Vertebrate Paleontology of the Cretaceous/Tertiary Transition of Big Bend National Park, Texas (Lancian, Puercan, Mammalia, Dinosauria, Paleomagnetism).

Barbara R. Standhardt
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VERTEBRATE PALEONTOLOGY
OF THE CRETACEOUS/TERTIARY TRANSITION
OF BIG BEND NATIONAL PARK, TEXAS

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
in
The Department of Geology

by
Barbara R. Standhardt
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August 1986
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ABSTRACT

Screen washing of material from new and previously known fossil localities in Late Cretaceous/early Tertiary deposits in Big Bend National Park, Texas resulted in establishing the presence of sediments of early Paleocene (Puercan) age in the upper Javelina Member of the Tornillo Formation. Deposition of the Tornillo Formation was probably continuous across the Cretaceous/Tertiary boundary. Preliminary paleomagnetic zonation indicates that the highest occurrence of dinosaurs at Big Bend is in a reversed interval. At least part of the early mafic stage of Laramide magmatism in the Big Bend area was post-early Paleocene in age. A new Maastrichtian locality in the upper Aguja Formation yielded a diverse fauna including the first ankylosaurid dinosaur and the first Cretaceous mammals known from Big Bend. A new genus of cimolomyid multituberculate was recovered from this locality. Four localities in the upper Javelina Member of the Tornillo Formation that contain Puercan mammals are described. Puercan faunas include a new ray, the earliest known scolecophidian snake, a new genus of mioclaenid condylarth, and new species of Ptilodus, Stygimys, Viridomys, and Protictis. A new multituberculate family is defined. Mixodectes malaris and Palaechthon nacimenti are present in deposits of late Puercan age at Big Bend. A new ray was found at localities of Tiffanian age. Re-examination of fossils from TMM locality 40147 in the lower Black Peaks Member of the Tornillo Formation shows that the locality is Torrejonian in age. TMM locality 41274 is early Tiffanian in age.
INTRODUCTION

PURPOSE

The object of this study was to critically analyze the sequence of vertebrate faunas present in Big Bend National Park at the time of the Cretaceous/Tertiary transition. New Late Cretaceous and early Paleocene fossil sites were located, and some previously known localities were recollected. The fossils were identified, the faunas were studied, and the ages of the sites were determined. In addition, the enclosing sediment sequences were studied to determine the presence or absence of disconformities. A tentative paleomagnetic section was derived by sampling a section extending through the Cretaceous/Tertiary interval. Biostratigraphy and paleomagnetic stratigraphy were combined to more precisely locate the Cretaceous/Tertiary boundary in the Park. Improved dating of sediments of Late Cretaceous/early Tertiary age resulted in information regarding the timing of the initiation of local magmatism associated with the Laramide orogeny.

LOCATION

Big Bend National Park is located in the southern portion of Brewster County, in the Trans-Pecos region of southwestern Texas (Fig. 1). The Park is bounded on the south by the Rio Grande, which forms the local border between the United States and the adjoining Mexican states of Chihuahua and Coahuila.
Figure 1. Geographic location of Big Bend National Park.

PREVIOUS WORK

Since the late nineteenth century, the Big Bend area has been a focus of attention by geologists. Von Streeruwitz (1892), in a report on the geology of Trans-Pecos Texas, indicated the presence of rocks of Cretaceous age. A topographic atlas followed (Hill, R.T., 1900). Recognition of the Late Cretaceous age of these sediments was first made by B. F. Hill (in Vaughn, 1900), and in 1904 a geologic map of West Texas was produced (Hill, B. F., and Udden).

Throughout the twentieth century, additional increasingly detailed studies have been made. Udden (1907) reported on the geology of the
Chisos region and introduced local stratigraphic nomenclature. Baker and Bowman (1917) described structural features of the Santiago and Sierra del Carmen ranges; Baker (1928, 1930a, 1930b, 1935) made several additional reports on tectonics of the region. A volume on the geology of Texas produced by the University of Texas in 1933 included contributions by Sellards on Pre-Paleozoic and Paleozoic systems, Adkins on Mesozoic systems, and Plummer on Cenozoic systems, each of which discussed Big Bend features. Reports on quicksilver deposits were made by B. F. Hill (1902), Schuett (1930), Ross (1935), and Yates and Thompson (1959). Additional structural studies include those by Poth (1979) on the northern portion of the Park, and DeCamp (1981) on Mesa de Anguila. The Christmas and Rosillos mountains were treated by Bloomer (1949), and J. B. Stevens (1969) dealt with the geology of the Castolon area. Ogley (1978) and Henry and Price (1984) studied calderas of the Chisos Mountains.

Sedimentological studies have been made of several rock units found in Big Bend National Park. Hopkins (1965) treated the Aguja Formation, Miller (1978) the Javelina Formation, and Schiebout (1970) the Black Peaks Formation. Schiebout's students continued with sedimentological analysis of the Hannold Hill Formation (Hartnell, 1980), the Black Peaks Formation (Rapp, 1982), and the Canoe Formation (Rigsby, 1982). Geomorphology of regional features has been discussed by Jenkins (1958) and Belcher (1975).

Authorization for the establishment of Big Bend National Park was made in 1935, and it was actually begun in 1944 (Maxwell, et al., 1967). This provided the impetus for the production of numerous guidebooks for visitors to the area. The West Texas Geological
Society sponsored several publications of this type (King et al., 1941; Maxwell et al., 1949; Jones et al., 1952; Lonsdale et al., 1955; Maxwell and Dietrich, 1965 and 1972). Additional general guides were published by the Bureau of Economic Geology of the University of Texas (Maxwell, 1968, 1969, 1971, and 1979). The New Mexico Geological Society also produced a guidebook to the Trans-Pecos region that included several articles dealing with features of Big Bend (Dickerson, 1980; Cobb and Poth, 1980; Muehlberger, 1980; Wilson, 1980). The most complete compilation of geologic information was that of Maxwell et al. (1967), which was the culmination of many years of work by the authors, who were intimately involved with the study of the geology of the Park since its early years.

Advancing study has lead to increased precision in dating rocks found in Big Bend. Studies may be divided into two basic types: those using physical characteristics of the rocks, and those using the fossils included within the rocks. The first category includes studies utilizing radiochemical dating (Maxwell et al., 1967; Daily, 1979; Gilliland and Clark, 1979; McDowell, 1979; Wilson, 1980; Henry and McDowell, 1982; Stevens et al., 1984). Paleomagnetic studies have been made of some volcanic rocks (Martinez et al., 1960) and sedimentary rocks of the Black Peaks Formation (Rapp, 1982; Rapp et al., 1983). A paleomagnetic study of the Tornillo Formation, in which the author is participating, is currently underway.

Paleontological dating of the sediments of Big Bend includes studies of both invertebrate and vertebrate fossils. Eley (1936) treated invertebrates in general, while Johnson (1944) described algal
reefs of the Terlingua district and Huffman (1960) and Bostik (1960) dealt with micropaleontology.

The study of vertebrate fossils of Big Bend National Park began with Udden, who collected numerous dinosaur remains from the Aguja Formation. These specimens were identified by Williston (in Udden, 1907). Dinosaurs remained the main fossil attraction for many years, and a museum was established in the Park for display of specimens (Maxwell, 1940). This museum was later destroyed by fire (Davies, 1983). Fossil-collecting expeditions were conducted by Maxwell in 1936 (Davies, 1983), and William Strain of the Texas College of Mines and Metallurgy (which later became Texas Western College, then the University of Texas at El Paso) in 1938 and 1939 (Maxwell et al., 1967). These expeditions concentrated on fossils from the Aguja Formation. William McAnulty of the University of Oklahoma visited Big Bend in 1938 with a field party that included D. E. Savage and Wann Langston, Jr. (Stovall, 1948; Maxwell et al., 1967). Other dinosaur-collecting parties were conducted by the American Museum in 1939 (Brown, 1941a) and Sinclair Oil and Refining Co. in 1940 (Brown, 1941b). Discoveries made by these expeditions included a giant crocodile (Colbert and Bird, 1954) and a nodosaur (Coombs, 1978). Davies (1983) has compiled an excellent detailed account of these early collections. Later studies of fossil reptiles from Big Bend were described by Lawson (1972, 1975, 1976) on dinosaurs and pterosaurs of the Tornillo Formation, Lehman (1982) on ceratopsians from the Aguja Formation, and Davies (1983) on hadrosaurs. Langston (pers. comm., 1985) has conducted studies of Big Bend fossil reptiles since his initial involvement in 1938.
Mammalian fossils were first discovered at Big Bend by J. A. Wilson in 1950 (Wilson, 1971). Since that time, Wilson and his students have discovered numerous mammalian fossil localities in the area. The Miocene Castolon local fauna of the Delaho Formation was described by Stevens et al. (1969) and Stevens (1977). J. A. Schiebout described Paleocene faunas from the Black Peaks Formation (1973, 1974), and her student Jill Hartnell (1980) reported Eocene mammals from the Hannold Hill Formation. Wilson and Schiebout have since detailed occurrences of brontotheres (Wilson, 1977) and perissodactyls (Wilson and Schiebout, 1984) from Big Bend. Lawson (1972) discovered mammalian fossils in the upper Javelina Formation, which he considered to be Paleocene in age.

Information garnered from paleontological research at Big Bend has been incorporated in reports on paleoecology (Lawson, 1972; Schiebout, 1973 and 1974; Davies, 1983), paleopedology (Schiebout, 1979), and biostratigraphy (Udden, 1907; Wilson, 1965; Maxwell et al., 1967; Maxwell and Dietrich, 1970; Wilson, 1971 and 1980). When combined with dating derived from techniques such as radiochemical dating (Wilson, 1980) and paleomagnetic studies (Rapp et al., 1983), paleontological studies can provide increased accuracy and precision in deciphering the geologic history of the region.

TECHNIQUES OF STUDY

Initial effort in this study was devoted to locating new fossil sites in rocks of Late Cretaceous and Paleocene age. Prospecting involved a walking survey of as many exposures of the Aguja Formation and the Javelina and lower Black Peaks members of the Tornillo Formation
as possible during the time available. Field work was conducted by the author and various field crews in March, April, and June of 1983, and in April, May, and October of 1984. A total of nine weeks was spent in the field.

When likely sites for recovery of mammalian fossils were found (indicated on the surface by gar scales or scraps of turtle shell and other fossil bone), the surface was scanned closely to recover any fossils visible. Material was then excavated and loaded in burlap or woven plastic bags to be transported either back to base camp or to Louisiana State University in Baton Rouge for screen washing. As no off-the-road vehicle travel is permitted in the Park, only small amounts were recovered from some localities. Larger amounts were collected from the more promising sites to be transported later by helicopter. In this way a total of approximately 16 tons was recovered for processing.

Screen washing was done in several ways. Initially, a shovel full of material was soaked in a bucket of water. The material was then placed in a screen box with supporting hardware cloth and #20-mesh screen wire. This was placed in a washtub full of water and gently moved up and down until most of the clay particles had disaggregated and passed out of the screen box. Any visible fossil material was removed while washing in order to prevent further breakage. The remaining material was dried on black plastic and bagged for transport back to the lab. Washing during the summer of 1983 was done in washtubs at the Castolon ranger residence. In 1984, washing was done in the Rio Grande at the Gravel Pit campsite southwest of Boquillas.
In the laboratory, the dried fossiliferous concentrate was picked through under microscopes by the author, volunteers, and student workers. All fossils were separated from the matrix and examined to recover identifiable remains. These were then studied in detail using a Wild M7S microscope. Broken teeth could often be reassembled. Selected fossils were drawn by the author using a camera lucida. Measurements were made with either a Leitz microscope reticule or a Fowler Max-Cal electronic digital caliper reading to the nearest 0.01 mm. The fossils recovered were compared with fossils or casts of fossils from a variety of localities and institutions, specimens of recent vertebrates, or, when these were unavailable, with published illustrations and descriptions. Recovered populations were inadequate for statistical analysis.

In addition to fossil collection, localities were mapped and placed within measured stratigraphic sections where possible. The Dawson Creek and eastern Tornillo Flat sections were studied in detail, and paleomagnetic samples were collected by Bruce MacFadden and Jorge Arellano. Some localities will require more detailed study for proper placement in a section, as they are in areas that are structurally complex, or are in isolated outcrops. Sections were measured by Brunton compass or hand level.
A zone of Laramide tectonism extending from the United States southeastward into Mexico (Fig. 2), and including the Big Bend National Park area, is known as the Sierra Madre Oriental (Enos, 1983). This includes the Chihuahua Tectonic Belt, an area also known as the Chihuahua Trough. The Rim Rock Fault, to the northwest of Big Bend, and the Diablo Plateau represent the northeastern boundary of this trough (Reaser and Underwood, 1980; Muehlberger, 1980). An eastern salient of the Sierra Madre Oriental is called the Coahuila Marginal Folded Belt; it merges with the Coahuila Platform, an area southeast of Big Bend that was positive relative to eastern and western basins at times during the Cretaceous (Enos, 1980).

Several Cretaceous and early Tertiary depositional basins are located in the region. The late Early Cretaceous (pre-Laramide) Bisbee Basin of Arizona and Sonora is situated at the northwestern margin of the Chihuahua Trough (Bilodeau and Lindberg, 1983, p. 173), about 600 kilometers northwest of Big Bend. The Ojinaga Basin is the nearest to Big Bend; it lies only 100 kilometers to the west and northwest. This basin lies on the eastern margin of the Chihuahua Trough; during the Early Cretaceous it received fluviatile deposits from elevated areas to the east (Campbell, 1980), while in the Late Cretaceous, deposits ranging in age from Cenomanian to Campanian and possibly Maastrichtian were received from the west and northwest (DeFord and Haenggi, 1971; Weidie et al., 1972).
Figure 2. Regional geologic features.
About 200 kilometers southeast of Big Bend lies the Sabinas Basin on the eastern margin of the Coahuila Platform. This area underwent a regression from Campanian to Maastrichtian time (Weidie, et al., 1972). Red beds of this age are also located in southeastern Chihuahua and western Coahuila in the Soledad-Jimenez-Santa Elena area (Weidie, et al., 1972), about 120 kilometers from Big Bend. The Parras Basin of southern Coahuila and the La Popa Basin of Nuevo Leon, about 400 kilometers south of Big Bend, contain thick deposits of Late Cretaceous sediments derived from the southern Coahuila Platform area and from the Sierra Madre Oriental to the west and southwest (McBride et al., 1975).

The Big Bend area is also considered a basin (Wilson, 1980, p. 208). Late Cretaceous and early Tertiary sediments were derived from the west as the Late Cretaceous sea regressed; the area is thus genetically linked to the Ojinaga and Sabinas basins, as well as to the Soledad-Jimenez-Santa Elena deposits.

The San Juan Basin of northwestern New Mexico, an important source of Late Cretaceous and early Tertiary vertebrate fossils, lies about 850 kilometers from Big Bend. It is separated from the northwestern extension of the Chihuahua Trough by an elevated area of southeastern Arizona and southwestern New Mexico known as the Mogollon Rim.

Uplifts in the Big Bend region include the Diablo Plateau of West Texas and the Serranias del Burro-Salado Arch, in Coahuila east of Big Bend. The Marathon dome is about 100 kilometers north of Big Bend. Deformed Paleozoic rocks exposed here record the convergence of the North American continent with South America during the formation of
Pangaea (Pindell and Dewey, 1982). The Devil's River uplift, about 200 kilometers east of Big Bend, is a shear zone offsetting the Marathon tectonic system from the Ouachita Tectonic Belt, which passes south and east of the central Texas Llano uplift, in which Precambrian basement is exposed (Pindell, 1985). Between the Devil's River and Llano uplifts lies the Edwards Plateau, which is set off from the Gulf Coastal Plain by the Balcones Escarpment. Late Cretaceous (Gulfian) coastal plain deposits outcrop in a continuous band across Texas, along the line of the Ouachita tectonic belt, and south into Mexico (Pessagno, 1969, Pl. 1), making a westward curve or embayment at the Rio Grande.

The northern portion of the Rio Grande passes through the Rio Grande Rift of Neogene age; east-west lineations possibly indicative of rifting are also present in Trans-Pecos Texas (Dickerson, 1980). Extending from the El Paso area through Trans-Pecos Texas into Mexico is an 80-kilometer-wide zone of west-northwest trending linear features termed the Texas Lineament (Albritton and Smith, 1957; Muehlberger, 1980). This zone of wrench faulting, which includes the Big Bend area, may indicate a fundamental crustal discontinuity (Muehlberger, 1980, p. 113).

LOCAL GEOLOGIC FEATURES

The Big Bend region presently displays a wide variety of geologic features reflecting a complex history (Fig. 3). The major portion of Big Bend National Park is situated within a graben about 60 kilometers wide known as the Sunken Block (Udden, 1907; Maxwell et al., 1967). This graben, which is elongate in a northwest-southeast direction,
Figure 3. Local geologic features.
preserves sediments ranging in age from lower Late Cretaceous to Recent.

The structural low is bounded on both sides by spectacular escarpments. To the east are the Santiago and Sierra del Carmen ranges, which are continued to the southeast by the Sierra Fronteriza in Mexico. A series of faults, mostly normal but with some thrusting (Cobb and Poth, 1980; Muehlberger, 1980), spans the eastern uplifted zone. On the west, the graben is also bounded by predominantly normal faults, including the major Terlingua Fault, which steps upward to the Sierra Ponce in Mexico and the Mesa de Anguila in the United States. The Terlingua Fault passes northwestward into the Terlingua Arch. Both eastern and western escarpments expose thick deposits of Early Cretaceous rocks, mostly limestones of Albian age (Maxwell et al., 1967). In addition, the Persimmon Gap area on the northeastern boundary of the Park (not shown in Fig. 3) includes exposures of Paleozoic rocks in a reverse-faulted monocline of the Santiago Mountains (Cobb and Poth, 1980). Paleozoic rocks are also exposed in the Solitario, a dome north of the Terlingua Arch.

