate at the ventrolabial base of the main cusp. The talonid basin is bordered

on its labial side by a sharp ridge that runs forward to terminate just labial of the posterolingual ridge of the main cusp.

Wear on the tooth is almost entirely restricted to its posterior half, especially on the back wall of the main cusp, on the posterior talonid rim, and on the broad labial slope of the talonid. One small wear facet is present on the labial wall of the main cusp, immediately ventral to its apex. An important wear facet is on the posterior wall of the main cusp, broad near the cusp's apex and narrowing ventrally, with convergence of the facet onto the posterolingual ridge of the main cusp at about two-thirds of the way down its length. Strong posterolabially directed wear is also present on the ventrally sloping posterior edge of the talonid and its broad labial slope.

Mx. AMNH 108682 is a moderately worn upper molar fragment with protocone, conules, and lingual cingula. The specimen provides no new information on morphological variation in species of *Gypsonictops*.

DISCUSSION: Unfortunately, neither UW 17047 nor AMNH 108682 provides new information on the phylogenetic affinities of *Gypsonictops lewisi*. If the identification is correct, a range extension southward of some 575 km is documented for the species.

UNIDENTIFIED SPECIMENS OF THERIANS

In addition to the specimens discussed above, a number of isolated teeth and jaw fragments remain unidentified and are listed below. Although most are fragmentary or heavily worn, some are excellently preserved and should be identifiable once larger samples and better comparative series become available.

Isolated incisors and canines, lower and upper

AMNH 80005, 86322, 86325 (2 specimens), 88335, 88492–88493, 109415, 109440, 109455, 109460, 109471, 109488

UW 15517, 17101, 17084, 17095

px

AMNH 80015, 86317, 86326, 88494–88495, 108681, 108685, 109418, 109450, 109453–109454, 109458, 109472, 109486–109487

UCMP 125340, 125343

UW 15515, 15529, 17048, 17068

mx

AMNH 80014, 80018, 86314–86315, 86319, 86334, 86339, 86348, 86349, 86358–86359, 86365, 88487, 88489–88490, 109413, 109433–109434, 109448–109449, 109459, 109476–109477

UCMP 125346, 125348

UW 15525, 15527, 15581, 17051, 17058, 17060, 17062, 17069, 17076–17077

Px

AMNH 109416

DP3

UCMP 125339

Mx

AMNH 86361

UCMP 125341–125342

UW 17097

Edentulous jaw fragments, lower and upper

AMNH 80006, 80009–80010, 80019–80020, 86340, 86353–86354, 88498–88499

UW 15518, 17096, 17099

NEW TAXA AND RANGE EXTENSIONS

The present research has allowed advances in knowledge of taxonomic diversity, greater appreciation of geologic and geographic ranges of species, and increased biostratigraphic utility of the fossils; results are summarized below.

NEW GENERA

Three previously unknown genera are recognized, though none is formally named herein. They are: (1) "Multituberculata, new genus and species, unnamed," representing a presently unidentifiable species of extraordinarily large body size; (2) "Dryolestidae, genus and species unidentified," a phylogenetic relict represented by materials inadequate for diagnosis; and (3) *Falepetrus barwini*, an advanced therian being described elsewhere (Clemens and Lillegraven, in press).

NEW SPECIES OF PREVIOUSLY DESCRIBED GENERA

Three new species of previously described genera are named. They are: (1) *Alphadon*

TABLE 9
Species-Level Taxa in "Mesaverde" Formation in
Bighorn and Wind River Basins of Wyoming

Taxon	Bighorn Basin	Wind River Basin
<i>Mesodma primaeva</i>		++
<i>Mesodma</i> sp.	+	+
<i>Cimolomys clarki</i>	++	++
<i>Meniscoessus intermedius</i>		++
<i>Paracimexomys priscus</i>		+
Multituberculata, n. gen. and sp., unident.		+
Dryolestidae, gen. and sp. unident.	+	
<i>Falepetrus barwini</i>		++
<i>Alphadon russelli</i>	++	++
<i>Alphadon halleyi</i>	++	++
<i>Alphadon sahnii</i>	++	++
<i>Alphadon lulli</i>	+	+
<i>Alphadon attaragos</i>	+	
<i>Pediomys</i> sp.	+	
<i>Paranyctoides megakeros</i>	+	
<i>Gypsonictops lewisi</i>		++

Symbols: +, present; ++, present, but also known from north of Wyoming in northern Montana and/or southern Alberta.

saahnii, most closely comparable to the Lancian species *A. wilsoni* and *A. marshi*; (2) *Alphadon attaragos*, with the smallest body size yet described for the genus; and (3) *Paranyctoides megakeros*, with a body size significantly larger than *P. sternbergi*. *Paranyctoides megakeros* represents the only known occurrence of the genus south of Alberta.

NEW RECORDS FOR WYOMING AND
GEOGRAPHIC RANGE EXTENSIONS

All species-level taxa except *Alphadon lulli* are reported from Wyoming for the first time. These include both new taxa (summarized immediately above) and geographic range extensions. Speaking only for the Judithian, the following range extensions are documented:

1. Extended into Wyoming from northern Montana, *Mesodma primaeva*, *Cimolomys clarki*, *Alphadon halleyi*, and *Gypsonictops lewisi*.
2. Extended into Wyoming from southern Alberta, *Meniscoessus intermedius* and *Alphadon russelli*.

3. Recognized for the first time both in Wyoming and in northern Montana, *Falepetrus barwini*.
4. Probably recognizable in northern Montana and southern Alberta as well as Wyoming, *Alphadon sahnii*.

GEOLOGIC RANGE EXTENSIONS INTO
JUDITHIAN RECORD

In addition to the new taxa summarized above, ranges of *Paracimexomys priscus* (species only) and *Alphadon lulli* (species only) are extended from rocks of Lancian age into the Judithian record.

JUDITHIAN OCCURRENCES PRESENTLY
RESTRICTED TO "MESAVERDE"
FORMATION OF WYOMING

Including the new genera and species, the following taxa are presently recognized in the Judithian only from the "Mesaverde" Formation of Wyoming: *Paracimexomys priscus*, Multituberculata, new genus and species, unnamed, Dryolestidae, genus and species unidentified, *Alphadon lulli*, *Alphadon attaragos*, and *Paranyctoides megakeros*.

TAXA COMMON TO BOTH BIGHORN AND
WIND RIVER BASINS

If we look only at the Wyoming Judithian record, counts from the existing faunal list (table 9) show that six species-level taxa are common to both the Bighorn and Wind River basins, four are known only from the Bighorn Basin, and six are known only from the Wind River Basin. Of the 12 species-level taxa known from the more southerly Wind River Basin, at least 8 also occur in rocks of Judithian age from farther north in Montana and/or Alberta (table 10); in all probability, the Judithian mammalian fauna of the coastal western interior was essentially homogeneous geographically, at least as far as from southern Alberta to central Wyoming.

BIOSTRATIGRAPHY

THE NATURE OF NORTH AMERICAN
LAND-MAMMAL "AGES"

The pioneering effort of Wood et al. (1941) established a continent-wide framework for

TABLE 10

Mammals in More Important Late Cretaceous Localities of North American Western Interior

To conserve space on the printed page, summary information for areas 1–13 is presented immediately below. See text concerning nature of "Edmontonian." See figure 1 for geographic reference.

