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## FIRST NORTH AMERICAN LAND MAMMAL AGES OF THE CENOZOIC ERA

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### INTRODUCTION AND METHODOLOGY

The Paleocene continental sediments of the western interior of North America preserve the world's most complete and most thoroughly studied record of early Cenozoic mammal evolution. In this chapter, we examine this record. Our examination updates and amplifies earlier ones, specifically, the Wood committee's work (Wood et al. 1941) on the first four North American Land Mammal Ages of the Cenozoic Era—the Puercan, the Torrejonian, the Tiffanian, and the Clarkforkian. For purposes of brevity, we will refer to these as "mammal ages." The Wood committee recognized a fifth mammal age, the Dragonian, between the Puercan and Torrejonian mammal ages. Van Valen (1978) later proposed another, the Mantuan, preceding the Puercan Mammal Age. We consider the Dragonian Mammal Age to be part of the Torrejonian and the Mantuan Mammal Age to be part of the Puercan (see below, for discussion of Torrejonian and Puercan mammal ages).

Although we do not discuss at great length the Paleocene Epoch per se, earlier work on North American mammalian faunas now regarded as Paleocene in age had a significant influence on the global recognition of this epoch. In 1874, Schimper proposed the Paleocene

Epoch in Europe based on fossil plants. The concept of this epoch, however, began to take form in the late nineteenth and early twentieth century. At that time, vertebrate paleontologists began to discover and describe mammalian faunas in the western United States which seemed to be more archaic than faunas of undisputed Eocene age but at the same time were probably not latest Cretaceous in age. Nevertheless, the Paleocene Epoch was not formally recognized by the U.S. Geological Survey until 1939 (D. E. Russell 1967). By the time the Wood committee's results were published in 1941, the Paleocene Epoch was more widely accepted in North America than in Europe.

The Wood committee correlated the beginning of the Paleocene Epoch with the beginning of the Puercan Mammal Age and the end of the Paleocene Epoch with the end of the Clarkforkian Mammal Age. As discussed below, the former correlation is still followed, but more recent correlations (Rose 1980, 1981a) suggest that the Clarkforkian Mammal Age straddles the Paleocene-Eocene epochal boundary. The last section of this chapter, concerning intercontinental correlations, discusses the correlation of the Clarkforkian Mammal Age.

Only a few concepts and comments on terminology are noted here, as these matters are treated fully elsewhere in this volume. We are concerned with two basic

types of units: the mammal "age" and the mammal "zone" (including subzone). The zone is treated as a subdivision of a mammal age. In general, we have attempted to follow the North American Stratigraphic Code (NASC; 1983) and the International Stratigraphic Guide (ISG; Hedberg 1976) in defining or redefining and characterizing these ages and zones. There is only one conceptual difference to keep in mind. We consider mammal ages and mammal zones to be a type of biochronologic unit, a unit that is not used by the NASC and is only briefly considered by the ISG. Such units are characterized by faunal content (see below for definitions). On a local or regional scale, stratigraphic position plays the key role in establishing the relative position of faunas independent of the fossil content. For broader correlations, faunal comparison remains the primary method. Within the limits of resolution now possible, we assume the boundaries of our biochronologic units to be synchronous. This does not mean that we regard such boundaries to be instantaneous, as is the case for a geochronologic unit, but rather that the biochronologic units can be used as approximations of geochronologic age. Finally, it must be noted that because these ages (and zones) are based on faunal content that in many instances cannot be defined with precision in type sections (specifically, first appearances), for the most part these units cannot yet be regarded as stages. This is, of course, one of the goals for the future.

The four mammal ages we discuss all differ in historical development; however, their defining and characterizing criteria are similar. This is not true for the zonations within these mammal ages. Three different types of zones are used in subdividing them. Both the Puercan and Torrejonian mammal ages are subdivided into three zones, all of which are defined and limited by the successive appearances of unrelated taxa, although some of the appearances do require a personal judgment with regard to taxonomic usage (i.e., differentiation of *Taeniolabis taoensis* from an unnamed species of the genus and a similar separation of *Peripitychus* from *Carsiopitychus*; see appropriate sections for further comment). Zones such as these are recognized by both the NASC and the ISG as one type of interval-zone.

The second type of zone is recognized for all five of the Tiffanian zones and for the oldest two Clarkforkian zones (but see the discussion of the Clarkforkian concerning its oldest zone, which is partly Tiffanian in age and which we have divided into two interval-subzones). These seven zones conform to the concept of a range-zone according to the ISG and to a type of interval-zone according to the NASC. Both codes are in agreement in calling these taxon-range-zones, or, more specifically,

lineage-zones, since the successive lowest appearances defining each of the zones form a presumed phylogenetic lineage. The final type of zone is represented by the youngest of the three zones in the Clarkforkian Mammal Age and is referred to as an abundance-zone by the NASC and an acme-zone by the ISG.

For consistency, we will follow the ISG terminology and refer to our three types of zones as interval-zones, lineage-zones, and acme-zones. Ideally, the use of interval-zones (*sensu* ISG) throughout would be preferred because these zones are less subjective than lineage-zones, which rely more heavily on a given paleontologist's taxonomic biases, and than acme-zones, which are potentially more influenced by various paleoecological factors and are more questionable units in attempts at faunal correlation.

The ISG suggests several options for naming and subsequent usage of zonal names. We have chosen the admittedly more cumbersome, but more precise, style of including the name of the commencing taxon and the closing taxon for both the interval- and lineage-zones. Thus, the oldest zone in the Puercan Mammal Age is the *Peradectes/Ectoconus* Interval-Zone, and the oldest in the Tiffanian Mammal Age is the *Plesiadapis praecursor/P. anceps* Lineage-Zone. If these zones are accepted and used elsewhere, we suggest that they be explicitly and fully written out before being abbreviated or shortened in whatever manner may be chosen. It is important to specify that unless otherwise indicated, the above method of naming zones, along with the method of defining the zones described below, does not change the sense of previously recognized zones. For informal, shorthand purposes, each zone is also referred to by an abbreviation of the mammal age(s) in which it occurs plus a subscript number indicating its sequence within the given mammal age. Thus, the above two zones are also known informally as the Pu1 interval-zone and the Ti1 lineage-zone, or simply Pu1 and Ti1, respectively. Specific peculiarities of several of the zones are discussed under their respective mammal ages.

For each of the four mammal ages and thirteen of the fourteen zones (and 2 subzones) discussed in this chapter, we provide a standardized definition and characterization. A formal definition is not given for the fourteenth zone, the *Phenacodus-Ectocion* Acme-Zone. The definitions for all four mammal ages and for the remaining thirteen zones (and 2 subzones) are based on the appearance of a single taxon. The characterizations for all of the ages and zones consist of five parts: (1) "first appearances" for taxa that appear for the first time within a mammal age or zone but not necessarily in the oldest faunas of that mammal age or zone; (2) "last appear-

ances" for taxa that appear for the last time within a mammal age or zone but not necessarily in the youngest faunas of that mammal age or zone; (3) "index fossils" for taxa restricted to a mammal age or zone; (4) "characteristic fossils" for all taxa (not just common taxa) that occur within a mammal age or zone but do not belong to one of the three preceding categories; and (5) taxa that are recognized before and after a given mammal age or zone but not within it. This last category is utilized to emphasize potential problems with sampling or taxonomy or both.

The lack of a consistent and up-to-date systematics hampers efforts to achieve a widely applicable biochronology (and biostratigraphy) based on mammals (see also Savage and Russell 1983). We have generally used the most recent systematic reviews, although there are a number of exceptions discussed in the appropriate mammal age or zone. For most usages in this chapter, the genus is the lowest taxonomic level considered.

In addition to definitions, characterizations, and discussions for each of the mammal ages and zones, we have provided two figures and two tables to augment the text. Figure 3.1 is a map of western North America which shows the approximate locations from which most Puercan through Clarkforkian mammalian faunas were recovered. Numbers shown are clusters of localities occurring in particular regions. These are the same numbers used in figure 3.2 (in pocket) showing the biochronologic correlation of all localities. The same numbers are also employed in tables 3.1 and 3.2, which identify, respectively, localities and taxa recovered from these localities.

Figure 3.2 is a correlation of Puercan through Clarkforkian faunas clustered according to geographic and/or geologic features, usually depositional basins. These sections are ordered from left to right in an approximately south to north and west to east pattern with two miscellaneous occurrences shown on the far right. Although the accompanying key is essentially self-explanatory, a few additional comments are in order. The approximate geochronologic ages and epochal and magnetic chonal boundaries are basically after Berggren et al. (1985). Placement of the boundaries for mammal ages and zones relative to the above units is for the most part estimated by means of correlation to magnetostratigraphic sections.

For some sections, within Clark's Fork and Bighorn basins, for example, one can place the biochronologically defined mammal ages and zones into a biochronostratigraphic context utilizing stratigraphic placement in conjunction with magnetostratigraphy. Such correlations provide a limited degree of confidence to chronostratigraphic and geochronologic assignments for some sec-

tions. This is not currently possible for many of the sections shown in figure 3.2, and thus a given portion of a formation should *not* be assumed to correlate across the chart to a given mammal age or zone (e.g., the lowermost portion of the Hoback Formation should *not* be assumed to be latest Torrejonian in age).

In some instances we lack or have only poorly known superposed faunas straddling mammal age and zonal boundaries. Thus, even approximate correlations of these biochronologic units to each other and to geochronologic and magnetostratigraphic units are equivocal. Such "gaps" in our knowledge of these biochronologic units are indicated in figure 3.2 (under the heading, "Zones"). Slanted lines for some zonal boundaries on the left margin do not imply diachroneity; these are simply the result of differences in thickness of some of the magnetostratigraphic columns compared to the relative durations of the magnetostratigraphic scale. Many of the stratigraphic sections shown are discussed in the text. More information regarding stratigraphic and faunal information can be obtained from the references listed under each major region in table 3.1.

As noted previously, tables 3.1 and 3.2 provide locality and taxonomic information, respectively. Table 3.1 is arranged according to the sections shown in figure 3.2. The localities or clusters of localities identified in figures 3.1 and 3.2 are listed in the table in numerical order. For clarification in some instances, localities listed under a single number are further subdivided using letter designations. The abbreviation in parentheses following a given locality is the zone to which the fauna from the locality is referred. References follow each of the major sections listed, and each reference is coded by number to the appropriate locality or localities. Although not complete, the references are extensive. The choice to include a reference was often influenced by how well the fauna(s) has been studied. Thus, the more poorly known, or less studied, faunas included all or most references, whereas the inclusion of references for better-studied faunas was somewhat more selective. The major categories of included references are faunal studies and revisions, major taxonomic studies, minor taxonomic papers relevant to faunal analysis, biostratigraphic-magnetostratigraphic studies, and stratigraphic papers germane to faunal interpretation. For completeness, many localities have been listed in the table even though these are not discussed in the text.

Table 3.2 is a faunal list (to the generic level) for the Puercan through Clarkforkian mammal ages. Unless they significantly alter a biochronologic range, most taxa questionably identified by authors are excluded or are included with a query. Most unpublished faunal accounts

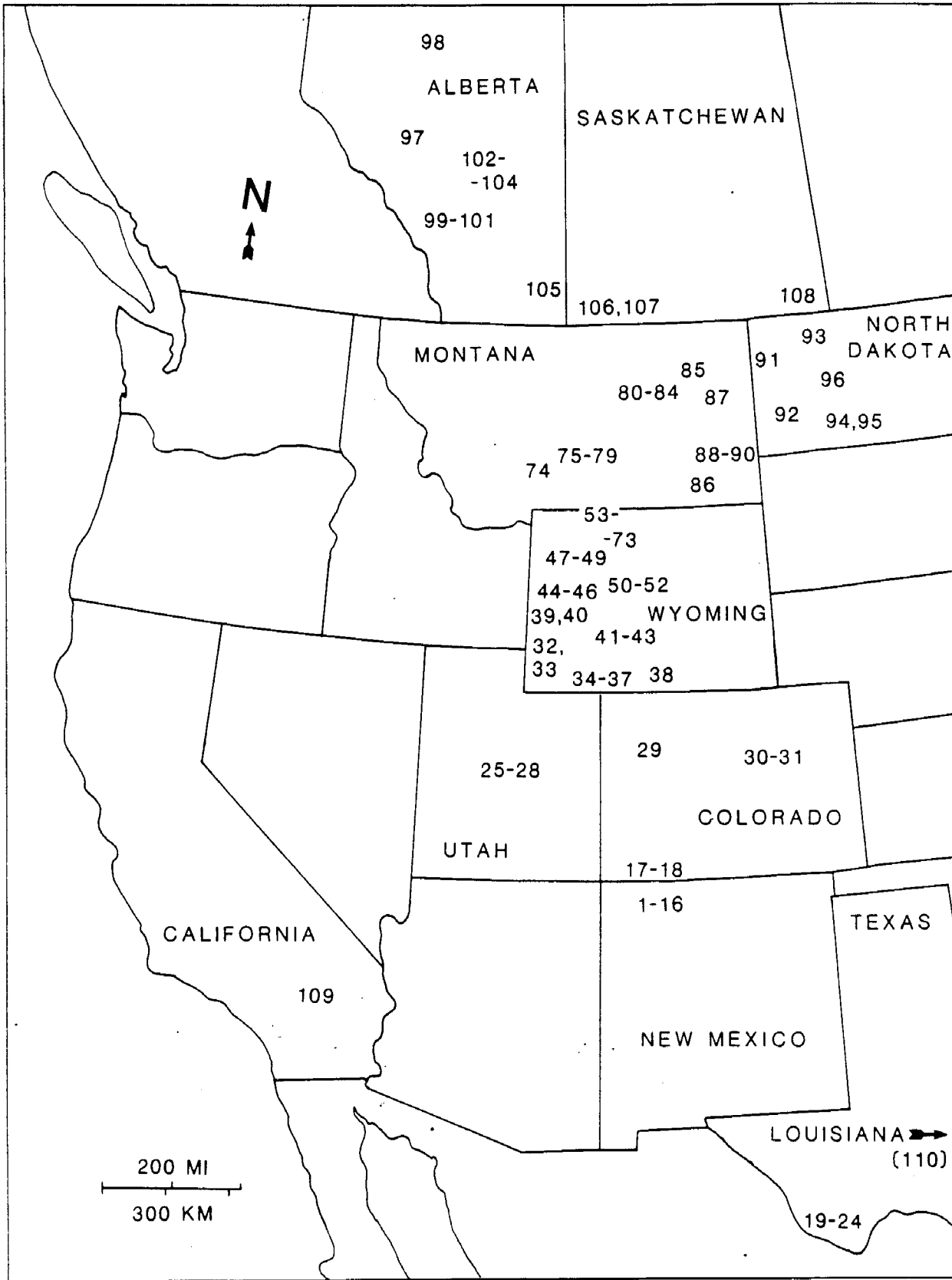


Fig. 3.1. Puercan through Clarkforkian mammal localities in the United States and Canada. The numbered localities are the same as those used in the correlation chart in fig. 3.2 and in tables 3.1 and 3.2. See table 3.1 for references and the Introduction for further comments.

TABLE 3.1

## Localities of the Puercan, Torrejonian, Tiffanian, and Clarkforkian North American Land Mammal Ages

Localities are numbered approximately from west to east and from south to north and agree with the numbers used in figs. 3.1 and 3.2 (in pocket), and table 3.2. Taxa in table 3.2 which are recorded as occurring at localities listed under a given number do not necessarily occur at all localities listed under that number. See introduction and methodology for further comments.

**San Juan Basin, New Mexico**

- 1 West Fork of Gallegos Canyon – includes Sinclair and Granger Loc. 4 (Pu3?).
- 2 *Ectoconus* zone, De-na-zin (= Barrel Spring Arroyo) and Alamo washes (Pu2).
- 3 *Taeniolabis* zone, De-na-zin (= Barrel Spring Arroyo) and Alamo washes (Pu3).
- 4 *Periprychus* site, De-na-zin Wash (= Barrel Spring Arroyo) (To1?).
- 5 Lower Kutz Canyon sites (To1).
- 6 West Kutz Canyon sites (low to high) – a. Bob's Jaw, b. Taylor Mound, c. Big Pocket (= KU Loc. 13), d. Bab's Basin, and others (To2).
- 7 South Kutz Canyon sites – O'Neill *Pantolambda*, Coprolite Point, and others (To3).
- 8 Animas River Valley (incl. Cedar Hill) (To2–3).
- 9 Lower Kimbetoh Arroyo – Black Toe, Black Stripe, plus others (Pu2?).
- 10 Upper Kimbetoh Arroyo – a. Head of Kimbetoh Arroyo, b. Dick's Dig (To1).
- 11 KU Loc. 9 (= Little Pocket) (To3).
- 12 Lower Betonnie-Tsosie Arroyo – Mammalon Hill, plus others (Pu2?).
- 13 Upper Betonnie-Tsosie Arroyo – Powerline (To1).
- 14 *Deltatherium* zone, Arroyo Torreon – lower part Sinclair and Granger Loc. 10 (To2).
- 15 *Pantolambda* zone, Arroyo Torreon – upper part Sinclair and Granger Loc. 10, Sinclair and Granger Loc. 11, microsite of Tsentas (To3).
- 16 Type area of Cope's "Puercan marls" (To2 or 3).
- 17 Mason Pocket near Tiffany (Ti4).
- 18 Bayfield and others (Ti5).

References: Archibald et al. (1983a): 2, 3, 9, 12; Archibald et al. (1983b): 9, 12; Butler et al. (1977): 2, 3; Conroy (1981): 6, 15; Cope (1875, 1877, 1885, 1888, plus 55 others, see Matthew, 1937, for most): various localities; Gazin (1968): 15; Gingerich (1983): 17; Granger (1917): 6–8, 17, 18; Granger and Simpson (1929): 3, 12, 14, 15; Lindsay et al. (1978, 1981): 2–4, 6–15; Lucas (1984): 1; MacIntyre (1966): 6c, 11, 12, 14, 15; Matthew (1897, 1937): 2, 3, 9, 12, 14, 15; Matthew and Granger (1921): 3, 14, 15, 17, 18; Osborn and Earle (1895); Reynolds (1936): 12; Rigby (1981): 12; Rigby and Lucas (1977): 12; D. E. Russell (1967): 2, 3, 6c, 9, 12, 14, 15, 17, 18, plus others?; Schoch (1981): 2?, 3, 9, 12; Schoch and Lucas (1981a): 5, 6; (1981b): 11?; Simpson (1935a,b,c): 17, 18; Simpson (1936a): 3, 12; (1955 in Simons 1960): 18?; (1959): 16; Sinclair and Granger (1914): 1–4, 9–16; Sloan (1981): 3, 6, 9, 11, 12; Taylor (1981): 5–7; Taylor and Butler (1980): 6a–d, 7, 14, 15; Tomida (1981): 5–7, 14, 15; Tsentas (1981): 14, 15; Van Valen (1978): 3, 6a?, 9, 12, 14, 15, 17; (1980): 15; R. Wilson (1951, 1956b): 6c; R. Wilson (1956a): 11, 14, 15; R. Wilson (1956c): 3, 11.

**Big Bend, Texas**

- 19 Schiebout-Reeves Quarry (West Tornillo Flats) (Ti1).
- 20 Eastern Tornillo Flats Washing Site (Ti3?).
- 21 Ray's Bone Bed and Annex (Ti3).
- 22 Joe's Bone Bed (Ti5).
- 23 New Taeniodont Site (Ti-Cf).
- 24 Southwall (Cf-Wa).

References: Gingerich (1976): 21, 22; Rapp et al. (1983): 19–24; Rose (1981a): 23, 24; D. E. Russell (1967); Schiebout (1974): 19–24; Schoch (1986): 20–24; J. A. Wilson (1965, 1967).

**Wasatch Plateau, Utah**

- 25 Gas Tank Hill Local Fauna (= Flagstaff Peak) (Pu2?).
- 26 Wagonroad (= lower part Loc. 4 of Gazin) (Pu3?).

TABLE 3.1

Localities of the Puercan, Torrejonian, Tiffanian, and Clarkforkian North American Land Mammal Ages—Continued

- 27 Dragon (= upper part Loc. 4 of Gazin) (To1).  
 28 Dragon (= Loc. 2 of Gazin) (To1).

References: Archibald et al. (1983a): 25, 26; Gazin (1938, 1939): 28; Gazin (1941b): 26–28; Robison (1980): 25–28; D. E. Russell (1967): 25–28; Schoch (1986): 26; Spieker (1960): 25; Tomida (1981): 26–28; Tomida (1982): 28; Tomida and Butler (1980): 26–28; Van Valen (1978): 25–28.

**Plateau Valley, Piceance Creek Basin, Colorado**

- 29 Plateau Valley (Cf1?).

References: Gingerich (1976, 1977, 1978); Gingerich and Childress (1983); Jepsen (1940); Krause (1980); Patterson (1933, 1936, 1937, 1939, 1949); Patterson and Simons (1958); Patterson and West (1973); Rose (1977, 1981a); D. E. Russell (1967); Simons (1960); R. C. Wood (1967).

**Denver Basin, Colorado**

- 30 Littleton Local Fauna – a. Alexander and b. South Table Mtn. localities (Pu1).  
 31 Corral Bluffs, Jimmy Camp Ck., West Bijou Ck. 1 (Pu2?–3?).

References: Brown (1943): 30b, 31; Gazin (1941a, 1963): 30b, 31; Middleton (1982): 30a; Middleton (1983): 30a, b, 31; D. E. Russell (1967): 30b, 31.

**Fossil Basin—Washakie Basin, Wyoming**

- 32 Little Muddy Creek (Ti1).  
 33 Twin Creek (Ti3).  
 34 Big Multi (Cf2).  
 35 UW loc. V77009–10, 77012, 77014, 78055 (To3?).  
 36 UW loc. V77005–08, 77013, 77015–16, 77061 (Ti4).  
 37 UW loc. V76008, 77059–60, 78052–54 (Ti5).  
 38 Swain Quarry (To3?).

References: Gazin (1956a, 1969): 32, 33; Gingerich (1983): 36, 37; Krause (1980): 34; Rigby (1980): 38; Rose (1981a): 34; D. E. Russell (1967): 33; Sloan (1981): 34, 38; Winterteld (1982): 35–37.

**LaBarge Creek, Green River Basin, Wyoming**

- 39 Chappo Type Locality (= Chappo–17) (Ti3).  
 40 Buckman Hollow Locality (= Chappo–1 and 12) (Cf2).

References: Dorr and Gingerich (1980): 39, 40; Gazin (1942, 1956c): 40; Gingerich (1983): 39; Gingerich and Childress (1983b): 40; Krause (1980): 40; Rose (1981a): 40; D. E. Russell (1967): 40.

**Bison Basin, Wyoming**

- 41 Saddle Locality (Ti2).  
 42 Ledge Locality, Saddle Annex, West End (Ti3).  
 43 *Titanoides* Locality (Ti5).

References: Gazin (1956b): 41–43; Gingerich (1983): 41–43; MacIntyre (1966): 41; D. E. Russell (1967): 41–43; Van Valen (1978): 41.

TABLE 3.1

Localities of the Puercan, Torrejonian, Tiffanian, and Clarkforkian North American Land Mammal Ages—Continued

**South and East of Powell, Wyoming**

- 68 Leidy Quarry (Pu1).  
 69 a. Cedar Point Quarry, b. Jepsen Quarry (Ti3).  
 70 Lower Sand Draw, Witter (= Croc. Tooth) Quarry, Divide Quarry, Sand Draw Anthill Locality (Ti4).  
 71 a. Middle Sand Draw, b. Sunday Locality (Ti5).  
 72 a. Foster Gulch (= Cleopatra Reservoir Quarry), b. Rough Gulch, c. Upper Sand Draw (Cf2).  
 73 a. Ries Locality, b. Foster Gulch Oil Well no. 1, (Cf).

References: Archibald (1982): 59; Bown and Gingerich (1973): 60; Butler et al. (1981): 55, 58–67; Gingerich (1976): 53, 54, 55a, b, c, 56a, c, 57c, 60, 68, 69a, b, 70, 71a, 72a, b, c; Gingerich (1978): 53; Gingerich (1980a): 69a; Gingerich (1982b): 55c; Gingerich (1983): 63, 69a; Gingerich and Rose (1979): 72b; Gingerich et al. (1980): 53, 54, 55a, b, c, d, e, f, 63, 68, 70, 71a, b; Jepsen (1930a): 57c; Jepsen (1930b): 55a, 56c, 59, 60; Jepsen (1937): 56c; Jepsen (1940): 55a, 59, 60; Jepsen and Woodburne (1969): 55a; Korth (1984): 56c; Krause (1980): 56b, 57c, e, 58c, 65; McKenna (1961): 56c; Middleton (1982, 1983): 59; Rose (1975): 55a, b, e, 57c, 60, 69a, 70, 72a; Rose (1978): 70; Rose (1979): 55f; Rose (1981a): 55a, b, e, f, 56b, c, 57a, b, c, d, e, 58a, b, c, 60, 65–67, 69a, 72a, b, 73a, b; Rose (1981b): 55a, 60, 65–67, 69a; Rose and Krause (1982): 55d, 66, 67, 70; D. E. Russell (1967): 55a, 56c, 60; Schoch and Lucas (1981b): 60; Simons (1960): 60, 69a; Simpson (1928, 1929a, 1929b): 56c; Simpson (1937c): 58a, c; Sinclair and Granger (1912): 72b; Sloan (1969): 59; Sloan and Van Valen (1965): 59; Van Valen (1978): 59, 60, 68, 69a; Van Valen and Sloan (1966): 56c; West (1973): 69a; (1976): 60, 69a; A. E. Wood (1962): 57a; R. C. Wood (1967): 56a, b, 58a, c, 66.

**Crazy Mountain Basin and Vicinity, Montana**

- 74 Bangtail Locality (Ti1).  
 75 Gidley Quarry (= Locality 4) (To3).  
 76 Silberling Quarry (= Locality 1) (To3).  
 77 Douglass Quarry (= Locality 63) (Ti1).  
 78 Scarritt Quarry (= Locality 56) (Ti2).  
 79 Locality 11 and Locality 13 (= Melville Locality) (Ti3).

References: Douglass (1908): 76; Gidley (1915, 1923): 75; Gingerich (1975a): 77; Gingerich (1976): 77, 79; Gingerich (1983): 78; Gingerich et al. (1983): 74; Krause and Gingerich (1983): 77; Rose (1981): 75, 76, 78; D. E. Russell (1967): 75, 76, 78; Schoch (1986): 76, 77; Simons (1960): 77; Simpson (1935d): 75, 76, 79; Simpson (1936a): 78; Simpson (1937a): 75–79; Simpson (1937b): 78; Sloan (1981): 75; Van Valen (1978): various localities; West (1971): 77.

**Eastern Montana and North Dakota (Missouri River Drainage and Powder River and Williston Basins)**

- 80 McKeever Ranch localities (Pu1).  
 81 Horsethief Canyon localities (To1?).  
 82 Hell's Hollow Local Fauna (including Worm Coulee #1) (Pu1).  
 83 a. Garbani Quarry, b. Biscuit Butte, c. Biscuit Springs, d. Yellow Sand Hill localities (Pu3?).  
 84 Mosquito Gulch localities (To1?).  
 85 Purgatory Hill (Pu3?).  
 86 Olive (Ti4).  
 87 Circle (Ti4).  
 88 Bechtold Site (Pu3?).  
 89 Medicine Rocks 1, Mehling Site (To3).  
 90 White Site, 7-UP Butte, Highway Blowout (Ti2).  
 91 Type of *Titanoides primaevus* near Buford, Williams Co.; McKenna's *Titanoides* material, McKenzie Co.; skull of *T. primaevus*; Williams Co.; all N. Dakota (Ti3?–5?).  
 92 Wannagan Creek Quarry (Ti4).  
 93 Donnybrook (To or Ti).  
 94 Lloyd and Hares Site (= Heart Butte) (To or Ti).