Within the down-dropped area of the graben, local uplifts due to folding, faulting, and igneous activity are present. The largest of these is the Chisos Mountains igneous center, which is composed of both intrusive and extrusive rocks of Eocene and Oligocene age (Maxwell et al., 1967, p. 171). The Chisos Mountains include two calderas, the Pine Canyon Caldera and the Sierra Quemada Caldera (Henry and Price, 1984). The Chisos form a central uplift surrounded by exposures of Late Cretaceous and early Tertiary deposits (Fig. 4). These sediments, of particular interest in this report, are predominantly soft marine
Figure 4. Outcrop of Late Cretaceous/early Tertiary sediments in Big Bend National Park. Adapted from Maxwell et al. (1967), Lawson (1972), Schiebout (1974), Rigsby (1982), and Davies (1983).
and terrestrial deposits recording a Late Cretaceous regression followed by Late Cretaceous and early Tertiary basin fill. Younger Tertiary and Quaternary alluvial deposits are also present. A small remnant of Late Cretaceous sediment uplifted by the Chisos tectonism is preserved within the Chisos Basin, surrounded by igneous intrusive rocks (Maxwell, et al., 1967, p. 85). Smaller intrusions such as the Grapevine Hills and Glenn Springs laccoliths are scattered within the graben region, and outcrops of Tertiary volcanics (tuffs, basalts, rhyolites) blanket extensive areas. The Christmas Mountains, northwest of the Chisos, form an additional, inferred volcanic center according to Stevens et al. (1984).

Many folds paralleling the general northwest-southeast direction of the graben are present within the Sunken Block. These include the Maverick anticline on the northwestern side of the Park, the Lone Mountain anticline northeast of the Chisos, and the San Vicente and Cow Heaven anticlines southeast of the Chisos. Between these latter two are the Mariscal Mountain and Sierra San Vicente uplifts, which are asymmetrically folded anticlines separated by the Solis Graben (Maxwell et al., 1967). Both ranges expose the Early Cretaceous rocks seen in the bounding escarpments of the Sunken Block. In addition, mafic sills intruded into Late Cretaceous rocks are included in the Mariscal Mountain faulted anticline (Maxwell et al., 1967).

Faults within the graben are also predominantly oriented northwest-southeast. Major faults include the Burro Mesa fault, which has down-dropped Tertiary volcanics northwest of the Chisos, the Cow Heaven fault along the eastern margin of the Cow Heaven anticline, and the Chalk Draw fault (not shown in Fig. 3), which runs northwestward from
the Rosillos Mountains intrusion just north of the Park to a point south of Santiago Peak, where it turns westward.

The Big Bend region is traversed by the Rio Grande, which has cut deep canyons through the escarpments bounding the graben and through the Mariscal Mountain anticline. Its course within the graben area is only partially influenced by structure. After leaving Santa Elena Canyon on the west, it is aligned generally along the direction of the Terlingua Fault on the down-dropped side (Maxwell et al., 1967, p. 22), and then meanders across an area of soft sediments in the southwestern corner of the Park until it reaches Mariscal Mountain, where it cuts across the fold and makes the turn to the northeast that gives the Big Bend area its name. The river rounds the northwestern corner of Sierra San Vicente, and then meanders on to cut through the eastern escarpment at Boquillas Canyon.

Intermittent streams with courses paralleling the general orientation of the graben include Long Draw and the portion of Terlingua Creek north of the Park, Tornillo Creek south of the Black Peaks, and Glenn and Juniper draws southeast of the Chisos. The latter two may exhibit radial drainage from the Chisos, as is apparently the case with Smoky and Alamo Creeks on the west and Estufa Canyon on the east.

GEOLeGIC HISTORY

Factors contributing to the present alignment of geologic features in a northwest-southeast direction may date back to the Precambrian. Sears and Price (1978) have hypothesized that the Siberian and North American cratons rifted apart about 1.5 billion years ago; Muehlberger (1980, p. 119) considered this a possible cause for the existing
structural grain. The Texas Lineament, in this view, marks the boundary between the North American craton on the north and accreted terrain on the south.

During the Late Paleozoic, convergence of North America with Africa and South America resulted in orogeny (locally, the Marathon uplift of late Pennsylvanian-early Permian age) and suture formation somewhere near the Big Bend area (Pindell and Dewey, 1982). Recent reconstructions of Pangaea place northern South America much closer to North America (Walper and Rowett, 1972) than was previously considered to be the case. Regional shearing stresses produced by compressive forces during convergence may have resulted in the formation of major wrench fault systems, e.g., the Texas Lineament-Texas Megashear (ibid., p. 111).

The breakup of Pangaea in the late Triassic and Jurassic resulted in a belt of rifting that closely followed the earlier line of suturing (Pindell and Dewey, 1982). While the actual disposition and direction of rifts are disputed (Pilger, 1981), it is generally agreed that the Rio Grande Embayment and the Chihuahua Trough resulted from rifting during the formation of the Gulf of Mexico (Walper, 1980, p.92; Bilodeau and Lindberg, 1983, p. 184). Rifting and subsequent inundation of retreating continental margins, combined with sea level changes (Vail, 1977), resulted in a regional sequence of sediments generally progressing from Triassic red beds (Schmidt-Effing, 1980) to Jurassic evaporites (Gries, 1980) and Cretaceous marine deposits. The Big Bend area preserves about 750 meters of Early Cretaceous marine sediments (Maxwell et al., 1967, p. 6). As North and South America gradually separated, left-lateral movement along several large
megashears in Mexico and Central America resulted in displacement of blocks of continental material to the southeast (Pindell and Dewey, 1982). This, combined with eastward movement and subduction of the Nicoya-Azuero Rise on the Farallon plate to form an island arc, resulted in a chain of elevated areas which could have served as a corridor or stepping stones for faunal interchange between North and South America during Late Cretaceous-early Tertiary time (Simpson, 1966; Rage, 1978; Schmidt-Effing, 1979; Gingerich, 1985).

During the Late Cretaceous, the western margin of North America was also affected by eastward subduction of the Farallon plate (Chadwick, 1985, and many others). These plate interactions resulted in the Late Cretaceous-early Tertiary Laramide orogeny, which caused volcanism and deformation in a wide belt extending from western Canada through Mexico. The Cretaceous epeiric sea regressed and terrestrial sediments were deposited along the eastern front of the orogenic belt. During this same period, sporadic volcanism from scattered centers around the margin of the Gulf of Mexico, possibly related to aulacogens, deposited volcanioclastic sediments in the region (Hunter and Davies, 1979). Thus, tuffs and bentonites in Big Bend Late Cretaceous and early Tertiary sediments (Maxwell et al., 1967, p. 300; Lawson, 1972, p. 47) may have had either eastern or western sources.

In the Big Bend area, several faults and folds are considered to be Laramide in origin (Maxwell et al., 1967; Muehlberger, 1980). Among these is the Mariscal anticline, which deforms a mafic sill intruded into Late Cretaceous sediments. The Mariscal Mountain sill has been dated using potassium-argon at 50-70 m.y.b.p. (Maxwell and Dietrich, 1970, p. 4); it is a member of a suite of mafic analcime-
bearing rocks of the region (Maxwell, et al., 1967, pp. 171, 172, 265). The sill is concordantly deformed within sediments of the Pen and Aguja formations, which it crosscuts at a low angle (stratigraphic dip is to the southwest). Maxwell et al. (1967, p. 300) felt that emplacement of this sill and other similar mafic intrusions probably took place in the Late Cretaceous, but at least part of the mafic intrusive activity was post-early Paleocene, as shown by the intrusion into upper Javelina sediments southeast of Dogie Mountain by an analcime-bearing mafic dike (#160, Maxwell et al., 1967, Pl. II). This dike passes 100 meters east of the early Paleocene Dogie fossil locality. The dike also does not parallel the axis of a syncline deforming these sediments, and may therefore be younger than the deformation.

Lawson (1972, p. 47) found a tuffaceous sandstone in the Tornillo Formation containing fresh glass shards, which could not have been transported a significant distance by water. This indicates a nearby source of volcanism. Schiebout (1970) and Rapp (1982) determined that during deposition of the mid-to-late Paleocene Black Peaks Member, volcanic detritus came from somewhat distant sources to the west. Laramide extrusives in southeastern Arizona have been dated ranging from 76 to 65 m.y.b.p. and younger (Hayes and Drewes, 1978; Marvin et al., 1978), somewhat earlier than in Trans-Pecos Texas. The stratigraphically lowest basalt in the western part of Big Bend National Park, the Alamo Creek Basalt, has been dated at 39 to 44 m.y.b.p. (Wilson, 1980, p. 209). This basalt as mapped by Maxwell et al. (1967, Pl. II) may possibly include unrecognized earlier flows; divergent paleomagnetic data are reported from part of the sample
studied by Martinez et al. (1960, in Maxwell et al., 1967, p. 116). The lowest basalt in the eastern part of the Park is a flow of limited extent within the Chisos Formation (sensu Rigsby, 1982); it has been recently dated by Daniel Krumenacher at 38 m.y.b.p. (pers. comm. to J. A. Schlebout, 1985).

Local volcanism was not definitely present until the middle Eocene and peaked in the Oligocene (Wilson, 1971, 1980). It involved two calderas in the Chisos area; the Sierra Quemada Caldera, which was the probable source of the Mule Ear Springs tuff about 34 m.y.b.p., and the Pine Canyon Caldera, which erupted volcaniclastics of the South Rim Formation at 33 m.y.b.p. (Henry and Price, 1984). Both calderas were part of a north-northwest trending eastern alkalic belt of igneous activity. This belt is paralleled by a similarly oriented western alkali-calcic belt of calderas in Chihuahua and western Trans-Pecos Texas (ibid., p. 8766). Magmatism of the Trans-Pecos region is viewed as the easternmost expression of an eastward sweep of magmatism that began near a subduction trench off western Mexico at least 100 m.y.b.p. (Coney and Reynolds, 1977).

During and following the termination of volcanism in the late Oligocene, erosion and deposition of sands and gravels took place. Initiation of Basin and Range extension in the Miocene, accompanied by rifting along the Rio Grande, led to reactivation of earlier faults with reversal of motion (Dickerson, 1980; Cobb and Poth, 1980), and development of the fault block mountains and bolsons of typical Basin and Range topography.

The Big Bend region is located at approximately 30° N. latitude; this position, combined with spatial separation from the Gulf of
Mexico, produces aridity. Desert vegetation predominates, and riparian habitats are limited to the valley of the Rio Grande. Higher, cooler elevations of the Chisos receive enough precipitation to foster a piñon-juniper woodland, and scattered springs provide limited water in lower elevations. Infrequent intense rains combine with sparse vegetation and relatively soft rocks to produce extensive badland outcrops of the Late Cretaceous-early Tertiary deposits.

STRATIGRAPHY

In the Big Bend area, the general regression of the Late Cretaceous sea to the east and southeast is recorded in the Pen, Aguja, and Tornillo formations. A generalized section is depicted in Figure 5. The earliest local non-marine sediments (lignites) are found in the lower Aguja Formation (Davies, 1983, p. 17).

Aguja Formation

Nomenclature.--This formation was named by Adkins (1933) after Sierra Aguja on the western edge of the Park, when Udden's (1907) original name for the deposits (Rattlesnake Beds) was found to be preoccupied. Maxwell et al. (1967, p. 79) considered the Aguja Formation to be disconformable over an erosional surface of the Pen Formation, but Hopkins (1965) interpreted the contact as gradational. Davies (1983, p. 17) also viewed the lower contact as gradational, with the base being the first sandstone over one meter thick at the top of the Pen Formation.

Lithology.--The Aguja Formation consists of up to 360 meters (Maxwell et al., 1967, p. 84) of mudstones and sandstones with some
Figure 5. Generalized Late Cretaceous/early Tertiary section in Big Bend National Park. Adapted from Maxwell et al. (1967), Schiebout (1974), Hartnell (1980), Rigsby (1982), and Davies (1983).
interbedded lignites and rare freshwater limestones, generally interpreted as having been deposited in a paralic environment by fluvially dominated deltaic processes (Davies, 1983, p. 21). The transition from marine to non-marine deposition takes place within the lower Aguja Formation, but because of variation in local delta construction and subsidence, higher marine incursions are recognized (Hopkins, 1965).

The deposits are irregularly interbedded, and of limited lateral extent; in rare instances, sandstone beds can be traced a few kilometers. The sandstones are drab ochres and greens. Occasional conglomerates are found, generally associated with thicker sand bodies; clasts include limestone, calcareous nodules, chert, clayballs, shell and bone fragments, and phosphatic coprolitic nodules. Sands are commonly cemented by calcite and hematite; gypsum and authigenic clays are also present, and jarosite has been observed.

Clays and silts are also drab, tending generally from darker gray-green, which weathers buff-yellow, in the basal part, to green and buff-yellow in the central portion, to varicolored purple, dark gray, and yellow in the upper part. Lignites are found most commonly in the central portion of the section, but occur throughout the lower part (Davies, 1983, p. 16). The Aguja Formation is very similar to the Lance and Hell Creek formations of Wyoming and Montana, as described by Carpenter (1982, p. 123). Reworking of sediments is common, and fossils exhibiting varied types of preservation may be found deposited together. It is therefore difficult to determine exactly the autochthonous faunal composition at any one level, but within
limits, it is probable that forms such as terrestrial mammals and freshwater rays lived in near proximity to each other.

The upper Aguja Formation is transitional with the lowermost Tornillo Formation; Maxwell et al. (1967, p. 81) placed the contact at the top of a sandstone above which the beds are predominantly varicolored bentonitic clay. This procedure has been followed by later workers (Lawson, 1972; Davies, 1983), and is used in the current study. It is noted that the Aguja-Tornillo contact is one of the few in the section that was considered conformable by Maxwell et al. (1967, p. 57).

Age.—The vertebrate fauna indicates a Judithian (late Campanian) age for the lower Aguja Formation. Davies (1983) reported Kritosaurus and a lambeosaurine hadrosaur at Big Bend. The vertebrate fauna from the newly discovered Running Lizard locality, which is in the upper Aguja Formation, indicates that the upper portion of the Aguja is Maastrichtian in age, as suggested by Lawson (1976).

Tornillo Formation

Nomenclature.—The Tornillo Formation (Tornillo Clays of Udden, 1907) was elevated to Group status by Maxwell et al. (1967, p. 88) and subdivided into the Javelina, Black Peaks, and Hannold Hill Formations, primarily on the basis of fossil vertebrates. Maxwell et al. (ibid.) did not include the Aguja Formation in their Tornillo Group, as was shown in their included Table 1 (ibid., p. 6).

With the discovery of Cenozoic mammalian fossils from the upper Tornillo Clays by J. A. Wilson (Wilson et al., 1952) it was recognized that the Tornillo Clays included deposits of both Cretaceous and
Tertiary age. Maxwell et al. (1967, pp. 88, 98, and 102) described lithologies of their Javelina, Black Peaks, and Hannold Hill Formations but stated (ibid., p. 97) that "... correlation would be difficult without the aid of vertebrate fossils." Lawson (1972) considered that the described lithologic distinctions were inaccurate, and this view has been borne out by later field work. Schiebout (1970, 1974), Hartnell (1980), Rapp (1982), and Rigsby (1982) have also commented on the difficulties of distinguishing these deposits in the field.

Nodules described by Maxwell et al. (1967, p. 88) as characteristic of the Javelina Formation are also frequently found in the Black Peaks deposits, contra Maxwell et al. (ibid., p. 98). Light gray and gray-white sandstones such as those described as being characteristic of the Black Peaks Formation (ibid.) are seen in the Javelina; e.g., east of Dogie Mountain and in exposures south of Dawson Creek. Lawson (1972, p. 10) found that except for the basal part of the Javelina member, which is intergradational with the Aguja Formation, sandstones of the Javelina Member are generally no darker than those of the Black Peaks Member. Significantly, vertebrate fossils definitely of Paleocene age have been found in deposits of typical Javelina appearance and mapped as Javelina (Maxwell, et al., Pl. II).

In a later publication (1976), Lawson used the term Tornillo Group; however, it is here considered a formation, and the Javelina, Black Peaks, and Hannold Hill deposits are included as members. The Big Yellow Sandstone, formerly considered to be the lowest member of the Canoe Formation (Maxwell et al., 1967, p. 107), is here placed in the Tornillo Formation as suggested by Rigsby (1982). The lithology of the Big Yellow is more similar to that of the Tornillo Formation,
and lacks the marked increase in volcanics associated with the higher Big Bend Park Group, according to Rigsby (1982). A revision of the formal stratigraphic nomenclature of the latest Cretaceous/early Tertiary portion of the Big Bend section is currently in progress (Schiebout et al., MS).

Lithology.—The Tornillo Formation is made up of interbedded mudstones and sandstones, with occasional conglomerates, dark carbonaceous layers, and rare freshwater limestones and tuffs (Lawson, 1972). In contrast to the Aguja Formation, sandstones are generally light gray to yellow brown, ranging from thin deposits of very limited lateral extent to thicker (up to 12 meters) deposits of greater extent (Lawson, 1972, p. 160). Sandstones range from lithic arkoses to feldspathic litharenites or feldspathic volcanic arenites (Schiebout, 1970; Rapp, 1982; Davies, 1983). Mudstones are varicolored, ranging from dark gray and purple to maroon, greenish gray, red, pink, and light gray. The clays are predominantly bentonitic with a high proportion of montmorillonite (Schiebout, 1970). An attempt was made in this study to determine whether the claystones are true bentonites by thin sectioning and searching for ghost shards, but to date it has not been possible to obtain adequate thin sections. Color banding of mudstones is prominent, and some color bands have been traced as much as 3 kilometers. Dark layers have been used for lateral correlation in the Black Peaks Member on western Tornillo Flat (Schiebout, 1973). Schiebout (1970) concluded that the prominent color banding resulted from soil-forming processes following deposition, and reflects variability of climate with alternating wet and dry periods of greater than seasonal duration.
The Tomillo Formation includes deposits laid down in a variety of sedimentary regimes, including streams, rivers, levees, swamps, lakes, and floodplains. Geometry is highly variable, and probably resulted from deposition in a laterally unrestricted, fine-grained, meandering river system (Davies, 1983). Clay balls are seen in most units. The noticeable color shift from drab browns, yellows, and purples of the upper Aguja Formation to the predominantly light grays, maroons, and reds of the Tomillo Formation is probably due to a change from reducing to oxidizing conditions within the sediments, reflecting a lowering of the level of the water table (Lawson, 1972).