Area	Formation	Province or state	Presumed "age" represented	Primary references
1	Upper part of Milk River Fm.	Alberta	Aquilan	Fox, 1970, 1971a, 1971b, 1972, 1976a, 1980, 1981, 1982, 1984; Clemens et al., 1979
2	Lower part of Oldman Fm.	Alberta	Judithian	Fox, 1976b; Clemens et al., 1979
3	Upper part of Oldman Fm.	Alberta	Judithian	L. S. Russell, 1952; Fox, 1974, 1979a, 1979b, 1979c, 1981; Clemens et al., 1979; this paper
4	Judith River Fm.	Montana	Judithian	Sahni, 1972; Fox, 1979c, 1981; Clemens et al., 1979; Clemens and Lillegraven, in press; this paper
5	"Mesaverde" Fm.	Wyoming (Bighorn Basin)	Judithian	this paper
6	"Mesaverde" Fm.	Wyoming (Wind River Basin)	Judithian	this paper
7	St. Mary River Fm.	Alberta	"Edmontonian"	L. S. Russell, 1975; Sloan and L. S. Russell, 1974; Clemens et al., 1979
8	Kirtland and Fruitland formations	New Mexico	"Edmontonian" and Lancian	Clemens, 1973b; Armstrong-Ziegler, 1978; Clemens et al., 1979; Archibald, 1982; Lehman, 1984; Flynn, in press
9	Scollard Fm.	Alberta	Lancian	Fox, 1974; Lillegraven, 1969; Clemens et al., 1979
10	Frenchman Fm.	Saskatchewan	Lancian ^a	Johnston, 1980
11	Hell Creek Fm.	Montana	Lancian	Sloan and Van Valen, 1965; Van Valen and Sloan, 1965; Estes and Berberian, 1970; Novacek and Clemens, 1977; Van Valen, 1978; Clemens et al., 1979; Lupton et al., 1980; Archibald, 1982; Archibald and Clemens, 1984
12	Type Lance Fm.	Wyoming	Lancian	Clemens, 1963, 1966, 1973a; Fox, 1974; Clemens et al., 1979; Archibald, 1982
13	North Horn Fm.	Utah	Lancian	Clemens, 1961; Clemens et al., 1979

Taxon	Area												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Triconodonta													
<i>Alticonodon lindoei</i>	+												
?Triconodontidae, n. gen. and sp.	+												
Multituberculata													
<i>Mesodma formosa</i>									+			+	
<i>Mesodma</i> cf. <i>M. formosa</i>											+		
<i>Mesodma hensleighi</i>									+		+	+	

TABLE 10—(Continued)

[illegible]

TABLE 10—(Continued)

Taxon	Area												
	1	2	3	4	5	6	7	8	9	10	11	12	13
cf. <i>Picopsis</i> sp.	+												
Tribosphenic upper molar	+												
<i>Falepetrus barwini</i>						+							
<i>Bistius bondi</i>								+					
Marsupialia													
<i>Alphadon creber</i>	+												
<i>Alphadon halleyi</i>			+	+	+	+							
<i>Alphadon russelli</i>			+		+	+							
<i>Alphadon lulli</i>					+	+					+	+	
<i>Alphadon sahnii</i>			+	+	+	+							
<i>Alphadon marshi</i>								?+	+		+	+	
<i>Alphadon</i> cf. <i>A. marshi</i>								+					
<i>Alphadon wilsoni</i>									+		+	+	
<i>Alphadon attaragos</i>					+								
<i>Alphadon praesagus</i>			+	+									
<i>Alphadon rhaister</i>							?+		+		+	+	
<i>Alphadon</i> cf. <i>A. rhaister</i>												+	
<i>Alphadon</i> sp.	+	+											
<i>Alphadon</i> ?, n. sp.								+					
cf. <i>Peradectes</i> sp.								+					
<i>Glasbuis intricatus</i>												+	
<i>Glasbuis twitchelli</i>											+		
<i>Albertatherium primus</i>	+												
Didelphidae, gen. and sp. indet.										+			
<i>Pediomys exiguus</i>	+												
<i>Pediomys clemensi</i>			+	+									
<i>Pediomys</i> sp. A			+										
<i>Pediomys prokrepjii</i>			+										
<i>Pediomys cooki</i>											+	+	
<i>Pediomys</i> cf. <i>P. cooki</i>							+	+					
<i>Pediomys elegans</i>									+		+	+	
<i>Pediomys</i> cf. <i>P. elegans</i>			+										
<i>Pediomys florencae</i>											+	+	
? <i>Pediomys</i> cf. <i>P. florencae</i>											+		
<i>Pediomys hatcheri</i>									+		+	+	+
<i>Pediomys</i> cf. <i>P. hatcheri</i>			+										
<i>Pediomys krejcii</i>									+		+	+	
<i>Pediomys</i> cf. <i>P. krejcii</i>							+						
<i>Pediomys</i> sp.					+								
? <i>Pediomyidae</i>				+									
<i>Aquiladelphus incus</i>	+												
<i>Aquiladelphus minor</i>	+												
<i>Eodelphis cutleri</i>	+		+	+			?+						
<i>Eodelphis browni</i>			+										
<i>Eodelphis</i> sp.	+		+	+									
<i>Eodelphis</i> ? sp.							+						
<i>Didelphodon vorax</i>									+		+	+	
<i>Didelphodon</i> ? sp.							+						
Eutheria													
<i>Gypsonictops lewisi</i>			+	+		+							
<i>Gypsonictops</i> , n. sp.								+					

TABLE 10—(Continued)

Taxon	Area												
	1	2	3	4	5	6	7	8	9	10	11	12	13
<i>Gypsonictops</i> sp.							+						
<i>Gypsonictops hypoconus</i>									+		+	+	
<i>Gypsonictops illuminatus</i>									+				
<i>Gypsonictops</i> cf. <i>G. illuminatus</i>											+		
<i>Cimolestes</i> sp.							+						
cf. <i>Cimolestes</i> sp.								+					
<i>Cimolestes incisus</i>											+	+	
<i>Cimolestes magnus</i>									+		+	+	
<i>Cimolestes cerberoides</i>									+				
<i>Cimolestes</i> cf. <i>C. cerberoides</i>										+	+		
<i>Cimolestes propalaeoryctes</i>									+		+		
<i>Cimolestes stirtoni</i>											+	+	
<i>Batodon tenuis</i>									+		+	+	
<i>Procerberus formicarum</i>											+		
Palaeoryctidae, gen. and sp. undet.			+										
<i>Telacodon laevis</i>												+	
<i>Paranyctoides maleficus</i>	+												
<i>Paranyctoides sternbergi</i>			+										
<i>Paranyctoides megakeros</i>					+								
Insectivora, n. gen. and sp. A	+												
Insectivora, n. gen. and sp. B	+												
<i>Protungulatum donnae</i>											+		
<i>Protungulatum</i> cf. <i>P. donnae</i>										+			
<i>Protungulatum gorgun</i>											+		
<i>Ragnarok harbichti</i>											+		
<i>Oxyprimus erikseni</i>											+		
<i>Mimatuta morgoth</i>											+		
<i>Purgatorius ceratops</i>											+		
Eutherian?	+												

^a Although received too late to be incorporated within the table, Johnston and Fox (1984) reported the following mammals from the base of the Ravenscrag Formation (which overlies the Frenchman Formation), latest Lancian in age, from southwestern Saskatchewan: *Mesodma thompsoni*, *Catopsalis*, n. sp., *Cimexomys* cf. *C. hausoi*, *Alphadon* sp., *Pediomys elegans*, *Procerberus* cf. *P. formicarum*, *Protungulatum* cf. *P. donnae*, *Oxyprimus* cf. *O. erikseni*, *?Oxyprimus* sp., *Ragnarok* sp., and *?Mimatuta* sp.

temporal correlation of North American Tertiary nonmarine rocks that was based on assemblages of mammalian fossils. Although heavily modified since its publication (see, for example, Woodburne, in press), the North American Provincial Ages developed by the Wood committee have been used extensively and successfully (see excellent review by Tedford, 1970) in geological and paleobiological research across the continent. Savage (1962) suggested modification of the name to North American Land-Mammal "Ages," leading to the acronym (NALMA), commonly used today.

Despite their long-standing success in practice, NALMAs do not fit precisely within definitions of any formalized category established for purposes of correlation or description by the general geological community (see ACSN, 1970 and references therein; and NACSN, 1983). The key elements of NALMAs are specified within the following quotation, often overlooked, from the Wood committee report (1941, p. 6):

... they are meant to cover all of Tertiary time, without reference to whether each year, century, or millennium is represented by a known fau-

nule or stratum. The type of each age necessarily belongs to it, and the sequence and approximate scopes of the ages are thus intended to be definitely fixed (barring new discoveries which should lead to radically different interpretations). However, the ages are not necessarily coextensive with their types, and the precise limits between successive ages are intended to be somewhat flexible and may presumably be modified in the light of later discoveries.