TABLE 3.1

Localities of the Puercan, Torrejonian, Tiffanian, and Clarkforkian North American Land Mammal Ages—*Continued*

- 95 a. Judson, b. Brisbane (Ti3).  
96 Riverdale (Ti4?).

References: Archibald (1981): 82; Archibald (1982): 80–84; Archibald and Clemens (1984): 80, 82; Archibald et al. (1982): 80, 82, 85; Archibald et al. (1983a): 83a, d; Clemens (1974): 83a; Clemens (pers. observ.): 88; Gingerich (1976): 89, 90; Gingerich (1983): 95a, b; Holtzman (1978): 91–96; Holtzman and Wolberg (1977): 87, 95b; Johnston and Fox (1984): 83a; Middleton (1982, 1983): 82; Novacek (1977): 83a, c, d; Novacek and Clemens (1977): 83a; Rose (1975): 86, 87, 89; Rose (1981b): 95a, b; D. E. Russell (1967): 85–87, other in N. Dak.; Simons (1960): 91; Sloan (1970): 89, 90; Sloan (1981): 85; Van Valen (1978): 85; Van Valen and Sloan (1965): 85; Wolberg (unpubl. 1978).

**Alberta and Saskatchewan**

- 97 Saunders Creek (Ti1?).  
98 Swan Hill Site 1 (Ti4).  
99 Alberta Core Hole 66–1 (= Balzac West) (Pu2?).  
100 a. Calgary 2E, b. Calgary 7E (To3).  
101 a. Cochrane I. b. Cochrane II (Ti1).  
102 Ericksons Landing (and L. S. Russell's "Red Deer" (1929)?) (Ti3).  
103 UADW–1 and UADW–2 (Ti3).  
104 Canyon Ski Quarry (Ti4).  
105 Police Point (Ti3?).  
106 RAV W–1 (Pu2?).  
107 Pine Cree Park (Pu2?).  
108 Roche Percée (Ti4).

References: Fox (1968): 99; Fox (1983b, 1984a–d): 103; Gingerich (1982a): 101; Johnston and Fox (1984): 99, 106; Krause (1977): 108; Krause (1978): 98, 100a, 101b, 102–105, 108; Krause and Gingerich (1983): 101; Krishtalka (1973): 105; Matthew (1914): 102; Rose and Krause (1982): 108; Novacek (1977): 101b; D. E. Russell (1967): 97, 100–102; L. S. Russell (1926): 100a; (in Rutherford, 1927): 101; L. S. Russell (1929): 100a, b, 101a, b, 102; L. S. Russell (1932, 1958): 100a, 101a, b; L. S. Russell (1948): 97; L. S. Russell (1967): 98; L. S. Russell (1974): 107; Simons (1960): 97; Simpson (1927): 102; Van Valen (1978): 98, 99.

**Miscellaneous sites**

- 109 Laudate (California (To2?).  
110 Junior Oil Company Beard No. 1 well (Louisiana) (To2?).

References: McKenna (1960): 109; D. E. Russell (1967): 109, 110; Simpson (1932): 110.

and faunal lists are not included in the table or in our faunal lists. Such faunal data are discussed in the text, however, where germane. Higher taxa are listed only as an aid in locating genera and species in the table and do not reflect any particular author's systematic views. Genera within a given family are listed biochronologically in the table and alphabetically in the faunal lists in the text. Following the genus are the zones in which it occurs and the localities at which it is found. The localities are identified by the same numbers used in the previous figures and table. Association of a taxon and a

specific number does not necessarily mean the taxon occurs at all localities listed under a given number. Rather than completely duplicating references for the localities listed in table 3.1 and the taxa listed in table 3.2, we felt that locality lists were of greater concern in this volume. Thus, it is necessary to consult the references listed in table 3.1 for additional taxonomic details. Unless indicated otherwise, all taxa listed in table 3.2 and discussed in the text have been reported in the literature or are in press except where noted (e.g., theses and dissertations).



TABLE 3.2  
Temporal Ranges for Puercan Through Clarkforkian Mammals

Arrows indicate ranges earlier than the Puercan or later than the Clarkforkian mammal ages. Symbols as follows: taxon known from zone (X), questionably known (?), not known (O). See table 3.1 for localities (diagonal line between localities indicates occurrence at one or more of the localities).

Taxon	L+ Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cf1 Cf2 Cf3 W+	Localities (and References)
<b>MULTITUBERCULATA</b>		
<b>Neoplagiulacidae</b>		
<i>Mesodma</i>	←--X--X--X--O--O--X--O--O--X--X	3?, 12, 20, 30, 36, 38, 52, 59, 60, 75, 80, 82, 83a, 85, 86, 95b, 103, 105, 106, 108.
<i>Neoplagiulax</i>	?←--O--X--X--O--O--X--X--X--X--X--X	6c, 11, 12, 20, 22, 32, 36, 38, 41, 45, 47, 55a, 69a, 75-78, 85-87, 95a, b, 103, 105, 106, 108, 109?
<i>Ectypodus</i>	X--O--O--X--X--X--X--X--X--X--O--O--X--X→	6c, 15?, 17, 20, 22, 32, 34, 36, 38, 41, 45, 47, 52, 55a, 57a-e, 58c, 69a?, 74, 75, 86, 87, 95b, 101b, 106, 108.
<i>Parectypodus</i>	X--X--X--X--X--O--O--X--O--X--O--O--X--O→	6c, 11, 12, 14/15, 20, 22, 28, 38, 55a, 58c, 75, 76, 85, 87, 95a, b, 98, 100a?, 105, 106.
<i>Mimetodon</i>	X--X--O--X--X--X	6c, 11, 20, 22, 50, 55a, 60?, 75, 103, 108.
<i>Xanocromys</i>	X	38.
<b>?Neoplagiulacidae</b>		
<i>Xyronomys</i>	X--O--O--O--X	38, 106.
<b>Ptilodontidae</b>		
<i>Kimbetohia</i>	X--X	12, 85.
<i>Ptilodus</i>	X--O--X--X--X--X--X--X--X--X	12, 14, 19, 20, 22, 28, 32, 35, 36, 38, 39, 41, 44, 50, 52, 60, 69a, 75-78, 87, 93a, b, 96, 101b, 103, 105, 108.
<i>Prochetodon</i>	X--X--X--X--X--X--X	40, 47?, 55a, 56b, d, 57a-d, 58c, 95a, 108.
<b>Cimolodontidae</b>		
<i>Cimolodon</i>	←--O--O--O--?	12?
<i>Anconodon</i>	X--X--X--X--X	6c, 41, 50?, 60, 75-77, 98, 100a, 101a, b.
<b>Eucosmodontidae</b>		
<i>Strygimys</i>	←--X--X--X--O--O--X	9/12, 59, 60, 75, 76, 82, 85, 100b?, 106.
<i>Acheronodon</i>	X	82.
<i>Eucosmodon</i>	X--X--X--X--X--?	3, 6, 8, 11, 12, 14/15, 50?
<i>Microcosmodon</i>	X--O--O--O--O--X--O--X--X--X--O--X--X	34, 52, 55a, 56b, 57a-e, 87, 95b, 103, 105, 106, 108.
<i>Pentacosmodon</i>	X	55a.
<i>Neoliotomus</i>	X--X--X--X--X--O→	29, 55a, 56b, d, 57a-d, 65.
<b>Taeniolabididae</b>		
<i>Catopsalis</i>	←--X--X--X--X--X--X--X--X	3, 9/12, 14/15, 28, 30, 50, 59, 60, 82, 100a, b.
<i>Taeniolabis</i>	X--X	1, 3, 26?, 83a, 85, 88?, 106.
<b>Family indet.</b>		
<i>Cimexomys</i>	←--X--X--X	59, 82, 85, 106.
<b>Taxon</b>	<b>L+ Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cf1 Cf2 Cf3 W+</b>	<b>Localities (and References)</b>

TABLE 3.2  
Temporal Ranges for Puercan Through Clarkforkian Mammals—Continued

Taxon	L + Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cfl Cf2 Cf3 W +	Localities (and References)
<b>MARSUPIALIA</b>		
Didelphidae		
<i>Peradectes</i>	X--X--X--O--O--X--X--X--X--X--X--O--?--X--X-->	3, 12, 17, 34?, 37?-39, 41, 50, 52, 55a, 56c, 57a-e, 58a-c, 59, 67, 69a, 82, 85, 87, 95b, 103, 105.
<i>Mimoperadectes</i>		?--> 58c.
<b>PROTEUTHERIANS</b>		
Leptictidae		
<i>Prodiacodon</i>	X--O--X--X--?--X--?--O--X--O--O--?--?-->	6c, 14/15, 38, 41, 47?, 55a, 57?a-e, 58?a-c, 67?, 75, 83a, c, d, 85, 101b?.
<i>Myrmecoboides</i>		38, 60, 69a, 74, 75.
Palaeoryctidae		
<i>Procerberus</i>	←--X--O--X	59, 82, 85.
<i>Cimolestes</i>	←--O--X--X	3, 12.
<i>Acmeodon</i>	X--X--X--O--O--X	6, 15, 28, 35, 38, 87.
<i>Palaeoryctes</i>	X--X--O--O--X--O--X--O--O--X--X	6c, 14/15, 35, 38, 55a?, 57a-d, 58c, 69a?, 87, 95a, b.
<i>Avunculus</i>		75.
<i>Stilpnodon</i>		75.
<i>Gelastops</i>		35, 38, 50, 60, 75, 76, 103.
<i>Pararyctes</i>		41, 95b, 101b, 103, 105.
<i>Aaptoryctes</i>		45, 55c.
Pantolestidae		
<i>Pantomimus</i>		38?.
<i>Leptonysson</i>		75.
<i>Paleotomus</i>		38, 45, 69a, 77, 78.
<i>Propalaeosinopa</i>		36-39, 47, 75-78, 87, 95a, b, 96, 102, 103, 105.
<i>Bisonalveus</i>		41, 69a, 77, 87, 95b, 103.
<i>Palaeosinopa</i>		36, 45, 56b, c, d, 57a-d, 58a-c, 67, 72a?, 87.
Pentacodontidae		
<i>Aphronorus</i>	X--O--X--X--O--?--	28, 32, 35, 50?, 60, 74-76, 77?, 93?, 103?.
<i>Pentacodon</i>	X--X	6, 8, 11, 14, 15.
<i>Coriphagus</i>	X--X	6, 11, 14, 60, 75, 76.
<i>Protentomodon</i>		56c.
Apatemyidae		
<i>Jepsenella</i>		38, 60, 75.
<i>Unuchinia</i>		55a, 78, 95a, b.
<i>Labidolemur</i>		17, 57e, 69a.
<i>Apatemys</i>		56c, 57a-e, 58a-c, 67.
Mixodectidae		
<i>Dracontolestes</i>		28.
<i>Mixodectes</i>		6, 7, 11, 14, 15, 38.
<i>Eudaemonema</i>		60, 75, 76.
Taxon	L + Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cfl Cf2 Cf3 W +	Localities (and References)

TABLE 3.2  
Temporal Ranges for Puercan Through Clarkforkian Mammals—Continued

Taxon	L + Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cfl Cf2 Cf3 W +	Localities (and References)
<b>INSECTIVORA</b>		
<b>Erinaceidae</b>		
<i>Cedrocherus</i>	X	69a.
<i>Litolestes</i>	X---X---X	55a, 87, 103.
<i>Leipsanolestes</i>	X---X---X---▶	34?, 49, 56c, 57e, 58?a-c, 67?.
<b>Erinaceomorpha, incertae sedis</b>		
<i>Mckennatherium</i>	X---X---O---X---O---X	32, 35, 38, 47, 60, 75, 103.
<i>Diacodon</i>	?---O---O---O---?	50?, 55a?, 101b?.
<i>Litocherus</i>	X---X---X---X	36, 37, 39, 41-44, 47?, 69a, 78, 95a, b, 103, 105.
<i>Diacocherus</i>	X---X---X---X---X---X---X	36, 37, 45, 55a, 56b, c, d, 57a-e, 58a-c, 67, 69a, 103.
<b>Nyctitheriidae</b>		
<i>Leptacodon</i>	?---O---O---X---X---X---X---X---X---X---O---?---?---▶	17, 36-38, 47, 55a, 56d?, 57e?, 58?a-c, 60?, 67?, 69a, 74, 75, 77, 78, 85, 95a?, b, 98, 101b, 103, 105.
<i>Pontifactor</i>	?---O---▶	34?.
<i>Plagioctenodon</i>	?---O---▶	57e?.
<b>?INSECTIVORA</b>		
<i>Xenacodon</i>	X	17.
<b>DERMOPTERA</b>		
<b>Plagiomenidae</b>		
<i>Elpidophorus</i>	X---O---X---X	47, 69a, 76, 78, 87, 102, 103.
<i>Planetetherium</i>	X---?	49, 56c.
<i>Plagiomene</i>	X---X---▶	57f, 58a-c, 67.
<i>Worlandia</i>	X---X---▶	57e, 58a-c, 67.
<b>PRIMATES</b>		
<b>Paromomyidae</b>		
<i>Purgatorius</i>	?◀---O---X---X	83a, d, 85, 106.
<i>Palaechthon</i>	X---X---X---X	6, 15, 28?, 38, 74-76.
<i>Paromomys</i>	X---O---X---X	6?, 10?, 35, 38, 60, 75, 76, 101b.
<i>Talpothenach</i>	X	6.
<i>Torrejonia</i>	X---X	6, 15.
<i>Palenochtha</i>	X---X	38, 50, 60, 75.
<i>Plesiolestes</i>	X---X---X	41, 50, 60.
<i>Ignacius</i>	X---O---X---X---X---X---O---O---X---X---▶	17, 36, 39, 45, 47, 57a-e, 58c, 60, 69a, 78, 86?, 87?, 95a, b, 103, 105, 108.
<i>Navajovius</i>	X---X---X	17, 20-22, 87?.
<i>Micromomys</i>	X---X---X---O---O---O---O---▶	55a, 103, 108.
<i>Phenacolemur</i>	X---X---X---X---X---▶	22, 29?, 34, 48, 49, 55a, 56b, c, 57a-e, 58a-c, 67.
<i>Tinimomys</i>	X---O---▶	34, 57e.
<b>Plesiadapidae</b>		
<i>Pronothodectes</i>	X---?	32?, 35, 53, 60, 75, 89, 100a, 101b?.
<i>Nannodectes</i>	X---X---X---X---X	17, 22, 32, 36, 37, 41, 42, 50, 74, 77, 95b.
Taxon	L + Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cfl Cf2 Cf3 W +	Localities (and References)

TABLE 3.2  
Temporal Ranges for Puercan Through Clarkforkian Mammals—Continued

Taxon	L+ Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cfl Cf2 Cf3 W+	Localities (and References)
<i>Plesiadapis</i>	X---X---X---X---X---X---X---X	29, 33, 34, 36, 37, 39-45, 47-52, 54, 55a, b, 56b, c, 57a-e, 58a-c, 63, 69a, 70, 72a, b, 76, 77-79, 86, 87, 90, 95a, b, 96, 98, 102, 103, 105, 108.
<i>Chiromyoides</i>	X---X---X---X---X	17, 21, 22, 34, 36, 37, 39, 45, 55b, 56c, d, 57a-d, 70, 72a, b.
Saxonellidae		
<i>Saxonella</i>	X	103.
Carpolestidae		
<i>Elphidotarsius</i>	X---X---O---X	50, 60, 75, 89, 101b.
<i>Carpodaptus</i>	X---X---X---X---X	17, 36, 39, 47, 50, 52, 69a, 78, 79, 86, 87, 95a, 98, 103-105, 108.
<i>Carpolestes</i>	X---X---X---X---X	34, 37, 40, 45, 49, 55a, b, e, 56b, c, d, 57c, e, 58a-c, 67, 70, 72a.
Picrodontidae		
<i>Draconodus</i>	X	28.
<i>Picrodus</i>	X---X---X---X---O---X	37, 38, 41, 50, 60, 69a, 74-76, 101b, 103.
<i>Zanycteris</i>	X---X	17, 47.
PRIMATES?		
Microsyopidae		
<i>Niptomomys</i>	X---X--->	34, 57?a-e, 58a-c, 67.
<i>Microsyops</i>	X---X--->	57a-d, 58a-c, 67.
CONDYLARTHRA		
Arctocyonidae		
<i>Ragnarok</i>	<---X	59, 68, 80.
<i>Protungulatum</i>	<---X---O---X	80, 82, 85.
<i>Baioconodon</i>	X---X---X	3, 30b, 106.
<i>Eoconodon</i>	X---X---X	2?, 3, 9/12, 59, 85, 106?.
<i>Platymastus</i>	X	12.
<i>Carcinodon</i>	X	106, 107.
<i>Oxyclaenus</i>	X---X---X	2?, 3, 9/12, 26, 28, 106.
<i>Loxolophus</i>	X---X---X---O---X	1, 2?, 3, 9/12, 13?, 25, 26?, 28, 31, 38, 106.
<i>Desmatoclaenus</i>	X---X---X---O---O---O---X	1, 2?, 3, 9/12, 26, 28, 41.
<i>Mimotricentes</i>	X---O---X---X---X---X---X---X---X---X	2?, 6, 8, 9?, 11, 12, 14, 15, 16, 21, 22, 28, 32, 38, 41, 42, 47, 50, 52, 55a, 56d?, 60, 69a, 75-77, 78?, 87, 85.
<i>Thangorodrim</i>	X	6, 11, 14, 15, 17, 28, 32, 35, 36, 38, 41, 42, 44, 52, 57a-d, 58?a-e, 60?, 67?, 69a, 77, 85, 100a?, 101b, 103.
<i>Chriacus</i>	X---X---X---X---X---X---X---X---O---O---O--->	6, 11, 14, 15, 17, 28, 32, 35, 36, 38, 41, 42, 44, 52, 57a-d, 58?a-e, 60?, 67?, 69a, 77, 85, 100a?, 101b, 103.
<i>Goniacodon</i>	X---X---X---X	6, 14, 15, 26, 28, 38, 60.
<i>Triisodon</i>	X---X	5, 6, 14.
<i>Prothryptacodon</i>	?---X	15?, 38, 75, 76, 99.
<i>Deuteroconodon</i>	X---X	6, (& Simpson's 1935 loc. 25).
<i>Deltatherium</i>	X---X	6, 7, 8, 11, 14.
Taxon	L+ Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cfl Cf2 Cf3 W+	Localities (and References)

TABLE 3.2  
Temporal Ranges for Puercan Through Clarkforkian Mammals—Continued

Taxon	L+ Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cfl Cf2 Cf3 W+	Localities (and References)
<i>Stelocyon</i>	X	53.
<i>Arctocyon</i>	X--X--X--X--X--X	8, 15, 22, 33, 36-39, 41-43, 50, 55a, 60, 69a, 75, 77, 87, 95a.
<i>Colpoclaenus</i>	X	50.
<i>Thryptacodon</i>	X--X--X--X--X--O--X--X--X--▶	17, 33, 36, 37, 39-45, 47, 55a, 56b, c, 57a-e, 58a-c, 67, 69a, 73b?, 77, 78, 86, 87, 95a, b.
<i>Lambertocyon</i>	X--X--X--O--X	29, 36, 37.
Mesonychidae		
<i>Microclaenodon</i>	X--X	6, 14, 60.
<i>Dissacus</i>	X--X--O--X--X--X--X--O--X--X--X--▶	14, 15, 17, 37-40, 42, 49, 55a, 56b, c, 57a-e, 58a-c, 60, 67, 69a, 72b, 75, 76, 78.
<i>Ankalagon</i>	X	15.
Periptychidae		
<i>Mimatuta</i>	◀--X	59, 68, 80, 82.
<i>Earendil</i>	X	59.
<i>Maiorana</i>	X	59.
<i>Escatepos</i>	X	12.
<i>Oxyacodon</i>	X--X	2, 3, 9, 12, 25, 26, 83a, d, 85.
<i>Conacodon</i>	X--X	2?, 3?, 9, 12, 31.
<i>Gillisonchus</i>	X--X	1, 2?, 3, 9, 12.
<i>Hemithlaeus</i>	X--X	2?, 3, 9/12.
<i>Ectoconus</i>	X--X	2?, 3, 9/12, 25, 26.
<i>Carsioptychus</i>	X--X	1, 2?, 3, 9, 12, 26, 31.
<i>Haploconus</i>	X--X--X--X--X	6, 11, 14, 16, 26, 28, 38.
<i>Anisonchus</i>	X--X--X--X--X--X	2?, 3, 5, 6, 9, 11, 12, 14, 15, 25, 26, 28, 35, 38, 50, 60, 75, 85, 106, 109, 110.
<i>Tinuviel</i>	X	85.
<i>Periprychus</i>	X--X--X--X--O--X--X	4-7, 8, 10, 11, 13-17, 19, 20, 21, 28, 38, 50.
Hyopsodontidae		
<i>Oxyprimus</i>	◀--X	59, 82, 85.
<i>Litomylus</i>	X--O--X--O--X--X--X--X--X	14/15, 28, 32, 35, 36, 38, 41, 42, 47, 50?, 52?, 60, 75, 77, 87, 106.
<i>Haplaletes</i>	X--O--O--X--O--X--X--X--X	22, 26, 38, 41, 43-45, 60, 75, 85, 87, 95a, b.
<i>Dorraletes</i>	X--O--X	39, 45, 95a.
<i>Aletodon</i>	X--X--X--O--X--X--X	17, 29, 34?, 37, 39, 44, 49, 57a-d, 58a-c, 67, 69a, 95b.
<i>Utemylus</i>	X	17.
<i>Phenacodaptes</i>	X--X--O--X	36, 37, 52, 55a, 56c?.
<i>Haplomylus</i>	X--X--X--▶	29?, 46, 49, 56b, c, 57a-e, 58a-c, 67.
<i>Apheliscus</i>	X--X--X--▶	34?, 40, 48, 49, 56b, 57a-d, 58a-c, 67.
<i>Hyopsodus</i>	X--▶	58c.
Taxon	L+ Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cfl Cf2 Cf3 W+	Localities (and References)

TABLE 3.2  
Temporal Ranges for Puercan Through Clarkforkian Mammals—Continued

Taxon	L + Pu1 Pu2 Pu3 Tol To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cf1 Cf2 Cf3 W +	Localities (and References)
Mioclaenidae		
<i>Bubogonia</i>	X	106.
<i>Choeroclaenus</i>	X--X	2/3/9/12.
<i>Bomburia</i>	X--X	2/3/9/12.
<i>Protoselene</i>	X--O--X--X--X--O--X--X	6, 7, 11, 12, 14, 15, 21, 28, 41?, 47.
<i>Promioclaenus</i>	X--X--O--X--X--X--X--X	2/3/9/12, 6, 7?, 11, 14, 15, 19, 32, 38, 41, 42, 47, 50, 60, 75, 76.
<i>Ellipsodon</i>	X--O--X	3, 6, 14, 26?, 38.
<i>Litaletes</i>	X--O--X	28, 60, 75.
<i>Mioclaenus</i>	X--X--X	5?, 6, 8, 11, 14, 15, 109?.
Phenacodontidae		
<i>Tetraclaenodon</i>	X--X	6, 7, 8, 11, 14, 15, 16, 35, 38, 60, 76, 94?, 100a, 109?.
<i>Ectocion</i>	X--X--X--X--X--X--X--X--X-->	21, 22, 29, 34, 36, 37, 39-44, 47, 49, 50, 52, 55a, 56b, d, 57a-e, 58a-c, 67, 72a?, b, 73a, b, 87, 95a, b, 96, 101a, b, 103, 105.
<i>Phenacodus</i>	X--X--X--X--X--X--X--X--X-->	17, 19, 20-22, 29, 33, 34, 36, 37, 39-44, 46-49, 51, 52, 55a, 56b, c, 57a-e, 58a-c, 67, 72a, b, 73b, 95a, b, 96, 102?.
<i>Prosthecion</i>		X 29.
NOTOUNGULATA		
Arctostylopidae		
<i>Arctostylops</i>	X--O--O--X--X	49, 55a, 57a-e, 58a-c, 67.
TILLODONTIA		
Esthonychidae		
<i>Esthonyx</i>	?--X--X--X-->	29, 34, 48, 49, 57a-e, 58a-c, 65, 67, 73a.
PANTODONTA		
Pantolambdidae		
<i>Pantolambda</i>	X--?	8, 15, 50?, 60?, 75, 94?.
<i>Caenolambda</i>	X--X	41, 42, 69a, 97?.
Titanoideidae		
<i>Titanoides</i>	X--X--X--X--X--O--?	21, 29, 43, 55a, 69a, 77, 78, 86, 91, 95a, b, 96, 103.
Cyriacotheriidae		
<i>Cyriacotherium</i>	X--X--X--X--?--X--X	48, 55a, d, 57a-d, 58a-c, 67, 70, 103, 108.
Barylambdidae		
<i>Barylambda</i>	X--X--X--O--X--X--?-->	21, 24, 29, 40, 55a, 63.
<i>Haplolambda</i>	X--X--O--X	17, 29, 55a.
Coryphodontidae		
<i>Coryphodon</i>	X--X--X-->	29, 46, 49, 56b, 57a-e, 58a-c, 65, 67, 72a, 73a, b.
DINOCERATA		
Uintatheriidae		
<i>Probathyopsis</i>	X--X--X--X--X-->?	29, 34, 40, 46, 55a, 56b, d, 57a-d, 58a-c, 67, 72b.
Taxon	L + Pu1 Pu2 Pu3 Tol To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cf1 Cf2 Cf3 W +	Localities (and References)

TABLE 3.2  
Temporal Ranges for Puercan Through Clarkforkian Mammals—Continued

Taxon	L + Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cf1 Cf2 Cf3 W +	Localities (and References)
<b>TAENIODONTIA</b>		
<b>Conoryctidae</b>		
<i>Onychodectes</i>	X--X	27, 3, 9, 12, 26.
<i>Conoryctella</i>	X--X	5, 6, 28.
<i>Conoryctes</i>	X--X	6, 60, 75, 76.
<i>Huerfanodon</i>	X	11?, 60.
<b>Stylinodontidae</b>		
<i>Wortmania</i>	X--X	2?, 3, 9, 12.
<i>Psittacotherium</i>	X--X--X--O--X--O--?	6, 14/15, 16, 20-23, 38, 76, 77.
<i>Ectoganus</i>	X--X--X--X--X-->	29, 40, 55a?, 56b?, c, d?, 57a-d, 58a-c, 67, 73a, b.
<b>CREODONTA</b>		
<b>Hyaenodontidae</b>		
<i>Prolimnocyon</i>	?--O--O--O--O--O--O--O--O-->	38.
<b>Oxyaenidae</b>		
<i>Tythaena</i>	X	69a.
<i>Dipsalodon</i>	X--?--O--X--?	29, 49, 55a, 58a-c?, 67.
<i>Oxyaena</i>	X--X--X--X--X-->	49, 55a?, 56b, d, 57a-e, 58a-c, 67.
<i>Palaeonictis</i>	X	58c.
<b>CARNIVORA</b>		
<b>Didymictidae</b>		
<i>Protictis</i>	X--X--X--X--X--X--X--X	6, 7, 8?, 11, 14, 15, 28, 37, 39, 41, 45, 47, 50, 55a-c, 60, 69a, 70, 75-77, 86, 95a, b, 103.
<i>Bryanictis</i>	X	60, 75, 76.
<i>Inyriictis</i>	X	15, 38.
<i>Didymictis</i>	X--X--X--X--X-->	34, 45, 48, 49, 55a, 56b, 57a-e, 58a-c, 67, 72a, b.
<b>Viverravidae</b>		
<i>Simpsonictis</i>	X--O--?	38?, 41, 60, 75.
<i>Raphictis</i>	X	69a.
<i>Viverravus</i>	X--O--X--X--X-->	34?, 40?, 49, 55a?. 56b, c?. 57a-e, 58a-c, 67.
<b>Family indet.</b>		
<i>Ictidopappus</i>	?--O--O--O--X	12?, 75.
<b>?Miacidae</b>		
<i>Uintacyon</i>	X--X-->	57a-e, 58a-c, 67.
<b>RODENTIA</b>		
<b>Ischyromyidae</b>		
<i>Acritoparamys</i>	X--O--O-->	56c.
<i>Apatosciuravus</i>	X--X--X-->	34?, 49?, 56b, 57e, f, 58c.
<i>Paramys</i>	X--X--X-->	40, 49, 56b, 57a-e, 58a-c, 67, 72b, 73b.
<i>Franimys</i>	X--O-->	57f.
<b>PALAEANODONTA</b>		
<b>Epoicotheriidae</b>		
<i>Amelotabes</i>	X	70.
<b>Metacheiromyidae</b>		
<i>Propalaeonodon</i>	X	55a.
<i>Palaeonodon</i>	X--X-->	57c, 58a-c, 67.
<b>Family incertae sedis</b>		
<i>Melaniella</i>	X	103.
Taxon	L + Pu1 Pu2 Pu3 To1 To2 To3 Ti1 Ti2 Ti3 Ti4 Ti5 Ti6 Cf1 Cf2 Cf3 W +	Localities (and References)

## PUERCAN MAMMAL AGE

### Introduction

The concept of the Puercan Mammal Age, like that of the Torrejonian Mammal Age, grew out of work done in the San Juan Basin, New Mexico, beginning in the late nineteenth century. The history of this work is discussed more fully in the introduction to the Torrejonian Mammal Age. It is sufficient to note here that the "type locality" of the Puercan Mammal Age in the "Rio Puerco area" (near Cuba, New Mexico) as recognized by Wood et al. (1941) is, in fact, Torrejonian in age.