**Age.**—The Tomillo Formation ranges in age from Maastrichtian (Late Cretaceous) to Bridgerian (middle Eocene). The Javelina Member contains Maastrichtian dinosaurs in the lower portion (Lawson, 1972; Davies, 1983) and early Paleocene (Puercan) mammals in the upper portion (this study). The lower portion of the Black Peaks Member is middle Paleocene (Torrejonian) in age (Wilson, 1967; this study), and the upper portion is late Paleocene (Tiffanian) in age (Schiebout, 1974). The Hannold Hill member contains faunas of early Eocene (Wasatchian) age (Hartnell, 1980). On the basis of sparse mammalian fossils, the Big Yellow Member is middle Eocene (Bridgerian) in age (Wilson and Schiebout, 1984).

**Topography.**—Previous workers (Schiebout, 1970; Rapp, 1982; Davies, 1983) have interpreted the relatively fine-grained sediments as being indicative of deposition on a broad alluvial plain of low relief, distant from tectonic activity. Rapp (1982, pp. 51-53) determined that during deposition of the Black Peaks Member of the Tomillo Formation, the major source rocks for sandstones were
silica-rich volcanics of a dissected magmatic arc. He also (ibid., p. 44) considered that the effect of tectonic uplift was probably not significant during deposition of the Black Peaks Member, because no drastic changes in stream type or lithology were found, and absence of pyroclasts in the Black Peaks Member indicated that volcanism was either not local or not contemporaneous (i.e., earlier).

Pyroclastic deposits (tuffs) are known from the upper Javelina Member (Lawson, 1972), and many mudstones of the deposits are bentonitic (Maxwell et al., 1967; Lawson, 1972; Davies, 1983). Lawson (1972) considered that some volcanism must have occurred relatively nearby to provide fresh shards found in a tuffaceous sandstone (exact stratigraphic level unstated) of the Tornillo Formation. During this study, volcanic rock fragments, very angular quartz fragments, water-clear euhedral, doubly-terminated quartz crystals with inclusions, and euhedral biotite, phlogopite, and muscovite micas were frequently noted in surveying sediment. At locality VL-109, fragments of pyroclastics such as vesicular basalt and rhyolite were frequently observed.

Coprolites from early Paleocene fossil localities in the Tornillo Formation commonly have an outer rind that includes shardlike fragments. This indicates that the original fecal material forming the coprolites was excreted upon or above a surface on which such fragments were exposed, much as a similar coating containing plant remains on coprolites found in the Whitemud Formation (Broughton et al., 1978, p. 451) suggested expulsion onto a surface strewn with plant debris. Fossils from the early Paleocene localities at Big Bend are also frequently opalized, an indication of high silica content either
in the enclosing sediments (mudstones) and/or in percolating groundwater. Chalcedony is also present at some localities.

Maxwell et al. (1967, p. 97) indicated a number of disconformities attributed to subaerial erosion due to tectonic pulsations (ibid., p. 299). One of their disconformities was a regional hiatus between the Late Cretaceous Javelina Formation and the mid-to-late Paleocene Black Peaks Formation. The Mariscal Mountain-Christmas Mountains arch was viewed (ibid., p. 301) as an early structural high that limited the Alamo Creek Basalt to the area to the west. The earliest Tertiary rocks (Black Peaks Member) were thought to have been deposited on an eroded surface between the deformed belt in the Santiago-Sierra del Carmen ranges in the east and the Mariscal-Christmas Mountain high on the west. My study shows, however, that older Tertiary rocks were deposited west of this arch. The arch or a similar one may well have been present, forming an elongate island or peninsula. Possible indirect evidence for this, at an earlier time, is provided by the dwarf fauna of pelecypods, gastropods, and ammonites found in the stratigraphically lower Pen Formation near Study Butte on the northwestern side of the Park (Maxwell et al., 1967, p. 77). The fauna includes Placenticeras sp. juv. cf. P. meeki (ibid., p. 78). The micromorph fauna may have been due to paedomorphosis resulting from geographic isolation (Mancini, 1978, p. 313).

Wilson (1971, p. 164) considered that the degree of Laramide tectonism inferred by Maxwell et al. (1967) from the suggested regional Cretaceous/Tertiary unconformity should be lessened, and that warping accompanying uplift was probably gentle. As Wilson observed (1971, p. 164), "There is no significant change in grain size from Aguja to
Black Peaks. A Cretaceous/Tertiary disconformity was presumed by Maxwell et al. (1967) partly because of accidents of collecting; at that time no early Paleocene fossil localities had been discovered. Later workers (Schiebout, 1970, 1974; Rapp, 1982) have found that the sandstone at the base of the Black Peaks section shows no more erosion than is seen at the base of other thick sandstones within the member (Schiebout, 1974, p. 14).

The foregoing composite of features indicates that modest topographic relief was probably present in localized areas of the Big Bend region during the Late Cretaceous and early Tertiary. Positive features may have included low hills, peninsulas, and offshore islands. The structures were probably elongate in a northwest-southeast direction consistent with regional pattern. Such positive areas may have contributed to localized unconformities within the Tornillo Formation, but they were probably of limited extent since the sedimentary model best fitting the deposits is that of a laterally unrestricted meandering river system (Davies, 1983). In sediments characterized by lateral variability, low uplifts raising previously deposited unindurated sandstones and mudstones may be represented only by unrecognized local zones of nondeposition. It is not until the Eocene that unroofing of older Comanchean limestones of the region is seen, reflected in reworked cobbles of the Hannold Hill Member (Wilson, 1971; Hartnell, 1980).

Modern geographic regions in areas that are tectonically similar to the model proposed for Late Cretaceous/early Tertiary time in the Big Bend region (i.e., a regressive regime bordered by uplift due to accretion of terranes from plate convergence) include southern New
Guinea and Sumatra (Howell, 1985). Both these areas have coastal plains 200–400 kilometers in width. Southern New Guinea has little relief, and offshore islands are infrequent and of low relief. On the eastern coast of Sumatra, however, offshore islands are common, and some have relief of more than 150 meters (Espenshade and Morrison, 1974). The Big Bend region lies about 500 kilometers east of the north-south line passing through southwestern New Mexico and southeastern Arizona, where volcanics of Late Cretaceous/early Tertiary age are present.

Although fossil localities representative of all early Paleocene faunal zones (Van Valen, 1978) have not as yet been found in Big Bend, it is quite possible that future exploration in the extensive outcrops of the upper Javelina Member, which was previously considered to be entirely Cretaceous in age, may yield such discoveries. Deposition may have been continuous across the Cretaceous/Tertiary boundary in some areas of the Park.
FOSSIL LOCALITIES AND BIOSTRATIGRAPHY

INTRODUCTION

The localities listed (Table 1) include those newly discovered in the Aguja and lower Tornillo Formations, as well as those previously described that were revisited during the course of this work. Attention was directed to localities low in the Black Peaks Member of the Tornillo Formation, described by Wilson (1967) and Schiebout (1974), as well as those in the Javelina Member. The results of the palynological study of Lawson (1972) and the paleomagnetic study of Rapp (1982) indicated that the upper part of the Javelina Member is Paleocene in age; therefore, the extent of exposures of possible Paleocene age in the area was greatly expanded. Many accessible outcrops of the Javelina Member as mapped by Maxwell et al. (1967, Pl. II) were prospected, and a number of new fossil localities of varying quality were discovered. The area of Javelina outcrops to the south and east of the Chisos Mountains has still not been completely prospected, as access to the lower River Road is limited to 4-wheel drive vehicles, which were available on only one trip (during which locality VL-144 was discovered).

Louisiana State University Museum of Geoscience (LSUMG) locality numbers were assigned following field work; localities are listed in the text in stratigraphic order (where known) together with field names and numbers, as well as known locality numbers in the Texas Memorial Museum (TMM) in Austin, Texas. Detailed geographic locality information is on file at the LSU Museum of Geoscience in Baton Rouge.
Table 1. Late Cretaceous/early Tertiary fossil localities discussed. * indicates mammalian fauna.

A. LSUMG localities (VL-X). # indicates locality also collected and numbered by Texas Memorial Museum (TMM).

<table>
<thead>
<tr>
<th>LSUMG no. (VL-X)</th>
<th>Name</th>
<th>Lithologic unit</th>
<th>Age</th>
<th>Page</th>
<th>Discussed</th>
</tr>
</thead>
<tbody>
<tr>
<td>* 9</td>
<td>Ray's Bonebed</td>
<td>upper Black Peaks</td>
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<td>65</td>
<td></td>
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<tr>
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<td>Rapp's Turtle</td>
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<td>Torr/Tiff</td>
<td>63</td>
<td></td>
</tr>
<tr>
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<td>Lancian</td>
<td>66</td>
<td></td>
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<td>Turtle Grits</td>
<td>lower Black Peaks</td>
<td>Torr?</td>
<td>60</td>
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<td>Lancian</td>
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<td>Lancian</td>
<td>52</td>
<td></td>
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<tr>
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<td>Puercan</td>
<td>67</td>
<td></td>
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<tr>
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<td>Dogie</td>
<td>upper Javelina</td>
<td>1t. Puercan</td>
<td>68</td>
<td></td>
</tr>
<tr>
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<td>upper Javelina</td>
<td>1t. Puercan</td>
<td>55</td>
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<tr>
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<td>Lancian</td>
<td>51</td>
<td></td>
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<tr>
<td>*111</td>
<td>Tom's Top</td>
<td>upper Javelina</td>
<td>1t. Puercan</td>
<td>46, 53</td>
<td></td>
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<td>Maximound</td>
<td>lower Javelina</td>
<td>Lancian</td>
<td>51</td>
<td></td>
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<tr>
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<td>Running Lizard</td>
<td>upper Aguja</td>
<td>Lancian</td>
<td>49</td>
<td></td>
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<tr>
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<td>Torr/Tiff</td>
<td>60</td>
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<tr>
<td>*122</td>
<td>C-Con</td>
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<tr>
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<td>Meditation</td>
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<td>Lancian</td>
<td>66</td>
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<td>Torr</td>
<td>61, 63</td>
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</tr>
<tr>
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<td>Snail's Place</td>
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<td>early Puer</td>
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<td>Lancian</td>
<td>63</td>
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<td>Alligator Alley</td>
<td>lower Black Peaks</td>
<td>Torr</td>
<td>61, 62</td>
<td></td>
</tr>
<tr>
<td>149</td>
<td>Port South</td>
<td>Aguja/Javelina</td>
<td>Lancian</td>
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<td>164</td>
<td>Oyster Island</td>
<td>lower Aguja</td>
<td>Campanian</td>
<td>47</td>
<td></td>
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<tr>
<td>166</td>
<td>Old Maverick Road</td>
<td>lower Aguja</td>
<td>Campanian</td>
<td>66</td>
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</table>

B. TMM localities also mentioned in this report.

<table>
<thead>
<tr>
<th>TMM no.</th>
<th>Name</th>
<th>Lithologic Unit</th>
<th>Age</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>*40147</td>
<td>T2</td>
<td>lower Black Peaks</td>
<td>Torrejonian</td>
<td>61</td>
</tr>
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<td>*40151</td>
<td>Juniper Canyon</td>
<td>lower Black Peaks</td>
<td>Torrejonian</td>
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<td>*41377</td>
<td>Schiebout-Reeves Q.</td>
<td>lower Black Peaks</td>
<td>Torr/Tiff</td>
<td>64</td>
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<tr>
<td>*41400 (= Tom's Top)</td>
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<td>1t. Puercan</td>
<td>46, 53</td>
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<tr>
<td>41436</td>
<td>Tyrannosaurus loc.</td>
<td>lower Javelina</td>
<td>Lancian</td>
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</tr>
<tr>
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<td>Alamosaurus loc.</td>
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<td>52</td>
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<td>41501</td>
<td>Quetzalcoatlus loc.</td>
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<td>1t. Lancian</td>
<td>41, 52</td>
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<td>upper Javelina</td>
<td>Puer/Torr</td>
<td>56</td>
</tr>
<tr>
<td>-</td>
<td>&quot;lower lignite&quot;</td>
<td>upper Javelina</td>
<td>Puer/Torr</td>
<td>56</td>
</tr>
</tbody>
</table>
Although many fossil localities were discovered, most of these yielded only a few fossils. Localities yielding many fossils, and therefore of major interest, include the following:

Tornillo Formation

- **Black Peaks Member**
  - TRM 40147; T2
  - LSUMG VL-134; Middle Peak = T2 upper level
  - LSUMG VL-148; Alligator Alley = T2 lower level

- **Javelina Member**
  - LSUMG VL-108; Dogie
  - LSUMG VL-111; Tom's Top

- **Aguja Formation**
  - LSUMG VL-113; Running Lizard

The general geographic location of selected localities within the Park is shown in Figure 6.

**DAWSON CREEK AREA**

Geology, Stratigraphy, and Fossil Levels

Particular attention was paid to the Dawson Creek area (Figure 7) in the northwestern corner of the Park, where numerous fossil localities had been discovered (Lawson, 1972; Davies, 1983). On the southern side of Dawson Creek (Plate 1), exposures on the northern limb of a syncline reveal a relatively thick section ranging from the uppermost Aguja Formation through the Javelina Member of the Tornillo Formation to the Alamo Creek Basalt and overlying tuffaceous deposits of the Chisos Formation.

During this study, two measured sections (located on Fig. 7) were made in conjunction with paleomagnetic sampling. Section DC-E is near the middle of the ridge south of Dawson Creek, and Section DC-W is on
Figure 6. General location of selected Late Cretaceous/early Tertiary fossil localities in Big Bend National Park. Numbers refer to LSU Museum of Geoscience vertebrate localities.
Figure 7. Dawson Creek area, showing lines of sections and fossil localities. Elevations in feet; contour interval = 20 ft. From U.S.G.S. Terlingua 7.5' Quadrangle, 1971.
Plate 1. Ridge south of Dawson Creek, from point near LSUMG VL-113. Aguja Formation mostly covered at base of ridge; Javelina Member of Tornillo Formation is the higher, lighter-toned sediments alternating with darker bands.
the western end of the ridge (Figure 8, Appendix I). Maxwell et al. (1967, pp. 94-95, Pl. VII, no. 14) included a measured section taken on the western end of these exposures that did not quite extend downward to the base of the Javelina Member. This is roughly equivalent to Section DC-W. The base of the Javelina Member is exposed to the east of Section DC-W along the base of the ridge, where a gray-buff bentonitic mudstone (Unit E9 of Section DC-E, Figure 8) overlies a yellow sandstone with cross-bedded lenses and limonitic concretions. At this level the sediments change in color from lower, predominantly yellowish, purple-tinged deposits to higher, light gray and lighter reddish deposits. This level is chosen on the basis of the color shift as the contact between the Aguja and Tornillo Formations.

Following previous authors (Maxwell et al., 1967, p. 81; Davies, 1983), the top of the sandstone (Unit E8) is taken to be the contact, at a stratigraphic level 48 meters above the level of LSUMG locality VL-113 (Running Lizard), which is at the base of the local exposure north of Dawson Creek. Lower strata are covered by valley fill, except for isolated outcrops. Unit E10, a purple mudstone, was used as a marker bed in correlating Section DC-E with Section DC-W. This unit is recognized on the eastern and western sides of a covered interval between the two sections. Unit E8 pinches out to the west of Section DC-E, so that at the contact just east of the base of Section DC-W, near Dawson Creek, the gray-buff bentonitic mudstone (Unit E9 = W1) overlies a buff, yellow, and gray mudstone with purple streaks, which is equivalent to Unit E7.

Southeast of Running Lizard (VL-113), on the northern side of the ridge, slumping and normal faulting of sediments below the high ridge
Figure 8. Dawson Creek stratigraphic sections. See unit descriptions in Appendix I.
is evident. Lenticular channel sandstones are exposed (Plate 2). Hide the Bone Hill (VL-110) is situated on a hill north of Dawson Creek that is cut by a small normal fault (estimated offset 10 meters) between the east and west ends of the hill. Section DC-E was taken west of this fault, where Unit E4 can be traced across the bed of Dawson Creek. Port South (VL-149), on the southern side of Dawson Creek, is in the zone of slumping, and its exact stratigraphic position is undetermined; however, it appears to be near the level of the Aguja/Tornillo contact. Correlative beds can be traced from higher beds along the top of the ridge to the northwest, across a normal fault that slightly offsets the strata (Plate 3), and around the end of the ridge to exposures on its western and southwestern flanks (Plates 4 and 5).

The large white hill in the right foreground of Plate 4 and on the right in Plate 5 is known as "Big Wing Hill." Remains of Quetzalcoatlus northropi Lawson, 1975 were found at TMM 41501, on the western flank of this hill. Plate 6 is a composite of two photographs showing the length of the hill from the north. Plates 7 and 8 are closer views of the area containing the pterosaur quarry. The position of the quarry was pointed out to the author on topographic maps, by TMM personnel, as being close to one of the Alamosaurus localities, TMM 41450-2. According to Lawson (1972, p. 19), the pterosaur quarry is slightly higher than the Alamosaurus quarry, in a yellow cross-bedded sandstone at approximately the 105-meter level of his Section 1. This level can be traced across Big Wing Hill, and is at the level of Unit W19 of Section DC-W. At this level, Unit W19, a yellow sandstone with large brown ovoidal concretions with platy splits, intertongues
Plate 2. Channel sand east of LSUNG VL-110.
Upper Aguja Formation.

Plate 3. Aerial view from the southeast of top of ridge, showing normal fault with minor relative offset down on the left, or west. In the photograph, which was taken to show continuity of beds across the fault, the western beds appear relatively elevated due to the angle from which the photograph was taken. Javelina Member, Tornillo Formation.
Plate 4. Aerial view (downdip) of exposures of the Javelina Member, Tornillo Formation, on the west end of the ridge south of Dawson Creek. The Alamo Creek Basalt is at the top edge. Pterosaur level (PT) and Tom's Top (VL-111) indicated.