It is clear that NALMAs were intended to represent time units, as indicated above and by the very use of the term "ages." According to present formalized usage (NACSN, 1983), however, an "age" (Art. 80) is a geochronologic unit that "... corresponds to the time span of an established chronostratigraphic unit (articles 65 and 66), and its beginning and ending corresponds to the base and top of the referent." According to the NACSN (1983, Art. 66), a chronostratigraphic unit "... is a body of rock established to serve as the material reference for all rocks formed during the span of the same time." Under that definition, the boundaries of time of any geochronologic unit (age, epoch, period, etc.) are synchronous (i.e., occur at the same time) with its chronostratigraphic (material) reference rock unit.

As unequivocally stated in the above quotation from the Wood committee, the temporal limits of a NALMA are not restricted by the time represented within the type section (chronostratigraphic referent unit) of any given NALMA. As discussed by Tedford (1970), that is the reason why Savage (1962) suggested use of quotation marks around the word "age" when used in reference to NALMAs; the term does not match exactly the concept used by the general geological community. The formalized terminology of a geochronologic unit (NACSN, 1983, p. 848) and a NALMA agree in being purely conceptual, dealing solely with geologic time, but differ in that the former has limits defined by a material (lithostratigraphic) referent while the latter has flexible limits.

The definition of a NALMA does not fit within concepts of biostratigraphic units as considered by the NACSN (1983, Arts. 48–54); no form of biozone is implied within the definition of a NALMA.

DORF'S LANCIAN AGE

Dorf (1942, p. 105) recognized the need for a temporal term for the time of deposition of the Lance Formation:

Definition of Lancian age—There does not exist at present a clearly defined temporal term for the latest Cretaceous of the Rocky Mountain region. For the practical purposes of clarity and precision it is here proposed to use Lancian age as a convenient provincial time term, based on the Lance Formation at its type locality near Lance Creek, Niobrara County, Wyoming. This time unit is delimited below by true Fox Hills time (i.e., latest Montanan age, characterized by marine sandstones comprising the well-defined *Sphenodiscus* zone), and delimited above by the beginning of Paleocene time. The terrestrial sediments of Lancian age carry the characteristic mammals¹ and dinosaurs² of the *Triceratops* zone, as well as the plants here described.

¹ Wood, H. E., et al., Bull. Geol. Soc. Amer., vol. 52, 8, 1941.

² Russell, L. S., Proc. Amer. Philos. Soc., vol. 69, 139–141, 1930.

It is debatable whether Dorf thereby defined a true age, a NALMA, or merely a geochron (temporal duration of a rock unit—in this case, the Lance Formation). We believe that Dorf was attempting to create a NALMA in the manner of the Wood committee (Wood et al., 1941), which he cited, but that he failed because his Lancian age is, in reality, either: (1) bounded earlier by Fox Hills time and later by Paleocene time; or (2) is the time during which the type Lance Formation was deposited. The fossils of the Lance Formation were used to identify this time, to be sure, but they do not define it.

THE NATURE OF RUSSELL'S STAGES

L. S. Russell (1964, 1975) attempted to establish a system of biological correlation for nonmarine rocks of Early and Late Cretaceous age in the North American western interior. Although similar in some respects to the concept of NALMAs as used for the Cenozoic, Russell's system of units was more broadly based, including in the definitions nonmammalian vertebrates, freshwater molluscs, and a few plants in addition to mammalian assemblages. Russell's (1975) approach to terminology and concept also

TABLE 11
Summary of Stratigraphic Distributions of Mammalian Taxa from the North American
Western Interior Late Cretaceous
See table 10 for more detailed information. See text concerning nature of "Edmontonian."

Taxon	Aquilan	Judithian	"Edmon- tonian"	Lancian
<i>Alticonodon lindoei</i>	x			
?Triconodontidae, n. gen. and sp.	x			
<i>Mesodma senecta</i>	x			
<i>Mesodma</i> sp.	x	x	x	x
<i>Cimexomys antiquus</i>	x			
<i>Paracimexomys magister</i>	x			
<i>Cimolodon electus</i>	x			
<i>Cimolodon similis</i>	x			
? <i>Cimolomys</i> sp. A	x			
? <i>Cimolomys</i> sp. B	x			
<i>Meniscoessus ferox</i>	x			
<i>Viridomys orbatus</i>	x			
<i>Symmetrodontoides canadensis</i>	x			
<i>Potamotelses aquilensis</i>	x			
<i>Picopsis pattersoni</i>	x			
cf. <i>Picopsis</i> sp.	x			
Tribosphenic upper molar	x			
<i>Alphadon creber</i>	x			
<i>Alphadon</i> sp.	x	x		x
<i>Albertatherium primus</i>	x			
<i>Pediomys exiguus</i>	x			
<i>Aquiladelphis incus</i>	x			
<i>Aquiladelphis minor</i>	x			
<i>Eodelphis cutleri</i>	x	x	?	
<i>Eodelphis</i> sp.	x	x		
<i>Paranyctoides maleficus</i>	x			
Insectivora, n. gen. and sp. A	x			
Insectivora, n. gen. and sp. B	x			
Eutherian?	x			
<i>Mesodma primaeva</i>		x		
<i>Paracimexomys judithae</i>		x		
<i>Paracimexomys magnus</i>		x		
<i>Paracimexomys priscus</i>		x		x
<i>Cimolodon</i> sp.		x	x	
<i>Cimolomys clarki</i>		x		
<i>Meniscoessus intermedius</i>		x		
<i>Meniscoessus major</i>		x		
Multituberculate, suborder, family incertae sedis		x		
Dryolestidae, gen. and sp. unident.		x		
cf. <i>Deltatheroides</i> sp.		x		x
<i>Falepetrus barwini</i>		x		
<i>Alphadon halleyi</i>		x		
<i>Alphadon russelli</i>		x		
<i>Alphadon lulli</i>		x		x
<i>Alphadon sahnii</i>		x		
<i>Alphadon attaragos</i>		x		
<i>Alphadon praesagus</i>		x		
<i>Pediomys clemensi</i>		x		
<i>Pediomys</i> sp. A		x		
<i>Pediomys prokrejci</i>		x		

TABLE 11—(Continued)

Taxon	Aquilan	Judithian	"Edmon-tonian"	Lancian
<i>Pediomys</i> cf. <i>P. elegans</i>		x		
<i>Pediomys</i> cf. <i>P. hatcheri</i>		x		
<i>Pediomys</i> sp.		x		
? <i>Pediomyidae</i>		x		
<i>Eodelphis browni</i>		x		
<i>Gypsonictops lewisi</i>		x		
<i>Palaeoryctidae</i> , gen. and sp. undet.		x		
<i>Paranyctoides sternbergi</i>		x		
<i>Paranyctoides megakeros</i>		x		
<i>Mesodma</i> cf. <i>M. thompsoni</i>			x	
<i>Mesodma</i> ? sp.			x	
<i>Paracimexomys</i> cf. <i>C. judithae</i>			x	
<i>Kimbetohia campi</i>			x	
<i>Cimolodus nitidus</i>			x	x
<i>Cimolomys gracilis</i>			x	x
<i>Eucosmodontidae</i> , n. gen. and sp.			x	
<i>Meniscoessus conquistus</i>			x	
<i>Meniscoessus robustus</i>			x	x
<i>Alphadon marshi</i>			?	x
<i>Alphadon</i> cf. <i>A. marshi</i>			x	
<i>Alphadon rhaister</i>			?	x
<i>Alphadon</i> ?, n. sp.			x	
cf. <i>Peradectes</i> sp.			x	
<i>Pediomys</i> cf. <i>P. cooki</i>			x	
<i>Peidomys</i> cf. <i>P. krejci</i>			x	
<i>Eodelphis</i> ? sp.			x	
<i>Didelphodon</i> ? sp.			x	
<i>Gypsonictops</i> , n. sp.			x	
<i>Gypsonictops</i> sp.			x	
<i>Cimolestes</i> sp.			x	
cf. <i>Cimolestes</i> sp.			x	
<i>Mesodma formosa</i>				x
<i>Mesodma</i> cf. <i>M. formosa</i>				x
<i>Mesodma hensleighi</i>				x
<i>Mesodma thompsoni</i>				x
? <i>Neoplagiaulax burgessi</i>				x
? <i>Neoplagiaulacidae</i> , gen. and sp. indet.				x
<i>Cimexomys minor</i>				x
<i>Cimexomys</i> cf. <i>C. hausoi</i>				x
<i>Ptilodontidae</i> , gen. and sp. undet.				x
<i>Catopsalis joyneri</i>				x
<i>Catopsalis</i> n. sp.				x
<i>Stygimys kuszmauli</i>				x
<i>Stygimys</i> aff. <i>S. kuszmauli</i>				x
<i>Cimolomys trochuus</i>				x
<i>Essonodon browni</i>				x
<i>Bistius bondi</i>				x
<i>Alphadon wilsoni</i>				x
<i>Alphadon</i> cf. <i>A. rhaister</i>				x
<i>Glasbius intricatus</i>				x
<i>Glasbius twitchelli</i>				x
<i>Didelphidae</i> , gen. and sp. indet.				x
<i>Pediomys cooki</i>				x