In 1959, Simpson reported the occurrence of Torrejonian fossils from the type area of the "Puerco" Formation near Cuba, New Mexico. He further noted that the "Puerco" and "Torrejon" formations could not be differentiated based on lithologic criteria and suggested that the Nacimiento Formation of Gardner (1910) be used in a restricted sense to replace these two "formations."

Wood et al. (1941) noted that the "most typical and only fossiliferous exposures" of the Puercan Mammal Age are "the escarpment running from northwest of Ojo Alamo about 25 miles to Arroyo Eduardo, east of Kimbetoh." Since about 1959, these exposures have also been recognized as yielding the type Puercan fauna (Simpson 1959). For purposes of discussion, these exposures will be divided into the De-na-zin (= Barrel Spring Arroyo) and Alamo washes, West Fork of Gallegos Canyon, Kimbetoh Arroyo, and Betonnie-Tsosie Arroyo.

The only correlative of the type Puercan assemblage recognized by Wood et al. is what we will formally term the "Mantua Lentil Local Fauna" from the Fort Union (= Polecat Bench) Formation, Wyoming (Jepsen 1940). Mantua is still retained in the Puercan Mammal Age by most authors (but see Van Valen 1978), although it is now known to be older than the type Puercan assemblage (*sensu* Simpson 1959) of the San Juan Basin. The evidence for this correlation is based on the stage of evolution of the mammals, the demonstrable superposition of type Puercan-like local faunas over Mantua-like local faunas in northeastern Montana, and faunal and magnetostratigraphic correlation between type Puercan-like local faunas in Montana and the type Puercan fauna of New Mexico (see below for further comments).

The number of new Puercan localities has increased greatly since Wood et al. Faunas referable to the Puercan Mammal Age have been reported from the North Horn Formation, Utah (Gazin 1941*b*; Tomida and Butler 1980; Robison 1980, pers. comm. to JDA 1984), the Denver Formation, Colorado (Gazin 1941; Middleton 1983, pers. comm. to JDA 1984), the Tullock Formation, Mon-

tana (Van Valen and Sloan 1965; Clemens 1974; Novacek 1977; Van Valen 1978; Archibald 1982), and the Ravenscrag Formation, Saskatchewan (Johnston 1980, Johnston and Fox 1984). Other small collections or single specimens of Puercan (or possible Puercan) age have also been reported from Wyoming (Leidy Quarry: Van Valen 1978), Montana (Bechtold Locality: Clemens and Simmons, pers. observ. 1984), Alberta (Alberta Core Hole 66-1: ?Torrejonian; Fox 1968; Van Valen 1978; Johnston and Fox 1984), and Saskatchewan (Pine Cree Park: L. S. Russell 1974; Van Valen 1978; Johnston and Fox 1984).

### Lancian/Puercan Boundary

Our knowledge of pre-Cenozoic North American mammal faunas has been greatly augmented since the conclusions of Wood et al. were published in 1941. The Wood committee noted the occurrence of the latest Cretaceous Lance fauna and its equivalents but refrained from naming a formal "time term." L. S. Russell (1964, 1975) proposed a series of Upper Cretaceous "stages," for including a Lancian "stage," Late Cretaceous terrestrial faunas from North America. As pointed out by Clemens et al. (1979), Russell's "stages" lack the "rigorous definition and precision of biostratigraphic stages, but have a genesis and character similar to the Cenozoic 'land mammal ages' currently used in North America." Although we know considerably more about the Lancian fauna than was available to the Wood committee (Clemens 1964, 1966, 1973; Sloan and Van Valen 1965; Lillegraven 1969; Van Valen 1978; Archibald 1982), we are still unable to clearly define a beginning for this age because sediments containing Lancian faunas are underlain by poorly fossiliferous or marine rocks.

Fortunately, this is not the case for the boundary of the Lancian with the younger Puercan Mammal Age. As discussed below, the Puercan Mammal Age can be characterized by the appearance of a host of new taxa, although there are very few appearances of taxa in the earliest Puercan faunas (Archibald 1981, 1982). The only new genus to appear at the very beginning of the Puercan is the didelphid *Peradectes* (see remarks on this taxon under the *Peradectes/Ectoconus* Interval-Zone). Several new species also occur in earliest Puercan faunas; these are *Mesodma garfieldensis*, *Acheronodon garbani* (known only from a single tooth), *Catopsalis alexanderi*, *Ragnarok engdahli*, and *Mimatuta minuial*. Of these taxa, only *Peradectes pusillus*, *Catopsalis alexanderi*, and *Mimatuta minuial* are known from more than a single local fauna (Van Valen 1978; Archibald 1982; Middleton 1982, 1983).



There are two potentially confusing topics regarding the recognition of the Lancian/Puercan boundary which require further comment. The first concerns the possibility of an additional mammal age between the Lancian and Puercan mammal ages, the so-called Bugcreekian Mammal Age (Sloan, pers. comm. to JDA 1984) representing the faunas from the Bug Creek sequence in northeastern Montana first described by Sloan and Van Valen in 1965. (As noted above, we reject a second additional mammal age, the "Mantuan," preferring to include it in the Puercan Mammal Age; see below for further discussion.) Archibald (1982) used stratigraphic position to argue that the Bug Creek sequence is a lateral equivalent to characteristic Lancian localities that also occur near the top of the Hell Creek Formation, and thus the faunal differences are due mostly to facies differences. Accordingly, in northeastern Montana, Archibald referred the Bug Creek sequence to the Bug Creek faunal-facies, the characteristic Lancian localities to the Hell Creek faunal-facies, and both of these to the Lancian Mammal Age. More recently, Dingus, Clemens, and Fastovsky (pers. comm. 1984) have found evidence to suggest that part or all of the Bug Creek sequence, although Lancian in age, may be younger than known typical Lancian localities. But until differences in time (and biostratigraphy) can be demonstrated more clearly between typical Lancian localities and part or all of the Bug Creek sequence, it is best to treat these as facies differences and not recognize a separate "Bugcreekian" age. This seems the more prudent approach given the problems (discussed below) of recognizing zonation within the type Puercan faunas of the San Juan Basin and its faunal equivalents.

The second topic, although also pertaining to the Bug Creek sequence, is of much broader scope and involves an assessment of the degree of precision in the correlation of the Lancian/Puercan boundary with the Cretaceous/Tertiary boundary. "Cretaceous" and "Tertiary" are units founded on analyses of the evolution of the marine faunas of Western Europe. Usually, the boundary is placed at a level recording the extinction of ammonites, many lineages of foraminiferans, and some other marine organisms. In coarse-scaled analyses, these extinctions often are presented as being massive, instantaneous, global events, but studies of higher stratigraphic resolution (e.g., Voight 1981, Ward 1984) suggest much less precipitous patterns of change during the transition from the Cretaceous to the Tertiary Period.

In western North America, sections containing interdigitating marine and nonmarine rocks that provide a direct basis for correlation of a Cretaceous/Tertiary boundary, characterized by changes in the marine biota,

with the evolution of the terrestrial biota have yet to be found. In the past, recognition of the Cretaceous/Tertiary boundary in continental sections was based on the assumption that the extinctions of dinosaurs and those lineages of marine organisms used to define the Cretaceous/Tertiary boundary in Europe were precisely contemporaneous events. Studies of the magnetostratigraphy of some marine and terrestrial sections provide limited support for this view through demonstration that the pertinent extinctions of marine or terrestrial organisms occurred during magnetic polarity chron 29R. The duration of this chron is usually given as about five hundred thousand years. It must be stressed that this estimate is based on radiometric age determinations with uncertainties of at least  $\pm$  one million years and on assumptions concerning constancy of seafloor spreading rates (see Dingus 1984 for further discussion of time resolution).

One of the following three operational definitions is used in common stratigraphic practice to identify the Cretaceous/Tertiary boundary in terrestrial deposits in western North America: (1) the stratigraphically highest record of dinosaurian remains, (2) the base of the first lignite overlying the stratigraphically highest record of dinosaurs (Brown 1952), or (3) extinction of *Aquilapollenites* or other palynological taxa (Tschudy 1970). In the southern part of the area where faunas of Lancian and Puercan mammal ages have been recognized (i.e., San Juan Basin, Wasatch Plateau, Denver Basin), the first or third operational definitions usually are employed. Farther north, in areas of deposition of the "Fort Union" lignites and coals, the second or third is utilized. Fine stratigraphic scaling is needed to even begin analyses of faunal or floral change on biologically significant time scales, yet these three operational definitions delimit geochronologically different interpretations of the placement of the Cretaceous/Tertiary boundaries (Archibald 1982, Archibald and Clemens 1982).

The issue of the degree of precision with which the Cretaceous/Tertiary boundary (still imprecisely defined on the basis of changes in the Western European marine biota) could be recognized in North American terrestrial deposits was brought to a head by Smit and van der Kaars (1984) who suggested that the Bug Creek Anthills Locality is within a Paleocene channel that cut down into Cretaceous sediments. Clearly, one of their purposes was to demonstrate that the Bug Creek faunal sequence is compatible with the catastrophic asteroid scenario for latest Cretaceous extinctions. This interpretation and its supposed consequences have been shown incorrect on several counts. Archibald (1984, in press) demonstrated that the stepwise extinctions within this sequence do not support catastrophic scenarios whether the Bug Creek

Anthills fauna is Cretaceous in age or not; Clemens (pers. observ. 1984) reported the discovery of a new Bug Creek-like locality demonstrably within uppermost Hell Creek sediments; Fastovsky (pers. comm. to WAC 1984) and Sloan (1985) have demonstrated that the sedimentological setting of Bug Creek Anthills is different from that reported by Smit and van der Kaars and does not clearly demonstrate either a Cretaceous or Paleocene age for the site, although a Cretaceous age is most strongly supported by the available evidence.

The relevance of the preceding comments to mammalian biochronology and biostratigraphy is that the assignment of the faunas from the Bug Creek sequence to either the Late Cretaceous or Paleocene Epoch is immaterial relative to their assignment to the Lancian or Puercan Mammal Age. There is certainly no reason that mammal ages should be concordant with any other time boundary, whether era, period, or epoch boundaries. This is the case with the Clarkforkian Mammal Age, which straddles the Paleocene/Eocene boundary (Rose 1981a), and also for other North American mammal ages relative to other epochs of the Cenozoic Era. The concordance of the Lancian/Puercan and the Late Cretaceous/Paleocene boundaries in North America probably has some biological reality because of the considerable extinctions that occurred preceding, at, and following these boundaries, but such concordance is not required by any theoretical constraints.

### Definition and Characterization

We define the Puercan Mammal Age to include faunas that occur during the time between the first appearance of the didelphid marsupial, *Peradectes*, and the first appearance of the periptychid condylarth, *Periptychus*.

Wood et al. (1941) noted that the following taxa first appeared in the Puercan Mammal Age: *Anisonchus*, *Condylarthra*, *Creodonta*, *Eucosmodon*, *Oxycloenus*, *Taeniodonta*, *Taligrada*. The genera in this list are still known to appear in the Puercan, although not at the earliest sites referable to this age. Of the four orders listed as first appearances, only the *Taeniodonta* retains a usage similar to that of Wood et al. (Schoch 1986, pers. com. to JDA 1984). This order is still considered to appear in the Puercan Mammal Age but, again, not at the earliest sites. Assuming that Wood et al. followed Matthew's (1937) concept of the *Condylarthra*, *Creodonta*, and *Taligrada*, the Puercan representatives of the *Condylarthra* were included in the *Hyopsodontidae*, the *Creodonta* were represented by the *Arctocyonidae*, and the *Taligrada* by the *Periptychidae*. The *Taligrada* is no

longer recognized, while the *Hyopsodontidae*, *Arctocyonidae*, and *Periptychidae* are now placed either within the *Condylarthra* (e.g., Romer 1966) or within various other orders (McKenna 1975, Szalay 1977). Representatives of the *Arctocyonidae* and the *Periptychidae* are now known to have appeared in the latest Cretaceous Lancian Mammal Age (Sloan and Van Valen 1965, Van Valen 1978), and representatives of the *Hyopsodontidae* also may have appeared in the same mammal age if *Oxyprimus* is referable to this family (Archibald 1982).

In addition to first appearances, the Wood et al. report (1941) identified the following "index fossils" that were thought to be restricted to the Puercan Mammal Age: *Carsiptychus*, *Conacodon*, *Ectoconus*, *Eocondon*, *Loxolophus*, *Onychodectes*, *Oxyacodon*, *Taeniolabis*, and *Wortmania*. Of these genera, only *Loxolophus* is now known from other than Puercan localities. *Loxolophus spiekeri* (Gazin 1938) is recognized in the Dragon Local Fauna of the Torrejonian Mammal Age (Van Valen 1978, Tomida and Butler 1980). *Carsiptychus* was considered a subgenus of *Periptychus* by Van Valen. As discussed in the section on the Torrejonian Mammal Age, this referral is not accepted here. Van Valen also reported a species of *Oxyacodon* from the Torrejonian, but Archibald et al. (1982) indicated that the specimen on which this species was based is referable to *Mixodectes*. We follow Russell (1980) in questionably retaining *Claenodon* as a synonym of *Arctocyon*, rather than placing both of these genera in synonymy with *Arctocyonoides* as done by Van Valen. Although not necessarily endorsing all other synonymies suggested by Van Valen, we use the following because they represent the most recent views: *Loxolophus* includes *Protogonodon*; *Mimotricentes* includes *Tricentes* (in part?); and *Chriacus* includes *Spanoxyodon*, *Tricentes* (in part?), and *Metachriacus*. Similarly, in this as well as in discussions of later mammal ages, we follow the recent taxonomic review of Novacek et al. (1985) for erinaceomorph insectivores.

A combined biochronologic-magnetostratigraphic correlation of Puercan local faunas from the Nacimiento Formation, San Juan Basin, New Mexico (Butler and Lindsay 1985), the North Horn Formation, Wasatch Plateau, Utah (Tomida and Butler 1980), and the Tullock Formation, northeastern Montana (Archibald et al. 1982), indicates that Puercan mammals first occur in sediments of reversed polarity and last occur in sediments of normal polarity. We interpret that the Puercan begins sometime during magnetic polarity chron 29R and ends within, or possibly at the end of, magnetic polarity chron 29N (Butler and Lindsay, 1985).

An updated list of first and last appearances, index

fossils, and characteristic fossils for the Puercan follows. Occurrences for these taxa are given in table 3.2.

First appearances: *Anisonchus*, *Chriacus*, *Desmatoclaenus*, *Ectypodus*, *Ellipsodon*, *Eucosmodon*, *Goniacodon*, *Haplaletes*, *Haploconus*, cf. *Ictidopappus*, *Lep-tacodon*(?), *Litomylus*, *Loxolophus*, *Microcosmodon*, *Mimotricentes*, *Oxyclaenus*, *Parectypodus*, *Peradectes*, *Prodiacodon*, *Promioclauenus*, *Protoselene*, *Ptilodus*, *Xyronomys*.

Last appearances: *Cimexomys*, *Cimolestes*, *Cimolodon*(?), *Mimatuta*, *Oxyprimus*, *Procerberus*, *Protungulatum*, *Purgatorius*, *Ragnarok*.

Index fossils: *Acheronodon*, *Baiiconodon*, *Bomburia*, *Bubogonia*, *Carcinodon*, *Carsioprychus*, *Choeroclaenus*, *Conacodon*, *Earendil*, *Ectoconus*, *Eoconodon*, *Escatepos*, *Gillisonchus*, *Hemithlaeus*, *Kimbetohia*, *Maiorana*, *Onychodectes*, *Oxyacodon*, *Platymastus*, *Taeniolabis*, *Thangorodrim*, *Tinuviel*, *Wortmania*.

Characteristic fossils: *Catopsalis*, *Mesodma*, *Neoplagiaulax*(?), *Stygimys*.

## Zonation

We recognize three interval-zones within the Puercan Mammal Age. From oldest to youngest, they are the *Peradectes/Ectoconus* Interval-Zone (Pu1), the *Ectoconus/Taeniolabis taoensis* Interval-Zone (Pu2), and the *Taeniolabis taoensis/Periprychus* Interval-Zone (Pu3). The most questionable aspects of this tripartite division concern the latter two interval-zones; they will be considered together.

### *Peradectes/Ectoconus* Interval-Zone (Pu1)

As noted previously, Van Valen (1978) recognized the Mantuan as a separate mammal age. This suggestion has not found wide acceptance, however. Van Valen's Mantuan is essentially equivalent to the *Peradectes/Ectoconus* Interval-Zone, which we define to include faunas that occur during the time between the first appearance of *Peradectes* and the first appearance of *Ectoconus*.

Discussion of the *Peradectes/Ectoconus* Interval-Zone is complicated by taxonomic issues surrounding *Peradectes*. Archibald (1982) followed Clemens (unpublished data in Archibald 1982) in treating the Puercan genus, *Thylacodon*, as a junior synonym of the Tiffanian and younger genus, *Peradectes*. Recently, Krishtalka and Stucky (1983) suggested this synonymy may not be correct. This is a taxonomic issue that has yet to be resolved (Clemens, pers. observ. 1984). The primary reason for naming this interval-zone for *Peradectes* is

that it is the only known genus that first appears in it. Further, this genus also is present in the three geographic regions where this interval-zone can be recognized.

The *Peradectes/Ectoconus* Interval-Zone is represented by the following: Mantua Lentil Local Fauna and Leidy Quarry, Bighorn Basin, northern Wyoming; Hell's Hollow Local Fauna and McKeever Ranch localities, northeastern Montana; and Littleton Local Fauna, Denver Basin, central Colorado. *Peradectes* is abundant in the Hell's Hollow Local Fauna but is much rarer in the other faunas. The Mantua Lentil Local Fauna was the first discovered representative of this interval-zone and may be the richest local fauna within it. However, the Littleton Local Fauna rivals the Mantua Lentil Local Fauna in the quality of preservation, if not in richness of specimens, whereas the sites in northeastern Montana are within the most complete biostratigraphic context. Until all these local faunas are fully published and compared, it seems imprudent to designate one over the other as the type.

The Mantua Lentil Local Fauna was first reported by Jepsen (1930b), at which time he described some of the taxa. Later, he provided a more detailed description for some of the multituberculates (1940). The only other major description of mammals from this local fauna has been provided by Van Valen's (1978) abbreviated description of a number of new condylarths. Additional references to taxa in the Mantua Lentil Local Fauna can be found in Sloan and Van Valen (1965), D. E. Russell (1967), Archibald (1982), and Middleton (1983). Van Valen (1978) also reported another locality, Leidy Quarry, in the southern Bighorn Basin, that is referable to the *Peradectes/Ectoconus* Interval-Zone. Leidy Quarry yielded two new species of condylarths that, according to Van Valen, belong to the genera *Ragnarok* and *Mimatuta*.

The Hell's Hollow Local Fauna and the small fauna from the McKeever Ranch localities in northeastern Montana were described by Archibald (1982). He informally used the terms "pre-mantuan" for the Hell's Hollow Local Fauna and "mantuan" for the McKeever Ranch localities to indicate probable faunal correlations with Mantua Lentil. The use of these terms might lead to confusion and thus should be dropped, although the implied correlations remain valid.

The Hell's Hollow Local Fauna appears to be older than the Mantua Lentil Local Fauna based on the presence of the multituberculates *Stygimys* aff. *S. kuszmauli* and *Cimexomys minor*, the proteutherian *Procerberus formicarum*, and the condylarths *Protungulatum* cf. *P. donnae*, *Ragnarok harbichtii*(?), *Oxyprimus erikseni*, and *Mimatuta morgoth* at Hell's Hollow. These taxa are

known from Lancian sites such as Harbicht Hill but are absent from Mantua Lentil (Van Valen 1978, Archibald 1982). Taxa present at Mantua Lentil but absent from Hell's Hollow include the multituberculates *Mesodma ambigua* and *Stygimys gratus*, a different species of the proteutherian *Procerberus*, and the condylarths *Eoconodon copanus*, *Ragnarok nordicum*, *Oxyprimus galadri- elae* and *O. putorius*, "*Oxyacodon*" *josephi*, *Maiorana noctiluca*, *Mimatuta minuial*, and *Earendil undomiel*. Taxa in common between these two local faunas are the multituberculates *Catopsalis alexanderi* and *Cimexomys hausoi* and the marsupial *Peradectes pusillus*. The McKeever Ranch localities are much less rich than Hell's Hollow, but the probable joint occurrence of the condylarths *Ragnarok nordicum* and *Mimatuta minuial* at both McKeever and Mantua Lentil suggest these faunas could be contemporaneous (Jepsen 1940; Van Valen 1978; Archibald 1982; Middleton 1982; Archibald et al. 1982).

The Littleton Local Fauna is the name that has been applied by Middleton (unpublished data and pers. comm. to Archibald 1984) to material collected from South Table Mountain (Gazin 1941a) and the Alexander Locality, Denver Basin, central Colorado. Middleton's unpublished analysis of the mammalian fauna suggests that the Littleton Local Fauna is slightly younger than the Mantua Lentil Local Fauna but older than the type Puercan faunas of the San Juan Basin.

Of the three geographic regions in which the *Peradectes/Ectoconus* Interval-Zone can be recognized, only the local faunas in northeastern Montana have been correlated to the magnetic polarity time scale. In this region, the Hell's Hollow Local Fauna lies within a reversed magnetozone that probably represents magnetic polarity chron 29R (Archibald et al. 1982). It is probable that this entire interval-zone lies within magnetic polarity chron 29R as the oldest portion of the *Ectoconus/Taeniolabis taoensis* Interval-Zone (the next highest interval-zone) within the San Juan Basin appears to lie just above the shift from reversed to normal polarity which is correlated with the change from magnetic polarity chron 29R to 29N.

Occurrences for the taxa listed below are given in table 3.2.

First appearances: *Baioconodon*, *Eoconodon*, *Peradectes*.

Last appearances: *Mimatuta*, *Oxyprimus*, *Ragnarok*.

Index fossils: *Acheronodon*, *Earendil*, *Maiorana*, "*Oxyacodon*" *josephi*.

Characteristic fossils: *Catopsalis*, *Cimexomys*, *Mesodma*, *Procerberus*, *Protungulatum*, *Stygimys*.

Taxa absent but known before and after Pu1: *Cimolestes*, *Cimolodon*(?), *Neoplagiaulax*(?), *Purgatorius*(?).

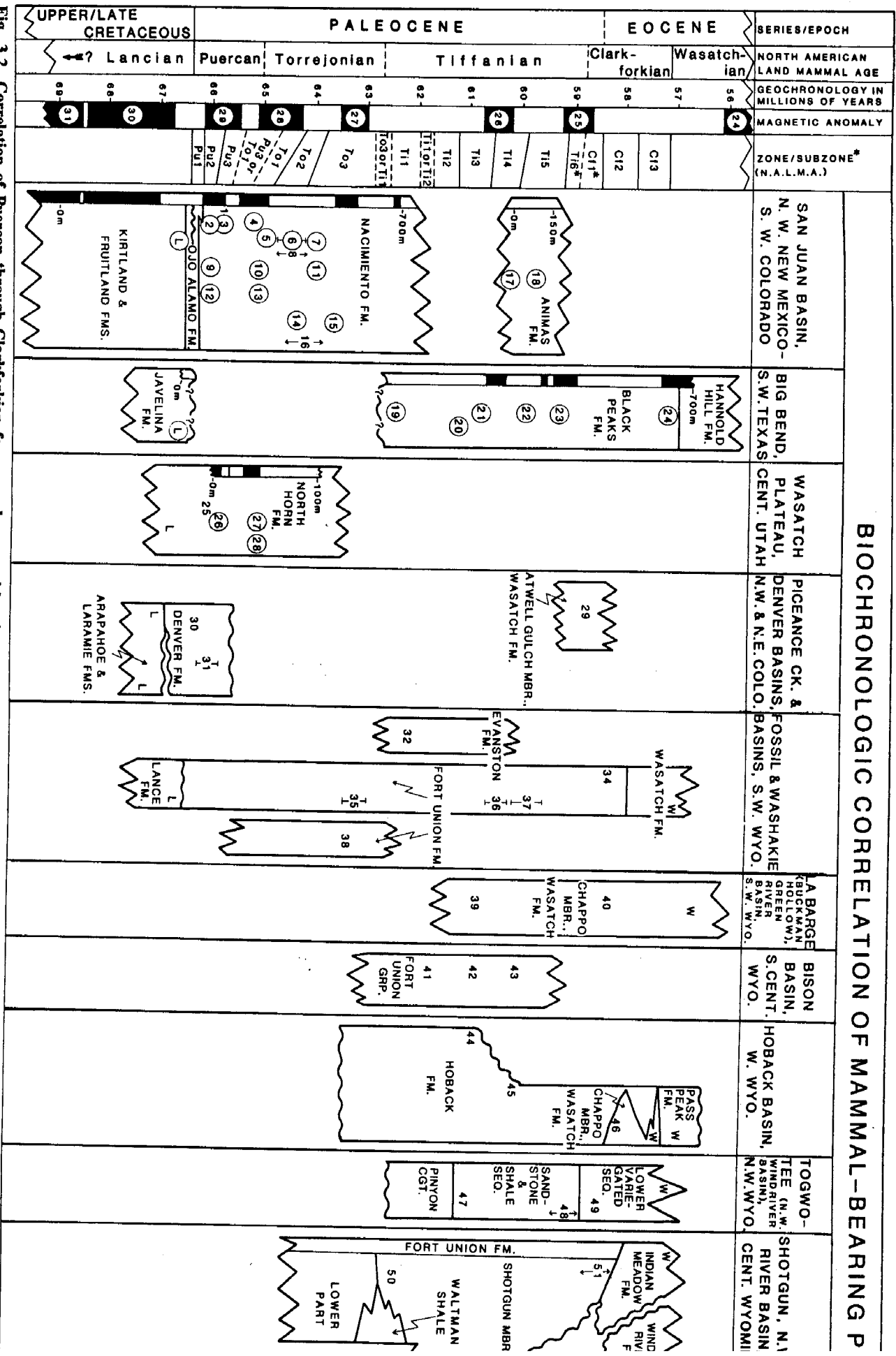
(Note that *Kimbetohia* would appear here except that earlier reports of this taxon from the Lancian Mammal Age of Wyoming [Clemens 1973] are incorrect according to pers. obser. of DWK.)