Plate 5. View to west (along strike) of the same deposits from the top of the ridge.
Plate 6. "Big Wing Hill," Dawson Creek area, from the north. The lower dark bed on the left is Unit W16, a maroon band. The pterosaur locality is at the right end of the hill. Javelina Member, Tornillo Formation.
Plate 7. View from the north of the west end of "Big Wing Hill," near the Quetzalcoatlus locality.

Plate 8. Closeup of pterosaur locality. Marvin Hass for scale, on right.
with the grayish yellow silty sands near the top of the eastern end of
the hill. This level is 138 meters above the base of Section DC-W.
The discrepancy between this measurement and that of Lawson (1972) may
be due to decrease in dip upsection, as the axis of the syncline is
approached. In Section DC-W, dip gradually decreases from 34° at the
level of Unit W8 to 6° at the level of Unit W37. The change in dip
may also contribute to the thicker section measured by Maxwell et al.
(1967, p. 95); they recorded 936 feet (285 meters) in their section 14,
whereas Section DC-W in my study is 835 feet (255 meters) thick. An
attempt was made to identify units described by Maxwell et al. (1967,
pp. 94,95), but this was not entirely successful due to the laterally
discontinuous nature and intertonguing of many of the beds. Maxwell
et al. (1967, p. 95) apparently introduced an arithmetic error in
their units 29 and 30, which are listed as being, respectively, 42 and
11 feet thick, but which appear on their Plate VII (no. 14) in more
realistic proportions, with a combined thickness of about 10 feet,
just above their lower coal bed. Recognition of Lawson’s units as
shown in his Section 1 (1972, p. 19) was more difficult; his color
designations in particular were found to be unreliable. Unit W30,
a yellow silty sandstone with a conglomerate of fossil wood at the
base, is easily recognized as unit 26 of Maxwell et al. (1967, p. 95),
and is also seen in Lawson’s Section 1 (1972, p. 19). This marker bed
was used as an aid in correlating and calibrating the earlier sections.

The first mammalian fossils from the Javelina Member of the
Tornillo Formation were reported by Lawson (1972, p. 142) from TMM
locality 41400. A fragmentary upper molar was identified as belonging
to a condylartha and was considered to be Paleocene in age. Lawson
(1972) stated that the locality was at the 122.7 meter level of his Section 1. In my study, initial efforts at locating and collecting from this locality went astray, as its location was marked in error as being on the hill to the west. Later communications with Kyle Davies, who provided a photograph (Plate 9) of TMM 41400, showed it to be the same as Tom's Top (VL-111). Plate 10 shows Tom's Top from a slightly different viewpoint. This locality is 169 meters above the base of Section DC-W. Lawson (1972, p. 19) showed the level of TMM 41400 to be at approximately 130-140 meters, rather than the stated 122.7 meters. Tom's Top is only 31 meters higher stratigraphically than the level from which remains of the Late Cretaceous Quetzalcoatlus northropi were recovered, and 35 meters above the highest occurrence of the sauropod Alamosaurus. The stratigraphic interval between these levels has been extensively prospected, with no intermediate fossils found to date. Future efforts should continue in this zone, which shows no evidence of faulting or obvious disconformities.

Lawson (1972) also described floras from two lignitic layers in the upper portion of the Javelina Member in the Dawson Creek section. He determined that the floras were Paleocene in age. The two levels are 216 and 224 meters above the base of Section DC-W.

Fossil Localities

Aguja Formation


Plate 10. Photograph taken by the author of Tom's Top (VL-111), seen to be the same locality as TMM 41400.
VL-113. Running Lizard (Field no. BS 8314). Lat. 29°17'42" N, Long. 103°31'29" W, Terlingua 7.5' Quad. Discovered by the author, 1983. The locality is at the base of the local exposure of the upper Aguja Formation. The sediments are yellowish siltstones and fine sandstones with interbedded ochre claystones, overlain by drab yellow, gray, and maroon mudstones, fine sandstones, and brown marls. Some of the siltstones are laminated. Surface prospecting yielded scraps of crocodile, turtle, and dinosaur bones, as well as gar scales. Screen washing (2.4 metric tons) recovered many additional fossils representing a varied fauna, including freshwater sharks and rays (Lonchidion selachos, Myledaphus bipartitus, and others), bony fishes (Amia cf. A. uintaensis, gars), amphibians (Albanerpeton nexusosus, Scapherpeton tectum), turtles (Compsemys victa), crocodiles, dinosaurs (coelurosaurs, carnosaurs, hadrosaurs, ankylosaurs, ceratopsians), and mammals. Running Lizard was the only site discovered to contain Mesozoic mammals. A fragmentary tooth identified as Alphadon marshi was recovered; this marsupial is known from the Lancian of Wyoming (Clemens, 1966) and the Edmontonian of New Mexico (Clemens, 1973). The new cimolomyid Jas tejana is relatively derived compared to Campanian forms. Fragmentary remains of ptilodontoid and eucosmodontoid multituberculates were also recovered. A tooth referred to cf. Euoplocephalus represents the first known occurrence of ankylosaurids at Big Bend. The small size of some of the dinosaur teeth indicates that juvenile dinosaurs are represented (Carpenter, 1982). Many coprolites and fragments of eggshell were also recovered.

In addition to vertebrates, remains of plants, ostracodes, gastropods, and unionids were recovered. Fossil wood and a wide
variety of seeds (Palmospermum), pods, plant parts, and particles which appear to be very dark amber also appear.

The fresh-water ostracode fauna, identified by Willem van den Bold, consists of:

- **Cyprinotus** sp. indet.
- **Virgatocypris** sp. indet.
- ?**Eucypris** sp. indet.
- ?**Cypria** sp. indet.
- ?**Procyprois** sp. indet.

The ostracode specimens all consisted of the entire carapace, with both valves. Recovery of ostracodes in vertebrate sites is very unusual. According to van den Bold, the presence of ostracodes in terrestrial sediments is a strong indicator of a lacustrine environment. The presumed lake at Running Lizard may have developed as a result of formation of a body of water between levees (a drenaja), as illustrated by Davies (1983, p. 32). Nearby exposures include channel sands (Plate 2).

The presence of the taxa Lonchidion selachos, Albanerpeton nexuosus, and Alphadon marshii indicates a Maastrichtian (probably Lancian) age for the Running Lizard fauna. A relatively large section of strata is present above this faunal level to the highest occurrence of dinosaurs in Dawson Creek. A Lancian age for Running Lizard implies increased rates of sedimentation in the Big Bend area during the latest Cretaceous, as suggested by Lawson (1976). The results of the paleomagnetic study tentatively support a Lancian age assignment for this fauna, as it appears to be in Anomaly 30 (see below).
VL-110. Hide the Bone Hill (Field no. BS 8315). Lat. 29°17'42" N, Long. 103°31'24" W, Terlingua 7.5' Quad. Discovered by the author, 1983. The locality is in the upper Aguja Formation, in an area of slumping and normal faulting. A normal fault is present between the eastern and western ends of the hill; estimated downdrop is 10 meters on the west. Fossils were recovered from an indurated beige channel sandstone lens and the enclosing beige and maroon mudstones. An anthill locality 5 meters north of the east end of the hill yielded a tooth of Odontaspis. Numerous fish, crocodile, and dinosaur remains were found both in situ and in float. 450 kg. were removed for screen washing, in progress. Age: Lancian.

VL-149. Port South (Field no. BS 8406). Lat. 29°17'38" N, Long. 103°31'12" W, Terlingua 7.5' Quad. Discovered by Adrian Hunt, 1984. The locality is in an area of slumping and normal faulting stepping down from the high ridge to the southeast; the exact stratigraphic level is undetermined, but appears to be the uppermost Aguja Formation or lowermost Tornillo Formation. A large carnosaur femur (LSUMG V-1226) was recovered from a light grayish beige silty sandstone. Age: Lancian.

Lower Javelina Member, Tornillo Formation

VL-112. Maximound (Field no. MCB 1-83). TMM 41450 (in part). Lat. 29°17'34" N, Long. 103°31'49" W, Terlingua 7.5' Quad. Discovered by Maxwell Brown, 1983. The locality is in a bentonitic purple-gray claystone overlain by lag deposits and detritus from the nearby ridge. The level is 95 meters above the base of Section DC-W. 450 kg. of material removed for screen washing; fish, turtle, and crocodile
remains were recovered. The locality is at the same level and about 100 meters east of a locality from which Lawson (1972) reported **Alamosaurus**. Age: Lancian.

**VL-106.** Bone Alley (Field no. BS 8302). TMM 41450 (in part). Lat. 29°17'36" N, Long. 103°31'52" W, Terlingua 7.5' Quad. Discovered by the author, 1983, later determined to be the same level and area as a locality from which Lawson (1972) reported **Alamosaurus**. The sediments are yellow siltstones with interbedded ledge-forming sandstones, containing numerous dinosaur bones. 100 meters above the base of Section DC-W. Age: Lancian.

**VL-145.** Small Gap (Field no. BS 8301). TMM 41450 (in part). Lat. 29°17'33" N, Long. 103°31'49" W, Terlingua 7.5' Quad. Discovered by the author, 1983. Slightly higher stratigraphically than VL-106, 108 meters above the base of Section DC-W. A few scraps of dinosaur bone were recovered in float at the base of a white sandy siltstone. Age: Lancian.

**TMM 41450.** **Alamosaurus** localities of Lawson (1972, p. 124). Stratigraphic levels shown in Section 1 of Lawson (1972, p. 19) as approximately 55 and 95 meters above the base.

**TMM 41501.** "Big Wing". Discovered by Douglas Lawson. Grayish yellow sandstone which yielded remains of the giant pterosaur, **Quetzalcoatlus northropi** Lawson, 1975. The stratigraphic level was shown by Lawson (1972, p. 19) at approximately 105 meters above the base of his Section 1. Field measurements taken during this study show this level at 138 meters above the base of Section DC-W. Age: late Lancian.
Upper Javelina Member, Torrillo Formation

VL-111. Tom's Top (Field no. TTL-1). TMM 41400 (TMM field no. WL-363). Lat. 29°17'29" N, Long. 103°31'46" W, Terlingua 7.5' Quad.

Originally discovered by TMM workers (Lawson, 1972); rediscovered by Tom T. LeFebvre in 1983. Mapped by TMM in error as being situated on the hill to the west, but identified as the same as TTL-1 by photographs. This was the first Paleocene mammal locality discovered in the Javelina Member (Lawson, 1972). Fragmentary remains were identified as condylarthran by Lawson (1972, p. 142). Fossils were recovered from the upper portion of a light gray sandstone lens with large brown concretions near the base, grading upward to darker gray bentonitic mudstones. Light gray and white calcite nodules are present. The fossil level is 169 meters above the base of Section DC-W, in the upper Javelina Member. In addition to surface prospecting, two metric tons of material were removed for screen washing. Most of the fossils are poorly preserved, but identifiable remains of freshwater rays, gars, amphibians (Habrosaurus dilatus, Opisthotriton kayi), lizards (Glyptosaurus cf. G. silvestris), snakes (Dunnophis cf. D. microechinis), and mammals were recovered.

The mammal fauna from Tom's Top includes five taxa, three of which are new; the other two are known from Torrejonian faunas. Table 2 displays the relationships of these taxa to similar taxa recovered from selected faunas ranging in age from Late Cretaceous to Torrejonian (middle Paleocene).
Table 2. Biostratigraphic comparison of mammals from Tom's Top (VL-111), with occurrences in other selected faunas.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Bug Creek</th>
<th>Mantua</th>
<th>Puerco</th>
<th>Dragon Kutz Canyon</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stygimys vastus</strong></td>
<td>G+</td>
<td>G+</td>
<td></td>
<td>G+</td>
</tr>
<tr>
<td><strong>Protictis terlinguae</strong></td>
<td></td>
<td></td>
<td></td>
<td>G+</td>
</tr>
<tr>
<td><strong>Mixodectes malaris</strong></td>
<td></td>
<td></td>
<td>S</td>
<td></td>
</tr>
<tr>
<td><strong>Palaechthon nacimienti</strong></td>
<td></td>
<td>G/</td>
<td>S</td>
<td>G</td>
</tr>
<tr>
<td><strong>Promioclaenus sp.</strong></td>
<td></td>
<td></td>
<td></td>
<td>G-</td>
</tr>
</tbody>
</table>

- **G** = Genus occurs in assemblage
- **S** = Species occurs in assemblage
- **+** = morphologically most similar species is more derived
- **-** = morphologically most similar species is less derived
- **/** = relative stage indeterminate
- **H** = *Hemithlaeus* zone of Puercan
- **T** = *Taeniolabis* zone of Puercan

Because the only species previously described, *Palaechthon nacimienti* and *Mixodectes malaris*, are known only from Torrejonian faunas, Tom's Top might be assigned a Torrejonian (middle Paleocene) age; however, this is contradicted by the paleomagnetic section (see below). Also, the other three mammal taxa recovered from this locality all show features that are relatively primitive with respect to known Torrejonian forms. *Stygimys vastus* n. sp., in particular, is more primitive than the Late Cretaceous species *S. kuszmauli*. *Stygimys vastus* n. sp. is the most primitive species of the genus yet...
reported, and it may be an early immigrant from Asia. *Stygimys*, a eucosmodontid, may be regarded as originating from Nemegtbaatar, which appears in the Campanian Barun Goyot Formation of Mongolia (Kielan-Jaworowska, 1974, p. 28). The earliest known appearance of eucosmodontids in North America is an identified as *Stygimys* sp. from the Late Campanian El Gallo Formation of Mexico (Lillegraven, 1972). In addition, the freshwater ray and the snake occurring at Tom's Top are the same taxa as are present at the late Puercan Dogie locality. The stratigraphic separation between Tom's Top and the Late Cretaceous *Quetzalcoatlus* *northropi* level is only 31 meters, with no apparent disconformity. An age assignment earlier than Torrejonian for the Tom's Top fauna implies chronologic range extension downward for *Palaechthon* nacimenti and *Mixodectes* malaris, and would suggest migration of these forms from south to north. Pending the recovery of additional material and the clarification of the paleomagnetic section, Tom's Top is tentatively assigned a late Puercan age, approximately the same as that of the Wagonroad fauna of Utah. Tomida and Butler (1980, p. 791) report the presence of a possible mixodectid and a primate somewhat similar to *Palaechthon*.

**VL-109. Hot White (Field no. BS 8303).** Lat. 29°17'29" N, Long. 103°31'50" W, Terlingua 7.5' Quad. Discovered by the author, 1983, at the location described for TMM locality 41400 by TMM workers. Examination of topographic maps combined with evidence from photographs compared with slide provided by Kyle Davies (1983) shows that TMM 41400 is actually situated on a small hill to the northeast. Turtle remains were found in an indurated white fine-grained silty
sandstone lens 185 meters above the base of section DC-W. 450 kg. were collected for washing, with crocodile and lizard remains recovered. Numerous clasts of volcanic rock fragments were observed in picking the screened material. Age: Puercan/Torrejonian.


Preliminary Paleomagnetic Stratigraphy

Bruce MacFadden of the University of Florida has provided preliminary results of the paleomagnetic study undertaken in conjunction with this study. The resulting paleomagnetic sections are, at present, tentative and include zones of problematical polarity that will require further study.

The tentative polarity zonation for the Dawson Creek sections is shown in Figure 9. In both sections DC-E and DC-W, a relatively thick basal normal polarity zone is present. In Section DC-E, this normal zone extends from the upper Aguja Formation into the basal strata of the Javelina Member of the Tomillo Formation. A reversal is indicated at approximately the 70 meter level, between units E11 and E12. In Section DC-W, the basal normal zone, which is entirely within the Javelina Member, extends upward to the 63 meter level, and the first reversal is between units W7 and WS. Based on lithologic correlations,
Figure 9. Preliminary paleomagnetic zonation of Dawson Creek sections. Solid = normal polarity; Open = reversed polarity; Hatchured = indefinite polarity.
the first reversal in Section DC-E is about 100 meters lower than the first reversal in Section DC-W. This may indicate either that the lithologic units used for correlation are time-transgressive over this relatively short distance, or that the correlations are in error, and unrecognized faulting may have uplifted the lower portion of the western section. A third alternative is that a disconformity may be present in Section DC-E. A disconformity, possibly at the base of unit E12, could have removed the sediments recording the upper portion of the normal zone. Unit E12 might then be correlative with unit W8.

Faunas of Maastrichtian age are present in the lower portions of both sections. The highest occurrence of dinosaurs in Section DC-W is in a reversed zone. Between this level and the basal normal zone is a short questionably normal zone. The highest occurrence of dinosaurs in the San Juan Basin of New Mexico was originally thought to occur in a zone of normal polarity (Lindsay et al., 1978). However, Butler and Lindsay (1983) later removed this normal zone from their paleomagnetic column, considering it to be a secondary overprint. The highest occurrence of dinosaurs in the Hell Creek Formation of Montana and in the Scollard Formation of Alberta also is in a reversed zone (Archibald et al., 1982). Because the highest occurrence of dinosaurs in Dawson Creek section DC-W is also in a reversed zone, this zone is tentatively correlated with the Fort Peck B− polarity zone of Archibald et al. (1982, p. 158). This is probably the reversed zone below Anomaly 29 of the Magnetic Polarity Time Scale, following Berggren et al. (1985). The relatively long normal zone at the base of the section is probably Anomaly 30, and the intervening
problematic normal zone may be either an overprint or a record of a spurious event.