TABLE 11—(Continued)

Taxon	Aquilan	Judithian	"Edmon- tonian"	Lancian
<i>Pedimys elegans</i>				x
<i>Pedimys florencae</i>				x
? <i>Pedimys</i> cf. <i>P. florencae</i>				x
<i>Pedimys hatcheri</i>				x
<i>Pedimys krejci</i>				x
<i>Didelphodon vorax</i>				x
<i>Gypsonictops hypoconus</i>				x
<i>Gypsonictops illuminatus</i>				x
<i>Gypsonictops</i> cf. <i>G. illuminatus</i>				x
<i>Cimolestes incisus</i>				x
<i>Cimolestes magnus</i>				x
<i>Cimolestes cerberoides</i>				x
<i>Cimolestes</i> cf. <i>C. cerberoides</i>				x
<i>Cimolestes propalaeoryctes</i>				x
<i>Cimolestes stirtoni</i>				x
<i>Batodon tenuis</i>				x
<i>Procerberus formicarum</i>				x
<i>Procerberus</i> cf. <i>P. formicarum</i>				x
<i>Telacodon laevis</i>				x
<i>Protungulatum donnae</i>				x
<i>Protungulatum</i> cf. <i>P. donnae</i>				x
<i>Protungulatum gorgun</i>				x
<i>Ragnarok harbichti</i>				x
<i>Ragnarok</i> sp.				x
<i>Oxyprimus erikseni</i>				x
<i>Oxyprimus</i> cf. <i>O. erikseni</i>				x
? <i>Oxyprimus</i> sp.				x
<i>Mimatuta morgoth</i>				x
? <i>Mimatuta</i> sp.				x
<i>Purgatorius ceratops</i>				x

differed from those involved in NALMAs. Russell considered his units to be chronostratigraphic in nature (stages in the sense of ACSN, 1970), relating times of existence of specific organisms to the physical limits of particular rock units. Such usage is exhibited in his text-figure 6 (1975, p. 158) in which discrete time gaps are seen between the limits, for example, of the Aquilan and Judithian or the Judithian and Edmontonian; each stage in Russell's scheme relates to faunal assemblages within strata representing deposition during distinct time units. No such gaps between the various "ages" are seen in plate 1 of Wood et al. (1941).

It seems clear from Russell's (1975, p. 138) introductory remarks that he intended the provincial subdivision of the Cretaceous (Russell, 1964, 1975) to be similar in concept

and utility to what had been done so successfully for the Cenozoic by way of NALMAs. He was quite incorrect, however, in stating that the NALMAs as originally defined "... are, more accurately, the equivalents of the European stages, now considered to be time-rock terms, designating the time of deposition of certain formations characterized by distinctive faunas." NALMAs, in contrast to stages, are not restricted in their definition by time represented within a particular stratigraphic type section. For historical reasons based in part upon a misconception, therefore, Russell's subdivisions for the Cretaceous (his stages) differ in fundamental concept, and thereby in practical utility, from Cenozoic North American land-mammal "ages" (of Wood et al., 1941).

A further problem exists in that Russell's

stages (of 1964 and 1975) were not properly formalized under the then-existing (ACSN, 1970, Art. 26a) or presently existing (NACSN, 1983, Art. 76) rules of stratigraphic nomenclature; the upper and lower limits of the stages were not defined at specified type sections within type areas in order to provide standards for the units. Without such standards, the units are meaningless. Thus, speaking practically, Russell's stages were inadequately defined and, technically, they are invalid.

NEW LATE CRETACEOUS LAND-MAMMAL "AGES"

GENERAL DISCUSSION

Fox (1978) updated the vertebrate paleontological definitions of Russell's (1964, 1975) nonmarine subdivisions of the North American Late Cretaceous. As Fox pointed out, as knowledge of Late Cretaceous mammals has increased, characterization of Russell's units has shifted nearly exclusively to mammalian assemblages. We follow that procedure in the sections below, in which we revise Dorf's and Russell's terminology from a chronostratigraphic basis to the philosophy employed within the North American land-mammal "ages." As has been the practice with terrestrial faunas described from rocks of Cenozoic age, paleontochronologic ranges of nonmammalian organisms can readily be considered within the framework of NALMAs. Only Late Cretaceous (i.e., Aquilan-Lancian) ages are considered, and the summaries (presented as much as possible in the style employed by Wood et al., 1941) are derived from data in tables 10 and 11.

We employ the same nomenclature (i.e., Aquilan-Lancian) established by Dorf (1942) and Russell (1964, 1975). Although a case could be made for using new terms to reduce confusion between the concepts employed here versus those originally defined by Dorf and by Russell, in practice most usage to date, rightly or wrongly, has not differed significantly from the intention implied within NALMAs. We feel, therefore, that confusion would be less by retaining Dorf's and Russell's terminology than by coining new terms.

Despite extensive recent research on North American Late Cretaceous mammalian as-

semblages, knowledge of the faunas (except perhaps for the Lancian) is low in comparison with those characteristic of most Cenozoic "ages." For that reason, the previously used system of faunal definitions (i.e., index fossils, first appearances, and characteristic fossils) must be given careful consideration. For example, immediately pre-Aquilan mammalian faunas are unknown, negating reality within the Aquilan for such categories as index fossils, first appearances, and characteristic fossils. Present listings and discussion are limited to the categories of first appearances (if the taxon is also known from younger rocks), last appearances (if the taxon is also known from older rocks), and unique occurrences (if the taxon is known only from a particular age).

The reader is cautioned to recognize the primitive nature of the unique occurrences category (based largely upon which species are *unknown* from older or younger rocks) and to realize that monographic inconsistencies in taxonomy make the category less reliable than what is ordinarily implied for the concept of an index fossil. For example, *Mesodma* sp. (see tables 10 and 11) occurs in all of the named Late Cretaceous "ages," but available material is inadequate to permit: (1) recognition and diagnosis of a new species; or (2) recognition of conspecificity with members of younger or older faunas. Nevertheless, knowledge of Late Cretaceous mammalian faunas from the western interior is on the threshold of practical utility for detailed geologic correlation of nonmarine rock units.

It could also be argued, with considerable justification, that it is premature even to attempt definition of Late Cretaceous NALMAs. Basically, we agree with that thought. Nevertheless, the terms have existed for more than two decades, and are commonly used in published evolutionary and geologic research. Our purposes are merely to: (1) summarize the present state of knowledge on the subject; (2) provide a practical framework of constraints upon which to build and refine geochronologic concepts as available information grows; (3) clarify specifically where additional research is needed most critically; and (4) encourage stability in concept and practice in use of the "ages."

The Edmontonian (Russell, 1964, 1975) causes a special problem. As can be seen from study of table 11, an Edmontonian NALMA is presently indefensible as defined on the basis of fossil mammals. Most species from rocks referred to L. S. Russell's Edmontonian stage (table 10) are either: (1) conspecific with representatives of the Lancian "age" (of present context); and/or (2) so poorly known as to have low degrees of certainty of identification. Nevertheless, comparisons of dinosaurian assemblages (see, for example, Langston, 1959; D. A. Russell, 1967, 1970, 1972; D. A. Russell and Chamney, 1967; Dodson, 1971; L. S. Russell, 1983) derived from strata referred to L. S. Russell's Edmontonian stage suggest the reality of a discrete interval of geologic time intermediate in age between the Judithian and Lancian "ages."