### ***Ectoconus/Taeniolabis taoensis* (Pu2) and *Taeniolabis taoensis/Periptychus* (Pu3) Interval-Zones**

One of the more difficult problems regarding the Puercan Mammal Age has been the inability to clearly identify zones within the type Puercan Mammal Age of San Juan Basin and then to extend this zonation beyond the limits of this basin. Accordingly, the following definitions of these two interval-zones are offered with the caution that substantial revision may be required. We define the *Ectoconus/Taeniolabis taoensis* Interval-Zone to include faunas that occur during the time between the first appearance of *Ectoconus* and the first appearance of *Taeniolabis taoensis*. Similarly, we define the *Taeniolabis taoensis/Periptychus* Interval-Zone to include faunas that occur between the first appearance of *Taeniolabis taoensis* and the first appearance of *Periptychus*.

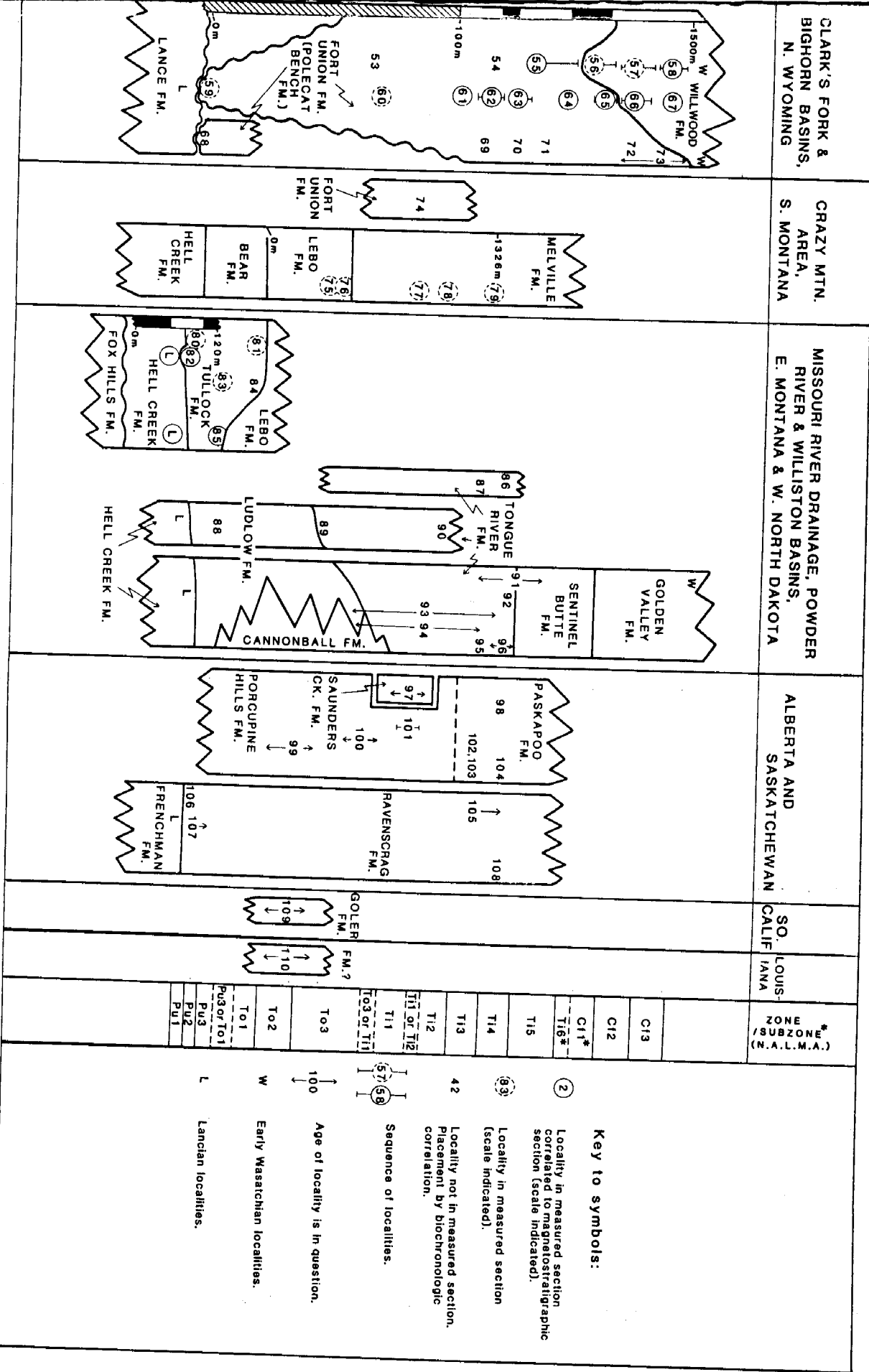
In 1892, Wortman recognized two faunal zones for Puercan assemblages within what are now called De-na-zin and Alamo washes (see Osborn and Earle 1895, Sinclair and Granger 1914). The formalization of these zones was accomplished by subsequent workers (Sinclair and Granger 1914, Matthew 1937). These zones are the lower "*Ectoconus* zone" (= "*Hemithlaeus* zone" of Van Valen [1978]) and the upper "*Taeniolabis* zone." There is little doubt that they are superposed within De-na-zin and Alamo washes and thus represent some difference in time. However, the slight faunal differences are probably due more to subtle ecological variation than to any marked difference in age (Lindsay et al. 1981). This view is strengthened by the absence of the multituberculate *Taeniolabis* in the other two major collecting areas for the type Puercan fauna, Kimbetoh and Bettonie-Tsowie arroyos. For this reason, the faunas from these two arroyos have been assigned to the lower "*Ectoconus* zone." Further complications arise because this "zone" in De-na-zin Wash may not be as fossiliferous as sites in Kimbetoh and Bettonie-Tsowie arroyos. Another collecting area for Puercan mammals lies northwest of De-na-zin and Alamo washes in the West Fork of Gallegos Canyon. Lucas (1984) recently described the small collection of mammals from this area. He argued that based on the presence of *Taeniolabis*, what we term the *Taeniolabis taoensis/Periptychus* Interval-Zone is present in

# BIOCHRONOLOGIC CORRELATION OF MAMMAL-BEARING P



**Fig. 3.2.** Correlation of Puercan through Clarkforkian faunas and mammal-bearing strata in the United States and Canada. Within basins or regions where some degree of stratigraphic control is possible, the basis for correlation is biostratigraphic. Correlation between basins or regions is almost exclusively done biochronologically except for those areas where magnetostratigraphic studies have been conducted. The calibration of the geochronology and the magnetic anomalies is that of Berggren et al. (1985). All other usages in this figure are based on references discussed in the text. The nonparallel zonal (or subzonal) boundary lines on the left are the result of correlation between the magnetostratigraphy of the mammal-bearing strata and the magnetic anomalies. The numbered localities are the same as those used in the map in fig. 3.1 and tables 3.1 and 3.2. See table 3.1 for faunal references and the Introduction for further comments.

# R/CAN THROUGH CLARKFORKIAN AGED STRATA IN THE U.S. AND CANADA



To accompany Woodburne, *Cenozoic Mammals of North America*. University of California Press, 1987.

the West Fork of Gallegos Canyon and that the *Ectoconus/Taeniolabis taoensis* Interval-Zone is absent.

The discovery of new local faunas and the reanalysis of previously discovered local faunas referable to the middle and/or late portion of the Puercan Mammal Age may eventually provide a securer basis for subdividing the middle and late portions of the Puercan. None of these analyses, however, are as yet published. Further, the available evidence suggests additional complications in simply extending the concepts of these two interval-zones beyond the San Juan Basin. Until these two interval-zones can be recognized more confidently outside of De-na-zin and Alamo washes, we recommend that (1) the *Ectoconus/Taeniolabis taoensis* and *Taeniolabis taoensis/Periptychus* interval-zones, considered formally, be restricted to De-na-zin and Alamo washes, and (2) in other parts of the San Juan Basin and in other regions, these two interval-zones be used provisionally and that this be indicated by the use of a question mark, that is, *Ectoconus/Taeniolabis taoensis* Interval-Zone(?) and *Taeniolabis taoensis/Periptychus* Interval-Zone(?) or Pu2(?) and Pu3(?).

In only two of the other four regions outside of San Juan Basin which have yielded middle and/or late Puercan assemblages does there appear to be a possibility that both the Pu2 and Pu3 interval-zones are present. These assemblages are from the Denver Formation, Colorado, and the North Horn Formation, Utah. Middleton (1983, pers. comm. to JDA 1984) has suggested that the vertical distribution of several condylarths in his Corral Bluffs section of the Denver Formation, Denver Basin, Colorado, lends meager support to the superposition of the Pu3 over the Pu2 interval-zone. It should be noted that the multituberculate *Taeniolabis* has not been recovered from sites in the Denver Basin. The possible occurrence of these two interval-zones in the North Horn Formation is suggested by some unpublished work by Robison (1980, pers. comm. to JDA 1984). Robison has a series of localities that appear to be older than the Wagonroad Local Fauna of Utah (Gazin 1941b, Tomida and Butler 1980). Among his supporting data are the absence of *Taeniolabis* from his new assemblage and its presence in the Wagonroad Local Fauna. He has named his new assemblage the Gas Tank Hill Local Fauna after the discovery locality of Gas Tank Hill (Van Valen 1978; = Flagstaff Peak Locality in Spieker 1960 and D. E. Russell 1967).

The two other major collecting regions in northeastern Montana and southwestern Saskatchewan have yielded assemblages that appear to be temporal correlatives of only one or the other of the interval-zones present in the type Puercan fauna of the San Juan Basin.

Although these faunas are middle to late Puercan in age, a more precise correlation to either Pu2 or Pu3 must be regarded with skepticism at least until the faunas from northeastern Montana have been fully described.

The first of these middle to late Puercan correlatives consists of several local faunas from the Tullock Formation, northeastern Montana. The Purgatory Hill Local Fauna was the first Puercan fauna in Montana to be discovered and briefly described (Van Valen and Sloan 1965, Van Valen 1978). Sloan (1970) assigned the Purgatory Hill Local Fauna a late Puercan age (the *Taeniolabis taoensis/Periptychus* Interval-Zone[?]) based in part on the presence of *Taeniolabis* at Purgatory Hill. The Garbani Local Fauna, located to the west of Purgatory Hill, appears to be correlative. It was collected from a series of localities occurring in a single channel complex (Archibald 1982); it is richer than Purgatory Hill, but most of the fauna has not been published (Clemens 1974; Novacek 1977; Novacek and Clemens 1977; Archibald et al. 1982).

The second important Puercan correlative occurs in southwestern Saskatchewan. The fauna from this site, RAV W-1, has recently been described (Johnston 1980, Johnston and Fox 1984). Johnston and Fox argue that RAV W-1 is older than, or very early within, the *Ectoconus/Taeniolabis taoensis* Interval-Zone(?) (= *Hemithlaeus* zone of these authors), even though a species of *Taeniolabis* is present. They argue that the species from the RAV W-1 and the Garbani local faunas are the same and that this species is more primitive than *Taeniolabis taoensis* from the type Puercan assemblage of the San Juan Basin. Based on stronger evidence from condylarths, Johnston and Fox (1984) argue for this earlier age, at least for RAV W-1 if not for Garbani Local Fauna. Analysis of new material of *Taeniolabis* from the Bechtold Site in southeastern Montana by N. B. Simmons (pers. com. to WAC 1984) indicates the presence of at least one species distinct from *T. taoensis*. Thus, the presence of *Taeniolabis* outside of the San Juan Basin should not necessarily, for the present, at any rate, be assumed to indicate that such sites are correlatives of the *Taeniolabis taoensis/Periptychus* Interval-Zone. To emphasize the possible specific differences between specimens referred to *Taeniolabis* from within and from outside the San Juan Basin, the name of the species from that basin is included in the zonal name.

Based on the preceding comments, we assign the various local faunas, localities, and regions as follows: (1) *Ectoconus/Taeniolabis taoensis* and *Taeniolabis taoensis/Periptychus* interval-zones—De-na-zin and Alamo washes, Nacimiento Formation, San Juan Basin, New Mexico; (2) *Ectoconus/Taeniolabis taoensis* Interval-

Zone(?) and/or *Taeniolabis taoensis*/*Periprychus* Interval-Zone(?)—Corral Bluffs, Denver Formation, Colorado (assignment of the associated West Bijou Creek-1 to one or the other of these interval-zones is uncertain); (3) *Ectoconus*/*Taeniolabis taoensis* Interval-Zone(?)—Kimbetoh and Betonnie-Tsosie arroyos, Nacimiento Formation, San Juan Basin, New Mexico; Gas Tank Hill Local Fauna, North Horn Formation, Utah; RAV W-1 Local Fauna, Ravenscrag Formation, Saskatchewan; (4) *Taeniolabis taoensis*/*Periprychus* Interval-Zone(?)—West Fork of Gallegos Canyon, Nacimiento Formation, San Juan Basin, New Mexico; Wagonroad Local Fauna, North Horn Formation, Utah; and, questionably, Purgatory Hill, Garbani, and associated local faunas, Tullock Formation, Montana, and the Bechtold Site, Ludlow Formation, Montana.

Magnetostratigraphic data do not contradict, but also do not offer significant support for, the recognition of the Pu2 and Pu3 interval-zones. A revised magnetostratigraphic correlation by Butler and Lindsay (1985) for the San Juan Basin indicates that both the Pu2 and Pu3 interval-zones occur in sediments of normal polarity interpreted as magnetic polarity chron 29N. A similar interpretation is given for sediments of normal polarity that yield the Wagonroad Local Fauna, Utah (Tomida and Butler 1980), and the Purgatory Hill Local Fauna, Montana (Archibald et al. 1982).

Because of the difficulties in sorting out middle and late Puercan faunas, tabulations of first and last appearances and index and characteristic fossils are very speculative. In addition, the "type" *Ectoconus*/*Taeniolabis taoensis* Interval-Zone in De-na-zin Wash is relatively unfossiliferous. Mammals from both this interval-zone and the *Taeniolabis taoensis*/*Periprychus* Interval-Zone are in need of systematic revision: the first major collections made in the type and surrounding areas do not have adequate provenience data. The most recent attempt to correlate mammals (only condylarths) according to the equivalent of interval-zones was done by Van Valen (1978). We offer the following update and expansion of his tabulation, but we emphasize that it should be used with caution, especially for the San Juan Basin. An asterisk denotes mammals known from the San Juan Basin but not necessarily limited to that region. Occurrences for the taxa listed below are given in table 3.2.

*Ectoconus*/*Taeniolabis taoensis* Interval-Zone(?) (Pu2 [?]).

First appearances: *Anisonchus*, *Bomburia*\*, *Carsioprychus*\*, *Choeroclaenus*\*, *Conacodon*\*, *Desmatoclaenus*\*, *Ectoconus*\*, *Ectypodus*, *Eucosmodon*\*, *Gilli-*

*sonchus*\*, *Haploconus*, *Hemithlaeus*\*, cf. *Ictidopappus*, *Kimbetohia*\*, *Litomylus*, *Loxolophus*\*, *Microcosmodon*, *Mimotricentes*\*, *Onychodectes*\*, *Oxyacodon*\*, *Oxyclaenus*\*, *Parectypodus*\*, *Promioclauenus*\*, *Protoselene*\*, *Ptilodus*\*, *Purgatorius unio*, *Taeniolabis* n. sp., *Wortmania*\*, *Xyromys*.

Last appearances: none.

Index fossils: *Bubogonia*, *Carcinodon*, *Escatepos*, *Platymastus*\*.

Characteristic fossils: *Baioconodon*, *Catopsalis*\*, *Cimexomys*, *Cimolestes*\*, *Eoconodon*\*, *Mesodma*\*, *Neoplagiaulax*\*, *Peradectes*(?)\*, *Purgatorius*, *Stygimys*.

Taxa absent but known before and after Pu2?: *Procerberus*, *Protungulatum*.

*Taeniolabis taoensis*/*Periprychus* Interval-Zone(?) (Pu3[?]).

First appearances: *Chriacus*, *Ellipsodon*\*, *Goniacodon*, *Haplaletes*, *Leptacodon*(?), *Prodiacodon*, *Promioclauenus*, *Tinuviel*.

Last appearances: *Baioconodon*, *Bomburia*\*, *Carsioprychus*\*, *Choeroclaenus*\*, *Cimexomys*, *Cimolestes*\*, *Cimolodon*(?)\*, *Conacodon*\*, *Ectoconus*\*, *Eoconodon*\*, *Gillisonchus*\*, *Hemithlaeus*\*, *Kimbetohia*, *Onychodectes*\*, *Oxyacodon*\*, *Peradectes*\*, *Procerberus*, *Protungulatum*, *Purgatorius*, *Taeniolabis* n. sp., *Wortmania*\*.

Index fossils: *Taeniolabis taoensis*\*, *Thangorodrim*.

Characteristic fossils: *Anisonchus*, *Catopsalis*\*, *Desmatoclaenus*, *Eucosmodon*\*, *Haploconus*, *Loxolophus*\*, *Mesodma*, *Neoplagiaulax*, *Oxyclaenus*\*, *Parectypodus*, *Peradectes*\*, *Promioclauenus*\*, *Stygimys*.

Taxa absent but known before and after Pu3(?): *Ectypodus*, cf. *Ictidopappus*, *Litomylus*, *Microcosmodon*, *Mimotricentes*, *Protoselene*, *Ptilodus*, *Xyromys*.

## TORREJONIAN MAMMAL AGE

### Introduction

The initial concept of the Torrejonian Mammal Age included only the *Pantolambda* zone of Osborn and Matthew (1909). As was correctly interpreted by them, the early pantodont, *Pantolambda*, was never a very common mammal during its "life zone." Sinclair and Granger (1914) recognized two faunal zones, a lower *Deltatherium* and an upper *Pantolambda*, in the Torrejonian interval. These two zones were later questioned by Matthew (1937) and other workers, largely because neither *Deltatherium* nor *Pantolambda* were abundant



enough to warrant much confidence in their stratigraphic range.

Until 1959, Puercan and Torrejonian fossils from the San Juan Basin were reported from the "Puerco" and "Torrejon" formations. These formations were the definitive basis for the Puercan and Torrejonian "Provincial mammal ages" of Wood et al. (1941). However, it was recognized early (Sinclair and Granger 1914) that those formations were identified only on the basis of paleontological criteria. In 1949 and 1950, G. G. Simpson, G. O. Whitaker, and others made a thorough search for mammals from exposures near Cuba Mesa, south of Cuba, New Mexico, where Cope (1875) had defined the Puerco Formation. Simpson (1959) reported the presence of definitive Torrejonian fossils from levels about 100 to 125 ft. (30–38 m) above the base (and higher) in strata identified as the type section of the "Puercan marls" of the west tip of Cuba Mesa. He concluded that the Puerco Formation of Cope and later workers, or at least the upper five-sixths of it, belong to the Torrejon Formation. He emphasized that the "Puerco" and "Torrejon" formations should be abandoned, as they were not defined (or differentiated) on lithologic criteria. He suggested that the Nacimiento Formation of Gardner (1910) be redefined and limited to include strata in the San Juan Basin which had previously been assigned to the Puerco and Torrejon formations and that the concept of Puercan and Torrejonian faunas be retained for separate and distinctive biochronologic units within the Nacimiento Formation. Those suggestions have been followed since 1959 and are endorsed here.

The concept of the Torrejonian Mammal Age has been substantially modified since the work of Wood et al. (1941). Between the Puercan and Torrejonian mammal ages, the Wood committee recognized a third, the "Dragonian" Mammal Age, based solely on the "Dragon local fauna" from the North Horn Formation, Utah. As discussed below, the Dragonian Mammal Age is now recognized as the first interval-zone within a redefined Torrejonian Mammal Age. One definite correlative of the Dragonian Mammal Age is now known from the San Juan Basin, New Mexico (Tomida 1981), and possible correlatives occur in the Tullock Formation, northeastern Montana (Archibald 1982; Clemens, pers. observ. 1984). Wood et al. recognized two correlatives of their Torrejonian Mammal Age, "Lebo and Rock Bench." "Lebo" clearly refers to Simpson's (1937a) Crazy Mountain Field, Montana, which is now considered to include Torrejonian and Tiffanian local faunas. "Rock Bench" Quarry on Polecat Bench in the Bighorn Basin, Wyoming, is still one of the major quarry samples of Torrejonian age. In addition to the local faunas noted above,

other Torrejonian sites are now known from the Goler Formation, California (McKenna 1960, West 1976); the Porcupine Hills Formation, Alberta (Russell 1958, Krause 1978); and the Fort Union Formation of Washakie (Rigby 1981) and Fossil (Gazin 1969) basins, Wyoming.

### Puercan/Torrejonian Boundary

The beginning of the Torrejonian Mammal Age is recognized by the appearance of the peripitychid, *Peripitychus carinidens*. *Peripitychus* is a distinctive member of Torrejonian faunas, including the Dragon Local Fauna of Utah on which the Dragonian Mammal Age was founded (Wood et al. 1941). Tomida and Butler (1980) established the magnetic polarity sequence in the North Horn Formation, Utah, showing the magnetic polarity sequence and biostratigraphic limits of the Dragon Local Fauna and the (Puercan) Wagonroad Local Fauna. Thus limited and correlated with the magnetic polarity sequence in the San Juan Basin (Lindsay et al. 1978), Tomida and colleagues were able to search the "Dragonian" interval and characterize its faunal content (Tomida 1981). It now appears that the Dragonian faunal interval is better assigned to the early Torrejonian Mammal Age because the Dragonian assemblage is dominated by Torrejonian mammals, including *Peripitychus*. Further, the paleomagnetic data suggest that the Dragonian assemblage temporally overlaps assemblages in the San Juan Basin which, based on faunal data, are assigned to the Torrejonian Mammal Age.

Two species of *Carsiopitychus*, *C. coarctatus* and *C. matthewi*, are recorded from Puercan sites in the Nacimiento Formation, San Juan Basin. As noted in the Puercan section, Van Valen (1978) considered *Carsiopitychus* to be a subgenus of *Peripitychus*. No reasons were given for this action, however. We treat these taxa as separate genera. *Carsiopitychus* differs from *Peripitychus* in a number of ways, especially in premolar cusp development, occlusal outline, and the distinctive posterior inclination of the premolars in *Carsiopitychus*. *C. matthewi* is more than 10 percent larger than *C. coarctatus* (Simpson 1936a), and the former species could be ancestral to *Peripitychus carinidens*. Thus, the Puercan/Torrejonian boundary in the San Juan Basin may be identified by an evolutionary event—the appearance of *Peripitychus* in sediments overlying those bearing the possible ancestor, *Carsiopitychus*.

The lowest stratigraphic occurrence of *Peripitychus carinidens* in the San Juan Basin is in the De-na-zin Wash (= Barrel Springs Arroyo) section where Sinclair and Granger (1914, p. 307) reported *Peripitychus* from

a level 173 ft. (53 m) above the *Taeniolabis* zone. This level is about 150 ft. (46 m) above the highest stratigraphic occurrence of diagnostic Puercan fossils (at UALP loc. 7691) in the De-na-zin section. *Periptychus* occurs slightly higher, about 240 ft. (73 m) (at UALP loc. 7782) and 250 ft. (76 m) (at UALP loc. 77114) above diagnostic Puercan fossils in the Betonnie-Tsosie and Kimbetoh sections, respectively (Lindsay et al. 1981). The highest stratigraphic records of all Puercan mammals known from the San Juan Basin occur in sediments with normal polarity, interpreted as magnetic polarity chron 29N. The lowest records of *Periptychus* in the San Juan Basin all occur in the next higher normal polarity magnetozone, interpreted as magnetic polarity chron 28N. Therefore, a stratigraphic interval of 150 to 250 ft. (46–76 m) with both normal and reversed polarity separates Puercan and Torrejonian assemblages in the San Juan Basin.

### Definition and Characterization

As pointed out earlier, the greatest departure from the Wood committee (1941) is the inclusion here of the Dragonian Mammal Age within the Torrejonian Mammal Age (Tomida and Butler 1980, Tomida 1981). According to this, we define the Torrejonian Mammal Age to include faunas that occur during the time between the first appearance of the periptychid condylarth, *Periptychus*, and the first appearance of the plesiadapid primate, *Plesiadapis*. As discussed above, the appearance of *Periptychus* is probably an evolutionary first appearance, best recorded in sediments of the San Juan Basin, from a species of *Carsiptychus*.

Tomida and Butler (1980) convincingly demonstrated that the sediments of the North Horn Formation, Utah, which yield the Dragon Local Fauna (the type fauna for the Dragonian Mammal Age), correlate best to the portion of the section in San Juan Basin that lies between the classical Puercan and Torrejonian faunas. Tomida (1981) further showed that the time representing the "Dragonian" Mammal Age in the San Juan Basin is also faunally distinct and shares greater affinity with the Torrejonian Mammal Age than with the Puercan Mammal Age. This "Dragonian," or earliest Torrejonian interval-zone, was designated the *Periptychus-Loxolophus* Chronozone by Tomida (1981) because the range of these mammals overlap during this interval and because the interval can be identified by its distinctive polarity sequences in the absence of fossils. As discussed below, our *Periptychus/Tetraclaenodon* Interval-Zone is equivalent to both the "Dragonian" Mammal Age and Tomida's *Periptychus-Loxolophus* Chronozone.

In addition to the inclusion of the "Dragonian" Mammal Age within an expanded Torrejonian Mammal Age, there have been changes in the taxonomic characterization of both these mammal ages. Of the five taxa listed by the Wood committee (1941) as first appearances for the "Dragonian" Mammal Age, only one, *Periptychus*, remains in this category. The others, *Catopsalis*, *Haploconus*, mixodectids, and *Ptilodus*, occur, or probably occur, in Puercan faunas. For the Torrejonian Mammal Age, only one of the seven genera (*Chriacus*) recognized as first appearances by the Wood committee has been reported from Puercan or older faunas. The other taxonomic characterizations (last appearances and index and characteristic fossils) for the "Dragonian" and the Torrejonian mammal ages have remained relatively unchanged except for some additions given below.

Based especially on the Kutz Canyon section, Torrejonian faunas appear in sediments of normal polarity (interpreted as magnetic polarity chron 28N), continue upward in sediments of reversed polarity, and are last known in superjacent sediments of normal polarity (interpreted as magnetic polarity chron 27N). As noted in the discussion of the Puercan/Torrejonian boundary ("Pu3"/To1), however, as much as 250 ft. (76 m) of unfossiliferous strata, including all of magnetic polarity chron 28R and part of the super- and subjacent normal magnetic polarity chrons, could separate Puercan from overlying Torrejonian faunas in the Betonnie-Tsosie and Kimbetoh arroyos. The faunal data permit a more accurate placement of the To1/To2 and To2/To3 boundaries relative to stratigraphy and magnetostratigraphy. For the latter, these boundaries occur, respectively, just above the base and slightly above the middle of magnetic polarity chron 27R (Butler and Lindsay 1985).

The following is an updated version of the Wood committee's (1941) faunal characterization of the Torrejonian (including their "Dragonian") Mammal Age. Occurrences for these taxa are given in table 3.2.

First appearances: *Acmeodon*, *Anconodon*, *Aphronorus*, *Arctocyon*, *Dissacus*, *Elphidotarsius*, *Elpidophorus*, *Gelastops*, *Ignacius*, *Mckennatherium*, *Mimeton*, *Myrmecoboides*, *Palaechthon*, *Palaeoryctes*, *Palenochtha*, *Paleotomus*, *Pantolambda*, *Paromomys*, *Periptychus*, *Picrodus*, *Plesiolestes*, *Prolimnocyon*, *Pronothodectes*, *Propalaeosinopa*, *Protictis*, *Psittacotherium*, *Simpsonictis*.