A more definite normal polarity zone is present in Section DC-W between the level of the highest occurrence of dinosaurs and the level of Tom's Top (VL-111). Based on the mammalian fauna, Tom's Top was tentatively assigned an early Torrejonian age. Earlier studies (Tomida and Butler, 1980; Taylor and Butler, 1980; Lindsay et al., 1981; Tomida, 1981; Butler and Lindsay, 1983) record faunas of Torrejonian age ranging from the middle of Anomaly 28 through the reversed zone between anomalies 28 and 27, and within Anomaly 27. In Section DC-W, only one normal zone is present between the highest occurrence of dinosaurs and the level of Tom's Top, with no apparent disconformity. This normal zone is tentatively interpreted to be Anomaly 29. This interpretation implies that the reversed zone containing the Tom's Top fauna is the reversed zone below Anomaly 28. This in turn suggests that the Tom's Top fauna may be the same age as the late Puercan Wagonroad fauna, which occurs in the upper portion of Anomaly 29 and the lower portion of the above reversed zone (Tomida and Butler, 1980). The Dragon fauna occurs in Anomaly 28 (Tomida and Butler, 1980; Butler and Lindsay, 1983). The earliest "Dragonian" faunas from the San Juan Basin also occur within Anomaly 28 (Tomida, 1981; Butler and Lindsay, 1983).

The two normal zones in Section DC-W above the level of Tom's Top may represent anomalies 28 and 27, suggesting a Torrejonian age for the Paleocene floras of Lawson (1972). LaBrecque et al. (1977) reported a short normal excursion event between anomalies 29 and 28. A similar short normal has been reported by Lindsay et al. (1978) and Tomida.
and Butler (1980) in the reversed magnetozone between normal zones containing faunas of Puercan and Torrejonian age. This short normal may be represented in the DC-W section by the normal zone at the level of the lower Paleocene flora of Lawson (1972). In this interpretation, the age of the floras would be late Puercan.

TORNILLO FLAT AREA

Eastern Tornillo Flat

Lower Javelina Member, Tornillo Formation

VL-101. Graveyard Ridge (Field no. BS-8308). Two km. N. of the Black Peaks; Lat. 29°25'45" N, Long. 103°06'22" W, McKinney Springs 7.5' Quad. Discovered by the author, 1983. Dinosaur limb bones and petrified wood were found in a brown marly concretionary sandstone and underlying purple mudstones. 225 kg. of mudstone removed for screen washing with no yield as yet. Age: Lancian?

Lower Black Peaks Member, Tornillo Formation

VL-103. Turtle Grits (Field no. MCB 2-83). Lat. 29°25'15" N, Long. 103°06'12" W, McKinney Springs 7.5' Quad. Discovered by Maxwell Brown. Trionychid bone fragments were found in a light gray concretionary sandstone. No screen washing as yet. Age: Torrejonian or Tiffanian.

VL-114. Bobwhite (Field no. MCB 3-83). Lat. 29°25'29" N, Long. 103°06'37" W, McKinney Springs 7.5' Quad. Discovered by Maxwell Brown, 1983. Scraps of turtle and mammal bones were found in a light beige sandstone with brown concretions with platy splits and the underlying siltstones. Exact stratigraphic level undetermined. Age: Torrejonian or Tiffanian.
TMM 40147. T2 of Wilson (1967). Maxwell et al. (1967, p. 100) indicated that this locality consists of two levels, both of which have been relocated. As the levels are separated by at least three meters of strata, it is considered that collections from the two levels should be separated where possible. Collecting data are inadequate for some specimens, but as far as is known, *Ptilodus mediaevus* has been recovered only from the lower locality, Alligator Alley (VL-148), and *Ptilodus douglassi* (including a recently collected specimen) only from the upper locality, the Middle Peak (VL-134). The sediments of the lower level have been affected by an intrusion of unknown age.

TMM 40147 was originally assigned a Torrejonian age by Wilson (1967); Schiebout (1974) later considered it to be Tiffanian. Table 3 shows the mammals from TMM 40147 together with forms reported from Torrejonian and Tiffanian localities in other areas. Taxa from both fossil levels have been combined in making this table. Study of previously unidentified fossils in the TMM collection as well as reappraisal of specimens discussed by Schiebout (1974) indicate a fauna with Torrejonian (mid Paleocene) rather than Tiffanian (late Paleocene) affinities. Rapp et al. (1983) showed this locality to be in a segment of undetermined magnetic polarity within a reversed zone. As Tsentas (1981) has noted, it is not possible to determine which reversed zone is represented. He reported the presence of *Mixodectes malaris* from the Pantolambda zone of the San Juan Basin. TMM 40147 could be in either the reversed zone below Anomaly 27, in an anomalously short Anomaly 27, or in the reversed zone above Anomaly 27. The locality is 36 to 44 meters above the local base of the Black Peaks Member of the Tomillo Formation. This is a higher
Table 3. Biostratigraphic comparison of mammals from TMM 40147 (T2), with occurrences from other selected faunas.

See Table 2 for abbreviations and symbols.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Kutz Canyon</th>
<th>Gidley</th>
<th>Swain</th>
<th>Type</th>
<th>Douglass</th>
<th>Bangtail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ptilodus mediaevus</td>
<td>G</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>G</td>
</tr>
<tr>
<td>Ptilodus douglassi</td>
<td>G/</td>
<td>S</td>
<td>G</td>
<td>G</td>
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<td>G+</td>
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<td>Mimetodon silberlingi</td>
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<td>G-</td>
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<tr>
<td>Parectypodus sinclairi</td>
<td>G-</td>
<td>S</td>
<td>G-</td>
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<td></td>
</tr>
<tr>
<td>Psittacotherium multifragum</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
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<tr>
<td>Mixodectes malarius</td>
<td>S</td>
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<tr>
<td>Prothryptacodon sp.</td>
<td>G</td>
<td>G</td>
<td>G</td>
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<tr>
<td>Periptychus carinidens</td>
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<tr>
<td>Tetracelaenodon puercensis</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
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</tr>
</tbody>
</table>

The stratigraphic separation than that of C-Con (VL-122), an early Tiffanian locality on western Tornillo Flat. Several kilometers separate the two areas, and there is no lateral contiguity of the basal sandstones between the areas. Many similar sandstones appear in exposures on western Tornillo Flat (Schiebout, 1974); probably the sandstones considered to be the base of the Black Peaks Member in the two areas are not the same.

VL-148. Alligator Alley (TMM 40147 in part; T2 lower level). Discovered by J. A. Wilson; also collected by M. C. McKenna. 36 to 38 meters above the local base of the Black Peaks Member, Tornillo
Formation. Unit 9 of Section 35 of Maxwell et al. (1967, p. 100).

The sediments are altered by an intrusion of unknown age. Fossils have been recovered from sandstone and gray clay with siderite nodules (one containing a well-preserved fossil arthropod). Coprolites and bones of gars, teleosts, turtles, lizards, crocodiles, and mammals have been recovered. Age: Late? Torrejonian.

VL-134. The Middle Peak (TMM 40147 in part; T2 upper level).

Discovered by J. A. Wilson. 41 to 44 meters above the local base of the Black Peaks Member, Tornillo Formation, in Unit 11 of Section 35, Maxwell et al. (1967, p. 100). Numerous scattered fossils of fish, turtles, crocodiles, and mammals. 930 kg. removed for washing which is in progress. The sediments do not wash well and will require the use of ultrasonic. Age: Late? Torrejonian.

VL-12. Rapp's Turtle. Discovered by Steve Rapp, 1980, northwest of the three Black Peaks. The skull of a large soft shelled turtle was found in a channel sandstone which also preserved the cast of the carapace. LSUMG specimen no. V-306. Age: Torrejonian/Tiffanian.

Western Tornillo Flat

**Javelina Member, Tornillo Formation**

VL-147. Rampart (Field no. BS 8307). 2 km. W of highway, on the same ridge as TMM 41436 of Lawson (1972), from which *Tyrannosaurus rex* fossils were recovered. (Lawson, 1976). Lat. 29°27'19" N, Long. 103°9'32" W, Grapevine Hills 7.5' Quad. Approximately 100 meters above the base of the Javelina Member (Lawson, 1976, p. 158). Dark brown concretionary sandstone capping cuestas. Dinosaur bones were discovered at VL-147 in 1983 by the author. Age: Lancian.
Black Peaks Member, Tornillo Formation

TMM 41377. Schiebout-Reeves Quarry (Schiebout, 1974). 21 meters above the local base of the Black Peaks Member. The sandstone considered to be the base of the Black Peaks Member on western Tornillo Flat is probably not the same sandstone as the one considered the base on eastern Tornillo Flat. No additional fossils have been found in recent surveys of this locality. The pantodont skeleton assigned to Caenolambda by Schiebout (1974) is being reevaluated by Schiebout (pers. comm., 1986) in comparison with new material from higher in the section. This locality was assigned a Torrejonian-Tiffanian boundary (middle to late Paleocene) age by Schiebout (1974).

VL-122. C-Con (TMM 41274). 23 meters above the local base of the Black Peaks Member (see TMM 41377, above). Scattered fossils of fish, crocodiles, and mammals in a calcite-cemented conglomerate at the base of a thick yellow sandstone have been recovered from screen washing. 225 kg. have been removed for washing and acid treatment, in progress. Schiebout (1974, p. 43) assigned a Torrejonian-Tiffanian boundary age to this locality. Table 4 displays the mammals from this locality together with forms reported from selected Torrejonian and Tiffanian localities.

Reappraisal of TMM specimens previously collected has resulted in an assemblage which combines Torrejonian and Tiffanian species. On the basis of the first appearance of Phenacodus, together with the presence of Paleotomus senior, this locality is assigned an early Tiffanian (early late Paleocene) age. This results in a range extension upward to the early Tiffanian for Periptychus carinidens and Promioclæenus acolytus.
Table 4. Biostratigraphic comparison of mammals from C-Con (VL-122).

See Table 2 for abbreviations and symbols.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Kutz Canyon</th>
<th>Swain</th>
<th>Type</th>
<th>Douglass</th>
<th>Bangtail</th>
<th>Mason Pocket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ptilodus sp. indet.</td>
<td>G—</td>
<td>G—</td>
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<tr>
<td>Paleotomus senior</td>
<td>G</td>
<td>S</td>
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<tr>
<td>Promioclaenus acolytus</td>
<td>S</td>
<td>S</td>
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<tr>
<td>Periptychus carinidens</td>
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<td>S</td>
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<td>Phenacodus bisonensis</td>
<td>S</td>
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<td>G+</td>
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<td>Phenacodus primaevus</td>
<td>G</td>
<td>S</td>
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</table>

C-Con consists of stringers of conglomerate at the base of a thick channel sandstone about 2 meters higher than the level of the Schiebout-Reeves Quarry. Rapp et al. (1983) show these levels in the reversed magnetozone below Anomaly 26 of the Magnetic Polarity Time Scale, in a section which includes higher Tiffanian fossil localities.

VL-9. Ray's Bonebed (TMM 40535, 40536, 40537, and 40148 in part). Discovered by Raymond Alf, 1962 (Wilson, 1967). 49 to 50 meters above the local base of the Black Peaks Member. The sediments are dark gray and maroon silty carbonaceous claystones with numerous calcite nodules. Fossils are frequently encrusted with barite. Two metric tons have been removed for washing; requires ultrasonic or chemical treatment to break down. Numerous fossils of freshwater snails, rays, gars, teleosts, amphibians, lizards, crocodiles, and mammals have been recovered. The fauna was discussed by Schiebout (1974), who assigned a Tiffanian age, in agreement with Wilson (1967). Gingerich (1976) and Rapp et al. (1983) indicated a mid-Tiffanian age.
OTHER AREAS IN BIG BEND NATIONAL PARK

Aguja Formation


One km. west of Peña Mountain, in steeply dipping basal sandstones and siltstones of the Aguja Formation. The brown and yellow sandstones and interbedded mudstones contain large oyster beds; vertebrate remains include marine sharks and freshwater (or brackish?) turtles. Age: mid Campanian.

Lower Javelina Member, Tornillo Formation

VL-123. Meditation (Field no. BS 8313). Lat. 29°25'8" N, Long. 103°12'7" W, 0.6 km. north of the north end of the Grapevine Hills intrusion. Discovered by the author, 1983. Turtle and dinosaur fragments were found in light maroon silty claystones with calcareous nodules, capped by yellowish beige sandstone with brown platy concretions. Age: Lancian?

VL-105. Barb's Bump (Field no. BS 8305). Lat. 29°25'32" N, Long. 103°12'22" W, Grapevine Hills 7.5' Quad. The locality is in an isolated cuesta outcrop in a faulted zone. The cuesta is capped by cross-bedded brown sandstone with conglomerate at the base, overlying yellowish silty sandstones and gray silty claystones. Dinosaur and turtle remains were found in the conglomerate and the underlying sediments. 340 kg. were removed for washing, with only scraps as yet recovered. Discovered by the author, 1983.

VL-102. Chilicotal North (Field no. BS 8309). 2 km. WSW of Chilicotal Spring; Lat. 29°14'8" N, Long. 103°8'57" W, Glenn Spring 7.5' Quad. Discovered by the author, 1983. Scraps of dinosaur bones
were found in purple and gray silty claystones. 35 kg. of material screen washed, with only small scraps recovered. Age: Maastrichtian.

**Upper Javelina Member, Tornillo Formation**

**VL-144. Snail's Place (Field no. BS 8404).** Near the Rio Grande, 0.8 km. W of Reed Camp. Lat. 29°2'50" N, Long. 103°20'44" W, Reed Camp 7.5' Quad. Discovered by the author, 1984. Gray silty claysones are exposed in a small platform outcrop below the pediment gravels. 30 kg. were washed, from which were recovered shells and opercula of at least 8 taxa of fresh water gastropods, as well as turtle, crocodilian, and mammal remains. Mammalian fossils include scraps of bones of a large mammal such as an arctocyonid, and a fragmentary multituberculate M1 tentatively assigned to *Stygimys gratus*. This taxon is known only from the Mantua Local Fauna (Jepsen, 1940) of early Puercan (earliest Paleocene) age, so this locality was also assigned an early Puercan age.

**VL-107. Glenn Eleven (Field no. BS 8311).** In the Glenn Draw area, 3.4 km. SE of Glenn Spring. Lat. 29°9' N, Long. 103°7'48" W, Glenn Spring 7.5' Quad. Discovered by the author, 1983. Fossils were found in a gray, silty, bentonitic claystone exposure covered by lag. The stratigraphic level is undetermined because the sediments are faulted within a syncline. The fossils are considered to be either in situ or to have been moved only very little from the site of deposition, because associated sacral and first caudal vertebrae of a eusuchian crocodile were found in articulated position. Fossils include gars, numerous turtles, crocodiles, and fragmentary teeth and bones of *Eoconodon coryphaeus*. 900 kg. were removed for washing,
but few fossils have been recovered from the screened material. *Eoconodon coryphaeus* has been reported only from deposits of Puercan age in the San Juan Basin (possibly both faunal levels; see Van Valen, 1978), so this locality was assigned a Puercan (early Paleocene) age.

**VL-108. Dogie** (Field nos. BS 8304, TMM WL-461). SE of Dogie Mountain, near Dike #160 of Maxwell et al. (1967, Pl. II). Lat. 29°19'38" N, Long. 103°27'11" W, Tule Mountain 7.5' Quad. Discovered by Robert Rainey (Davies, 1983 pers. comm.). The locality is in light gray and pink bentonitic mudstones with interbedded sandy siltstone lenses having limonitic and gypsiferous concretions. Numerous fossils were found in surface prospecting and from screen washing of 2.8 metric tons of sediment. Some chalcedony is present in the sediments, and gypsum and authigenic clays are common. Preservation is extremely varied; many very fragile small bones are silicified and opalized. Other fossils are less well-preserved, and some appear to have been digested. Coprolites are common. Some creep of the soft sediments is evident on the low hills, which are undermined by pseudokarst that has formed deep, hazardous holes. The exact stratigraphic level within the upper Javelina Member has not as yet been determined, as faulting is present to the west in the eastern limb of the Maverick anticline.

Fossils found in initial investigations by TMM workers included a mammalian premolar which did not appear to belong to a Cretaceous mammal (Langston, 1983 pers. comm.). In my study, this locality yielded the largest mammalian fauna of early Paleocene age. In addition, many fossils of lower vertebrates were recovered. These include a new species of freshwater ray, *Amia*, *Atractosteus*, teleosts,
amphibians (frog), turtles, lizards (*Glyptosaurus cf. G. silvestris*), snakes, and crocodiles. Fossil snakes include the earliest reported "blind snake" or scolecophidian. Crocodile remains include some teeth of Cretaceous aspect (Langston, 1985 pers. comm.). Table 5 displays the mammalian taxa from Dogie together with similar taxa from selected localities of Puercan and Torrejonian age.

Table 5. Biostratigraphic comparison of mammals from Dogie (VL-108).

See Table 2 for abbreviations and symbols.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Mantua</th>
<th>Puerco</th>
<th>Purgatory</th>
<th>Wagon</th>
<th>Dragon</th>
<th>Upper</th>
<th>Kimberto</th>
<th>Kutz</th>
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<tr>
<td></td>
<td>H</td>
<td>T</td>
<td>Purga-</td>
<td>Wagon</td>
<td>Dragon</td>
<td>Upper</td>
<td>Kimberto</td>
<td>Kutz</td>
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<tr>
<td><em>Ptilodus</em> <em>torridus</em></td>
<td>G-</td>
<td>G-</td>
<td>C+</td>
<td>G+</td>
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<td><em>Mesodma</em> <em>thompsoni</em></td>
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<tr>
<td><em>Viridomys</em> <em>bovorbatus</em></td>
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<td><em>Peratherium</em> sp.</td>
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<td><em>Gelastops</em> sp.</td>
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<td><em>Protictis</em> <em>terlinguae</em></td>
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<td>G+</td>
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<tr>
<td><em>Eoconodon</em> sp.</td>
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<tr>
<td><em>Carsioptychus</em> <em>coarctatus</em></td>
<td>S</td>
<td>G+</td>
<td>G+</td>
<td>G+</td>
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<tr>
<td><em>Haploconus</em> <em>inopinatus</em></td>
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<td>G/</td>
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<td>G/</td>
<td>G/</td>
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<tr>
<td><em>Ellipsodon</em> <em>priscus</em></td>
<td>S+</td>
<td>S+</td>
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<td>G+</td>
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<tr>
<td><em>Nexus</em> <em>plexus</em></td>
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On the basis of the presence in the fauna of *Eoconodon*, *Ellipsodon priscus*, and *Carsioptychus coarctatus*, the Dogie locality is assigned a Puercan (early Paleocene) age. A mid-to-late Puercan age is suggested by the relatively derived state of *Ptilodus torridus*, when
compared to *Ptilodus* *tsosie* and *Kimbetohia campi* from the Hemithlaeus zone of the Nacimiento Formation in the San Juan Basin. *Mesodma thompsoni* is also known from the lower Nacimiento Formation (Sloan, 1981).