Thus we are suggesting that, with further fieldwork, an Edmontonian NALMA may eventually be documentable on the basis of fossil mammals; as presently represented in collections, however, it cannot be justified. In short, we are placed in the unsettling position of recognizing the probable existence of a discrete interval of geologic time that is not yet documentable using the criterion of choice (i.e., mammalian species) employed in the present paper. We suspect that the situation is analogous to how the Clarkforkian NALMA of the North American late Paleocene-early Eocene was considered prior to rejuvenated fieldwork, development of a solid biostratigraphic framework, and subsequent thorough review of the concept by Rose (1981).

Similar, but less severe, problems exist with the Aquilan, Judithian, and Lancian NALMAs as defined below. The Aquilan is defined by a single fauna with an extremely limited geographic distribution, presently known only from a small area of southern Alberta. The Judithian is defined according to faunas from northerly realms (central Wyoming to southern Alberta). Because of uncertainties of identifications of mammalian fossils, we are unsure of how faunas from the upper Fruitland and lower Kirtland formations of northwestern New Mexico (see Clemens et al., 1979, p. 42; Flynn, in press) relate in time to the more northerly assemblages. Present

correlations between the two areas are tenuous.

Problems exist both at the beginning and at the end of the Lancian NALMA. Definition of the earlier extreme is hampered by the paucity of information available to limit an Edmontonian "age," as discussed above. The end of the Lancian (see Clemens et al., 1979; Archibald, 1982), as observed in the Hell Creek Formation in northeastern Montana, is presently under active research by William A. Clemens, J. David Archibald, and others. The problem of the age of the "Bug Creek faunal facies" (see Clemens et al., 1979, pp. 47-50; Smit and van der Kaars, 1984) has yet to be resolved. The following is a quotation from a letter from Clemens to Lillegraven (November 1983) that summarizes the situation as it presently stands: "Arguments on stage of evolution of Bug Creek faunal facies organisms (multituberculates and condylarths) indicate they are older than the oldest, certainly Puercan (post-dinosaur) faunas. However, are they of Cretaceous age? I still suspect they are but cannot demonstrate it. Therefore I suggest that you indicate the Lancian taxa that are limited to the Bug Creek faunal facies." Lancian taxa restricted to or beginning in the "Bug Creek faunal facies" are marked with asterisks in the definition of the Lancian "age," below. Mammalian taxa (see footnote to table 10) closely related to those otherwise known only from the "Bug Creek faunal facies" were reported recently by Johnston and Fox (1984) from the base of the Ravenscrag Formation of southwestern Saskatchewan in association with several varieties of dinosaurs. Johnston and Fox (1984, p. 215) interpreted the faunas as representing very latest Lancian time.

DEFINITIONS OF "AGE" TERMS

As was the procedure of Wood et al. (1941, p. 8) some doubtfully referred or inadequately documented specimens are intentionally ignored; the lists, therefore, are less complete than those provided in tables 10 and 11. The system used here differs from that of Wood et al. (1941) in our emphasis on species-level (rather than generic) taxonomy. The proposed time units are presented in order of

decreasing relative geologic age. "Characteristic fossils" are not defined. Because of problems discussed above, an Edmontonian "age" is not defined on the basis of mammals as a new provincial time term.

AQUILAN "AGE"

The Aquilan "age" is defined as a new provincial time term, based on mammalian fauna from upper part of Milk River Formation of southern Alberta, faunal type area in Verdigris Coulee, 29 km east of village of Milk River. The name Aquilan is in reference to the Eagle Sandstone with which the Milk River Formation intergrades (Sahni, 1972).

PRINCIPAL MAMMALIAN FAUNAL CORRELATIVES: None known.

FIRST APPEARANCE: *Eodelphis cutleri*.

UNIQUE OCCURRENCES: *Alticonodon lindoei*, ?Triconodontidae (new genus and species), *Mesodma senecta*, *Cimexomys antiquus*, *Paracimexomys magister*, *Cimolodon electus*, *Cimolodon similis*, ?*Cimolomys* sp. A, ?*Cimolomys* sp. B, *Meniscoessus ferox*, *Viridomys orbatus*, *Symmetrodontoides canadensis*, *Potamotelses aquilensis*, *Picopsis pattersoni*, cf. *Picopsis* sp., *Alphadon creber*, *Albertatherium primus*, *Pediomys exiguus*, *Aquiladelphus incus*, *Aquiladelphus minor*, Insectivora (new genus and species A), Insectivora (new genus and species B), eutherian?

COMMENT: The Aquilan mammalian fauna is unique, with only one species presently known to occur in a younger "age."

JUDITHIAN "AGE"

The Judithian "age" is a new provincial time term, based upon mammalian fauna from Judith River Formation of north-central Montana, faunal type area adjacent to Chouteau and Blaine county line in breaks a few kilometers north of Missouri River. Principal mammalian faunal correlatives: Faunas from Oldman Formation (southern Alberta), Judith River Formation (northernmost Montana; unpublished fauna under study by W. A. Clemens), "Mesaverde" Formation (Bighorn and Wind River basins, Wyoming).

FIRST APPEARANCES: *Paracimexomys priscus*, cf. *Deltatheroides* sp., *Alphadon lulli*.

LAST APPEARANCES: None recognized.

UNIQUE OCCURRENCES: *Mesodma primaeva*, *Paracimexomys judithae*, *Paracimexomys magnus*, *Cimolomys clarki*, *Meniscoessus intermedius*, *Meniscoessus major*, *Multituberculata* (suborder and family incertae sedis), *Dryolestidae* (genus and species unidentified), *Falepetrus barwini*, *Alphadon halleyi*, *Alphadon russelli*, *Alphadon sahnii*, *Alphadon attaragos*, *Alphadon praesagus*, *Pediomys clemensi*, *Pediomys* sp. A, *Pediomys prokrejci*, *Eodelphis browni*, *Gypsonictops lewisi*, *Palaeoryctidae* (genus and species undetermined), *Paranyctoides sternbergi*, *Paranyctoides megakeros*.

COMMENT: The Judithian "age" is highly diagnostic in its mammalian fauna; only three species are recognized that continue into younger strata.

LANCIAN "AGE"

The Lancian "age" is a new (or modified) provincial time term, based upon mammalian fauna from type Lance Formation of east-central Wyoming in Niobrara County, faunal type area in valleys of Lance Creek and its tributaries north of town of Lance Creek. Principal mammalian faunal correlatives: Faunas from Scollard Formation (south-central Alberta), Frenchman Formation (southwestern Saskatchewan), basal Ravenscrag Formation (southwestern Saskatchewan), Hell Creek Formation (northeastern Montana), Lance Formation (Bighorn Basin and Rock Springs Uplift, Wyoming), Laramie Formation (northeastern Colorado), and lower part of North Horn Formation (central Utah).

LAST APPEARANCES (including taxa recorded from strata referred to Russell's, 1964 and 1975, Edmontonian stage; see tables 10 and 11): *Paracimexomys priscus*, cf. *Deltatheroides* sp., *Alphadon lulli*, *Cimolodon nitidus*, *Cimolomys gracilis*, *Meniscoessus robustus*, *Alphadon marshi*, *Alphadon rhaister*.

UNIQUE OCCURRENCES (taxa restricted to or beginning with "Bug Creek faunal facies" marked with asterisks): *Mesodma hensleighi*, ?*Neoplagiaulax burgessi*, *Cimexomys minor*, **Catopsalis joyneri*, **Stygimys kuszmauli*, **Stygimys* aff. *S. kuszmauli*, *Cimolomys trochuus*, *Essonodon browni*, *Bistius bondi*, *Al-*

phadon wilsoni, *Glasbius intricatus*, *Glasbius twitchelli*, *Pedionomys cooki*, *Pedionomys elegans*, *Pedionomys florencae*, *Pedionomys hatcheri*, *Pedionomys krejci*, *Didelphodon vorax*, *Gypsonictops hypoconus*, *Gypsonictops illuminatus*, *Cimolestes incisus*, *Cimolestes magnus*, *Cimolestes cerberoides*, *Cimolestes propalaeoryctes*, *Cimolestes stirtoni*, *Batodon tenuis*, **Procerberus formicarum*, *Telacodon laevis*, **Protungulatum donnae*, **Protungulatum* cf. *P. donnae*, **Protungulatum gorgun*, **Ragnarok harbichti*, **Oxyprimus erikseni*, **Mimatuta morgoth*, **Purgatorius ceratops* (questionable record).