Last appearances: *Ellipsodon*, *Goniacodon*, *Haploconus*, *Ictidopappus*, *Loxolophus*, *Oxyclaenus*, *Strygimys*, *Xyronomys*.

Index fossils: *Ankalagon*, *Avunculus*, *Bryanictis*, *Caenolambda*, *Conoryctella*, *Conoryctes*, *Coriphagus*, *Deltatherium*, *Deuteronodon*, *Draconodus*, *Dracon-*

*tolestes*, *Eudaemonema*, *Huerfanodon*, *Intyrictis*, *Jepsonella*, *Leptonysson*, *Litaletes*, *Microclaenodon*, *Mioclaenus*, *Mixodectes*, *Pantomimus*, *Pentacodon*, *Prothryptacodon*, *Stelocyon*, *Stilpnodon*, *Talpohenach*, *Tetraclaenodon*, *Torrejonia*, *Triisodon*, *Xanoclomys*.

Characteristic fossils: *Anisonchus*, *Catopsalis*, *Chriacus*, *Desmatoclaenus*, *Ectypodus*, *Eucosmodon*, *Hapaletes*, *Leptacodon*, *Litomyilus*, *Mesodma*, *Mimotricentes*, *Neoplagiaulax*, *Parectypodus*, *Peradectes*, *Prodiacodon*, *Promioclaenus*, *Protoselene*, *Ptilodus*.

Taxa absent but known before and after the Torrejonian: *Microcosmodon*.

## Zonation

Tomida (1981) designated three faunally distinct and apparently superposed subdivisions of the expanded Torrejonian Mammal Age as follows: *Periptychus-Loxolophus* Chronozone, *Deltatherium* Chronozone, and *Pantolambda* Chronozone. Although Tomida's chronozones are acceptable, we apply the terminology of interval-zones to be consistent with terminology used in other parts of this chapter.

The recommended Torrejonian interval-zones are the *Periptychus/Tetraclaenodon* Interval-Zone (To1), the *Tetraclaenodon/Pantolambda* Interval-Zone (To2), and the *Pantolambda/Plesiadapis praecursor* Interval-Zone (To3). The *Periptychus/Tetraclaenodon* Interval-Zone (To1) is equivalent to the *Periptychus-Loxolophus* Chronozone of Tomida (1981) which is also equivalent to the Dragonian Mammal Age of Wood et al. (1941). The *Tetraclaenodon/Pantolambda* Interval-Zone (To2) is approximately equivalent to the *Deltatherium* Zone of Osborn (1929) and the *Deltatherium* Chronozone of Tomida (1981). The *Pantolambda/Plesiadapis praecursor* Interval-Zone (To3) is approximately equivalent to the *Pantolambda* Zone of Osborn (1929), as recognized by Sinclair and Granger (1914) and the *Pantolambda* Chronozone of Tomida (1981). These three interval-zones are best represented in Kutz Canyon, New Mexico, although the type fauna for the *Periptychus/Tetraclaenodon* Interval-Zone (the "Dragonian" Mammal Age) is from the North Horn Formation, Utah, and the type faunas for the *Tetraclaenodon/Pantolambda* (actually Osborn's *Deltatherium* Zone) and the *Pantolambda/Plesiadapis praecursor* Interval-Zones [the traditional Torrejonian Mammal Age] are from the Nacimiento Formation, Arroyo Torreon (Ojo Encino), New Mexico.

The equivalent of a fourth Torrejonian interval-zone (To4) has been proposed (e.g., Gingerich 1975a, 1976; Gingerich, Houde, and Krause 1983) based primarily on faunal differences between the Gidley Quarry Local

Fauna, Crazy Mountain Field, Montana (with *Pronothodectes matthewi*), and the Rock Bench Quarry Local Fauna, Bighorn Basin, Wyoming (with *Pronothodectes jepi*). Following this interpretation, the Gidley Quarry Local Fauna would represent the To3 interval-zone, and the Rock Bench Local Fauna would represent the To4 interval-zone. Other suggested correlatives of the *Pronothodectes jepi* (To4) "interval-zone" are the Cub Creek Local Fauna, Wyoming (with *Pronothodectes jepi*?), and possibly the Calgary 2E Local Fauna.

We reject a fourth Torrejonian interval-zone (To4) at this time, primarily because an unpublished magnetostratigraphic section indicates that the Cub Creek Local Fauna comes from sediments with normal magnetization (Butler, pers. comm. to EHL 1984) and is overlain by an early Tiffanian fauna (Ti1) from sediments having reversed magnetization. The *Pantolambda/Plesiadapis praecursor* Interval-Zone (To3) is correlated in the San Juan Basin (where *Pronothodectes* has never been recorded) with magnetic polarity chron 27N and the upper part of magnetic polarity chron 27R, which suggests that the Cub Creek Local Fauna from sediments with normal polarity should probably be correlated with the *Pantolambda/Plesiadapis praecursor* Interval-Zone (To3). The Rock Bench Quarry in Wyoming appears, however, to be bracketed by reversed polarity (Butler, pers. comm. to EHL 1984), which, if correlated with magnetic polarity chron 26R rather than 27R, would support the interpretation of a short To4 interval-zone between the To3 and Ti1 interval-zones.

The appearance of *Plesiadapis praecursor* establishes the upper limit of the *Pantolambda/Plesiadapis praecursor* Interval-Zone and the beginning of the Tiffanian Mammal Age. Gingerich, Houde, and Krause (1983) note the appearance of *Microcosmodon*, *Carpodaptes*, *Nannodectes*, *Ectocion*, and *Phenacodus* as well as *Plesiadapis* at the beginning of the Tiffanian. A species of *Microcosmodon* has since been described from the Puercan Mammal Age (Johnston and Fox 1984).

It is important to point out that *Pantolambda* was apparently never common in North America and thus it is hazardous to base a biostratigraphic interval-zone on it. Subsequent collecting from the *Tetraclaenodon/Pantolambda* Interval-Zone (To2) may provide additional specimens of *Pantolambda*, which would shift downward the biostratigraphic position of the To2/To3 boundary. However, we believe the To2/To3 division is justified on the basis of the existing fossil record and the biostratigraphic framework for that record. We retain the appearance of *Pantolambda* as the basis for the To3 interval-zone for historical reasons and because we have not found a more suitable taxon to replace it. We have

changed the criterion for the To1/To2 boundary to the appearance of *Tetraclaenodon* rather than that of *Deltatherium* because, like *Pantolambda*, *Deltatherium* is poorly represented in the existing record, whereas *Tetraclaenodon* is one of the most common taxa in the To2 and To3 faunal intervals (except at Gidley Quarry, Crazy Mountain Basin, Montana).

### ***Periptychus/Tetraclaenodon* Interval-Zone (To1)**

We define this interval-zone to include faunas that occur during the time between the first appearance of *Periptychus* and the first appearance of *Tetraclaenodon*. The Dragon Local Fauna of Utah has the best faunal representation of the *Periptychus/Tetraclaenodon* Interval-Zone. It was described by Gazin (1938, 1939, 1941*b*), with notable additions and revisions by Wilson (1956*b*), MacIntyre (1966), Szalay (1969), West (1976), and Tomida and Butler (1980). In the last contribution, a revised faunal list and discussion were presented.

The faunal characterization provided by Wood et al. (1941) for what we term the *Periptychus/Tetraclaenodon* Interval-Zone is in need of considerable revision. The single index fossil recognized by these authors as *Dracoclaenus* has been synonymized with *Protoselene* by Van Valen (1978). *Protoselene* ranges from the Puercan Mammal Age (as *P. bombadili* of Van Valen [1978]) through the Torrejonian Mammal Age (as *P. opisthacus*), but the species *P.* (= *Dracoclaenus*) *griphus* appears to be restricted to the *Periptychus/Tetraclaenodon* Interval-Zone (Tomida and Butler 1980).

The Wood committee (1941) recognized the first appearance of the following genera in the Dragonian Mammal Age (i.e., the *Periptychus/Tetraclaenodon* Interval-Zone): *Catopsalis*, *Haploconus*, mixodectids, *Periptychus*, and *Ptilodus*. *Catopsalis* was subsequently revised to include Late Cretaceous species from Asia which were formerly placed in the genus *Djadochtherium* (Kielan-Jaworowska and Sloan 1979), and species referable to this genus also have been reported from Lancian and Puercan sites (D. E. Russell 1967; Sloan 1981; Middleton 1982; Archibald 1982). *Ptilodus* is now represented by a species (*P. tsosiensis*) in the Puercan faunas of San Juan Basin (Sloan 1981). Both *Haploconus*(?) *elichistus* and an unnamed mixodectid (Gazin 1941*b*, Szalay 1969) are questionably present in the late Puercan ("Pu3") Wagonroad Local Fauna, North Horn Formation, Utah. *Dracontolestes* of the Dragon Local Fauna is the oldest definite mixodectid (Szalay 1969).

*Oxyclaenus* was the only genus whose last appear-

ance was noted in the Wood committee's Dragonian Mammal Age (= To1 interval-zone), and both *Anisonchus* and *Ellipsodon* were noted as characteristic fossils. These assignments remain valid, but additional taxa are given below.

In addition to the Dragon Local Fauna, the *Periptychus/Tetraclaenodon* Interval-Zone is documented in strata of the Nacimiento Formation of the San Juan Basin (Tomida 1981) and possibly in the Tullock Formation of Montana (Archibald 1982; Clemens, pers. observ. 1984).

As noted in the discussion of the Puercan/Torrejonian boundary, mammals assigned to the *Periptychus/Tetraclaenodon* Interval-Zone have been found at sites superposed over localities yielding Puercan faunas in De-na-zin Wash and Kimbetoh and Betonnie-Tsosie arroyos (Lindsay et al. 1981), although a considerable stratigraphic interval separates these sites. In the Kutz Canyon section of the San Juan Basin, faunas of the *Periptychus/Tetraclaenodon* Interval-Zone are also present; here they are not underlain by known Puercan sites (although unfossiliferous strata are present, probably representing Puercan time) but are overlain by faunas referable to the *Tetraclaenodon/Pantolambda* Interval-Zone (Taylor and Butler 1980; Taylor 1981). In Kutz Canyon, the lowest stratigraphic occurrence of *Tetraclaenodon* is UALP locality 75139 (Bob's Jaw). *Periptychus* does not occur at this locality, but it does occur approximately 33 ft. (10 m) lower at UALP locality 7899. Both UALP localities 75139 and 7899 occur in strata with reversed polarity, interpreted as the lower portion of magnetic polarity chron 27R by Butler and Lindsay (1985). The lowest stratigraphic occurrence of the *Periptychus/Tetraclaenodon* Interval-Zone in Kutz Canyon (UALP loc. 7896, located 138 ft. [42 m] below UALP loc. 75139) is in strata with normal polarity, correlated with the upper part of magnetic polarity chron 28N (see Puercan/Torrejonian boundary discussion). Thus, the *Periptychus/Tetraclaenodon* Interval-Zone is interpreted to correlate with the upper part of magnetic polarity chron 28N and the lower part of magnetic polarity chron 27R (Butler and Lindsay 1985).

A tabulation of taxa in the *Periptychus/Tetraclaenodon* Interval-Zone is as follows. Occurrences for the taxa listed below are given in table 3.2.

First appearances: *Acmeodon*, *Aphronorus*, *Conoryctella*, *Litaletes*, *Mioclaenus*, *Palaechthon*, *Paromomys*, *Periptychus*, *Protictis*, *Triisodon*.

Last appearances: *Oxyclaenus*.

Index fossils: *Draconodus*, *Dracontolestes*.

Characteristic fossils: *Anisonchus*, *Catopsalis*, *Chriacus*, *Desmatoclaenus*, *Goniacodon*, *Haploconus*,

*Litomylus*, *Loxolophus*, *Mimotricentes*, *Parectypodus*, *Protictis*, *Protoselene*, *Ptilodus*.

Taxa absent but known before and after To1: *Ec-typodus*, *Haploconus*, *Ictidopappus*(?), *Mesodma*, *Neoplagiaulax*, *Peradectes*, *Prodiacodon*, *Promioclaenus*, *Stygmimys*.

### ***Tetraclaenodon/Pantolambda* Interval-Zone (To2)**

We define this interval-zone to include faunas that occur during the time between the first appearance of *Tetraclaenodon* and the first appearance of *Pantolambda*. This interval-zone is best represented in Kutz Canyon, San Juan Basin, New Mexico (Taylor and Butler 1980, Taylor 1981), and includes the Angel Peak Local Fauna of Wilson (1951). In Kutz Canyon this interval-zone is recorded between the 436 ft. and 663 ft. (133 m and 202 m) level of the Kutz Canyon magnetostratigraphic section (Taylor 1981, fig. 11.2), superposed over the *Peripitychus/Tetraclaenodon* Interval-Zone and subjacent to the *Pantolambda/Plesiadapis praecursor* Interval-Zone. This interval-zone is also subjacent to the *Pantolambda/Plesiadapis praecursor* Interval-Zone in the area of Arroyo Torreón (= Ojo Encino), San Juan Basin. The *Tetraclaenodon/Pantolambda* Interval-Zone correlates with the lower half, more or less, of magnetic polarity chron 27R.

The Laudate Local Fauna (McKenna 1960, West 1976) from the poorly fossiliferous Goler Formation in southern California is also tentatively assigned to the *Tetraclaenodon/Pantolambda* Interval-Zone. Another fauna that might belong in the *Tetraclaenodon/Pantolambda* Interval-Zone is the Calgary 2E Local Fauna (L.S. Russell 1958, Krause 1978) from the Porcupine Hills Formation of Alberta. Only seven mammal taxa, including *Tetraclaenodon* and a primate near *Palaechthon* or *Torrejonia* (Krause 1978), are known from the Calgary 2E Local Fauna (D. E. Russell 1967).

The following is a taxonomic tabulation of the *Tetraclaenodon/Pantolambda* Interval-Zone. Occurrences for the taxa are given in table 3.2.

First appearances: *Anconodon*, *Conoryctes*, *Coriphagus*, *Deltatherium*, *Deuteronodon*, *Dissacus*, *Microclaenodon*, *Mixodectes*, *Palaeryctes*, *Pentacodon*, *Prothrypiacodon*(?) *Psittacotherium*, *Tetraclaenodon*, *Torrejonia*.

Last appearances: *Conoryctella*, *Ellipsodon*, *Gonia-codon*, *Triisodon*.

Index fossils: *Talpothenach*.

Characteristic fossils: *Acmeodon*, *Anisonchus*, *Captosalis*, *Chriacus*, *Ectypodus*, *Eucosmodon*, *Haplo-*

*conus*, *Mimotricentes*, *Mioclaenus*, *Palaechthon*, *Parectypodus*, *Peripitychus*, *Prodiacodon*, *Promioclaenus*, *Protoselene*, *Protictis*, *Ptilodus*, *Triisodon*.

Taxa absent but known before and after To2: *Aphronorus*, *Desmatoclaenus*, *Ictidopappus*(?), *Litaletes*, *Litomylus*, *Loxolophus*, *Mesodma*, *Neoplagiaulax*, *Peradectes*, *Stygmimys*.

### ***Pantolambda/Plesiadapis praecursor* Interval-Zone (To3)**

We define this interval-zone to include faunas that occur during the time between the first appearance of *Pantolambda* and the first appearance of *Plesiadapis praecursor*. This interval-zone (To3) is much better represented than the *Tetraclaenodon/Pantolambda* Interval-Zone (To2), both paleontologically and geographically. The best representation of faunas of the *Pantolambda/Plesiadapis praecursor* Interval-Zone in the San Juan Basin is from the "type" Torrejonian on the east side of the Continental Divide at the head of Arroyo Torreón near Ojo Encino. This area was collected during the 1890s by J. L. Wortman and W. Granger for the American Museum of Natural History (designated loc. 10 by Sinclair and Granger [1914]). Many institutions have collected from these strata over a period of almost ninety years, and new discoveries are still found in the well-exposed and richly fossiliferous deposits. Tsentas (1981) reported a productive new screen-washing site (BUNM-77-184) from the *Pantolambda/Plesiadapis praecursor* Interval-Zone in the type area that promises to yield small mammals not previously recorded from these strata.

Other diverse and well-known local faunas in the *Pantolambda/Plesiadapis praecursor* Interval-Zone are those from Gidley Quarry and Siberling Quarry (Simpson 1937a, Rose 1981b) of the Crazy Mountain Basin, Montana; Rock Bench Quarry (Jepsen 1930b, 1940; Rose 1981a) in the Bighorn Basin, Wyoming; and Swain Quarry (Rigby 1980) in the Washakie Basin, Wyoming. Less diverse local faunas that are tentatively assigned to this interval-zone include O'Neill, Coprolite Point, and Little Pocket (KU loc. 9), in or near Kutz Canyon, San Juan Basin; Cub Creek, Bighorn Basin; Medicine Rocks, southeastern Montana; Donnybrook, Lloyd, and Hares, western North Dakota; the Calgary faunas, Alberta; and faunas from Fossil Basin, Wyoming.

In the San Juan Basin, the *Pantolambda/Plesiadapis praecursor* Interval-Zone is superposed above the *Tetraclaenodon/Pantolambda* Interval-Zone in Kutz Canyon as well as in Arroyo Torreón (= Ojo Encino). The lowest (and only) occurrence of *Pantolambda* in the

Kutz Canyon section is at UNM locality 113, reported by Lucas and O'Neill (1981). Lucas and O'Neill considered this locality to be about 33 feet (10 m) above the Big Pocket Locality (KU loc. 13) of Wilson (1951). In 1982, O'Neill, Butler, and Lindsay visited UNM locality 113. In tracing this site, a correlation with the 664 foot (202 m) level in Butler and Lindsay's Kutz Canyon section was found. This is about 128 feet (39 m) above Big Pocket, at the 534 foot (163 m) level. Thus, one can cautiously suggest that faunas of the *Pantolambda/Plesiadapis praecursor* Interval-Zone occur above the 664 foot (202 m) level in the Kutz Canyon section. This interpretation places the Coprolite Point (UALP loc. 7650) and other sites above the 656 foot (200 m) level (Taylor 1981, fig. 11.2) of the Kutz Canyon section in the *Pantolambda/Plesiadapis praecursor* Interval-Zone. Bab's Basin (UALP loc. 7671) occurs near the top of the *Tetraclaenodon/Pantolambda* Interval-Zone according to this interpretation. Fossil mammals are very rare above the Coprolite Point site, at the 842 foot (256 m) level in the Kutz Canyon magnetostratigraphic section.

*Pantolambda* also occurs at UALP locality 7595, which is near (if not identical to) KU locality 9 between Kutz Canyon and type Torrejonian at Ojo Encino (= Arroyo Torreon). The strata containing UALP locality 7595 occurs up section, although it is separated by a broad covered interval from the Kimbetoh Arroyo magnetostratigraphic section of Lindsay et al. (1981). The short stratigraphic interval in the upper drainage of Kimbetoh Arroyo which yields *Pantolambda* has reversed polarity and is correlated with magnetic polarity chron 27R. Puercan sites lower in the section are from strata with normal polarity, correlated with magnetic polarity chron 29N, and the lowest stratigraphic record of *Periprychus* in the Kimbetoh section (at UALP loc. 77114) is recorded from the next higher normal magnetozone, correlated with magnetic polarity chron 28N. The occurrence of *Pantolambda* in the Ojo Encino section of the San Juan Basin is from normally magnetized strata, correlated with magnetic polarity chron 27N according to the revised magnetostratigraphic correlation of the San Juan Basin (Butler and Lindsay 1985). Polarity determinations have not been established in exposures of the Nacimiento Formation north of Aztec, New Mexico, where Granger (1917) collected the type of *Pantolambda*. Nor have paleomagnetic determinations been established for KU locality 15, Sandoval County, New Mexico, where Wilson (1956a) reported *Pantolambda*.

A summary of the magnetostratigraphic data for the *Pantolambda/Plesiadapis praecursor* Interval-Zone (To3) based largely on work done in the San Juan Basin shows that the To2/To3 boundary occurs in reversely

magnetized strata and that the To3 interval-zone continues up section well into normally magnetized strata correlated with magnetic polarity chron 27N. It is not possible to identify a magnetostratigraphic limit for the Torrejonian/Tiffanian boundary in this area as definitive Tiffanian taxa such as *Plesiadapis* have not been collected from the Nacimiento Formation of the San Juan Basin. As mentioned previously in the general discussion of the zonation of the Torrejonian, superposition of a Tiffanian (Ti1) fauna over the Torrejonian Cub Creek Local Fauna occurs in the Cub Creek magnetostratigraphic section (Butler, pers. com. to EHL 1984), Clark's Fork Basin, Wyoming. Other faunas close to the boundary but considered Tiffanian are the Black Peaks faunal sequence in Texas (Schiebout 1974) and the Cochrane faunas in Alberta. These faunas and their biochronologic placement will be discussed below (section on Torrejonian/Tiffanian boundary).

The *Pantolambda/Plesiadapis praecursor* Interval-Zone is dominated by *Tetraclaenodon* and *Mimotricentes* in the San Juan Basin, New Mexico; by *Ptilodus*, *Paromomys*, and *Promioclænus* in the Crazy Mountain Basin, Montana; by *Ptilodus* and *Palaechthon* in the Big Horn Basin, Wyoming; and by *Paromomys* and *Mimotricentes* in Swain Quarry near the Colorado-Wyoming border. In general, the *Pantolambda/Plesiadapis praecursor* Interval-Zone is dominated by *Ptilodus*, *Mimotricentes*, and *Promioclænus*; primates, especially *Palaechthon* or *Paromomys*, may be as dominant in northern faunas, whereas *Tetraclaenodon*, *Periprychus*, and *Mixodectes* may be as dominant in southern faunas. Plesiadapid and carpolestid primates show a strong affinity for northern latitudes, in contrast to mixodectids, which occur more frequently in southern latitudes during the time represented by the *Pantolambda/Plesiadapis praecursor* Interval-Zone.

A taxonomic listing for the *Pantolambda/Plesiadapis praecursor* Interval-Zone follows. Occurrences for the taxa are given in table 3.2.

First appearances: *Aphronorus*, *Arctocyon*, *Elphidotarsius*, *Elpidophorus*, *Gelastops*, *Ignacius*, *Mckenatherium*, *Mimetodon*, *Myrmecoboides*, *Palenochtha*, *Paleotomus*, *Pantolambda*, *Picrodus*, *Plesiolestes*, *Prolimnocyon*, *Pronothodectes*, *Propalaeosinopa*, *Simpsonictis*.

Last appearances: *Conoryctes*, *Coriphagus*, *Deltaetherium*, *Deuterogonodon*, *Goniacodon*, *Haploconus*, *Ictidopappus*, *Litaletes*, *Loxolophus*, *Microclaenodon*, *Mioclænus*, *Mixodectes*, *Pentacodon*, *Prothryptacodon*, *Srygimys*, *Tetraclaenodon*, *Torrejonia*, *Xyromomys*.

Index fossils: *Ankalagon*, *Avunculus*, *Bryanictis*, *Eudaemonema*, *Huerfanodon*, *Intyrichtis*, *Jepsenella*.

*Leptonysson, Pantomimus(?)*, *Prolimnocyon(?)*, *Stelocyon*, *Stilpnodon*, *Xanoclomys*.

Characteristic fossils: *Acmeodon*, *Anconodon*, *Anisonchus*, *Catopsalis*, *Chriacus*, *Dissacus*, *Ectypodus*, *Eucosmodon*, *Haplaletes*, *Leptacodon*, *Litomylus*, *Mesodma*, *Mimotricentes*, *Neoplagiaulax*, *Palaechthon*, *Palaeoryctes*, *Parectypodus*, *Paromomys*, *Peradectes*, *Periptychus*, *Prodiacodon*, *Promioclaenus*, *Protictis*, *Protoselene*, *Psittacotherium*, *Ptilodus*.

Taxa absent but known before and after To3: *Desmatoclaenus*, *Microcosmodon*.

## TIFFANIAN MAMMAL AGE

### Introduction

Walter Granger (1917) first used the term *Tiffany* to refer to strata and their contained faunas in the northern San Juan Basin, southern Colorado. The "Tiffany beds" are now assigned to a distal facies of the Animas Formation, which intertongues with the Nacimiento and San Jose formations to the south. Stratigraphically, the Tiffany beds are probably equivalent to part of the Cuba Mesa Sandstone member, the unfossiliferous basal unit of the San Jose Formation. Definite placement of these beds between the underlying Nacimiento Formation and the overlying San Jose Formation has never been demonstrated because they are separated from distinctive exposures of these formations by thick and discontinuous sandstones.

"Tiffany" refers to a small settlement in southern Colorado, not far from the New Mexico state line. The first collection of fossil mammals from Tiffany beds was made by J. W. Gidley (Gidley, in Wegemann 1917), but Granger's collection was the first of significance to be studied in detail. The principal locality found by Granger, Mason Pocket, yielded a rich microfauna intermediate in evolutionary grade between "Torrejon" and "Wasatch" faunas. For this reason, Granger (1917) suggested that the Tiffany fauna of Colorado might be correlative with the Clark's Fork fauna of Wyoming. He tentatively regarded both of these as early Eocene in age, while noting that Matthew was inclined to place both in the late Paleocene. The Tiffany Local Fauna from Mason Pocket (and fossils from slightly higher stratigraphic levels in the vicinity) was fully described by Simpson (1935a, 1935b, 1935c), and only minor additions and modifications have been published since then.

During the 1920s and 1930s, a number of additional new mammalian faunas were discovered which resemble the Tiffany fauna in general aspect. These were all in northern basins. Simpson (1927) described a small faunal

sample from Erickson's Landing in the Paskapoo Formation of Alberta which he regarded as equivalent to the Tiffany-Clark's Fork faunas, and Russell (1929) added a number of new localities and taxa from Alberta. Jepsen (1930b, 1940) described a remarkable sequence of Puerco, Torrejon, Tiffany, and Clark's Fork faunas from Polecat Bench in the Clark's Fork Basin, Wyoming, and Simpson (1936b, 1937a, 1937b) detailed a similar but less extensive sequence from the Crazy Mountain Field in Montana. These demonstrated clearly that Tiffany faunas represented the upper Paleocene and differed from those of the Torrejon faunas from beds below as well as from the Clark's Fork faunas from beds above (Simpson 1933).

In 1941, the Wood committee named the Tiffanian Land Mammal Age based on the fauna from the Tiffany beds of Colorado. At the time, two principal correlatives were named, Bear Creek and Silver Coulee. These referred, respectively, to the Bear Creek Local Fauna, Fort Union Formation, Montana (Simpson 1928, 1929a, 1929b; Jepsen 1937), and to the Silver Coulee Local Fauna and beds, Fort Union Formation (= Polecat Bench Formation), Wyoming (Jepsen 1930b, 1940). Although the many quarries and localities discovered in the Silver Coulee beds confirm the Tiffanian Mammal Age assigned to them by the Wood committee (1941), the Bear Creek Local Fauna has since been determined to be of Clarkforkian age (Rose 1981a). (See Clarkforkian Mammal Age and introduction and methodology for further comments.)