Several range extensions follow from the assignment of a Puercan age to the Dogie fauna. *Viridomys* was previously known from the early Campanian of Canada (Fox, 1971). *Haploconus inopinatus* is known from the Dragon Canyon Local Fauna (Gazin, 1941), and *Peratherium* was previously reported only from the early Eocene (Krishtalka and Stucky, 1983). *Peratherium* is also present in the Puercan of the San Juan Basin (University of Arizona Laboratory of Paleontology specimens). *Gelastops* is known from Torrejonian faunas (Simpson, 1937; Rigby, 1980), but has also been reported from the Puercan Purgatory Hill fauna as *Gelastopus* (*sic*) sp. (Van Valen, 1978, p. 69). *Gelastops* sp. from Dogie is intermediate in morphology between the Cretaceous and early Puercan *Cimolestes* and *Gelastops parcus* of the Torrejonian.

**Lower Black Peaks Member, Tornillo Formation**

*TMM 40151. Juniper Canyon (TMM Field no. T10).* In the Juniper Canyon area SE of Robber's Roost, at the base of a thick yellowish sandstone overlying gray and maroon mudstones. Discovered by J. A. Wilson. This locality was revisited during this study, but no additional fossils were found. Wilson found lower jaw fragments which he identified as ?*Claenodon* sp. cf. *C. procyonoides* (Wilson, 1967, p. 161). Schiebout (1974, p. 20) assigned the specimen to ?*Deuterogonodon* sp. I have not seen the specimen, but as illustrated by Wilson and Schiebout, it is the appropriate size for *Deuterogonodon*
Van Valen, 1978, based on remains from Kutz Canyon in the San Juan Basin (Nacimiento Formation, Torrejonian). This agrees with Wilson (1967) in indicating a Torrejonian age for this locality.

SUMMARY

Five vertebrate fossil localities in Big Bend National Park were found that included mammals of Late Cretaceous/early Tertiary age. Running Lizard, in the upper Aguja Formation, yielded the first Cretaceous mammals from Big Bend, in addition to a diverse dinosaur fauna. Running Lizard is assigned a Maastrichtian, probably Lancian, age, based on the similarity of the vertebrates to the fauna of the Lance Formation of Wyoming.

Dodie, which yielded the largest mammalian fauna described in my study, is assigned a late Puercan (early Paleocene) age. Tom's Top yielded a smaller mammalian fauna that combines Torrejonian and relatively primitive forms. This fauna is also assigned a late Puercan age, based on the tentative paleomagnetic zonation, the presence of primitive forms, and the presence of lower vertebrates also found at Dogie.

Glenn Elevan is assigned a Puercan age based on the presence of *Eoconodon coryphaeus*, and Snail's Place is assigned an early Puercan (Mantuan) age, based on the presence of a fragmentary tooth of *Stygimys gratus*.

Figure 10 illustrates the relative stratigraphic and chronologic placement of the localities discussed.
Figure 10. Composite stratigraphic and age placement of Late Cretaceous/Paleocene fossil localities of Big Bend National Park.
Lower vertebrates.—Terminology follows Estes (1964). For teeth and skeletal remains, the dimensions L, W, and occasionally H and D are used, with standard connotations. Carpenter (1982) utilized W as a measure for the anteroposterior dimension of dinosaur teeth; in this study L is used for this measure.

Multituberculates.—Cusp terminology follows Clemens (1963) and Krause (1977). Measurements follow Novacek and Clemens (1977). See Figure 11 for orientation of measurements of $M_b$.

Therians.—Cusp terminology and measurements follow Van Valen (1966), Lillegraven (1969), and Schiebout (1974). In addition, the term obliconid (Rigby, 1980) is used for the cusp developed at the anterior end of the cristid obliqua on some periptychid molars.

Measurements of small fossils were made with a Fowler Max-Cal electronic digital caliper measuring to 0.01 mm., or with a Leitz ocular with reticule mounted in a Wild M7S microscope. These measurements are not considered to be as reliable as those determined using a microscope specifically designed for measurement, such as the Ehrenreich "Shop-Scope" described by Lillegraven and Bieber (1986). Accuracy of measurements is therefore effectively limited to tenths of millimeters. Repetition of measurements by the author in an attempt to evaluate their reliability resulted in observed error ranging from zero to 0.18 mm., with most variation occurring in cases where specimen orientation was more likely to affect measurement. Camera lucida
outlines were extensively utilized both in comparing morphologic features and in producing illustrations.

ABBREVIATIONS

LSUMG = Louisiana State University Museum of Geoscience
V = LSUMG vertebrate specimen
VL = LSUMG vertebrate locality
TMM = Texas Memorial Museum, Austin
AMNH = American Museum of Natural History
UCMP = University of California Museum of Paleontology, Berkeley
UALP = University of Arizona Laboratory of Paleontology, Tucson

I\textsuperscript{X}, I\textsubscript{X} = upper or lower incisor, respectively
C\textsuperscript{u}, C\textsubscript{1} = upper or lower canine, respectively
P\textsuperscript{X}, P\textsubscript{X} = upper or lower premolar, respectively
M\textsuperscript{X}, M\textsubscript{X} = upper or lower molar, respectively

M\textsuperscript{b}, M\textsubscript{b} = P\textsuperscript{4}, P\textsubscript{4} of earlier authors; the first non-replaced tooth of multituberculates

L = Length, maximum anteroposterior dimension
W = Width, maximum transverse dimension
H = Height
D = Diameter

N = total number in sample

AW = Anterior width, or trigonid width of lower molars
PW = posterior width, or talonid width of lower molars

D\textsubscript{s} = in multituberculates, the distance from the base of the anterior slope of M\textsubscript{b} to the first serration.
d = deciduous tooth
+
= indicates minimum dimension, or actual measure of an incomplete specimen
est. = estimated

Figure 11. Measurements of multituberculate M_b's.
Taxa included in this section are those either newly discovered or reviewed from Big Bend. Taxa previously reported, but not here reviewed, are included in the revised faunal lists in Appendix II.

Most of the fossils recovered during this study were dissociated. In addition to comparison to more complete specimens, size, morphology, and preservation were used in making taxonomic associations, which are tentative. When the available material probably represents a previously undescribed species, but the material is inadequate for formal description, the abbreviation sp. is used following the generic name. If the material is considered adequate for generic or higher taxonomic identification, but not for specific, whether to a species previously described or a new species, the abbreviation sp. indet. has been used. An attempt has been made to avoid the use of "cf." in identifications; however, in a few cases it has been used for consistency with earlier publications.

All illustrations are by the author. Figures include a line representing one millimeter, except where otherwise noted.

Class CHONDRICHTHYES
Order SELACHII
Suborder HYBODOINTIDEA
Family HYBODONTIDAE
Genus Lonchidion Estes, 1964
Lonchidion selachos Estes, 1964
Figure 12, Table 6

Referred specimens.—LSUMG V-1336-1338; V-1352; complete and partial teeth.

Locality.—Running Lizard (VL-113).

Distribution.—Lance Formation, Wyoming; Hell Creek Formation, Montana; upper Aguja Formation, Big Bend National Park, Texas. Lancian (Maastrichtian).

Description.—The teeth are small, elongate, and slightly bulbous, with a prominent but relatively low central cusp and falcate lateral cusps, joined by a longitudinal crest that has variably developed intermediate cuspules. A labial buttress is joined to the central cusp by a ridge; the buttress is slightly swollen on V-1352 and has a small wear facet. The enamel is smooth, and the crown is slightly constricted above the root. On the only specimen (V-1337) on which part of the root is preserved, it is short and highly vascularized.

Discussion.—Referral to Lonchidion selachos is based on similarity to the type (Estes, 1964, Fig. 1). The teeth lack striations, pustules, and the convexity of the crest described in other species of Lonchidion (Estes and Sanchiz, 1982), and have strong, falcate lateral cusps and accessory cusps. Their size falls within the range (2-6 mm.) given by Estes (1964, p. 9) for specimens of L. selachos from the Lance Formation.

Table 6. Measurements of complete teeth of Lonchidion selachos

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Length</th>
<th>Width</th>
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<tr>
<td>LSUMG V-1336</td>
<td>3.64</td>
<td>1.21</td>
</tr>
<tr>
<td>LSUMG V-1352</td>
<td>3.81</td>
<td>1.28</td>
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</table>
Figure 12. Lonchidion selachos

A–C LSUMG V-1336; tooth in occlusal, labial, and basal views
D LSUMG V-1337; partial tooth in labial view. Note partial root.
E,F LSUMG V-1352; tooth in occlusal and labial views
Suborder GALEOIDEA

Family ODONTASPIDAE

Genus Odontaspis Agassiz, 1838

Odontaspis sp. indet.

Figure 13

Referred specimen.—LSUMG V-1342, partial upper tooth.

Locality.—Running Lizard (VL-113).

Distribution.—Upper Aguja Formation, Big Bend National Park, Texas. Lancian (Maastrichtian).

Description.—L=2.36+ (est. L=3.0), W=1.32. This worn, incomplete tooth has a high, stout central cusp and a low, triangular lateral cusp on the unbroken side. Neither cusp is sigmoidal, and plications are not visible. The root has a distinct median furrow on the lingual side.

Discussion.—Referral to Odontaspis is based on the high, erect central cusp, presence of lateral cusp(s), and distinct median furrow on the lingual side of the root. Lamna lacks this furrow. The abraded state of the tooth possibly indicates that the fossil was reworked; this locality is considered to be of freshwater origin.

Figure 13. Odontaspis sp. indet. LSUMG V-1342, partial tooth, in A. occlusal; B. labial; C. lingual; and D. medial views.
Family MITSUKURINIDAE

Genus Scapanorhynchus Woodward, 1889

Scapanorhynchus texanus (Roemer, 1852)

Figure 14

Lamna texana Roemer, 1852:29, Pl. 1, , Fig. 7.


Referred specimens.—LSUMG V-1526, V-1532; partial teeth and fragments.

Localities.—Old Maverick Road (VL-166), Oyster Island (VL-164); both lower Aguja Formation (Campanian).


Description.—The teeth are large, with a tall, bladelike cusp flattened labially, and with strong vertical striations on the lingual face. No striations are present on the labial face. The ventrolabial border of the crown peaks in the center of the tooth. The root is slightly constricted below the crown, and a distinct furrow divides the lingual boss of the root. One medial and two lateral foramina are present within the furrow.

Discussion.—This species is widely represented in North America and its presence in the Big Bend area is not unexpected.
Figure 14. *Scapanorhynchus texanus*

A. LSUMG V-1532, partial tooth, in lingual view
B, C. LSUMG V-1526, partial tooth, in labial and medial views.

Family ANACORACIDAE

Genus *Squalicorax* Whitley, 1939

*Squalicorax kaupi* (Agassiz, 1843)

Figure 15

*Corax kaupi* Agassiz, 1843: 225.

*Corax falcatus* Williston, 1900:252.


Referred specimen.—LSUMG V-1534, isolated tooth.

Locality.—Oyster Island (VL-164); lower Aguja Formation (Campanian).


Description.—L=9.04. The tooth has an asymmetrical, trenchant blade with a slight indentation on the posterior margin. The worn
bases of 9 denticles can be seen on the subvertical blade between the indentation and the apex of the tooth, in a space occupying approximately half of this distance. The anterior portion of the blade is slightly gibbous. The lower limit of enamel is concave on the lingual face, which is convex; this limit is slightly concave and poorly defined on the labial face, which is almost flat. The root is high and numerous foramina are present on the labial side.

Discussion.—Referral to *Squalicorax kaupi* is based on the size, the slight gibbosity of the anterior blade, and the small number of denticles (Cappetta and Case, 1975).

Figure 15. *Squalicorax kaupi*. LSUMG V-1534, fragmentary tooth.

A. labial view  B. lingual view.

**Referred specimens.**—LSUMG V-1340, 1341; complete teeth.

**Locality.**—Running Lizard (VL-113).

**Distribution.**—Lance Formation, Wyoming; St. Mary River Formation, Alberta; upper Aguja Formation, Big Bend National Park, Texas. Lancian (Maastrichtian).

**Description.**—The moderately acute central cusp has broad, convex shoulders sloping to the wide base. No secondary cusps are present. The crown has a ventrolabial projection; V-1341 has a short vertical ridge above this projection, but this ridge is not present on V-1340. The median sulcus of the broad root opens lingually to a small furrow at the base of the root boss. One or two foramina are located on the lingual face of the root below the indistinct lower edge of the crown. On the basal aspect, the root is bifurcated into two wide flanges separated by the median furrow, which opens centrally into a shallow circular depression.

**Discussion.**—The referred teeth differ from the type (Estes, 1964, Fig. 5) in being slightly less acute, and in having fewer labial striations. They are also slightly smaller and have a smaller labial opening for the median sulcus, as in teeth referred to this species by Langston (1975, p. 1597), from the St. Mary River Formation.
Figure 16. *Squatyrhina americana*, isolated teeth


F-J. LSUMG V-1341, in: occlusal, basal, labial, lingual, and medial views.
Table 7. Measurements of teeth of Squatirhina americana.

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Length</th>
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<td>LSUMG V-1340</td>
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<td>1.01</td>
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<tr>
<td>LSUMG V-1341</td>
<td>1.29</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Genus Cretorectolobus Case, 1978

Cretorectolobus olsoni Case, 1978

Figure 17

Cretorectolobus olsoni Case, 1978, p. 188.

Referred specimens.—LSUMG V-1339, complete tooth; V-1353, partial tooth.

Locality.—Running Lizard (VL-113); Maastrichtian.

Distribution.—Judith River Formation, Montana; upper Aguja Formation, Big Bend National Park, Texas. Campanian-Maastrichtian.

Description.—Dimensions of the complete tooth are: L=1.63, W=1.19. The teeth have tall, acute central cusps that curve slightly lingually. The wide, low shoulders bear lateral cusps with crenulated margins. Labially, a prominent uvula, or basal protuberance, overhangs the base of the root. There is no "pleat," or ridge, above this uvula. Multiple foramina are present on the lingual face of the root, just below the ventral margin of the enamel. A narrow median furrow is present at the lingual base of the root; in basal aspect this furrow becomes a narrow, straight groove separating the wide root into two portions. Small foramina are present in the basal face of the root.
Figure 17. *Cretorectolobus olsoni*. LSUMG V-1339, isolated tooth, in:

A. occlusal; B. basal; C. lingual; D. labial; E. medial; and F. lingual oblique views.
Discussion.—The referred teeth are slightly smaller than those from the Judith River Formation, which range from 2 to 5 mm. in size (Case, 1978, p. 188). They also lack the short "pleat" seen in the Montana specimens, but otherwise fit the diagnosis well. The occurrence of this form in upper Aguja Formation represents a range extension into the Maastrichtian.

? Orectolobidae

Figure 18

Referred specimen.—LSUMG V-1349, dermal denticle.

Locality.—Running Lizard (VL-113).

Distribution.—upper Aguja Formation, Big Bend National Park, Texas. Lancian (Maastrichtian).

Description.—The base is 1.52 mm. in diameter. It is circular and fluted, with a fusiform, sharp spine set at an angle to the base.

Discussion.—This specimen is similar to that assigned to Cretorectolobus olsoni by Case (1978, p. 188). The specimen may belong to either Cretorectolobus olsoni or Squatirhina americana, both of which are present at this locality.

Figure 18. ?Orectolobid dermal denticle. LSUMG V-1349, in:

A. dorsal; B. lateral views.
Order BATOIDEA
Family SCLORORHYNCHIDAE
Genus Ptychotrygon Jaekel, 1894

Ptychotrygon slaughteri Cappetta and Case, 1975

Figure 19


Referred specimen.—LSUNG V-1331, isolated tooth.

Locality.—Running Lizard (VL-113); Maastrichtian.

Distribution.—Woodbine and upper Aguja Formations, Texas.

Cenomanian and Maastrichtian.

Description.—The tooth is small (L=1.33, W=0.71). It has a low, rounded central cusp traversed by a longitudinal ridge. In occlusal view, the crown has a rounded rhomboidal outline, with a slight labial bulge which overhangs the root slightly. A short ridge descends the labial side of the apical; this ridge bifurcates into branches that curve outward over the labial bulge. Near the end points of these ridges, short, straight longitudinal ridges angle toward the lateral corners of the tooth. On the lingual side of the central cusp, two short ridges join to make an inverted "v" pointing toward the apex of the tooth. The ventral margin of the crown on the lingual side of the tooth makes a slight dip underneath the slightly concave, steep lingual face of the central cusp. The roots are stout and broad, and their margins are visible in occlusal view. Two lateral foramina are present below the lingual edge of the crown, and a wide central canal separates the roots into two triangular portions. The anterior root face is not vertical, but bulges outward at the base.
Discussion.—This species was described by Cappetta and Case (1975, p. 306), who separated it from a group of teeth referred to Ptychotrygon triangularis by McNulty and Slaughter (1972, p. 650). Diagnostic characters include: oblique labial face bearing two convergent crests and lingual face with an abrupt, steep slope having a medial depression limited above by a short crest. The disposition of described ornamentation is very similar to that displayed by V-1331, differing in the shape of the lingual crest and the presence of more numerous, slightly longer labial crests converging toward the apex. Also, the occlusal outline of V-1331 is not as wide as in specimens illustrated by the authors, and the anterior face of the root is not vertical in lateral profile. This fossil may represent a morphological intermediate between *P. hooveri* and *P. slaughteri*, but the arrangement of crests favors assignment to *P. slaughteri*. This represents a considerable range extension for the species.