COMMENT: As discussed above, the younger limit of the Lancian "age" (see Johnston and Fox, 1984) is under active research by W. A. Clemens, J. David Archibald, and others. Tentatively, Clemens and Archibald are recognizing "Premantuan" and "Mantuan" faunal assemblages that are post-Lancian in age and appear to straddle the Mesozoic-Cenozoic boundary. Some species from the "Bug Creek faunal facies" (marked with asterisks in list of Unique Occurrences, above) appear to continue upward into the "Premantuan" and younger faunas (see Archibald, 1982, and Archibald and Clemens, 1984, for preliminary evaluations). Thus, upon further documentation of post-Lancian faunas, some species listed above as unique occurrences may be considered first occurrences.

CORRELATION OF MAMMAL-BEARING LATE CRETACEOUS FORMATIONS OF MONGOLIA

In the Mongolian People's Republic (MPR), fossil mammals have been recovered from rocks of Late Cretaceous age at a few localities (see Clemens et al., 1979, pp. 34-37 for review) in the nonmarine Djadokhta and Barun Goyot formations and possibly at a Late Cretaceous site of undetermined stratigraphic position near Bugeen Tsav. For geographic details and discussion of the faunas, see Gradzinski et al. (1977, fig. 1). Attempts to determine ages of faunas recovered from these Asian Late Cretaceous continental sediments have not had the benefit of radioisotopic or magnetostratigraphic data and have involved biostratigraphic methods alone, usually with-

out clearly stated methodology (e.g., Guo, 1984).

Generally, as studies have progressed in recent years, the postulated ages of these Late Cretaceous sites have become younger and younger within a Late Cretaceous context, with the Djadokhta Formation coming to be regarded as approximately equal in age to the Judith River Formation of North America; the other Asian Late Cretaceous sites, believed to be younger still, are therefore generally thought to be compressed into the late Campanian and Maastrichtian. Thus the Barun Goyot Formation, including the redbeds of Khermeen Tsav (Khermeen Tsav Formation of Kielan-Jaworowska, 1974a; see Kielan-Jaworowska, 1979, p. 6; Rozhdestvenskii, 1977, p. 109), is generally regarded to be slightly younger than the Djadokhta Formation, although the physical relationships are unknown and the type Barun Goyot is some distance from the type Djadokhta. Rozhdestvenskii (1977, p. 109) assigned the Khermeen Tsav beds a Campanian-Maastrichtian age. In the same year, Barsbold (1977) assigned an early Campanian age to the lower part of the Barungoiotskaya Svita near Khermeen Tsav and referred to the upper Barungoiostkaya Svita as late Campanian.

In any case, the Nemegt Formation physically overlies the Barun Goyot Formation (Gradzinski et al., 1977, fig. 12) and is, therefore, aside from any possible time-transgressive boundary problems, younger than the Barun Goyot Formation. Thus far, the Nemegt Formation has not yielded mammals, but its age has a direct bearing on the age of the underlying Barun Goyot Formation and, therefore, indirectly on that of the Djadokhta Formation. The Bugeen Tsav locality has not been fitted with certainty into the stratigraphic scheme. The multituberculate *Buginbaatar*, the sole fossil mammal reported from Bugeen Tsav, has been assigned the age of late Maastrichtian or early Paleocene (Kielan-Jaworowska and Sochava, 1969; Kielan-Jaworowska, 1974b). Trofimov (1975) and Badamgarav and Reshetov (1976) regarded *Buginbaatar* as questionably early Paleocene in age. In a more recent paper, Gradzinski et al. (1977, p. 302) regarded the beds at Bugeen Tsav (at Khaichin-Ula I, part of the Svita

Dzunmod of Russian authors) as biostratigraphic equivalents of the Nemegt Formation on the basis of (mainly unpublished) Russian work. Rozhdestvenskii (1977, p. 109) has stated that the age is the same (Maastichtian in his view) as that of the "Nemegetu." Much work remains to be accomplished before the stratigraphic and biostratigraphic relationships of these vaguely defined units can be stated more clearly. The following historical summary represents an attempt to keep track of what has been said, often in obscure reports, and is admittedly more exhausting than exhaustive. We begin with the Djadokhta Formation.

The Djadokhta Formation (Berkey *in* Granger and Gregory, 1923, p. 8; Berkey and Morris, 1927) yielded the first Cretaceous mammals known from Asia. The type locality of the Djadokhta Formation is at Bayn Dzak (lat. 44°12'N, long. 103°44'E) northeast of Bulgan, MPR. Estimates of age of the Djadokhta Formation have ranged widely. Early papers (e.g., Simpson, 1925, 1928; Gregory and Simpson, 1926; but also as late as Marinov, 1957) wisely referred the Djadokhta to Late (or Upper) Cretaceous, without attempting further refinement. However, the primitive nature of the "pre-ceratopsian" dinosaur *Protoceratops andrewsi* from the Djadokhta Formation led many workers to suspect that the Djadokhta was not of latest Cretaceous age (Granger and Gregory, 1923). No attempts were made in these early papers to relate the Djadokhta Formation to Cretaceous marine stages/ages based on European stratotypes, nor could this have been done. In the absence of fossiliferous marine interbeds, radioisotopic dating, or magnetostratigraphy, attempts since the 1920s to place the Djadokhta Formation into a temporal framework have remained crude. Age estimates have been based on "stage of evolution" of Asian forms and on biostratigraphic comparisons of various sorts (Gradzinski et al., 1977; Fox, 1978), generally with North American forms rather than with European ones. However, these efforts have been difficult because of endemism of many organisms involved. Moreover, correlation with marine stages/ages unfortunately cannot be accomplished directly, although such correlations are incorrectly implied by much of

the previously published comment on Mongolian Late Cretaceous units.

Novozhilov (1954), Rozhdestvenskii (1957), and Van Valen (1966) concluded that the mammals of the Djadokhta Formation might not have been derived from that unit at all, but rather were let down onto the present Djadokhta surface from some now-missing, overlying, younger unit of Tertiary age, possibly as young as the North American Clarkforkian near the Paleocene/Eocene boundary (Van Valen, 1966, p. 51). However, this divergent train of thought was soon put to rest by Kielan-Jaworowska (1969), who reported the same species of mammals in situ within the Djadokhta Formation.

Sahni (1968, p. 343) remarked in passing that the Djadokhta beds are Cenomanian-Turonian in age. His estimate postulated the oldest age of which we are aware. It may have reflected unpublished opinion of the time, but no rationale was given. Later, Sahni (1972, p. 325) repeated the estimate of Cenomanian or Turonian age, attributing it to Kielan-Jaworowska ([1968], actually 1969).

Gradzinski et al. (1969, p. 37), evidently on the basis of a draft of the manuscript of Kielan-Jaworowska's (1969) paper rather than the corrected published version, remarked in passing that the Djadokhta Formation is of Turonian or Santonian age. However, at the time of publication of her papers, Kielan-Jaworowska (1969, 1970a, 1970b; see also Clemens, 1970 and Lefeld, 1971) estimated the Djadokhta Formation to be Coniacian or Santonian in age. This determination was based on fossil mammals which, at that time, were thought intermediate in stage of evolution between those of the Paluxian (Slaughter, 1965; L. S. Russell, 1975) Forestburg site of Texas and the Judithian of Montana and Alberta. In this conclusion, Kielan-Jaworowska was influenced by the opinions of Dr. R. E. Sloan (Kielan-Jaworowska, 1969, p. 173). Thus, she was considering North American biostratigraphic units *believed to be* equivalent in age to the European-based marine Albian and mid-Campanian, respectively, as calibration points on which to base an estimate of an intermediate age.