In recent years, many new Tiffanian faunas have been discovered and described which add considerably to our understanding and characterization of the Tiffanian Mammal Age. These faunas have come from strata ranging geographically from northern Alberta to southern Texas, including the Paskapoo (Swan Hills) and the Ravenscrag (Police Point) formations, Alberta (D. E. Russell 1967, Krishtalka 1973); the Ravenscrag Formation, southern Saskatchewan (Roche Percée—Krause 1977, 1978); the Fort Union Formation, central Montana (Bangtail—Gingerich et al. 1983); the Tongue River Formation, eastern Montana (Circle and Olive—Wolberg 1979); the Tongue River and possibly the Sentinel Butte formations, western North Dakota (Brisbane, Judson, and other localities—Holtzman 1978); the Fort Union Formation, Clark's Fork and Bighorn basins, northern Wyoming (Cedar Point, Witter, Schaff, and Long Draw quarries—Gingerich 1976, Rose 1981a); the Hoback Formation, Hoback Basin, Wyoming (Battle Mountain and Dell Creek—Dorr 1952, 1958, 1978); the "sandstone and shale sequence," Togwotee Pass area, Wyoming (Love Quarry—McKenna 1980); the Shotgun

member, Fort Union Formation, Wind River Basin, Wyoming (Keefer Hill and Malcolm's locality—Patterson and McGrew 1962; Gazin 1971; Krishtalka et al. 1975); the Fort Union Group, Bison Basin, Wyoming (Saddle, Ledge, and the *Titanoides* localities—Gazin 1956a); the Chappo Member, Wasatch Formation, Wyoming (Chappo Type Locality—Dorr and Gingerich 1980); the Evanston Formation, Fossil Basin, Wyoming (Twin Creek and Little Muddy Creek—Gazin 1956b, 1969); and the Black Peaks Formation, Big Bend area, Texas (Ray's Bone Bed and Joe's Bone Bed—Schiebout 1974). The relative ages of these faunas as well as other largely undescribed Tiffanian faunas are discussed in the section on zonation of the Tiffanian Mammal Age.

### Torrejonian/Tiffanian Boundary

The only known clear superposition of Tiffanian over Torrejonian faunal assemblages is on the divide between Hunt Creek and Cub Creek near the Wyoming/Montana state line in the Clark's Fork Basin. In this area, 144 feet (44 m) of continuous section separates strata yielding the Cub Creek Local Fauna (To3) from strata that yield the "Eagle Nest" Local Fauna (Ti1) (Lindsay, pers. observ. 1984). In the Crazy Mountain Basin, earliest Tiffanian faunas (specifically, Locality 68 and Douglass Quarry) overlie Torrejonian faunas (Gidley and Silberling quarries), but there is a covered interval of approximately 984 to 1,640 feet (300–500 m) between these faunas which has yielded only sporadic fossils. To the south on Polecat Bench in the Bighorn Basin, an early Tiffanian assemblage (from UM loc. 263) is known from strata about 492 feet (150 m) above, and separated by, a fault from the Torrejonian Rock Bench Quarry.

The Schiebout-Reeves Quarry (UT loc. 41274), located about 75 ft. (23 m) above the base of the Black Peaks Formation on Tornillo Flats, Big Bend area of Texas, has yielded a fauna with *Promioclauenus acolytus* (a species known only from Torrejonian faunas), plus the condylarth *Phenacodus* and the pantodont *Caenolambda* (Schiebout 1974, Rapp et al. 1983). Approximately 66 ft. (20 m) stratigraphically above the Schiebout-Reeves Quarry, the Black Peaks strata have yielded a fauna that includes the primate *Navajovius* and the pantodont *Titanoides*, both genera known only from Tiffanian deposits. Fossils from this level are considered equivalent to the *Plesiadapis rex*/*P. churchilli* Lineage-Zone (Ti3) in Wyoming. Slightly higher in the Black Peaks Formation, the fauna from Joe's Bone Bed is considered correlative with the *Plesiadapis simonsi*/*P. gingerichi* Lineage-Zone (Ti5) (Rapp et al. 1983). Thus, the Black Peaks Formation appears to show superposition

of a Tiffanian faunal sequence, with the possibility of a subjacent Torrejonian fauna (UT loc. 41274). We consider the lower Black Peaks fauna (e.g., UT loc. 41274) to be early Tiffanian in age. Although it lacks primates that distinguish Tiffanian lineage-zones, it includes *Phenacodus* and *Caenolambda*, genera not otherwise known from the Torrejonian Mammal Age. The rationale for this interpretation is based, in part, on the Black Peaks magnetostratigraphic sequence.

The Cochrane I and II faunas from central Alberta have been considered either Torrejonian (Krause 1978) or Tiffanian (Russell 1929, 1958; Gingerich 1982a) based on faunal similarity. The most recent interpretation for biochronologic assignment of these faunas (Gingerich 1982a) is that they should be considered Tiffanian in age. This is based, in part, on reidentification of "*Pronothodectes* sp." from Cochrane II as *Nannodectes* cf. *N. intermedius* and "*Meniscotherium semicingulatum*" from Cochrane II as *Ectocion collinus*, which also occurs in the Cochrane I Fauna. According to this interpretation, the Cochrane faunas include some of the earliest records of *Nannodectes* and *Ectocion* in addition to several genera characteristic of Torrejonian faunas (e.g., *Elphidotarsius*). On the basis of these records, it is possible to characterize the Torrejonian/Tiffanian boundary using first appearances of a number of mammalian genera.

In the Crazy Mountain Basin, earliest Tiffanian faunas include the oldest known records of *Plesiadapis*, *Nannodectes*, *Ectocion*, *Phenacodus*, and several less common genera (Krause and Gingerich 1983). These genera are also present at another earliest Tiffanian locality, Keefer Hill in the Wind River Basin (Gingerich 1976, West 1976), where their appearance coincides with the first appearance of *Carpodaptes* (Rose 1975). Patterson and McGrew (1962) assigned Keefer Hill an early Tiffanian age, as did MacIntyre (1966) and Gingerich (1975). However, Gazin (1971) and Rose (1975, 1977) regarded Keefer Hill as latest Torrejonian in age because of the large number of typically Torrejonian primate genera ("*Pronothodectes*," which is now, in part, placed in *Nannodectes*; *Palenochtha*, *Palaechthon*, *Plesiolestes*, *Torrejonia*, *Paromomys*, and *Elphidotarsius*) that occur here. Placement of Douglass Quarry and Keefer Hill in either the latest Torrejonian or the earliest Tiffanian mammal ages requires a decision that is, to some extent, arbitrary. These faunas are clearly intermediate between those of the Torrejonian and the Tiffanian mammal ages, and there is no clear faunal precedent deciding the question one way or the other. However, it is customary to use the first appearance datum (FAD of Van Couvering and Berggren [1977]) of a taxon, rather than the last appearance datum (LAD),



to set boundaries of successive biostratigraphic units (George et al. 1969; Murphy 1977; Woodburne 1977). Following this procedure, we emphasize the first appearance of *Plesiadapis*, *Nannodectes*, *Ectocion*, and *Phenacodus* at Keefer Hill and Douglass Quarry—rather than the last appearances of the various primates noted above—in placing these localities and their contained faunas at the base of the Tiffanian Mammal Age and not in the Torrejonian Mammal Age. If the first appearance of a single genus is to be taken as defining the Tiffanian Mammal Age (Woodburne 1977), *Plesiadapis* is the most appropriate for this purpose. *Plesiadapis* has traditionally served as a taxon marking the beginning of the Tiffanian Mammal Age (Wood et al. 1941), and it has been thoroughly studied biostratigraphically (Gingerich 1976).

It should be noted that all of the genera first appearing at the beginning of the Tiffanian Mammal Age are plausibly derived from genera present in the Torrejonian Mammal Age of North America. The boundary between the Torrejonian and the Tiffanian mammal ages is thus probably a product of intracontinental evolution and dispersal. This is in contrast to the boundary between the Tiffanian and the Clarkforkian mammal ages, which is apparently marked by a major immigration of new genera, families, and even orders of mammals from Asia.

### Definition and Characterization

We define the Tiffanian Mammal Age to include faunas that occur during the time between the first appearance of the plesiadapid primate, *Plesiadapis*, and the first appearance of the Rodentia.

The Wood committee (1941) listed the following taxa as making their first appearance in the Tiffanian Mammal Age: *Palaeosinopa*, *Phenacodus*, *Plesiadapis*, *Probathyopsis*, Rodentia, and *Thryptacodon*. This list remains almost unchanged except for the Rodentia, which do not appear until the Clarkforkian Mammal Age. Two of the five genera noted as last appearances for the Tiffanian Mammal Age, *Anisonchus* and *Arctocyon*, retain this distinction. However, of the other three, *Leptacodon* is questionably reported from the Clarkforkian Mammal Age whereas well-documented records of *Tetraclaenodon* and *Pantolambda* are not known beyond the Torrejonian Mammal Age. Wood et al. (1941) listed the following as index fossils for the Tiffanian Mammal Age: *Barylambda*, *Bathyopsoides*, *Labdolemur*, *Phenacodus grangeri*, *Sparactolambda*, and *Titanoides*. *Sparactolambda* is now considered a synonym of *Titanoides* and *Bathyopsoides* a synonym of

*Probathyopsis*. Of the index fossils listed by Wood et al., only *Titanoides* is still restricted to the Tiffanian. The genus *Ectypodus* was given as the single characteristic fossil for the Tiffanian. This remains valid although the list has been greatly augmented, now including eleven genera.

Paleomagnetic sections have been developed in Clark's Fork and Bighorn basins, northern Wyoming (Butler et al. 1980, 1981), in conjunction with major fossil localities. The signature of these paleomagnetic sections is one of the more distinctive for any in Paleocene terrestrial sediments in the Western Interior. Although not all of the fossiliferous portion of this section has been amenable to magnetostratigraphic analysis, the available portion extends from within magnetic polarity chron 26R through 24R (27R through 24R, Butler, unpublished data and written communication to EHL 1984) and includes the Paleocene/Eocene boundary. In these basins Tiffanian faunas extend from magnetic polarity chron 26R into 25N.

Rapp et al. (1983) published the Black Peaks paleomagnetic sequence, correlating the Schiebout-Reeves Quarry (UT loc. 41274) with the Torrejonian/Tiffanian boundary. The lower part of the Black Peaks Formation, including UT locality 41274 and the sites (UT locs. 40147 and 41217) correlated with the Ti3 lineage-zone, has reversed polarity. Joe's Bone Bed, correlated with the Ti5 lineage-zone, occurs in the overlying and shorter reversed magnetozone. Rapp et al. (ibid.) correlated these magnetozones (and faunas) with magnetic polarity chrons 25R (includes the Ti5 fauna) and 26R (includes the Ti1 and Ti3 faunas), which is consistent with the paleomagnetic correlation of Tiffanian lineage-zones in the Clark's Fork Basin (Butler et al. 1981) and is compatible with reinterpretation of the San Juan Basin magnetostratigraphic sequence by Butler and Lindsay (1985).

To summarize, we place the Torrejonian/Tiffanian boundary at or near the boundary of magnetic polarity chrons 27N and 26R. The *Pantolambda/Plesiadapis praecursor* Interval-Zone (To3) is correlated with magnetic polarity chron 27N (e.g., the type section for the Torrejonian Mammal Age in Arroyo Torreon, New Mexico, and Cub Creek, Wyoming) and the upper part of magnetic polarity chron 27R (e.g., Kutz Canyon sites, New Mexico). The *Plesiadapis praecursor/P. anceps* (Ti1) and *P. anceps/P. rex* (Ti2) lineage-zones (including the lower Black Peaks fauna, UT loc. 41274) are correlated with the lower part of magnetic polarity chron 26R. The *P. rex/P. churchilli* Lineage-Zone (Ti3) is correlated with the top of magnetic polarity chron 26R and most of 26N. The *P. churchilli/P. simonsi* Lineage-Zone (Ti4) is

correlated with the top of magnetic polarity chron 26N and the base of chron 25R. The *P. simonsi*/*P. gingerichi* Lineage-Zone (Ti5) is correlated with most of magnetic polarity chron 25R and about the lower one-third of chron 25N. The *P. gingerichi*/Rodentia Interval-Subzone (Ti6) of the *P. gingerichi*/*P. cookei* Lineage-Zone (Ti6-Cf1) is correlated with about the middle one-third of magnetic polarity chron 25N.

These data suggest that the Tiffanian commences early in magnetic polarity chron 26R (also see discussion of zonation in the Torrejonian section). Paleomagnetic samples were also analyzed from the area for the type Tiffanian Mammal Age in southern Colorado, including the important Mason Pocket Quarry (Butler et al. 1981). The entire section was magnetically reversed and, based on faunal correlation to the Clark's Fork-Bighorn basins, was assigned to magnetic polarity chron 25R.

The following taxonomic characterization of the Tiffanian Mammal Age is updated from Wood et al. (1941). Occurrences for the taxa are provided in table 3.2.

First appearances: *Aletodon*, *Arctostylops*, *Barylambda*, *Carpolestes*, *Chiromyoides*, *Cyriacotherium*, *Diacocherus*, *Didymictis*, *Dipsalodon*, *Ectocion*, *Ectoganus*, *Esthonyx*(?), *Haplolambda*, *Labidolemur*, *Lambertocyon*, *Micromomys*, *Neoliotomus*, *Oxyaena*, *Palaeosinopa*, *Phenacodaptes*, *Phenacodus*, *Phenacolemur*, *Plesiadapis*, *Probathyopsis*, *Prochetodon*, *Thryptacodon*, *Titanoides*, *Viverravus*.

Last appearances: *Acmeodon*, *Anconodon*, *Anisonchus*, *Aphronorus*, *Arctocyon*, *Catopsalis*, *Desmotaclaenus*, *Elphidotarsius*, *Elpidophorus*, *Eucosmodon*(?), *Gelastops*, *Haplaletes*, *Litomylus*, *Mckennatherium*, *Mesodma*, *Mimetodon*, *Mimotricentes*, *Myrmecoboides*, *Neoplagiaulax*, *Palaechthon*, *Palenochtha*, *Paleotomus*, *Pantolambda*, *Paromomys*, *Periptychus*, *Picrodus*, *Plesiolestes*, *Promioclauenus*, *Pronothodectes*(?), *Propalaeosinopa*, *Protictis*, *Protoselene*, *Psittacotherium*, *Ptilodus*, *Simpsonictis*(?).

Index fossils: *Aaptoryctes*, *Amelotabes*, *Bisonalveus*, *Caenolambda*, *Carpodaptes*, *Cedrocherus*, *Colpoclaenus*, *Diacodon*(?), *Dorraletes*, *Litolestes*, *Litocherus*, *Melaniella*, *Nannodectes*, *Navajovius*, *Pararyctes*, *Pentacosmodon*, *Propalaeonodon*, *Protoselene*, *Raphictis*, *Saxonella*, *Tytthaena*, *Unuchinia*, *Utemylus*, *Xenacodon*, *Zanycteris*.

Characteristic fossils: *Chriacus*, *Dissacus*, *Ectypodus*, *Ignacius*, *Leptacodon*, *Microcosmodon*, *Palaeoryctes*, *Parectypodus*, *Peradectes*, *Prodiacodon*, *Prolimnocyon*.

Taxa absent but known before and after the Tiffanian: *Prolimnocyon*.

## Zonation

The large number of mammalian faunas belonging to the Tiffanian Mammal Age in the Western Interior and the fact that many of these are isolated geographically in separate depositional basins has led to some difficulty in determining the relative ages of localities and their contained faunas. In recent years, considerable progress has been made toward placing Tiffanian localities into successive biostratigraphic zones. These biostratigraphic zones are faunally equivalent to the biochronologic zones used here. This progress can be measured to some degree by comparing the temporal distribution of localities outlined here with views current ten to fifteen years ago (e.g., Sloan and Van Valen 1965; D. E. Russell 1967; Sloan 1970). This has been achieved almost entirely by application of the stratigraphic principle of faunal succession and correlation wherever two or more faunas are preserved in stratigraphic sequence.

As recognized by the authors of this chapter, the Tiffanian Mammal Age is subdivided into five lineage-zones (Ti1–Ti5) and one interval-subzone (Ti6) (part of a sixth lineage-zone, Ti6-Cf1) based on five apparently nonoverlapping species of the primate *Plesiadapis* that have been argued to form successive evolutionary stages. *Plesiadapis* is one of the most abundant and most widely distributed genera of late Paleocene mammals and is a suitable taxon for lineage-zonation, although as noted in the introduction and methodology section, interval-zones are preferable because they are less arbitrary. The five lineage-zones and one interval-subzone of the Tiffanian that we recognize are the *Plesiadapis praecursor*/*P. anceps* Lineage-Zone (Ti1), the *P. anceps*/*P. rex* Lineage-Zone (Ti2), the *P. rex*/*P. churchilli* Lineage-Zone (Ti3), the *P. churchilli*/*P. simonsi* Lineage-Zone (Ti4), the *P. simonsi*/*P. gingerichi* Lineage-Zone (Ti5), and the *P. gingerichi*/Rodentia Interval-Subzone (Ti6) of the *P. gingerichi*/*P. cookei* Lineage-Zone (Ti6-Cf1). The first three lineage-zones are represented by faunas from the Crazy Mountain Basin, Montana (Simpson 1937b, Gingerich 1976), and the second through fifth lineage-zones and the sixth interval-subzone are represented by faunas from the Clark's Fork-Bighorn basins, Wyoming (Gingerich 1976, Gingerich et al. 1980).

### *Plesiadapis praecursor*/*P. anceps* Lineage-Zone (Ti1)

We define the *Plesiadapis praecursor*/*P. anceps* Lineage-Zone to include faunas that occur during the time be-

tween the first appearance of *P. praecursor* and the first appearance of *P. anceps*.

Earliest Tiffanian faunas are currently known from central Alberta to southern Wyoming (and probably southern Texas), but this zone remains one of the least well known for the Tiffanian Mammal Age. The samples recovered from Ti1 localities are either small or as yet only partially described. Small samples are known from Cochrane I and II in central Alberta (L. S. Russell 1929, 1932, 1958), the Little Muddy Creek Locality in the Fossil Basin of southwestern Wyoming (Gazin 1969), and the Bangtail Locality in the western Crazy Mountain Basin of south-central Montana (Gingerich et al. 1983). The Schiebout-Reeves Quarry in the Big Bend area of Texas (Schiebout 1974, Rapp et al. 1983) can probably also be included.

One of the largest and potentially most important collections from the Ti1 lineage-zone, that from Keefer Hill in the northern Wind River Basin, is still largely undescribed; among higher taxa only primates have received thorough attention (Gazin 1971). Preliminary faunal lists have been published for the Keefer Hill Local Fauna (Keefer 1961, D. E. Russell 1967). Many of the taxa cited in these preliminary lists would be new records for the Ti1 lineage-zone; however, until these temporal range extensions are substantiated through detailed description and analysis, we feel it is premature to record them as definite occurrences.

A second major locality, Douglass Quarry in the eastern Crazy Mountain Basin, was worked in 1940 by a field party from Princeton University. That collection was recently described by Krause and Gingerich (1983), but a much larger collection obtained since 1982 by field parties from the State University of New York at Stony Brook remains to be studied. Douglass Quarry is especially important because it has been placed in stratigraphic sequence between Gidley and Silberling quarries (To3) below and Scarritt Quarry above (Ti2) (Simpson 1937a, Krause and Gingerich 1983). Very near Douglass Quarry, and at stratigraphically similar levels, are a number of mammal-bearing fossil localities, one of which (loc. 68) yielded the type specimen of *Ectocion montanensis*, now considered a junior synonym of *E. collinus* (Gingerich 1982a).

New localities, such as Bangtail in the Crazy Mountain Basin (Gingerich et al. 1983), and new collections from previously known localities such as Cochrane Site II in Alberta (R. C. Fox, pers. com. to DWK 1984) promise to add considerably to our knowledge of mammals during the Ti1 lineage-zone. The Cochrane localities, like Keefer Hill, have only recently been assigned an earliest Tiffanian age (Gingerich 1982a). Un-

fortunately, earliest Tiffanian mammals have not been found in the Polecat Bench section; this interval is therefore the only one of the five Tiffanian lineage-zones not yet represented in that stratigraphic sequence. It is still not possible to provide reliable estimates of mammalian diversity for the Ti1 lineage-zone, nor is it possible to make an adequate comparison of northern faunas with their southern counterparts. Preliminary data suggest that *Ectocion* and *Ptilodus* were dominant forms during the earliest portion of the Tiffanian Mammal Age.

In addition to the appearance of the defining taxon, *Plesiadapis praecursor*, other taxa such as *Nannodectes intermedius* and *Aphronorus orieli* are important in recognizing the Ti1 lineage-zone. A notable genus restricted to this zone is *Colpoclaenus*.

Occurrences for the taxa given below are presented in table 3.2.

First appearances: *Bisonalveus*, *Caenolambda*, *Carpodaptus*, *Diacodon*(?), *Ectocion*, *Nannodectes*, *Pararyctes*(?), *Phenacodus*, *Plesiadapis*, *Thryptacodon*, *Titanoides*.

Last appearances: *Anisonchus*, *Aphronorus*, *Catopsalis*, *Eucosmodon*(?), *Gelastops*, *Palaechthon*, *Palenochtha*, *Pantolambda*, *Paromomys*, *Pronothodectes*(?).

Index fossils: *Aphronorus orieli*, *Colpoclaenus*, *Plesiadapis praecursor*, *Nannodectes intermedius*.

Characteristic fossils: *Anconodon*, *Arctocyon*, *Chriacus*, *Elphidotarsius*, *Ectypodus*, *Leptacodon*, *Litomytus*, *Mckennatherium*, *Microcosmodon*, *Mimetodon*, *Mimotricentes*, *Myrmecoboides*, *Neoplagiaulax*, *Paleotomus*, *Peradectes*, *Periptychus*, *Picrodus*, *Plesiolestes*, *Prodiacodon*(?), *Promioclauenus*, *Propalaeosinopa*, *Proctictis*, *Psittacotherium*, *Ptilodus*.

Taxa absent but known before and after Ti1: *Acmeodon*, *Desmatoclaenus*, *Dissacus*, *Elpidophorus*, *Haplaletes*, *Ignacius*, *Mesodma*, *Palaeoryctes*, *Paractypodus*, *Prolimnocyon*(?), *Protoselene*, *Simpsonictis*.

### ***Plesiadapis anceps*/*P. rex* Lineage-Zone (Ti2)**

We define the *Plesiadapis anceps*/*P. rex* Lineage-Zone to include faunas that occur during the time between the first appearance of *P. anceps* and the first appearance of *P. rex*.

Late early Tiffanian (Ti2) localities are currently known only from Montana and Wyoming. Like the Ti1 lineage-zone, the Ti2 lineage-zone is poorly known paleontologically and is poorly represented geographically. Papers on the Crazy Mountain Basin Scarritt Quarry of south-central Montana (Simpson 1936b,

1937b) and the Bison Basin Saddle Locality of south-central Wyoming (Gazin 1956b) are the only faunal studies completed to date for the Ti2 lineage-zone. Both local faunas are small, however, and at least the Scarritt Quarry sample appears to be biased in favor of small mammals (Rose 1981a, 1981b). An updated faunal list for Scarritt Quarry appears in Rose (1981a), but since this time the sample from Scarritt Quarry has been approximately quadrupled by field parties from the State University of New York at Stony Brook. The small mammals *Litocherus*, *Neoplagiaulax*, and *Propalaeosinopa* are dominant forms at Scarritt Quarry (Rose 1981a), whereas the large condylarth *Phenacodus* is overwhelmingly dominant at the Saddle Locality, Bison Basin, Wyoming (Gazin 1956b). Much smaller collections of Ti2 lineage-zone mammals are known from UM locality 263 in the Polecat Bench section, Bighorn Basin, Wyoming, and several localities (White Site, 7-Up Butte, Highway Blowout) in the Medicine Rocks area of southeastern Montana.

First appearances: *Litocherus*, *Pararyctes*, *Unuchinia*.

Last appearances: *Anconodon*, *Desmatoclaenus*, *Plesiolestes*, *Simpsonictis*(?).

Index fossils: *Plesiadapis anceps*, *Nannodectes gazini*.

Characteristic fossils: *Arctocyon*, *Bisonalveus*, *Carpodaptus*, *Caenolambda*, *Chriacus*, *Dissacus*, *Ectocion*, *Ectypodus*, *Elpidophorus*, *Haplaletes*, *Ignacius*, *Leptacodon*, *Litomytus*, *Mimotricentes*, *Nannodectes*, *Neoplagiaulax*, *Paleotomus*, *Peradectes*, *Phenacodus*, *Picrodus*, *Plesiadapis*, *Prodiacodon*, *Promioclacenus*, *Propalaeosinopa*, *Protictis*, *Protoselene*, *Ptilodus*, *Thryptacodon*, *Titanoides*.

Taxa absent but known before and after Ti2: *Acmeodon*, *Aphronorus*, *Diacodon*(?), *Elphidotarsius*, *Gelastops*, *Mckennatherium*, *Mesodma*, *Microcosmodon*, *Mimetodon*, *Myrmecoboides*, *Palaeoryctes*, *Parectypodus*, *Periptychus*, *Prolimnocyon*(?), *Psittacotherium*.

### ***Plesiadapis rex*/P. churchilli Lineage-Zone (Ti3)**

We define the *Plesiadapis rex*/P. churchilli Lineage-Zone to include faunas that occur during the time between the first appearance of P. rex and the first appearance of P. churchilli.

The middle part of the Tiffanian Mammal Age is much better represented, both paleontologically and geographically, than the previous two lineage-zones. Approximately 50 percent more genera are represented in

the Ti3 lineage-zone than in either the Ti1 or Ti2 lineage-zones. Furthermore, more than double the number of localities are represented for faunas in the Ti3 lineage-zone than either of the previous Tiffanian lineage-zones, and these localities range from southern Texas to central Alberta, a distance of almost 1,900 miles (3,000 km). Cedar Point Quarry, in the Bighorn Basin of northwestern Wyoming, contains the largest known sample (almost 2,000 specimens) and lies stratigraphically beneath Witter (= Croc. Tooth) and Divide quarries (both in the Ti4 lineage-zone). Several mammalian taxa from Cedar Point Quarry have been described (e.g., adapisoricids—Krishtalka 1976a, Gingerich 1983; nyctitheriids—Krishtalka 1976b; apatemyids—West 1973; plesiadapids—Gingerich 1976; carpolestids—Rose 1975; arctocyonids—Van Valen 1978; phenacodontids—West 1971, 1976; carnivores—Gingerich and Winkler 1985; creodonts—Gingerich 1980a; pantodonts—Simons 1960), and Rose (1981a) has presented a preliminary list of the entire fauna. The Cedar Point Local Fauna is dominated by *Plesiadapis* and *Ptilodus*. Smaller samples that have received more detailed descriptive treatment are known from the Big Bend area of Texas (Ray's Bone Bed and Annex—Schiebout 1974), the Bison Basin of Wyoming (Ledge, Saddle Annex, and West End localities—Gazin 1956b), the Williston Basin of North Dakota (Judson and Brisbane localities—Holtzman 1978), the Chappo Type Locality (Dorr and Gingerich 1980), the Hoback Basin of Wyoming (Battle Mountain Locality—Dorr 1958), and southeastern Alberta (Police Point Local Fauna—Krishtalka 1973). Wolberg (1979) has presented a preliminary faunal list for the Circle Local Fauna of eastern Montana. Several mammalian taxa from two recently discovered localities (UADW-1 and UADW-2) in central Alberta have recently been described by Fox (1983b, 1984a, 1984b, 1984c, 1984d; preliminary faunal list in 1984a). Specimens from these localities are particularly noteworthy because of their relative completeness.

First appearances: *Aletodon*, *Barylambda*, *Chiromyoides*, *Cyriacotherium*, *Diacocherus*, *Dorraletes*, *Labidolemur*, *Lambertocyon*, *Litolestes*, *Micromomys*, *Navajovius*, *Prochetodon*, *Zanycteris*.

Last appearances: *Acmeodon*, *Aphronorus*(?), *Bisonalveus*, *Caenolambda*, *Elphidotarsius*, *Elpidophorus*, *Gelastops*, *Promioclacenus*, *Protoselene*.