Figure 19. *Ptychotrygon slaughteri*. LSUUMG V-1331, tooth, in:

A. occlusal; B. basal; C. lingual; D. lateral; and E. labial views.
Family DASYATIDAE

Genus Myledaphus Cope, 1876

Myledaphus bipartitus Cope, 1876

Figure 20


Referred specimens.—LSUMG V-1343-1347, individual teeth; V-1348, 17 isolated teeth; V-1350, tooth in matrix sample.

Locality.—Running Lizard (VL-113); Maastrichtian.

Distribution.—Oldman, Edmonton, and Milk River Formations, Alberta; Judith River Formation, Montana; Lance and Mesa Verde Formations, Wyoming; Wasatch Formation, Colorado; upper Aguja Formation, Big Bend National Park, Texas. Campanian-Eocene.

Description.—The specimens range in size from 1 to 4 mm. The teeth have polygonal (rhombic or hexagonal) crowns that are divided into anterior and posterior portions by a low ridge. Wear has obscured the pattern on the anterior portion of the specimens; V-1343 has faintly visible anterior wrinkles. The posterior crown ornamentation is visible on most of the teeth; it consists of low wrinkles (4 per mm.) running from the central ridge over the posterior margin of the crown and down the sides. Roots are generally robust, vertical and bifurcated by a median canal that has a central foramen and lateral wall foramina. Foramina also appear on the exterior walls of the root below the ventral margin of the crown. In addition, the root has many tiny foramina scattered over the surface. Some specimens have slightly more rounded outlines and no visible ridges (Fig. 20D). One specimen (V-1347) has roots that are relatively short, with lingual protuberances (Fig. 20Q).
Figure 20. *Myledaphus bipartitus* teeth.

A-C LSUNG V-1343; occlusal, posterior, and basal views
D-F LSUNG V-1344; occlusal, posterior, and basal views
G-I LSUNG V-1345; occlusal, posterior, and basal views
J-M LSUNG V-1346; occlusal, posterior, basal, and lateral views
N-Q LSUNG V-1347; occlusal, posterior, basal, and lateral views.
Discussion.—Referral to **Myleaphus bipartitus** is based on the polygonal outline, presence of a transverse ridge with posterior wrinkles, and vertical roots. The more rounded specimens, which lack visible ornamentation other than the transverse ridge, may simply be more worn or rounded by stream transport, rather than representing another taxon. Preservation is variable in the sample. Some specimens are black and poorly preserved; others are reddish brown or brown and well preserved. The black specimens may have been reworked from lignitic layers lower in the section.

**Genus Dasyatis** Rafinesque, 1810

*Dasyatis matrix* n. sp.

Figures 21-23

**Type.**—LSUMG V-726; isolated lateral tooth (female).

**Referred specimens.**—LSUMG V-725, 727, 772, 780, 871, 974, isolated teeth; LSUMG V-729, 731, 732, 733, vertebral centra.

**Localities.**—Dogie (VL-108) and Tom's Top (VL-111); late Puercan.

**Distribution.**—upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan.

**Etymology.**—Reference is to the small clast-like size of the teeth, and to the taxonomic relationship of the species to the rays.

**Diagnosis.**— Teeth with transversely elongated, triangular crowns that are ornamented with vermiculate ridges, which spread inward from the anterior and posterior margins. Crowns higher than roots; occlusal surfaces tilted at an angle to the root. Submedian vertical bulge on the anterior of the crown. Concave folds on either
Figure 21. Dasyatis matrix n. sp., isolated teeth.

A-E  LSUMG V-726 (type); occlusal, basal, anterior, posterior, and lateral views
F, G  LSUMG V-727; occlusal and basal views
H    LSUMG V-772; occlusal view
I-M  LSUMG V-974; occlusal, basal, anterior, posterior, and lateral views
N-R  LSUMG V-780· (male); occlusal, basal, anterior, posterior, and lateral views
side of a central rounded slope. Roots relatively large, with flaring triangular bases and median canal. Differs from other described species of *Dasyatis* in the nature of the surface ornamentation and in having a triangular occlusal surface.

**Description.**—The teeth range in size from 0.5 to 1.5 mm. The crown is taller than the root. Occlusal surfaces are basically triangular, with a concave, slightly bilobate anterior margin. The occlusal surface is covered with tortuous, occasionally anastomosing ridges that spread from the anterior and posterior margins onto a median transverse sinuous depression. The anterolateral corners are drawn out into projecting wings whose inner edges step down from the occlusal surface. There is a submedian bulge on the anterior face below the occlusal surface. The posterior face is gently folded transversely, so that a medial descending ridge of variable width is bounded by concave transverse sulci on either side. The enamel is smooth, except for the occlusal surface and its margins.

The roots are large, with flaring or bulging triangular bases that may be slightly rounded. There is a narrow groove encircling the root immediately below the base of the crown. The median canal is wide and deep, and usually has one median foramen; two are observed in some specimens. These may be of equal size and symmetrically arranged, or unequal and asymmetrical. Lateral foramina are occasionally present high on the lingual root surface. The anterior ventral margin of the crown is sinuous or concave upward; the posterior is straight or gently convex.

Specimens LSU 19780 and V-725 are presumed to represent males of this species; they are relatively more high-crowned, and have more
acute cusps. Ornamentation of the anterior slope of the teeth is similar to that in specimens which are relatively flatter, and which are presumed to belong to females. LSUMG V-780 (Fig. 21 N-R) has a constricted, concave posterior slope, and lacks a carina. The lateral wings and anterior submedian bulge are less prominent than in teeth referred to females. LSUMG V-725 (Fig. 22) lacks lateral "ears" and the anterior bulge seen in the other larger specimens, but has similar wrinkling on the anterior slope. LSUMG V-725 is the smallest of the referred specimens; it differs from the larger referred teeth in lacking lateral "ears" and an anterior bulge. This small tooth may represent another taxon, but is at present provisionally referred to Dasyatis matrix.

The referred vertebral centra range in diameter from 1 to 4 mm. They are spool-shaped, with parallel anterior and posterior borders. In anterior/posterior view, the outline is circular to oval. The centra are amphicoelous. In lateral view, dense bordering rims are visible on the sides. Some have notochordal canals. Distributed symmetrically about the rims are openings for bases of non-calcified arches and processes, which are arranged in either four single, or eight paired openings.

Discussion.—Referral to Dasyatis is based on the transversely elongate crown shape and the transverse orientation of the groove between vermiculate ridges of the occlusal surface. In lateral view the crowns differ from those of other species of Dasyatis in having flatter occlusal surfaces. The posterior folding and central slope resemble features of teeth of D. (=Trygon) alveolatus Leriche, 1940. D. alveolatus is an early Paleocene species known from the Kincaid
Formation of Texas. Specimens of *D. alveolatus* were collected by H. V. Andersen and identified from the LSUMG micropaleontology collection by Earl Manning. *Dasyatis matrix* differs from *D. alveolatus* in having a flatter, triangular occlusal surface and in having vermiculate ornamentation rather than a pattern of circular depressions. The referred vertebral centra closely resemble those of the recent species *D. sabinae*.

Figure 22. *Dasyatis matrix* n. sp. LSUMG V-725, tooth (male).

A. occlusal view; B. basal view; C. anterior view;
D. posterior view; E. lateral view.
Figure 23. *Dasyatis matrix* n. sp., vertebral centra; in medial, ?dorsal, and ?lateral views

A–C  LSUMG V-733a  D–F  LSUMG V-732a
G–I  LSUMG V-731a  J–L  LSUMG V-729a
Genus *Rhombodus* Dames, 1881

*Rhombodus tortus* n. sp.

**Figure 24**

Batoidea (in part) Schiebout, 1973, pp. 41, 44; Fig. 16c, p. 48.

*Type.*—LSUMG V-236, isolated tooth (lower, female); from Ray's Bonebed (VL-9).

*Referred specimens.*—LSUMG V-226-229; 231-236; 93 isolated teeth: V-230, vertebral fragments; TMM 40535-a,b; 2 unnumbered teeth; Ray's Bonebed, TMM 41274-a,b; 2 unnumbered teeth, C-Con.

*Localities.*—Ray's Bonebed (VL-9), mid-Tiffanian; C-Con (VL-122), early Tiffanian.

*Distribution.*—Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Tiffanian.

*Etymology.*—Latin tortus, crooked, with reference to the appearance of the teeth in lateral view.

*Diagnosis.*—Teeth with rhomboidal (females) or triangular (males) occlusal surfaces; crowns larger than roots in all dimensions; sides of crowns not vertical; female teeth with obtuse-angled sides in anteroposterior view, male teeth trapezoidal in anteroposterior view. Occlusal surface ornamented with small circular pits; anterior and posterior faces with vertical wrinkles; anterior margin a jagged shelf. Prominent posterior vertical ridge on most teeth. Postero-basal roll present. Roots robust and generally bifurcated; external foramina frequently present below anterior base of crown. Differs from *R. binkhorsti* in lacking transverse separation of occlusal surface into two parts; differs from *P. levis* in having ornamented occlusal surface.
Description.—The teeth range in size from 1 to 3 mm. The occlusal surfaces are polygonal; rhombic in females and triangular in males. This surface is ornamented with tiny circular pits or alveoli; the pattern may extend past the posterior margin onto the lingual side of the crown. The sides are wrinkled to a varying extent with vertical furrows; the wrinkles may extend onto the lower portion of the lingual side. A transverse fold on the posterior side distorts the lateral outline of the teeth; this produces a protrusion over the posterior of the roots that almost obscures the roots in occlusal view. On most teeth a strong posterior ridge is present that rarely bears a vertical carina; this ridge descends from the posterior corner of the occlusal surface to form an additional bulge on the posterior protrusion.

The anterior face below the occlusal surface roughly parallels the posterior face; near its base there is a jagged transverse rim. Beneath this rim, the crown angles back to the root in a flat or slightly concave overhang. In anterior view, the lower margin of the crown is sinuous, with a dip in the center. An indented ring separates the crown from the root in basal view. The root is high and robust, projecting posteriorly, and usually bifurcated. Most teeth have a medial foramen of varying size in the central root canal. Some also have lateral foramina in the wall of the canal. Foramina are also present in some specimens high on the anterior of the root. Referred male teeth differ from those of females in having high cusps and an occlusal surface that is triangular, with a depression variably developed into an anteroposteriorly oriented sulcus on the anterior surface.
Figure 24. *Rhombodus tortus* n. sp.: teeth.

A-E  LSUMG V-236 (type); occlusal, basal, anterior, posterior, and lateral views;
F-G  LSUMG V-233; occlusal and basal views;
H,I  LSUMG V-235; occlusal and lateral views;
J-L  TMM 40535-b, male; occlusal, basal, and lateral views;
M-Q  LSUMG V-231, male; occlusal, basal, anterior, posterior, and lateral views.
Discussion.--Referral to *Rhombodus* is based on the diamond-shaped flat occlusal surface and the relatively high crown. The ornamentation resembles that seen in *Dasyatis* (=*Trygon*) *alveolatus* Leriche, 1940, and that seen in *Myleadaphus* *pygmaeus* (Quaas, 1902) as illustrated by Stromer and Weiler (1930, Pl. II, Fig. 15a). *Rhombodus* *tortus* teeth differ from those of *Myleadaphus* in having less vertical sides, and occlusal surfaces tilted with respect to the root; they differ from teeth of *Dasyatis* in having flat, rhomboidal crowns rather than arched, transversely elongate crowns.

Class OSTEICHTHYES

Order AMIIFORMES

Genus *Amia* Linnaeus, 1766

*Amia* cf. *A. uintaensis* (Leidy, 1873)

Figure 25

*Amia* cf. *uintaensis* (Leidy). Boréske, 1974, p. 64.

Referred specimens.--LSUMG V-1332, partial vertebral centrum; V-1370, tooth cap.

Locality.--Running Lizard (VL-113).

Distribution.--Lance Formation, Wyoming; Hell Creek Formation, Montana; Ojo Alamo Formation, New Mexico; Aguja Formation, Texas.

Maastrichtian.

Description.--L=9.5. V-1332 preserves the major portion of the right half of a vertebral centrum. The centrum is amphicoelous, and dorsally it exhibits the lateral borders of a neural arch facet that is wider at the anterior and posterior ends. The remnant of the right basapophysis is present; it projects slightly posteriorly. In sagittal
view, the margin of the centrum below the basapophysis is concave. The referred tooth cap is a simple pointed cone, lacking carinae.

Discussion. — Referral to Amia cf. A. uintaensis is based on the large size and the concave ventral outline of the vertebral centrum, as discussed by Boreske (1974, p. 64). The simple, unkeeled tooth cap is referred on the basis of resemblance to tooth caps in the Recent Amia calva. Many other similar caps that possess keels were recovered from this locality, but it is not certain whether they are from teeth of amiids or gars. Amia cf. A. uintaensis has been previously reported from the Aguja Formation of Big Bend National Park (Boreske, 1974).

Figure 25. Amia cf. A. uintaensis.

A-D. LSUMG V-1332, partial vertebral centrum, in: posterior, dorsal, lateral, and medial views; E,F. LSUMG V-1370, tooth cap. Lateral and occlusal views.
Amia sp. indet.

Figure 26

Referred specimens.--LSUMG V-723, partial vertebral centrum; V-724, marginal tooth; V-773, edentulous partial right dentary.

Locality.--Dogie (VL-108).

Distribution.--Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Puercan (early Paleocene).

Description.--Vertebra: L=2.03, W=4.19. V-723 preserves the upper portion of an amphicoelous centrum. Two hourglass-shaped neural facets are situated on either side of the median dorsal groove. The remnants of basapophyses are present at the ventral lateral margins. A chordal foramen is present. The angle between the basapophyses is approximately 120°.

The dentary fragment preserves rectangular bases of six teeth. The exterior is pitted. The isolated tooth is strongly recurved and has a simple pointed conical cap that lacks carinae.

Discussion.--The referred specimens of this smaller Amia species may belong to A. fragosa (Jordan), 1927, which is known from Paleocene deposits (Boreske, 1974, p. 37). Diagnostic elements such as styliform palatal teeth have not yet been recovered.
Figure 26. *Amia* sp. indet.

A,B. LSUMG V-723, partial vertebra; sagittal and dorsal views

C. LSUMG V-724, marginal tooth

D,E. LSUMG V-773, partial right dentary; dorsal and external views.
Order LEPISOSTEIFORMES
Family LEPISOSTEIDAE
Genus Atractosteus Rafinesque, 1820

Atractosteus sp. indet.

Figure 27

Referred specimens.--LSUMG V-722, partial dermopalatine; V-717, dermal bone; V-719, fangs; V-721, teeth; V-720, palatal teeth; V-713, vertebra fragments; V-768, lateral line scales; V-714, fulcral scales; V-712, lepidotrichia; V-718, bone fragments.

Locality.--Dogie (VL-108).

Distribution.--Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Puercan (early Paleocene).

Description.--The dermopalatine preserves two rows of teeth; the inner teeth are about twice the size of the outer. The bases of the teeth are fluted, and the sides are finely striated. A few teeth are unbroken and retain enamel caps, which are conical and lack carinae. The mesial edge of the bone is smoothly tapered; distally longitudinal flanges are present. The referred isolated teeth include large fangs, medium-sized marginal teeth, and small palatal teeth. All lack carinae on the enamel caps; the caps of the larger fangs are falciform. The referred dermal bone, V-717, is thick at one end but tapers smoothly to a thin edge. It is sculptured with ridges that bear scattered enamel tubercles. Lateral-line scales are rhombic and covered with ganoine, which is perforated by many tiny foramina.

Discussion.--Referral to Atractosteus is based on the presence of a row of enlarged teeth on the dermopalatine, as described by Wiley (1976, p. 61). V-722 is comparable in size to specimens of medium-
sized, non-juvenile Recent Atractosteus spatula, the alligator gar. Teeth of A. spatula from the lower Mississippi River, however, have enamel caps that bear one or two carinae. The enamel pattern on the referred dermal bone specimen, V-717, is similar to that illustrated for various skull elements of A. occidentalis (Cretaceous) and A. simplex (Eocene) by Wiley (1976, pp. 68-69).

Figure 27. Atractosteus sp. indet.

A,B. LSUMG V-722, dermopalatine fragment; ventral and lateral views.
C,D. LSUMG V-719, fang; lateral view and cap detail.
E. LSUMG V-717, dermal bone.
F,G. LSUMG V-768, lateral line scale; dorsal and ventral views.
Lepisosteidae indet.

Figure 28

Referred specimens.--Many, including LSUMG V-1360-1369, V-1376; teeth, scales, lepidotrichia, vertebrae, and dermal bone fragments.

Localities.--LSUMG VL-9, 107, 109, 111, 112, 113, 122, 134, 144, and 148. Specimens described below are from Running Lizard (VL-113), which is Maastrichtian in age.

Distribution.--Aguja Formation and Javelina Formation (Javelina and Black Peaks Members), Big Bend National Park, Texas. Late Cretaceous (Maastrichtian) to Late Paleocene (Tiffanian).

Description.--Dermal bone: V-1376 includes fragments of thick dermal bone, some of which is covered with sheets of enamel. Other fragments have enamel distribution more restricted to round tubercles and oblong patches.

Teeth: Large fangs have enamel caps with keels that extend to the base of the enamel. Smaller teeth have more elongate, lanceolate enamel caps with keels that extend only part way down the sides of the cap. Fine striations are present on the sides of the teeth.

Scales: Shape is generally rhomboidal, varying from very long and narrow to relatively broad with convex margins, depending on body position. Some retain small pointed lateral denticles on the margin. Some very small scales are teardrop shaped. Midline scales are polygonal. The ganoine surface is variably smooth or rough, generally with few perforations. V-1369 differs in having ganoine limited to parallel strips posteriorly.
Figure 28. Lepisosteidae indet. from Running Lizard (VL-113).