At the same time, McKenna (1969) estimated, on the basis of his existing view of

stage of evolution of its vertebrate fauna, that the Djadokhta Formation might be equivalent in age to the marine Cenomanian stage. However, as Fox (1978) noted, this estimate is much too old. In his discussion of the fossil vertebrates of the Judith River Formation of Montana, Sahni (1972, p. 325) misquoted Kielan-Jaworowska's "1968" (actually 1969) paper, saying that the Cretaceous mammal localities of Djadokhta Formation were regarded as Cenomanian or Turonian in age. In actuality, Kielan-Jaworowska had estimated by the time the paper was published that they are Coniacian-Santonian. Rozhdestvenskii (1971, 1972, 1977, table 1) placed the Djadokhta Formation at about the Santonian-Campanian boundary, but regarded the "Belly River" of Canada as contemporary. In the standard text on the geology of Mongolia, Marinov et al. (1973, p. 479) cited unspecified work by Barsbold that the Djadokhta Formation is "Santonian-Campanian."

The next estimates of age of the Djadokhta Formation by Kielan-Jaworowska were Coniacian (1974a, 1974b) and then Santonian (1975a, 1975b). Sulimski (1975) called the Djadokhta Formation ?Santonian. However, Sloan (1976) returned the Djadokhta Formation to the Coniacian, whereas Barsbold (1977) returned to the more general term "lower Senonian." Somewhat younger estimates have been made by: (1) Rozhdestvenskii (1974, 1978) and Belyaeva et al. (1978), Campanian; (2) Fox (1977, 1978), medial Campanian (in terms of nonmarine "ages," closer to Judithian than to Aquilan); (3) Gradzinski et al. (1977) and Kielan-Jaworowska and Sloan (1979), ?upper Santonian and/or ?lower Campanian; and (4) Osmolska (1980), ?lower Campanian. Rozhdestvenskii based his estimate on biostratigraphy of dinosaurs. Fox's and Osmolska's correlations were based on a variety of fossil vertebrates believed closely related to, and in some cases probably identical to, taxa from nonmarine Cretaceous rocks in North America. These vertebrates, however, cannot be correlated directly with marine cephalopods and microfossils of the European type Santonian, Campanian, or Maastrichtian.

Recently, following evidence from studies of charophytes by Karczewska and Ziembin-

ska-Tworzydło (1983), Kielan-Jaworowska (1982, 1984) returned to earlier views, tentatively correlating the Djadokhta Formation with the boundary (or slightly older or younger) between Coniacian and Santonian. Thus, even now, there is no universal agreement on the age of the Djadokhta Formation.

The Barun Goyot Formation (originally known as the Lower Nemegt Beds: Gradzinski et al., 1969, p. 37) is based on the type locality at Khulsan (lat. 43°30'N, long. 101°7'–8'E). This formation was variously estimated to be: (1) possibly contemporaneous with, or somewhat younger than, the Djadokhta Formation (ibid.); (2) possibly Campanian (Kielan-Jaworowska and Barsbold, 1972); (3) Campanian, and possibly lower Campanian (Kielan-Jaworowska, 1974a, 1974b); (4) near or questionably mid-Campanian (Kielan-Jaworowska, 1975a, 1975b; Gradzinski et al., 1977; Osmolska, 1980; Kielan-Jaworowska and Trofimov, 1980); (5) Santonian in the lower part and Campanian in the upper part (Shuvalov and Chkhikvadze, 1975); (6) approximately equivalent in age to the North American St. Mary River and Two Medicine formations (Maryanska and Osmolska, 1975); and (7) in the younger half of the Campanian (Judithian or younger; Fox, 1978). As with the Djadokhta Formation, Fox's and Osmolska's correlations were based on a large variety of fossil vertebrates correlated to North America and then indirectly to Europe, not directly from Asia westward to Europe.

However, Stankevitch and Khand (1976, p. 361, abstract in English) dated the Barun Goyot Formation as Santonian-Maastrichtian on the basis of ostracodes, and Karczewska and Ziembinska-Tworzydło (1983) dated it as late Santonian (tentatively accepted by Kielan-Jaworowska, 1984) on the basis of charophytes. If the assumption is accepted that the Barun Goyot Formation is equal in age or slightly younger than the Djadokhta Formation, then the Djadokhta would also be late Santonian or even older if the charophyte data are to be relied upon.

The Nemegt Formation originally was known informally as the Nemegetu section of Obruchev (Marinov, 1957) and later more formally as the Upper Nemegt Beds (Gradzinski et al., 1969, p. 37). These were rede-

finned as the Nemegt Formation by Gradzinski and Jerzykiewicz (1974). Discovery of spectacular dinosaur remains in these beds following World War II by Efremov and others (Efremov, 1954; Chudinov, 1966) made these deposits justly famous.

The Nemegt Formation overlies the Barun Goyot Formation and was dated loosely as Campanian or Maastrichtian by its original formal describers. Later, it was dated as late Campanian or early Maastrichtian (Nowinski, 1971; Kielan-Jaworowska and Barsbold, 1972; Osmolska et al., 1972). Rozhdestvenskii (1971, 1972, 1974, 1977, 1978) placed the Nemegt Formation in the Maastrichtian, but nevertheless believed the Nemegt to be older than the Lance Formation of North America. Shuvalov and Chkhikvadze (1975) also correlated the Nemegt Formation with the Maastrichtian. Gradzinski et al. (1977) considered the Nemegt Formation to be ?upper Campanian and ?lower Maastrichtian. Fox (1978) made a similar estimate of its age, possibly equivalent to the Edmontonian of North America (late Campanian to early Maastrichtian in his view). Osmolska (1980) placed the Nemegt Formation in the ?late Campanian to ?Maastrichtian. Maryanska and Osmolska (1981) regarded *Saurolophus angustirostris*, a Nemegt dinosaur, as "probably not older than the late Campanian." Barsbold (1971, 1972) regarded the gastropods and pelecypods (Martinson, 1961) of the Nemegt Formation as characteristically Maastrichtian (see also Martinson, 1973, 1975; Martinson et al., 1969). Karczewska and Ziembinska (1970) as well as Kyansep-Romashkina (1975) thought that the Nemegt charophytes suggest undifferentiated Campanian-Maastrichtian age. Recently, however, Kielan-Jaworowska (1982) placed the Nemegt Formation earlier, correlating it with the North American Aquilan and the European-based lower Campanian.

Although no mammals are known from the Nemegt Formation, it superposes the Barun Goyot Formation; thus, if the Nemegt were as old as early Campanian, as Kielan-Jaworowska (1982) would have it, the Barun Goyot Formation would also be of that age or older, as would the Djadokhta Formation. On the other hand, if the Barun Goyot were equivalent in age to the Judithian (or youn-

ger), as Fox (1978) would have it, the Nemegt Formation would have to be equivalent to the Judithian (or younger, as Rozhdestvenskii, 1971, would have it). We prefer Rozhdestvenskii's interpretation, but the matter is not settled.

At present, interpretations of stratigraphic ranges of fossil vertebrates in Cretaceous Mongolian formations yield biostratigraphic correlations that conflict with the correlation based on charophytes from the same formations. However, we tentatively accept Fox's correlation on the basis of the whole vertebrate fauna of the mammal-bearing Djadokhta and Barun Goyot formations. We believe that the Djadokhta and Barun Goyot formations are approximately equivalent in age, respectively, to the older and younger parts of the North American Judithian land-mammal "age." However, we stress that the evidence, especially that from fossil mammals, is slim. Moreover, in terms of the European-based Campanian and Maastrichtian marine stages, which can be correlated with southern Mongolia only by indirect methods, we believe that the Djadokhta and Barun Goyot formations probably correlate with the upper Campanian and/or lower Maastrichtian of the type areas in Europe, where the stage/age framework had its origin. In terms of radioisotopic dating, that would have been about 75 million years ago (see Berggren et al., in press).

SUMMARY

This is the first systematic account of mammalian remains from the Late Cretaceous (Judithian) "Mesaverde" Formation of the North American western interior. The fossils are of biogeographic importance because they represent the most southerly, well-documented record of Judithian mammals known from the continent. Fossils were recovered from nonmarine rocks in Wyoming in multiple localities in the southern Bighorn Basin and in a single stratigraphic level (two localities) in the southeastern Wind River Basin.