Index fossils: *Cedrocherus*, *Chiromyoides minor*, *Melaniella*, *Nannodectes simpsoni*, *Plesiadapis rex*, *Raphictis*, *Saxonella*, *Tythaena*.

Characteristic fossils: *Acmeodon*, *Arctocyon*, *Carpodaptus*, *Chriacus*, *Dissacus*, *Ectocion*, *Ectypodus*, *Haplaletes*, *Ignacius*, *Labidolemur*, *Leptacodon*, *Lito-*

*cherus*, *Litomylus*, *Mckennatherium*, *Mesodma*, *Microcosmodon*, *Mimetodon*, *Mimotricentes*, *Myrmecoboides*, *Nannodectes*, *Neoplagiaulax*, *Paleotomus*, *Palaeoryctes*, *Pararyctes*, *Parectypodus*, *Peradectes*, *Periptychus*, *Phenacodus*, *Picrodus*, *Plesiadapis*, *Prodiacodon*(?), *Propalaeosinopa*, *Protictis*, *Psittacotherium*, *Ptilodus*, *Thryptacodon*, *Titanoides*, *Unuchinia*.

Taxa absent but known before and after Ti3: *Diacodon*(?), *Prolimnocyon*(?).

### ***Plesiadapis churchilli*/P. *simonsi* Lineage-Zone (Ti4)**

We define the *Plesiadapis churchilli*/P. *simonsi* Lineage-Zone to include faunas that occur during the time between the first appearance of P. *churchilli* and the first appearance of P. *simonsi*.

The type Tiffanian fauna from the Mason Pocket Locality of southwestern Colorado lies within the Ti4 lineage-zone and was described in detail by Simpson (1935a, 1935b, 1935c). Samples of very few other Ti4 lineage-zone localities have been treated in full, those from the Rock Springs Uplift of southwestern Wyoming (Winterfeld 1982), Malcolm's Locality in the Wind River Basin of central Wyoming (Krishtalka et al. 1975), the Riverdale Locality in the Williston Basin of central North Dakota (Holtzman 1978), and Swan Hills Site 1 in central Alberta (L. S. Russell 1967) being the exceptions. Probably the largest sample (more than 5,000 specimens) of Ti4 lineage-zone mammals comes from the Roche Percée localities in southeastern Saskatchewan. Only the multituberculates (Krause 1977), primates (Krause 1978), and a pantodont (Rose and Krause 1982) have been described from the Roché Percée Local Fauna. Wolberg (1979) has presented a preliminary faunal list for the Olive Locality of eastern Montana. Included in Wolberg's list are several taxa that are otherwise unknown from the Ti4 lineage-zone (e.g., *Nyctitherium*, *Protentomodon*, cf. ? *Purgatorius*, *Phenacolemur*); they have not been included in the lists below pending publication of full descriptions and analyses. Swan Hills Site 1 is the most northerly Tiffanian (and Paleocene) fossil mammal locality known (L. S. Russell 1967). Several localities (e.g., Airport, Witter Quarry, Divide Quarry) in the Bighorn Basin are especially significant because they have been placed in stratigraphic relationship to localities that have yielded mammals from either the earlier Ti3 or the later Ti5 lineage-zones or both.

Although the faunal composition of none of the Ti4 lineage-zone localities has been analyzed, it appears that, as in the Ti3 lineage-zone, *Ptilodus* and *Plesiadapis* are dominant.

First appearances: *Haplolambda*, *Palaeosinopa*, *Phenacodaptes*.

Last appearances: *Labidolemur*, *Litomylus*, *Mesodma*, *Pararyctes*, *Periptychus*, *Zanycteris*.

Index fossils: *Amelotabes*, *Chiromyoides caesor*, *Nannodectes gidleyi*, *Plesiadapis churchilli*, *Utemylus*, *Xenacodon*.

Characteristic fossils: *Aletodon*, *Arctocyon*, *Barylambda*, *Carpodaptes*, *Chiromyoides*, *Chriacus*, *Diacocherus*, *Dissacus*, *Ectocion*, *Ectypodus*, *Haplaletes*, *Ignacius*, *Lambertocyon*, *Leptacodon*, *Litolestes*, *Litocherus*, *Microcosmodon*, *Micromomys*, *Mimetodon*, *Mimotricentes*, *Nannodectes*, *Navajovius*, *Neoplagiaulax*, *Peradectes*, *Phenacodus*, *Picrodus*, *Plesiadapis*, *Prochetodon*, *Propalaeosinopa*, *Protictis*, *Ptilodus*, *Thryptacodon*, *Titanoides*.

Taxa absent but known before and after Ti4: *Diacodon*(?), *Dorraletes*, *Mckennatherium*, *Myrmecoboides*, *Palaeoryctes*, *Paleotomus*, *Parectypodus*, *Prodiacodon*, *Prolimnocyon*(?), *Psittacotherium*, *Unuchinia*.

### ***Plesiadapis simonsi*/P. *gingerichi* Lineage-Zone (Ti5)**

We define the *Plesiadapis simonsi*/P. *gingerichi* Lineage-Zone to include faunas that occur during the time between the first appearance of P. *simonsi* and the first appearance of P. *gingerichi*.

The vast majority of Ti5 lineage-zone localities are from the Clark's Fork and Bighorn basins. The mammalian fauna from the best known of these, Princeton Quarry, was recently reexamined by Rose (1981a, 1981b). The Princeton Quarry sample is dominated by *Phenacodaptes* and *Plesiadapis*, but like Scarritt Quarry in the Ti2 lineage-zone, it probably contains an overrepresentation of small forms owing to size sorting. Much smaller collections of Ti5 lineage-zone mammals have been described from the following localities: Bayfield (northern San Juan Basin, Colorado—Simpson 1935a, 1935b, 1935c), Joe's Bone Bed (Big Bend area, Texas—Schiebout 1974), several UW localities (eastern Rock Springs Uplift, Wyoming—Winterfeld 1982), the *Titanoides* Locality (Bison Basin, Wyoming—Gazin 1956b), and Dell Creek Quarry (Hoback Basin, Wyoming—Dorr 1952, 1958, 1978).

First appearances: *Arctostylops*, *Carpolestes*, *Didymictis*, *Dipsalodon*, *Ectoganus*, *Neoliotomus*, *Oxyaena*, *Phenacolemur*, *Probathyopsis*, *Viverravus*.

Last appearances: *Arctocyon*, *Carpodaptes*, *Diacodon*(?), *Dorraletes*, *Haplaletes*, *Litolestes*, *Litocherus*, *Mckennatherium*, *Mimetodon*, *Myrmecoboides*, *Nannodectes*, *Navajovius*, *Neoplagiaulax*, *Paleotomus*, *Picro-*

*dus*, *Propalaeosinopa*, *Protictis*, *Psittacotherium*(?), *Ptilodus*, *Unuchinia*.

Index fossils: *Aptoryctes*, *Chiromyoides potior*, *Pentacosmodon*, *Plesiadapis fodinatus*, *Plesiadapis simonsi*, *Propalaeonodon*.

Characteristic fossils: *Aletodon*, *Barylambda*, *Chiromyoides*, *Cyriacotherium*, *Diacocherus*, *Dissacus*, *Ectocion*, *Ectypodus*, *Haplolambda*, *Ignacius*, *Lambertocyon*, *Leptacodon*, *Microcosmodon*, *Micromomys*, *Mimotricentes*, *Palaeoryctes*, *Palaeosinopa*, *Parectypodus*, *Peradectes*, *Phenacodaptes*, *Phenacodus*, *Plesiadapis*, *Prochetodon*, *Thryptacodon*, *Titanoides*.

Taxa absent but known before and after Ti5: *Chriacus*, *Labidolemur*, *Prodiacodon*, *Prolimnocyon*.

### ***Plesiadapis gingerichi*/Rodentia Interval-Subzone (Ti6) of the *P. gingerichi*/*P. cookei* Lineage-Zone (Ti6-Cf1)**

*Plesiadapis gingerichi* was recently described by Rose (1981), who interpreted it to be phylogenetically and temporally intermediate between *P. simonsi* (latest Tiffanian, Ti5) and *P. cookei* (middle Clarkforkian, Cf2). Following Rose, we define the *Plesiadapis gingerichi*/*P. cookei* Lineage-Zone to include faunas that occur during the time between the first appearance of *P. gingerichi* and the first appearance of *P. cookei*.

In working out the relationships of the *Plesiadapis gingerichi*/*P. cookei* Lineage-Zone (Ti6-Cf1) as first defined by Rose (1980, 1981), it became apparent that this lineage-zone straddles the Tiffanian/Clarkforkian boundary. To specify this relationship clearly, we further subdivide this lineage-zone into two interval-subzones. The end of the first interval-subzone (Ti6) and the commencement of the second interval-subzone (Cf1) equals the Tiffanian/Clarkforkian boundary, which corresponds to the first appearance of rodents (and other taxa). Thus, we define the first interval-subzone, the *Plesiadapis gingerichi*/Rodentia Interval-Subzone, to include faunas that occur during the time between the first appearance of *P. gingerichi* and the first appearance of the Rodentia.

Within the Clark's Fork Basin, local faunas referable to the *P. gingerichi*/*P. cookei* Lineage-Zone occur in the lowest 328 ft. (100 m) of strata containing Clarkforkian faunas and in strata extending approximately 328 ft. (100 m) below the first occurrence of Clarkforkian faunas. Thus, the lower 328 ft. (100 m) of this section yield mammals that are referable to the *P. gingerichi*/Rodentia Interval-Subzone.

At present, the *Plesiadapis gingerichi*/*P. cookei* Lineage-Zone (Ti6-Cf1) can only be recognized with

certainty within the Clark's Fork Basin, probably because there are few other localities of early Clarkforkian age. Several other faunas that will be discussed under the Rodentia/*P. cookei* Interval-Subzone (Cf1) portion of the Ti6-Cf1 lineage-zone may, however, be referable to this second subzone. For now, local faunas belonging to the Ti6 interval-subzone appear to be restricted to the Clark's Fork Basin and are very poorly known. Thus, the sole purpose in recognizing two interval-subzones within the *P. gingerichi*/*P. cookei* Lineage-Zone is to highlight the fact that this lineage-zone straddles the Tiffanian/Clarkforkian boundary.

Occurrences for the taxa listed below are given in table 3.2.

First appearances: *Esthonyx*(?), *Plesiadapis gingerichi*, *P. dubius*.

Last appearances: *Mimotricentes*.

Index fossils: none.

Characteristic fossils: *Carpolestes*, *Chiromyoides*, *Cyriacotherium*, *Diacocherus*, *Didymictis*, *Dipsalodon*, *Ectocion*, *Ectoganus*, *Leptacodon*, *Neoliotomus*, *Oxyaena*, *Palaeosinopa*, *Phenacodus*, *Phenacolemur*, *Probathyopsis*, *Prochetodon*, *Prolimnocyon*(?).

Taxa absent but known before and after Ti6: *Aletodon*, *Arctostylops*, *Barylambda*, *Chriacus*, *Dissacus*, *Ectypodus*, *Haplolambda*, *Ignacius*, *Labidolemur*, *Lambertocyon*, *Microcosmodon*, *Micromomys*, *Palaeoryctes*, *Parectypodus*, *Peradectes*, *Phenacodaptes*, *Prodiacodon*, *Thryptacodon*, *Titanoides*, *Viverravus*.

## **CLARKFORKIAN MAMMAL AGE**

### **Introduction**

Granger (1914) applied the term *Clark Fork* to a stratigraphic interval in the Clark's Fork Basin of northwestern Wyoming (specifically, at the southeastern end of Polecat Bench) where he had found fossils he recognized to be older than what we refer to as the Wasatchian Mammal Age (see also Sinclair and Granger 1912). This "Clark Fork fauna" was described by Matthew (1915a, 1915b, 1915c), Granger (1915), Jepsen (1930b, 1940), and Simpson (1929c, 1937c). The fauna proved to be so distinctive that, in 1941, Wood et al. formally proposed the Clarkforkian as a North American provincial age, "based on the Clark Fork member (and faunal zone) of the Polecat Bench Formation." They selected Granger's locality on Polecat Bench as the type locality. Wood et al. (1941), like most workers before and after, considered the Clarkforkian the last of the Paleocene provincial ages, what we call the Clarkforkian Mammal Age.

Several factors—relatively small collections, in-

adequate stratigraphic documentation, and confusion of lithologic, temporal, and biochronologic units—led to skepticism about the legitimacy of the Clarkforkian Mammal Age. This culminated in R. C. Wood's (1967) detailed reappraisal and ultimate rejection of the Clarkforkian as a valid land mammal "age." Intensive collecting in the Clark's Fork Basin during the past several years, however, has yielded thousands of new specimens that clearly reaffirm the existence of a distinctive Clarkforkian fauna (Gingerich and Rose 1977; Rose 1978, 1980, 1981a; D. Parris, unpublished data and written communication to KDR, 1984). In addition, these collections indicate that, contrary to earlier belief, Clarkforkian assemblages in the type area are not restricted to the Fort Union Formation (= Polecat Bench Formation) but occur primarily in the lower part of the variegated Willwood Formation. Approximately the upper 328 ft. (100 m) of the Fort Union Formation along Polecat Bench contain mammals of early Clarkforkian age, but there is no lithologic basis at present to justify separating this unit as the "Clark Fork member."

The Wood committee (1941) did not recognize any faunal correlatives of the Clarkforkian Mammal Age. Correlatives of this age are now recognized and have been discussed by Rose (1981a). These faunas occur in the following formations: the Fort Union and Willwood formations, Clark's Fork and Bighorn basins, northern Wyoming and southern Montana (Rough Gulch, Foster Gulch, Ries Locality, Bear Creek, and others—Sinclair and Granger 1912; Simpson 1928, 1929a; 1929b; Jepsen 1937; Van Houten 1944; Van Valen and Sloan 1966; Gingerich and Rose 1979); the "lower variegated sequence," Togwotee Pass area, northwestern Wyoming (probably the "Low" and "Rohrer" localities and definitely other localities—McKenna 1972, 1980); the Chappo Member, Wasatch Formation, Hoback Basin, western Wyoming (several localities—Dorr 1952, 1958, 1978; Dorr and Steidtmann 1970; Dorr et al. 1977), and Green River Basin, southwestern Wyoming (Buckman Hollow Locality of La Barge Creek—Gazin 1942, 1956a; Dorr and Gingerich 1980); the Fort Union Formation, Washakie Basin, southwestern Wyoming (Big Multi Locality, unpublished data, see Rose 1981a); the Atwell Gulch Member, Wasatch Formation, Piceance Creek Basin, northwestern Colorado (Plateau Valley—Patterson 1933, 1936, 1937, 1939, 1949; Patterson and Simons 1958; Patterson and West 1973); possibly localities in the Black Peaks Formation, Big Bend area, southwestern Texas (Schiebout 1974).

Rose (1981a) provided stratigraphic sections and descriptions and ranges of Clarkforkian mammals from

the type area as well as a discussion of the Clarkforkian assemblages from elsewhere (listed above).

### Tiffanian/Clarkforkian Boundary

In the Clark's Fork Basin, the beginning of the Clarkforkian Mammal Age can be recognized by the first occurrence of the orders Rodentia and Tillodontia (*Esthonyx*) and the genera *Haplomytus* (Condylarthra) and *Coryphodon* (Pantodonta). As discussed below, it is the appearance of the Rodentia that we use to define the beginning of this mammal age (Gingerich and Gunnell 1979; Rose 1980, 1981a). These first appearances were apparently all immigrants. There is no evidence at present that any of them appeared significantly earlier than the others; rather, their first occurrence seems to have been synchronous. This suggests that these mammals arrived in a single wave of immigration (see also Repenning 1967). Nonetheless, their geographic source is uncertain. A Central American center of origin has been suggested (Sloan 1970; Gingerich 1976; Gingerich and Rose 1977), but recent discoveries in the Paleocene of China suggest that rodents and tillodonts may have originated in Asia (Wang 1975; Zhou et al. 1977; Gingerich 1980c; Zhang 1980; Dawson et al. 1984).

The first occurrence of any of these four immigrants is, in practice, a good indication of the beginning of the Clarkforkian Mammal Age. None is very common, however, in the early part of the Clarkforkian Mammal Age; all four constitute only 6 to 7 percent of the individuals presently known for this time. By the middle of the Clarkforkian Mammal Age and during the remainder of this period, these groups were well established and accounted for 15 to 25 percent of the known individuals (Rose 1981a).

As we have already indicated, the beginning of a (land) mammal age is defined by the initial occurrence of a single taxon (as advocated by Woodburne [1977] and Murphy [1977]). We have selected the appearance of the Rodentia as the herald of Clarkforkian time (Rose 1981a). Identification of fragmentary rodent remains to lower taxonomic levels is difficult; however, ordinal characteristics of rodents are distinctive, and, in practice, the presence of any rodent is an indication that the Tiffanian/Clarkforkian boundary has been crossed. Wood et al. (1941) listed the Tiffanian as the oldest record of Rodentia. This was based on the occurrence of rodents at Bear Creek, Montana (Jepsen 1937), a locality that is now argued to be of Clarkforkian age (Van Valen and Sloan 1966; Sloan 1970; Rose 1975, 1977, 1981a; Gingerich 1976). More recently, Korth (1984) has

suggested that the original Tiffanian age assignment for the Bear Creek Local Fauna is correct and thus that the appearance of rodents in North America occurred during the Tiffanian Mammal Age. (It should be noted that Korth incorrectly stated that Rose [1981a] indicated an Eocene age for Bear Creek; in fact, Rose's correlations clearly indicate a Paleocene age.) We argue that a Clarkforkian age assignment for the Bear Creek Local Fauna is more in keeping with the evidence based on the co-occurrence of taxa (including rodents) in Clarkforkian faunas, Clark's Fork Basin, Wyoming, and in the Bear Creek Local Fauna (Rose 1981a). Further, simply by definition, the Bear Creek Local Fauna is Clarkforkian in age (even if it could be shown to be older than the type Clarkforkian faunas), because it yields rodents (but not taxa indicating a post-Clarkforkian age).

The only Clarkforkian faunas known outside of the Clark's Fork Basin which may overlie Tiffanian faunas and thus include the Tiffanian/Clarkforkian boundary are from strata preserved in the Togwotee Pass area, the Hoback Basin (both in western Wyoming), and the Plateau Valley area (Colorado). Collections from these strata do not yet permit precise location of the Tiffanian/Clarkforkian boundary.

### Definition and Characterization

Rose's (1980, 1981a) recent study of the mammalian fauna from the area of the type Clarkforkian Mammal Age permits a definition and characterization that is modified and much expanded from that of Wood et al. (1941). Accordingly, we define the Clarkforkian Mammal Age to include faunas that occur during the time between the first appearance of the Rodentia and the first appearance of the Artiodactyla. Rose reported seventy species of mammals from the Clarkforkian Mammal Age of the Clark's Fork Basin. These species are primarily of Paleocene aspect; several taxa typical of the Wasatchian Mammal Age also are present, however, whereas many standard Wasatchian forms are absent. Thus, the Clarkforkian fauna is truly intermediate, combining elements of both the Paleocene and Eocene. Exposures yielding the type Clarkforkian fauna in the Polecat Bench-Clark's Fork Basin area occur in an interval about 1,542 ft. (470 m) thick in the upper Fort Union and lower Willwood formations. The earliest Clarkforkian faunas are found about 1,148 ft. (350 m) above the level of the late Tiffanian Princeton Quarry.

The Wood committee (1941) recognized four genera that appear in the Clarkforkian Mammal Age: cf. *Coryphodon*, *Ectocion*, *Esthonyx*, and *Oxyaena*. Of these

taxa, only *Coryphodon* and *Esthonyx* are now known to appear for the first time in this mammal age; *Ectocion* and *Oxyaena* have been recorded from Tiffanian faunas. The last appearances recorded by Wood et al. for the Clarkforkian Mammal Age were *Carpolestes* and *Plesiadapis*. Except for a single specimen of *Plesiadapis dubius* from an early Wasatchian fauna (Rose and Bown 1982), these last appearances remain valid. The single index fossil listed for the Clarkforkian Mammal Age by the Wood committee was *Plesiadapis cookei*. This remains a valid assignment, but now additional taxa also can be recorded as index fossils for the Clarkforkian Mammal Age. Finally, the characteristic fossils originally recognized for this mammal age—*Didymictis*, *Ectypodus*, *Phenacodus*, *Probathyopsis*, *Thryptacodon*—remain valid but can be supplemented.

In addition to the updated faunal listings provided below, several aspects of Clarkforkian faunas merit further comment. Relatively common index fossils of the Clarkforkian include *Plesiadapis cookei*, *Carpolestes nigridens*, *Aletodon gunnelli*, *Apheliscus nitidus*, *Haplomylus simpsoni*, *Dissacus praenuntius*, *Esthonyx xenicus*, *E. ancylion*, and *Acritoparamys atavus*. Some of these species, such as *Plesiadapis cookei* (see below), are restricted to only part of the Clarkforkian Mammal Age. All occur in at least one Clarkforkian fauna outside of the Clark's Fork Basin in addition to the type Clarkforkian fauna. The other index fossils noted below are too rare or too limited in distribution to be useful as index fossils. Five genera that were thought to appear first in the Clarkforkian Mammal Age by Rose (1977) and Gingerich and Rose (1977) are now recorded from Tiffanian faunas. These genera are *Ectoganus* (*Lampadophorus*), *Dipsalodon*, *Arctostylops*, *Probathyopsis*, and *Oxyaena*. The most characteristic and most common mammals of the Clarkforkian Mammal Age are phenacodontid condylarths (*Ectocion osbornianus*, *Phenacodus primaevus*, and *P. vortmani*), which together constitute about 50 percent of the individuals at most levels in the Clark's Fork Basin (Rose 1981a, 1981b). *Ectocion* is ubiquitous and the most common mammal at most localities. Phenacodontids persist into Wasatchian time but exhibit a dramatic decline in abundance at the Clarkforkian/Wasatchian boundary.

As discussed in the characterization of the Tiffanian Mammal Age, magnetostratigraphic sections have been developed in the Clark's Fork and Bighorn basins, northern Wyoming (Butler et al. 1980, 1981). These sections encompass all three of the zones recognized by Rose (1981a) for the type Clarkforkian Fauna as well as most of the older Tiffanian faunas and a portion of the next younger Wasatchian faunas. In the Clark's Fork and



Bighorn basins, Clarkforkian faunas extend from magnetic polarity chron 25N into 24R.

The following list of taxa characterizing the Clarkforkian Mammal Age is an update of Wood et al. (1941) based in large measure on the work of Rose (1981a). Occurrences are given in table 3.2.

First appearances: *Acritoparamys*, *Apatemys*, *Apatosciuravus*, *Apheliscus*, *Coryphodon*, *Franimys*, *Haplomylus*, *Hyopsodus*, *Leipsanolestes*, *Microsyops*, *Mimoperadectes*(?), *Niptomomys*, *Palaeonodon*, *Paramys*, *Plagioctenodon*(?), *Plagiomene*, *Pontifactor*(?), *Tinimomys*, *Uintacyon*, *Worlandia*.

Last appearances: *Aletodon*, *Arctostylops*, *Carpolestes*, *Chiromyoides*, *Cyriacotherium*, *Diacocherus*, *Dipsalodon*, *Haplolambda*, *Lambertocyon*, *Microcosmodon*, *Palaeoryctes*, *Phenacodaptes*, *Plesiadapis*, *Prochetodon*, *Titanoides*(?).

Index fossils: *Acritoparamys atavus*, *A. atwateri* (= *Paramys annectens*), *Aletodon gunnelli*, *Apheliscus nitidus*, *Carpolestes nigridens*, *Chiromyoides major*, *Cyriacotherium psamminum*, *Dissacus praenuntius*, *Esthonyx ancylion*, *E. xenicus*, *Haplomylus simpsoni*, *Palaeonictis*, *Plagiomene accola*, *Planetetherium*, *Plesiadapis cookei*, *Prosthecion*, *Protentomodon*.

Characteristic fossils: *Barylambda*, *Bisonalveus*, *Chriacus*, *Didymictis*, *Dissacus*, *Ectocion*, *Ectoganus*, *Ectypodus*, *Esthonyx*, *Ignacius*, *Labidolemur*, *Leptacodon*(?), *Neoliotomus*, *Oxyaena*, *Palaeosinopa*, *Parectypodus*, *Peradectes*, *Phenacodus*, *Phenacolemur*, *Probrathyopsis*, *Prodiacodon*(?), *Prolimnocyon*(?), *Thryptacodon*, *Viverravus*.

Taxa absent but known before and after the Clarkforkian: *Micromomys*.

## Zonation

In the Clark's Fork Basin, the Clarkforkian Mammal Age can be subdivided into one subzone and two zones (Rose 1980, 1981a). The first subzone in the Clarkforkian Mammal Age, the Rodentia/*Plesiadapis cookei* Interval-Subzone (Cf1), is the second of two interval-subzones within the *Plesiadapis gingerichii*/*P. cookei* Lineage-Zone (Ti6-Cf1). The second zone in the Clarkforkian Mammal Age is the *Plesiadapis cookei* Lineage-Zone (Cf2). As was the case for the first five zones of the Tiffanian Mammal Age, the above two zones are lineage-zones because it is argued that they represent the duration of successive species within a single evolving lineage of *Plesiadapis*.

The *Plesiadapis gingerichii*/*P. cookei* Lineage-Zone (Ti6-Cf1), as defined by Rose (1980, 1981a), straddles the Tiffanian/Clarkforkian boundary. We have therefore

recognized two interval-subzones within this lineage-zone. The first of these, the *Plesiadapis gingerichii*/Rodentia Interval-Subzone (Ti6), corresponds to the Tiffanian portion of the Ti6-Cf1 lineage-zone, and the second, the Rodentia/*P. cookei* Interval-Subzone (Cf1), corresponds to the Clarkforkian portion of this lineage-zone (see zonation of the Tiffanian Mammal Age).

The second Clarkforkian zone mentioned above, the *Plesiadapis cookei* Lineage-Zone, only bears the name of the taxon defining the beginning of the zone. This is because the third and final Clarkforkian zone recognized by Rose is not based on the first appearance of a single (name-bearing) taxon and thus is neither a lineage-zone nor an interval-zone. This third zone, the *Phenacodus-Ectocion* Acme-Zone (Cf3), is, as the name suggests, based on the simultaneous abundance of the two named condylarths.

Recognition of the above zonation within the Clark's Fork section has been augmented by the use of species of *Phenacolemur* and *Esthonyx* (Rose 1981a). *Esthonyx xenicus* occurs within the *Plesiadapis gingerichii*/*P. cookei* Lineage-Zone and through the lowest 98 ft. (30 m) of strata bearing faunas referable to the *Plesiadapis cookei* Lineage-Zone. *Esthonyx ancylion* continues above the 98 ft. (30 m) level in strata bearing faunas of the *Plesiadapis cookei* Lineage-Zone into about the lowest 66 ft. (20 m) of strata with faunas assigned to the *Phenacodus-Ectocion* Acme-Zone. *Esthonyx grangeri* continues through the remainder of the *Phenacodus-Ectocion* Acme-Zone (and the Clarkforkian Mammal Age) and into the Wasatchian Mammal Age. *Phenacolemur pagei* first appears in the later part of the Tiffanian Mammal Age and continues into the Clarkforkian Mammal Age, coexisting with *Esthonyx xenicus* and *E. ancylion*. *Phenacolemur praecox* follows *P. pagei* and, as does *Esthonyx grangeri*, continues into the Wasatchian Mammal Age. Although these additional taxa may prove to be helpful in further delimiting Clarkforkian zones, it must be kept in mind that each of the two genera involved is argued to constitute an evolving lineage that is somewhat arbitrarily divided into species.