Faunal comparisons were emphasized among mammalian assemblages from the "Mesaverde" (Wyoming), Judith River (Montana), and Oldman (Alberta) formations. A tacit assumption was that the ani-

mals lived essentially contemporaneously; thus most differences observed within species collected from the various areas were considered to be a result of individual or populational variation rather than evolutionary change expressed through a significant interval of geologic time. These assumptions seem justified because all three nonmarine mammalian assemblages are temporal equivalents of approximately the same cephalopod-based more easterly marine biostratigraphic unit, the *Baculites gregoryensis* Zone (or as many as four zones higher, about 2 million years younger), part of the standard zonation of Upper Cretaceous rocks of the North American western interior. Little evidence exists to suggest that the limits of the marine invertebrate zonation are significantly time-transgressive from one geographic area to another.

The Red Bird Silty Member of the Pierre Shale as seen at Redbird, eastern Wyoming, holds the largely endemic, temperate-water, invertebrate assemblage characteristic of the *Baculites gregoryensis* (cephalopod) Zone. The rock unit also yields a newly described planktonic foraminiferal assemblage that we correlate to the warm-water upper Taylorian and/or lower Navarroan foraminiferal stages of the Gulf Coast. Comparison of microfaunal species ranges between the two areas suggests correlation of the Red Bird Silty Member with the *Globotruncana elevata* Subzone and/or the next higher *Rugotruncana subcircumnodifer* Subzone of the Gulf Coast. The upper part of the *G. elevata* Subzone of the Gulf Coast is characterized by the total-range zone for *G. calcarata* (considered locally as a "Zonule" of the *G. elevata* "Subzone").

The top of the *Globotruncana calcarata* Zone is recognized as the boundary between the Campanian and Maastrichtian European stages at Gubbio, Italy. The rocks at Gubbio represent an important reference section for the European Late Cretaceous in terms of correlation to the presently recognized stratotypes for the Campanian (France) and Maastrichtian (Netherlands) stages. Identical species-level criteria are used by micropaleontologists in defining the Campanian-Maastrichtian boundary at Gubbio, the northern Atlantic seaboard of the United

States, and the Gulf Coast sections. The boundary at each place is at the top of the *G. calcarata* (total-range) Zone.

Correlations based on range zones of geographically wide-ranging species of foraminiferans show that the mammal-bearing strata of the Oldman, Judith River, and "Mesaverde" formations, which almost universally have been considered solidly Campanian in age, lie precariously close to the revised Campanian-Maastrichtian boundary, and even possibly overlapping into the early Maastrichtian. It is clear that the generally recognized Campanian-Maastrichtian boundary, which is based on molluscan faunas within the western interior, must be relocated earlier in Cretaceous time in light of new evidence from the discipline of micropaleontology.

The mammalian fossils from the Oldman, Judith River, and "Mesaverde" formations were deposited essentially contemporaneously in nonmarine sediments near the western shoreline of the Western Interior Seaway during the regressive phase of the Claggett cyclothem. The probable proximity of the Judithian faunas to the Campanian-Maastrichtian boundary suggests that the mammals lived within the late phases of geomagnetic Polarity Chron 33 or the early part of Polarity Chron 32. This part of the Upper Cretaceous section of the western interior, however, lacks a reliable magnetostratigraphic zonation. The Judithian mammals correlate stratigraphically with the lower part of the *Aquilapollenites quadrilobus* palynomorph Interval Zone of the northern Rockies.

Sixteen species-level taxa are recognized from the "Mesaverde" Formation of Wyoming. Three previously unknown genera are reported, but none is formally named. These include a presently unidentifiable multituberculate of extraordinarily large body size, a phylogenetically relictual dryolestoid (previously unknown in North America from post-Jurassic rocks), and a new variety of advanced therian referable neither to the marsupials nor to the eutherians. Three new species of previously described genera are named. They include a variety of *Alphadon* (a marsupial) close to Lancian species, a tiny form of *Alphadon*, and a large version of an insectivore previously unknown south of Alberta.

All species-level taxa except *Alphadon lulli* are reported from Wyoming for the first time, and new records involve both geographic and geologic range extensions. Four species (two multituberculates, one marsupial, and one eutherian) are extended southward from northern Montana. Two species (multituberculate and marsupial) are extended into Wyoming from southern Alberta. A "therian of metatherian-eutherian grade" and a marsupial are recognized for the first time both in northern Montana and central Wyoming. Two species (multituberculate and marsupial) typical of Lancian rocks are extended into the Judithian. Six species-level taxa of Judithian age are presently recognized only from the "Mesaverde" Formation of Wyoming.

Comparison of Judithian species-level taxa known from up and down the western coastline of the Western Interior Seaway suggest that the mammalian fauna was essentially homogeneous, at least as far as from southern Alberta to central Wyoming.

The equivocal position of the "Mesaverde," Judith River, and Oldman mammalian faunas with regard to local boundaries of the European-based Campanian and Maastrichtian stages underlines the need for provincial geochronological terminology applicable to Late Cretaceous nonmarine faunas of the North American western interior. Russell (1964, 1975) defined the terms (in decreasing relative geologic age) Aquilan, Judithian, Edmontonian, and Lancian specifically for that purpose, on the basis of fossil vertebrates, invertebrates, and plants. These terms were intended to be strict chronostratigraphic units (i.e., stages, restricted to time represented within the deposition of the stratotype sections).

Unfortunately, Russell's stages were not properly formalized under the rules of stratigraphic nomenclature; the upper and lower limits of the stages were not defined at type sections. Furthermore, Russell's intention of usage resembled that for North American land-mammal "ages" (in the senses of Wood et al., 1941; Savage, 1962; Tedford, 1970) as applied successfully to the Cenozoic. However, he incorrectly interpreted the Cenozoic "ages" (intended to be pure time units with flexible boundaries not restricted to time rep-

resented at the type sections) as time-rock (chronostratigraphic) units. Thus, Russell's stages were inadequately defined, technically invalid, and based in part on a misconception.

Using mammalian assemblages exclusively, we revise Dorf's (1942) and Russell's (1964, 1975) terminology from geochronological and chronostratigraphic bases, respectively, to the philosophy employed within North American land-mammal "ages" (as defined by Wood et al., 1941); only Late Cretaceous ages are considered.

In a balance of judgment based on recent usage and with the intention of minimizing confusion, we employ the same nomenclature (i.e., Aquilan-Lancian) established by Dorf (1942) and Russell (1964, 1975). Aquilan, Judithian, and Lancian North American land-mammal "ages" are defined, using the criteria of first appearances, last appearances, and unique occurrences of mammalian species-level taxa. An Edmontonian "age" (chronologically intermediate between the Judithian and Lancian) is not named because such a term is presently indefensible on the basis of mammalian systematics. Nevertheless, comparisons of dinosaurian assemblages derived from strata referable to Russell's Edmontonian stage suggest to us the reality of a discrete unit of geologic time that should, with increased information, be definable on the basis of mammalian assemblages.

Definition of the younger boundary of the Lancian "age" is under active research by others, and the present faunal criteria soon will be modified.

Although admittedly premature in attempting to define Late Cretaceous North American land-mammal "ages," Russell's stage terms are longstanding, and the names commonly are used incorrectly in application to published evolutionary and geological research. Our purposes, therefore, were to: (1) summarize the status of knowledge on the subject; (2) provide a practical framework of constraints upon which to build and refine geochronologic concepts as available information grows; (3) clarify specifically where additional research is needed; and (4) encourage stability in concept and practice in the use of "ages."

Correlation of the Late Cretaceous rocks

of Mongolia with those of North America and Europe is a highly sought-after objective that has been attempted by almost all authors who have dealt with the Mongolian Cretaceous. Unfortunately, few authors have stated the premises upon which their efforts rest. The history of these attempts is a depressing one, full of contradictions and conclusions that go far beyond available evidence. Moreover, stratigraphic practices and degrees of adherence to international rules vary from author to author.

We concur with Fox (1978) that the Djadokhta of eastern Asia and the Judith River and Oldman faunas of North America are essentially of the same age and that, more indirectly, the Djadokhta Formation is therefore approximately late Campanian or even early Maastrichtian in age. This compresses the faunas of the Barun Goyot and Nemegt formations, plus that of the poorly known Bugeen Tsav locality in southwestern Mongolia, into an interval of time equivalent to the Judithian and/or Lancian North American land-mammal "ages" and to the latest Campanian or, more probably, Maastrichtian stages as typified in western Europe. We believe that the vertebrate evidence of this correlation, weak as it is, is nevertheless stronger than that provided by charophytes and ostracodes for more ancient age assignments.

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