## Rodentia/*Plesiadapis cookei* Interval-Subzone (Cf1) of the *P. gingerichii*/*P. cookei* Lineage-Zone (Ti6-Cf1)

The rationale and basis for the subdivision of the Ti6-Cf1 lineage-zone are discussed under the *Plesiadapis gingerichii*/Rodentia Interval-Subzone (Ti6) within the Tiffanian Mammal Age. The definition of the Ti6-Cf1 lineage-zone can be found in the same discussion. We define the Rodentia/*Plesiadapis cookei* Interval-Subzone

to include faunas that occur during the time between the first appearance of the Rodentia and the first appearance of *P. cookei*. It can be further noted that "the Clarkforkian part of the *P. gingerichi* zone [= Cf1 interval-subzone] is recognized by the mutual occurrence of *P. gingerichi* and any of the taxa characterizing the beginning of the Clarkforkian: *Paramys*, *Coryphodon*, *Esthonyx*, or *Haplomytus*" (Rose 1981a, p. 27).

At present, the *Plesiadapis gingerichi*/*P. cookei* Lineage-Zone can be recognized with certainty only within the Clark's Fork Basin, probably because there are few other localities of early Clarkforkian age. The only other local fauna (in addition to those from the type area in the Clark's Fork Basin) that can tentatively be referred to the Ti6-Cf1 lineage-zone is that of Bear Creek. This local fauna occurs at the northern end of Clark's Fork Basin in southern Montana. Although this local fauna lacks *P. gingerichi*, the joint occurrence of *Chiromyoides potior*, *Carpolestes nigridentis*, *Phenacodaptes sabulosus*, and *Haplomytus simpsoni* and the absence of *Plesiadapis cookei* argues for reference to the *Plesiadapis gingerichi*/*P. cookei* Lineage-Zone (Rose 1981a). Further, the presence of *Acritoparamys atavus* (Korth 1984) supports the argument that this local fauna is referable to the Clarkforkian portion of this lineage-zone (Rose 1981) (= Cf1 interval-subzone). As noted in the discussion of the Tiffanian/Clarkforkian boundary, there are three areas where this boundary may be preserved (the Togwotee Pass area and Hoback Basin, western Wyoming, and Plateau Valley, Colorado); thus, there is some possibility of recovering additional fossils referable to the *P. gingerichi*/*P. cookei* Lineage-Zone in the future.

As is the case for the fauna of the Ti6 interval-subzone of the *Plesiadapis gingerichi*/*P. cookei* Lineage-Zone, the fauna of the Cf1 interval-subzone is poorly known. This probably accounts for the absence of some characteristic Clarkforkian forms from this interval-subzone (e.g., *Plagiomene accola*, *Worlandia inusitata*, *Ignacius graybullianus*, *Aletodon gunnelli*, *Dissacus praenuntius*, *Oxyaena aeguidens*, and *Uintacyon rudis*).

Occurrences for the taxa listed below are given in table 3.2.

First appearances: *Acritoparamys*, *Apatemys*, *Apatosciuravus*, *Apheliscus*, *Coryphodon*, *Haplomytus*, *Leipsanolestes*, *Paramys*, *Planetetherium*.

Last appearances: *Haplolambda*, *Lambertocyon*, *Phenacodaptes*, *Plesiadapis gingerichi*.

Index fossils: *Prosthecion*, *Protentomodon*.

Characteristic fossils: *Aletodon*, *Barylambda*, *Carpolestes*, *Chiromyoides*, *Cyriacotherium*(?), *Diacocherus*, *Didymictis*, *Dipsalodon*(?), *Dissacus*, *Ectocion*,

*Ectoganus*, *Esthonyx*, *Microcosmodon*, *Neoliotomus*, *Oxyaena*, *Palaeosinopa*, *Peradectes*(?), *Phenacodus*, *Phenacolemur*, *Plesiadapis dubius*, *Probathyopsis*, *Prochetodon*, *Prolimnocyon*(?), *Thryptacodon*, *Viverravus*.

Taxa absent but known before and after Cf1: *Arctostylops*, *Chriacus*, *Dipsalodon*, *Ectypodus*, *Ignacius*, *Labidolemur*, cf. *Leptacodon packi*, *Micromomys*, *Palaeoryctes*, *Parectypodus*, *Prodiacodon*.

### *Plesiadapis cookei* Lineage-Zone (Cf2)

*Plesiadapis cookei* is restricted to the middle of the Clarkforkian Mammal Age, and its appearance marks the beginning of the lineage-zone bearing its name. It is relatively common in this interval, accounting for up to 11 percent of the individuals in subintervals (Rose 1981a). It disappears abruptly and without issue in the Clark's Fork Basin section and apparently elsewhere, and its conspicuous absence is characteristic of the succeeding *Phenacodus-Ectocion* Acme-Zone. Based on these data, we define this lineage-zone to include faunas that occur between the first and last appearances of *Plesiadapis cookei*.

In the Clark's Fork Basin section, the *Plesiadapis cookei* Lineage-Zone can also be recognized by the overlapping ranges of *Aletodon gunnelli* and *Microcosmodon rosei*, the former species appearing at the beginning of the interval zone and the latter disappearing at about the end. Several other species first or last appear during this lineage-zone (see list below). Within the Clark's Fork Basin, local faunas referable to the lineage-zone occur in the middle 656 ft. (200 m) of strata containing Clarkforkian faunas.

Of the three Clarkforkian zones, the *Plesiadapis cookei* Lineage-Zone (Cf2) can be recognized over the widest geographic area. The first series of sites to be noted is to the south and east of Clark's Fork Basin in the Bighorn Basin. The major sites are Rough Gulch, Foster Gulch, and Ries localities. The first two localities have produced *Plesiadapis cookei*, suggesting assignment to Cf2. Rose (1981a) reported that one of the largest and most diverse Clarkforkian assemblages outside of the Bighorn Basin occurs in the Togwotee Pass area in northwestern Wyoming. As noted earlier, there is the possibility that the Tiffanian/Clarkforkian boundary is preserved in this section, but the Clarkforkian assemblages so far discovered appear to be referable definitely only to Cf2, in part because *P. cookei* occurs. Lower localities that are less well known and lack *P. cookei* may belong to the Ti6-Cf1 lineage-zone and thus preserve the Tiffanian/Clarkforkian boundary. The local fauna from the La Barge area (= Buckman Hollow) of

the Green River Basin, Wyoming, is one of the few mammalian assemblages originally assigned to the Clarkforkian Mammal Age (Gazin 1942, 1956c). Among other occurrences, the presence of *P. cookei* in this local fauna suggests referral to Cf2. The final area that has yielded mammals definitely belonging to the *Plesiadapis cookei* Lineage-Zone (including the namesake) is in Bitter Creek, the Washakie Basin, Wyoming. The single site of Clarkforkian age from this area, the Big Multi Locality, has produced a large and diverse assemblage (Rose 1981a). All but one of the mammals from the site, a *Navajovius*-like microsypid, have been recovered from the type area for the Clarkforkian Mammal Age. However, two genera common in the type Clarkforkian assemblage, *Coryphodon* and *Haplomylus*, are absent from Big Multi. As noted above, both the Hoback Basin, Wyoming, and Plateau Valley, Colorado, have also produced Clarkforkian assemblages, but assignment to Cf2 or another zone is uncertain at present.

Occurrences for the taxa listed below are given in table 3.2.

First appearances: *Aletodon gunnelli*, *Esthonyx ancyllion*, *Franimys*, *Ignacius graybullensis*, *Microsyops*, *Niptomomys*, *Palaeonodon*, *Phenacolemur simonsi*, cf. *Plagioctenodon krausae*, *Plagiomene*, cf. *Pontifactor bestiola*, *Tinimomys*, *Uintacyon*, *Worlandia*.

Last appearances: *Chiromyoides*, *Esthonyx xenicus*, *Microcosmodon*, *Prochetodon*.

Index fossils: *Chiromyoides major*, *Plesiadapis cookei*.

Characteristic fossils: *Acritoparamys*(?), *Aletodon*, *Apatemys*, *Apatosciuravus*, *Apheliscus*, *Arctostylops*, *Barylambda*, *Carpolestes*, *Chriacus*(?), *Coryphodon*, *Cyriacotherium*, *Diacocherus*, *Didymictis*, *Dipsalodon*, *Dissacus*, *Ectocion*, *Ectoganus*, *Ectypodus*, *Esthonyx*, *Haplomylus*, *Ignacius*, *Labidolemur*, *Leipsanolestes*, cf. *Leptacodon packi*, *Neoliotomus*, *Oxyaena*, *Palaeoryctes*, *Palaeosinopa*, *Paramys*, *Parectypodus*, *Peradectes*, *Phenacodus*, *Phenacolemur*, *Planetetherium*(?), *Plesiadapis dubius*, *Probathyopsis*, *Prodiacodon*(?), *Protimnocyon*(?), *Thryptacodon*, *Viverravus*.

Taxa absent but known before and after Cf2: *Micromomys*.

### ***Phenacodus-Ectocion* Acme-Zone (Cf3)**

According to Rose (1981a), the beginning of the *Phenacodus-Ectocion* Acme-Zone occurs immediately following the last appearance of *Plesiadapis cookei*. This acme-zone can be "further recognized by the evolutionary first occurrence of *Esthonyx grangeri* and *Phenacolemur praecox* (which make their appearance during but not at

the beginning of the zone)" (ibid., p. 28). For the present, we do not offer a formal definition of this zone. The above comments, with the additional note that the end of this zone is marked by the appearance of the *Artiodactyla*, can be used to recognize the zone. Common taxa during this zone are *Ectocion*, *Phenacodus*, *Probathyopsis*, and *Didymictis*.

Outside of the Clark's Fork and Bighorn basins, no assemblages can be referred with certainty to the *Phenacodus-Ectocion* Acme-Zone. In addition to the sites of uncertain age noted in the discussions of the other two Clarkforkian zones, two sites from the Big Bend area of Texas may be referable to the Clarkforkian Mammal Age, with one possibly belonging to the Cf3 acme-zone. This site, Southwall, produced only two taxa, *Hyracotherium angustidens* and *Barylambda* sp. (Schiebout 1974). As Rose (1981a) indicates, the presence of *Hyracotherium* elsewhere suggests a Wasatchian age because this genus is not known from any definitely identified Clarkforkian site. In contrast, *Barylambda* is known from Tiffanian sites in the Bighorn and Clark's Fork basins in Wyoming, the Clarkforkian site of Buckman Hollow in Wyoming, and the latest Tiffanian or earliest Clarkforkian sites from Plateau Valley in Colorado (Gingerich and Childress 1983). It is also known from a Wasatchian site in Baja California (Flynn and Novacek 1984). Coupling these data with the observation that the first appearance of *Hyracotherium* is a better indicator of age than the last appearance of *Barylambda*, Southwall is likely to be Wasatchian in age.

Occurrences for the taxa listed below are given in table 3.2.

First appearances: *Esthonyx grangeri*, *Hyopsodus*, *Mimoperadectes*(?), *Phenacolemur praecox*.

Last appearances: *Arctostylops*, *Aletodon*, *Apheliscus nitidus*, *Carpolestes*, *Cyriacotherium*, *Diacocherus*, *Dipsalodon*(?), *Dissacus praenuntius*, *Esthonyx ancyllion*, *Haplomylus simpsoni*, *Palaeoryctes*, *Plesiadapis*.

Index fossils: *Palaeonictis peloria*(?) (but rare).

Characteristic fossils: *Acritoparamys*(?), *Apatemys*, *Apatosciuravus*, *Apheliscus*, *Barylambda*(?), *Chriacus*, *Coryphodon*, *Didymictis*, *Dissacus*, *Ectocion*, *Ectoganus*, *Ectypodus*, *Esthonyx*, *Ignacius*, *Leipsanolestes*, cf. *Leptacodon packi*, *Microsyops*, *Niptomomys*, *Oxyaena*, *Palaeonodon*, *Palaeosinopa*, *Paramys*, *Peradectes*, *Phenacodus*, *Phenacolemur*, *Plagiomene*, *Probathyopsis*, *Prodiacodon*(?), *Thryptacodon*, *Uintacyon*, *Viverravus*, *Worlandia*.

Taxa absent but known before and after Cf3: *Franimys*, *Labidolemur*, *Micromomys*, *Parectypodus*, cf. *Plagioctenodon krausae*, cf. *Pontifactor bestiola*, *Protimnocyon*, *Neoliotomus*, *Tinimomys*.

## INTERCONTINENTAL CORRELATIONS AND CONCLUSIONS

The North American mammalian succession of Puercan through Clarkforkian mammal ages is the best known such succession in the world. Other successions are either less complete or only now being fully examined. Here, we will briefly discuss and correlate the other age-equivalent faunas. A fuller global treatment and more complete comparison of mammalian paleofaunas is provided by Savage and Russell (1983).

### Europe

Correlation of North American faunas to European faunas not only involves the more specific comparisons of fossil mammals but also the more general determination of the Paleocene/Eocene boundary. This would also be the case for the Late Cretaceous/Paleocene boundary, but no earliest Paleocene mammalian faunas have been reported from Europe or elsewhere in the world. As discussed under the section dealing with the Lancian/Puercan boundary, the lack of any detailed correlations between continental and marine sections makes determination of the Upper Cretaceous/Paleocene boundary in continental sections speculative at best. The situation is improved for the Paleocene/Eocene boundary, but even this boundary has long been controversial. This is due, in part, to a paucity of detailed, well-correlated marine and continental biostratigraphic sections spanning the boundary and, in part, to ambiguity in the original definition of "Paleocene."

"Paleocene" was originally used chronostratigraphically by Schimper (1874), a paleobotanist, for floras from the *Sables de Bracheux* (Thanetian), *Travertins Anciens de Sézanne* (Thanetian), and *Lignites et Grès du Soissonais* (Sparnacian and Cuisian, respectively) in the Paris Basin (France). At the same time, he included the London Clay (Sparnacian/Cuisian) and its fossil floras in the Eocene Series. In other words, French Sparnacian and Cuisian beds were included in the Paleocene, whereas their English equivalents were included in the Eocene Series. This contradiction in usage is the source of much ambiguity in placement of the Paleocene/Eocene boundary, making a redefinition desirable (Pomeroy 1969; Schorn 1971; Gingerich 1975b).

Paleobotanists sometimes place the Paleocene/Eocene boundary at the top of the Paris Basin Cuisian Stage or Substage (top of Planktonic Foraminiferal Zone P9) or between the Sparnacian and Cuisian (top of Zone P7). Invertebrate paleontologists sometimes place the

boundary between the Sparnacian and Cuisian stages (top of Zone P7), at the base of the Ypresian Stage (base of Zone P6b; Berggren 1972), or at the base of the London Clay (base of Zone P6a; Curry et al. 1978). Vertebrate paleontologists generally place the Paleocene/Eocene boundary at the base of the Sparnacian Stage in the Paris Basin (base of Planktonic Foraminiferal Zone P5; D. E. Russell 1967, 1968), reflecting the profound change from a mammalian fauna dominated by archaic multituberculates, plesiadapiform primates, and condylarths to one dominated by modern orders (e.g., Rodentia, Perissodactyla, Artiodactyla).

Added to this complexity of definitions of the Paleocene/Eocene boundary in Europe is the problem of correlating North American mammal ages to the type areas in Europe. Some authors have argued that the Paleocene/Eocene boundary falls at the base of what we call the *Plesiadapis cookei* Lineage-Zone (Cf2) (Gingerich 1976; Gingerich and Rose 1977; Rose 1981a). This is based largely on what are thought to be parallel lineages of *Plesiadapis* in the Bighorn and Paris basins. Rose (1981a) noted "that the early Clarkforkian (*P. gingerichi* Zone) correlates most closely with the upper *P. tricuspis* Zone (latest Thanetian, late Paleocene), whereas the middle Clarkforkian (*P. cookei* Zone) correlates most closely with the *P. russelli* Zone (early Sparnacian = early Ypresian, early Eocene)." He also indicated that this correlation suggests that rodents, *Esthonyx*, and *Coryphodon* reached Europe after their first appearance in North America (which occurs at the beginning of the Clarkforkian Mammal Age). Similarly, *Hyracotherium* may occur slightly earlier in Europe than in the Western Interior of North America. He argued that earlier reports (Jepsen and Woodburne 1969) of pre-Wasatchian *Hyracotherium* in the Clark's Fork Basin are very doubtful; a fauna from Baja California containing *Hyracotherium* that was first thought to be Paleocene in age now seems to be Wasatchian (Flynn and Novacek 1984) in age. This leaves the Southwall Locality from Texas (Schiebout 1974) as the only possible pre-Wasatchian locality bearing *Hyracotherium*, although a Wasatchian age seems likeliest.

More recently, Wing (1984) has argued that the Paleocene/Eocene boundary falls within the lower part of the Wasatchian Mammal Age rather than within the Clarkforkian Mammal Age as advocated by Rose and Gingerich. This is based on the presumed first appearance of the Eocene index pollen species, *Platycarya platycaryoides*, in sediments bearing Wasatchian mammals. *P. platycaryoides* first occurs at or near the boundary of the standard nannofossil zones 9 and 10 in marine sections from Alabama, California, South Caro-

lina, and Virginia (Wing 1984). This same boundary is also the generally accepted Paleocene/Eocene boundary in marine sections. Based on his work on pantodonts, Lucas drew similar conclusions to those of Wing and argued that the Paleocene/Eocene boundary falls within the Wasatchian Mammal Age (S. Lucas, unpublished data and pers. comm. to JDA 1984).

Although redefinition and correlation of the Paleocene/Eocene boundary is certainly important, it is beyond the scope and intent of this chapter. Briefly, the position taken by Wing is defensible based on our greater ability to correlate pollen and marine nanofossils on an intercontinental scale. For now, however, we have questionably retained the Paleocene/Eocene boundary at the boundary of the Cf1 and Cf2 lineage-zones (indicated in fig. 3.2 by a dotted line). Of more concern here is the intercontinental correlation of mammalian faunas at the level of the mammal age, or, if possible, even zonal level, and the way in which our discussions of the Paleocene/Eocene boundary affect such correlations. There are, however, two older Paleocene local faunas in Europe which are not affected by the controversies surrounding the placement of the Paleocene/Eocene boundary.

The oldest European Paleocene mammalian fauna is the Hainin Local Fauna from the type area of the Montian Stage (or substage of the Danian Stage) in Belgium (Russell et al. 1982). This local fauna includes endemic taxa mixed with North American forms which suggest affinity with the Torrejonian Mammal Age (Vianey-Liaud 1979, Savage and Russell 1983). The second-oldest assemblage appears to be the Walbeck Local Fauna of central Germany. Based solely on stage of evolution, this fissure-fill assemblage appears to be late middle Paleocene (Russell et al. 1982). It could be the temporal equivalent of the early Tiffanian Mammal Age and correlate with the earliest Thanetian marine deposits (Savage and Russell 1983).

Disagreements over age assignments and correlation become evident with the next group of local faunas. These are grouped as the Cernaysian localities by Russell et al. (1982) and include about ten localities, mostly in the Paris Basin of northern France (Savage and Russell 1983). They have not yielded any of the larger herbivores such as pantodonts or uinatheres known from presumably comparable faunas in North America or Asia. As discussed above, Rose (1981a; Gingerich 1976; Gingerich and Rose 1977) uses lineages of plesiadapids in North America and Europe to argue that the Ti6-Cf1 lineage-zone is a temporal equivalent of at least the younger Cernaysian faunas, which thus, according to these arguments, correlate with the Tiffanian/Clarkfork-

ian boundary. The Cernaysian faunas correlate to the later part of the Thanetian Age; accordingly, they, and at least the Ti6-Cf1 lineage-zone, would represent the latest Paleocene faunas in Europe and North America, respectively. Wing's (1984) correlation (following Costa et al. 1978) would suggest that the Cernaysian faunas are somewhat older and would correlate with later Tiffanian, rather than earlier Clarkforkian, faunas. As noted above, his correlation places the Paleocene/Eocene boundary within the Wasatchian Mammal Age, considerably later than the above faunas. As was also noted above, Lucas similarly places the epochal boundary within the Wasatchian Mammal Age. However, he considers the Cernaysian faunas to be younger than Wing, Rose, or Gingerich do, suggesting they correlate with the Cf2 lineage-zone.

## Asia

Paleocene mammals have been discovered in both China and Mongolia. Because of the quickened pace of recovery of Paleocene mammals from China, suggested correlations are tentative. Faunal equivalents of the Puercan Mammal Age have not been documented at this time.

The multituberculate *Buginbaatar transaltaiensis* from the Buginstav Basin of Mongolia is believed to be earlier Paleocene in age (Trofimov 1975, Savage and Russell 1983). Considerably more material has been recovered from China. Li and Ting (1983) record nine different major collecting areas for the Paleocene Epoch. Of these, three basins (Nan-xiong, Chi-jiang, and Qian-shan) have produced early to late Paleocene faunas that Li and Ting correlate to the "Dragonian" (= To1 interval-zone) through Tiffanian mammal ages of North America. Another basin (Tan-tou) is noted as having early to late Paleocene faunas, but reference to North American mammal ages are not given. The Cha-ling Basin is said to have produced early through middle Paleocene faunas and is correlated to the Torrejonian Mammal Age by Li and Ting. Localities from the Xuan-cheng and Turpan basins and the Nao-mu-gen-area have yielded faunas of late Paleocene age which they correlate with the Tiffanian Mammal Age. Finally, the Shi-men Basin has produced a few mammals that they simply refer to the Paleocene. Except for those faunas from the Turpan Basin, which is in northwestern China, all of the faunas come from eastern China.

Clearly, China has already proven to have faunal sequences that may soon rival those in North America. Some interesting faunal patterns are already appearing between North America and China, such as the greater abundance of pantodonts and anagalidans in China com-

pared to North America. This suggests a considerable degree of endemism, or at least faunal separation of the two areas. At the same time, there are supposed notoungulates and edentates in China, suggesting a faunal tie to South America, presumably via North America (see Savage and Russell 1983).

A last fauna to note is the Gashato Fauna from Mongolia. Savage and Russell indicate that similarities of the Gashato Fauna to the early Eocene fauna from the Naran Bulak Formation, also in Mongolia, have been used to suggest that these two are contemporaneous (Dashzeveg and McKenna 1977, Rose 1980). They imply that a later Paleocene age for the Gashato Fauna is also possible because, unlike the fauna from the Naran Bulak Formation, it lacks *Hyopsodus*, a tapiroid, *Altanius* (an omomyid primate), *Pachyaena*, *Coryphodon*, and a hyaenodontid. More recently, D. E. Russell (pers. comm. to JDA 1985) has further clarified the situation for Naran Bulak. He reports that there are two faunal levels at Naran Bulak: one "is essentially the same as that of Gashato, and overlying it is a Holarctic early Eocene fauna." Thus, both Gashato and a lower fauna of Naran Bulak could be late Paleocene.

## Africa

A fauna from the Ouarzazte Basin, Morocco, constitutes the only suggested Paleocene fauna from Africa (Cappetta et al. 1978). It includes palaeoryctids, creodonts, and possible carnivores and is associated with chondrichthyan and osteichthyan fishes and reptiles. On the basis of some of the chondrichthyans and invertebrates, the fauna appears to be Montian or earlier Paleocene in age (Savage and Russell 1983).

## South America

Within the Cenozoic Era, the earliest known faunas from South America are not earlier than late Paleocene in age. This is determined primarily by the superposition of the mammal-bearing Rio Chico Formation on the marine Salamanca Formation; the latter unit has been correlated with the Dano-Montian Stage of Europe based on foraminiferans (Loeblich and Tappan 1957, Savage and Russell 1983). The five or so faunas from the Rio Chico Formation occur in the southern part of Argentina near the Atlantic coast. The Itaboraí Fauna of Brazil, inland from Rio de Janeiro, can be approximately correlated with the Rio Chico faunas. Together, the Itaboraí and Rio Chico faunas include what is known of the Riochican Mammal Age, which is late Paleocene in age (Simpson 1940; Marshall et al. 1977; Savage and Russell 1983).

These fauna are notably endemic, with a variety of marsupials, edentates, native South American ungulates, and condylarths. One group of the native ungulates, the Notoungulata, has been reported from the Paleocene of China and North America, whereas the edentates have been reported from China. Only some of the condylarths suggest definite faunal ties to areas outside of South America.

## CONCLUSIONS

Since the publication of Wood et al. (1941) some forty years ago, our knowledge of North American land mammal ages has been greatly enhanced. This is particularly true for the Puercan through Clarkforkian mammal ages, which have helped to firmly entrench the concept of a Paleocene Series/Epoch in the paleontological and geologic literature. This does not mean we have anything approaching a firm biochronostratigraphic framework for the continental rocks deposited in western North America during this interval of time. The definitions and characterizations of the mammal ages and zones included in this chapter still rest heavily on faunal data, but the increased emphasis on tighter stratigraphic controls for these faunas suggests that a truly chronostratigraphic framework (stages) is not unrealistically far ahead. Such a suggestion for one of the mammal ages included in this chapter, the Clarkforkian Mammal Age, has already appeared (Rose 1981).

Clearly, if one is to suggest an agenda for future progress in further refining the Puercan through Clarkforkian mammal ages, the development of a chronostratigraphic framework would head this list. This will require even more detailed biostratigraphic and stratigraphic fieldwork coupled with continued emphasis on systematic work and faunal correlation. More specifically and more immediately, there are a number of aspects of these particular mammal ages and zones that require attention. Rather than list all of them, we note only a few in approximate geochronologic order, oldest to youngest.

First, there is the need for a thorough, systematic review of many Puercan taxa, especially among the condylarths, such as arctocyonids. A more thorough, more detailed review of most families of condylarths will be of benefit for the later mammal ages discussed in this chapter. Other Puercan mammals, for example, the taeniolabidids, are now being reexamined in the light of new discoveries so that the systematics of such biostratigraphically important groups will be more fully understood.

Second, the Puercan/Torrejonian boundary represents a gap in our knowledge of the mammalian faunas.

Sediments yielding mammals of Torrejonian age definitely overlie (or can be closely correlated to) sediments yielding mammals of Puercan age both in the San Juan Basin and on the Wasatch Plateau. The sediments between those yielding Puercan and Torrejonian faunas in both areas, however, are largely unfossiliferous. Another area with possible superposition of Torrejonian over Puercan faunas in the type area of the Hell Creek Formation, Montana, warrants further study.

Third, neither the Torrejonian/Tiffanian boundary nor the Ti1/Ti2 boundary are well understood at the present time. As discussed earlier, a probable superpositional relationship of Tiffanian over Torrejonian faunas exists in the Clark's Fork-Bighorn Basin, Wyoming. A similar but stratigraphically less tightly controlled situation occurs in the Crazy Mountain Basin, Montana. One difficulty in placing the Torrejonian/Tiffanian boundary is attributable to the differences between northern and southern Torrejonian faunas (e.g., the lack of plesiadapids in southern Torrejonian faunas).

Fourth, although faunas are now known bracketing the Tiffanian/Clarkforkian boundary, particularly in the Clark's Fork Basin, the latest Tiffanian faunas remain to be more fully documented. This may lead to a fuller characterization of the *Plesiadapis gingerichi*/Rodentia Interval-Subzone (Ti6), which for the present can only be definitely recognized by the appearance of the name-bearing taxon. Similarly, within the Clarkforkian Mammal Age, it would be desirable to modify or recast the *Phenacodus-Ectocion* Acme-Zone (Cf3) as a lineage-zone or, preferably, as an interval-zone to enhance its utility in faunal correlation, provided that taxa appropriate for this purpose can be found.

Fifth, and finally, there is the need to expand the magnetostratigraphic framework so as to encompass more of the mammal-producing sections, which, in turn, will provide additional checks on faunal correlation throughout the Western Interior of North America. Where possible, radiometric dates should also be obtained in association with mammal-bearing sediments to provide better calibration points outside of the Western Interior.

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