A-C. LSUMG V-1363b, vertebral centrum; anterior, dorsal, and ventral views. D. LSUMG V-1363a; anterior view.
O. LSUMG V-1369, scale. P. LSUMG V-1368, midline scale.
Q-U. LSUMG V-1366, miscellaneous scales.
Lepidotrichia: These fin elements vary from small and short to very large and elongate. Ganoine is distributed in thin longitudinal strips. V-1362 has a more elaborate pattern of anastomosing whorls.

Vertebrae: Referred specimens are opisthocoelous. The shape of the centrum varies from oblong to subtriangular, with a ventral constriction.

Discussion.--From the wide variety of size, shape, and ornamentation of elements, it is probable that two or more species of gar are present at Running Lizard (VL-113). It is for this reason that specimens from this locality were selected for discussion and illustration. The locality represents a lacustrine habitat.

Class AMPHIBIA
Order ALLOCAUDATA
Family ALBANERPETONTIDAE
Genus Albanerpeton Estes and Hoffstetter, 1976
Albanerpeton nexuosus Estes, 1981

Figure 29


Referred specimen.--LSUMG V-1371; partial right maxilla.

Locality.--Running Lizard (VL-113).

Distribution.--Lance Formation, Wyoming; upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.--The specimen is triangular in lateral view. The anterior and posterior margins are broken off. Externally, four foramina are visible--three in an irregular row at midheight, and one more dorsally situated. Internally, a supradental shelf is present.
Two complete teeth remain in the jaw. The teeth are pleurodont, non-pedicellate, weakly tricuspid, and slightly spatulate. The tiny cusps are anteroposteriorly aligned and appear beadlike in occlusal view. The teeth show a line of pigmentation at the tips. No grooves or striations are present. In sagittal view the teeth are chisellike. They protrude one-third of their height below the edge of the bone. Two foramina are visible internally at the base of the tooth row, and one foramen appears above the shelf.

**Discussion.**—Referral to *Albanerpeton nexuosus* is based on size and resemblance to specimens from the Lance Formation as described by Estes (1964, Fig. 44; 1981, p. 24). The teeth of V-1371 more closely resemble teeth of this species than those of *A. galaktion* Fox and Naylor, 1982, from the Milk River Formation, in that the apices are more perfectly aligned anteroposteriorly than those illustrated by Fox and Naylor (1982, Fig. 4).

Estes (1964) originally grouped skull elements of *A. nexuosus* with vertebral elements of *Prodesmodon copei* Estes, 1964. The skull elements were later recognized as distinct (Estes, 1981). Fox and Naylor (1982) erected a new family and suborder for the genus on the basis of distinct features that include the lizard-like line of external foramina on the dentary and maxilla and the pleurodont, chisel-like, faintly tricuspid, non-pedicellate teeth that usually lack a foramen at the base. Both of these characters are present in V-1371.
Figure 29. *Albanerpeton nexuosus*. LSUMG V-1371, partial right maxilla.

A. internal view; B. external view; C. anterior view; D. teeth in occlusal view.
Order CAUDATA
Suborder PROTEOIDEA
Family BATRACHOSAUROIDIDAE
Genus Opisthotriton Auffenberg, 1961

Opisthotriton kayi Auffenberg, 1961

Figure 30


Referred specimen.—LSUMG V-935; partial vertebra.

Locality.—Tom's Top (VL-111).

Distribution.—Western North America. Late Cretaceous (Campanian) to Late Paleocene (Tiffanian).

Description.—L=5.08+; estimated width between tips of prezygapophyses=3.0. V-935 preserves most of the anterior portion, including the left prezygapophysis and the neural arch. The anterior cotyle is broken off; the remaining centrum is plugged with calcified material that has a central depression. The prezygapophyseal facet is tilted rather steeply from the horizontal; this appears to be due to distortion. The posterior cotyle is circular and slightly concave. Two rib bearers are present on each side. They are closely adpressed and oriented obliquely posterior. Lateral foramina are present below the leading edge of the ventral lamina of the transverse process. Antero-posteriorly oriented dorsal and ventral ridges are present. The ventral keel has been bent dextrally by distortion. Prominent posterior basapophyses, which extend anteriorly to the level of the posterior of the prezygapophysis, are also present. The posterior portion of the neural arch is broken off.
Figure 30. *Opisthotriton kayi*. LSUMG V-935, posterior cervical or anterior trunk partial vertebra, in:

A. anterior; B. posterior; C. dorsal; D. ventral; E. left lateral; and F. right lateral views.
Discussion.—Referral to **Opisthotriton kayi** is based on the presence and development of posterior basapophyses, size, and the presence of opisthocoely, which is indicated by the concave posterior cotyle. These features are discussed by Estes (1981, pp. 33-35).

The dorsal rib bearer of V-935 is relatively larger than in Cretaceous specimens from the Lance Formation as illustrated by Estes (1964, Fig. 38). It more closely resembles rib bearers of specimens from the Middle Paleocene Tongue River Formation of Montana, as illustrated by Estes (1976, p. 506). The relatively short length of the specimen and the relatively small anterior wing of the ventral lamina of the transverse process indicate that V-935 is either an anterior trunk or posterior cervical vertebra.

**Suborder AMBYSTOMATOIDEA**

**Family SCAPHERPETONTIDAE**

**Genus Scapherpeton Cope, 1877**

**Scapherpeton tectum** Cope, 1877

**Figure 31**


Referred specimen.—LSUMG V-1333; partial vertebra.

Locality.—Running Lizard (VL-113).

Distribution.—Western North America. Late Cretaceous
(Campanian) through Late Paleocene (Tiffanian).

Description.—L=4.87+. The cotyle is procoelous, with W=3.06, H=3.65. A notochordal foramen is situated in the upper third of the cotyle. The cotyle is oval in outline, with a rounded margin. Basapophyses are not present. In ventral view, the centrum is hourglass shaped, with a weak central keel and a small subcentral foramen. Breakage has removed all but the bases of the rib bearers, which are hollow and connected by a web of bone, visible in right lateral view. A large lateral foramen extends from the center of the centrum (in lateral view) posteriorly through the transverse process.

Discussion.—Referral to Scapherpeton tectum is based on the oval outline of the cotyle, the high position of the notochordal foramen, the presence of a ventral keel, the absence of basapophyses, and the two rib bearers connected by a web of bone. These features are indicated by Estes (1981, p. 50) as distinguishing vertebrae of this species. The ventral keel of V-1333 is relatively weak, indicating it is probably a cervical or anterior vertebra (Estes, 1964, p. 63; 1975, p. 366).
Figure 31. *Scapherpeton tectum*. LSUMG V-1333, partial vertebra, in:

A. anterior; B. posterior; C. dorsal; D. ventral; E. left lateral; and F. right lateral views.
Suborder SALAMANDROIDEA

Family SIRENIDAE

Genus Habrosaurus Gilmore, 1928

Habrosaurus dilatus Gilmore, 1928

Figure 32


Referred specimen.—LSUMG V-927; partial atlas.
Locality.—Tom's Top (VL-111).
Distribution.—Western North America. Late Cretaceous (Campanian) to Late Paleocene (Tiffanian).

Description.—L=3.5, W=5.5. V-927 lacks a neural arch. The specimen is trapezoidal in dorsal view, with a rounded anterior protuberance produced by the intercotylar process, which is directed slightly ventrally. The condylar surface is strap shaped, and it is continuous across the intercotylar process. The condylar surface is ventrally deflected at the midline, producing an open V-shaped dorsal outline in anterior view. The posterior cotyle is circular. A rounded ventral median ridge is present. Asymmetrical anterior and posterior foramina are situated on either side of this ridge. Laterla fossae are present behind the condyles.

Discussion.—Referral to Habrosaurus dilatus is based on the lateral fossae, circular posterior condyle, strap-shaped condylar surface, median ventral ridge, and sub-central foramina, as discussed by Estes (1982, p. 94). The dorsal margin of the intercondylar process is more open, and the ventrolateral foramina are less symmetrical in
V-927 than in UCMP 49519 as illustrated by Estes (1964, p. 75, Fig. 37a).

Figure 32. Habrosaurus dilatus. LSUMG V-927, partial atlas, in:
A. anterior; B. posterior; C. right lateral;
D. dorsal; and E. ventral views.

Order ANURA
Indeterminate Frog

Figure 33

Referred specimen.—LSUMG V-782; distal left humerus fragment.

Locality.—Dogie (VL-108).

Distribution.—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Puercan.

Description.—The diameter of the abraded ball is 1.8 mm. The ball is relatively small, and its dorsoventral axis forms a slightly
obtuse angle with the remnant of the shaft. The entepicondyle is relatively small and has a rounded tip. The crista medialis is distinct, and a groove is present on its ventral side. The fossa cubitus ventralis is deepest on the medial side. A ridge descends the lateral side of the shaft toward the ectepicondyle, which is broken so that its size and shape cannot be determined. The medial border of the olecranon scar ascends the dorsal side toward the mid-line of the shaft; the lateral boundary is not discernable.

Discussion.--V-782 is recognized as belonging to a frog because of the prominent distal ball (Hecht and Estes, 1960, p. 3). The worn and broken state of the specimen precludes more detailed assignment at this time.

Figure 33. Indeterminate frog. LSUMG V-782; distal left humerus fragment, in:

A. ventral; B. dorsal; C. medial; and D. lateral views.
Class REPTILIA
Order TESTUDINES
Family BAENIDAE?
Genus Compsemys Leidy, 1856

**Compsemys victa** Leidy, 1856

Figure 34


**Referred specimen.**--LSUMG V-1354; plastron fragment.

**Locality.**--Running Lizard (VL-113).

**Distribution.**--Late Cretaceous (Maastrichtian) to mid Paleocene (Torrejonian) of New Mexico, North Dakota, and Wyoming (Gaffney, 1972, p. 289). Upper Aguja Formation, Big Bend National Park, Texas; Maastrichtian.

**Description.**--The specimen is abraded, but it preserves a number of closely spaced, flat-topped enamel tubercles on the surface. About 5 to 7 tubercles are present in 5 linear mm. The edge of the fragment exhibits distinct bone lamellae beneath the ornamented surface.

**Discussion.**--The combination of the lamallar bone structure characteristic of turtle bone (Zangerl, 1969, p. 313) with the enamelled tuberculate ornamentation indicates that this specimen belongs to Compsemys victa. Among the turtles, this type of ornamentation has been reported as unique to this form, a turtle of uncertain familial affinities that is currently assigned to the Baenidae (Gaffney, 1972).
The size of the tubercules in V-1354 agrees well with that reported by Hay (1910, p. 310).

Figure 34. *Compsemys victa*. LSUMG V-1354, plastron fragment.

A. External view. B. Lateral view.

Order LACERTILIA

Family ANGUIDAE

Genus *Glyptosaurus* Marsh, 1871

*Glyptosaurus cf. G. sylvestris* Marsh, 1871

Figure 35


Referred specimens.--LSUMG V-791, partial left maxilla; V-916a, cephalic osteoderm; V-916b, c, d, and V-794a, body osteoderms.
Localities.--Dogie (VL-108) and Tom's Top (VL-111).

Distribution.--Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (lower Paleocene).

Description.--Maxilla: V-791 preserves 5 teeth that are obtuse with horizontal apical cutting edges. Striations, present both labially and lingually, are confined to the crown. The teeth increase in size anteriorly but do not become greatly expanded. The length of the largest tooth is 0.81 mm.

Osteoderms: V-916a is a cephalic osteoderm that is platelike and hexagonal in outline. It is covered with tubercles, some of which are joined. Scattered small foramina are present in the intertubercular depressions. The tubercles show a tendency toward arrangement in concentric rows. The remaining specimens are body osteoderms. Most are rectangular to subrectangular, with keels and tuberculate ornamentation that shows a variably concentric arrangement. The anterior gliding surface is approximately one-third of the length. The osteoderms are relatively thick and have an oblique lateral surface that is faintly rugose. Scattered foramina are present in the intertubercular depressions.

Discussion.--The presence of tuberculate dermal armor places the specimens within the subfamily Glyptosaurinae, and the presence of hexagonal cephalic osteoderms likewise places the specimens within the tribe Glyptosaurini, according to Sullivan (1986, p.34). Within this tribe, the genera Paraglyptosaurus and Glyptosaurus posses platelike rather than bulbous osteoderms. The teeth of V-791 resemble those of Glyptosaurus rather than those of Paraglyptosaurus in that they are relatively less expanded and do not show a basal constriction or
Figure 35. *Glyptosaurus* cf. *G. sylvestris*.

A-C. LSUMG V-791, partial L. maxilla, in external, internal, and occlusal views.

D. LSUMG V-916a, cephalic osteoderm.

E. LSUMG V-916c, body osteoderm.

F. LSUMG V-916d, body osteoderm.

G. LSUMG V-794a, body osteoderm.
internal grooves as illustrated by Gilmore (1928, Fig. 66). The specimens from Big Bend are therefore referred to *Glyptosaurus*. The teeth resemble those of *G. sylvestris*, which ranges in western North American Bridgerian (mid Eocene) deposits from Wyoming to New Mexico (Sullivan, 1986). The concentric ring pattern is not as strongly developed on the Puercan Big Bend specimens as in Eocene *G. sylvestris*. The discovery of fossils probably referrable to this species represents a considerable chronological range extension for the tribe Glyptosaurini.

**Order SERPENTES**

**Suborder SCOLECOPHIDIA**

**Family ?Anomalepididae**

**Genus Suffosio n. genus**

**Type species.**—*Suffosio praedatrix* n. sp.

**Distribution.**—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Puercan (early Paleocene).

**Etymology.**—Latin; mining or undermining, with reference to the life habits of scolecophidians. The gender is feminine.

**Diagnosis.**—Scolecophidians having vertebrae with very depressed neural arches and a strong dorsal anteroposterior bar on the centrum.

*Suffosio praedatrix* n. sp.

Figure 36

**Type.**—LSUMG V-797; isolated vertebra.

**Locality.**—Dogie (VL-108).

**Distribution.**—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Puercan (early Paleocene).
Etymology.--Latin; huntress.

Diagnosis.--Vertebrae about the same size as in Typhlops punctatus, with vertebrae having very depressed neural arches (height of neural arch approximately equal to height of cotyle). Dorsal margin of arch between zygosphenes horizontal, with no median lobe. Centrum with strong anteroposterior dorsal bar, rather than weak, emarginated and interrupted dorsal ridge as in Typhlops or double cone structure as in Leptotyphlops.

Description.--L=2.01+. V-797 preserves most of the vertebra. The condyle, tips of the prezygapophyses, and the posterior margin of the neural arch are broken off. The neural arch is very low. In anterior view the height of the neural arch is approximately equal to the height of the cotyle. The outline of the neural canal in anterior view is trilobate; the larger dorsal lobe is gently arched. The zygosphene width is 1.00 mm. In dorsal view, the zygosphene has a straight anterior margin that lacks a median lobe. In anterior view, the dorsal surface of the neural arch between the zygosphenes is horizontal. The cotyle is oval, wider than high, and is oriented slightly ventrad. No paracotylar foramen is visible on the base of the left prezygapophysis, which is the more complete. In ventral view, the centrum is cylindrical. A moderately large, off-center, ventral foramen is present at midlength. A weak collar is present at the anterodorsal border of the cotyle. The lateral margin of this collar is angulated, so that in anterior view the ventral outline of the cotyle appears slightly squared. The remaining prezygapophysis is oval and relatively wider than in Typhlops punctatus. The broken base of a
Figure 36. *Suffosio praedatrix* n. g., n. sp.
LSUMG V-797 (type); vertebra, in:

A. anterior; B. posterior; C. left lateral;
D. right lateral; E. dorsal; and F. ventral views.
small prezygapophyseal process is preserved. The surface of the synapophysis is abraded, but the shape of the remaining base indicates it was oval shaped. In posterior view, the posterior portion of the neural arch is very gently arched dorsally. On either side, below the broken posterior margin, triangular cavities are present representing the zygantra. The neural arch has a rudimentary ridge at the posterior margin. The dorsal surface of the centrum, visible inside the neural arch, shows a strong anteroposterior central bar that is wider anteriorly and narrows posteriorly. The bar is bordered on either side by shallow grooves. A lateral foramen is present on the right side of the vertebra, but none is visible on the left.

Discussion.—Referral to the suborder Scolecophidia, the blind snakes, is based on resemblance to vertebrae of Recent Typhlops and Leptotyphlops, with which the specimen has been directly compared. V-797 exhibits the highly depressed vertebral shape, the lack of neural spine or hemal keel, the oval cotyle, and relatively large subcentral foramen characteristic of these snakes (Rage, 1984, p. 8). V-797 resembles the vertebrae of the anomal epidid Liotyphlops in having a more depressed neural arch than is present in Typhlops and Leptotyphlops (List, 1966, p. 33). On this basis Suffosio praedatrix is tentatively assigned to the Anomal epididae. Comparison with actual specimens of members of this family has not yet been made, but based on List's illustrations (1966, Plate 13), Suffosio differs from Liotyphlops in having a relatively narrower centrum and a more constricted waist between the pre- and postzygapophyseal wings. The existence or relative development of a dorsal bar on the centrum in anomal epidids has not been described.
Suffosio praedatrix is the oldest scolecophidian yet reported. Fossils of members of this suborder have been recovered from deposits of the Eocene of Belgium and France, the Miocene of France and Saudi Arabia, and the sub-Recent of Mauritius (Crochet et al., 1981; Thomas et al., 1982; Rage, 1984). The strong dorsal bar of the vertebral centrum probably represents a primitive condition from which the double-cone structure seen in Leptotyphlops and the narrow ridge of Typhlops may have been derived.

Suborder ALETHINOPHIDIA

Family BOIDAE

Genus Dunnophis Hecht, 1959

Dunnophis cf. D. microechinis Hecht, 1959

Figure 37


Referred specimens.--LSUMG V-866, V-942, partial vertebrae; V-796, vertebral fragments.

Localities.--Dogie (VL-108) and Tom's Top (VL-111).

Distribution.--Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

Description.--L=3.51, est. W=3.9. The centrum is narrow and is separated from the lower sides of the neural arch by deep grooves. The grooves extend from the lower lateral borders of the cotyle posterior, not quite extending to the anterior border of the condyle. A short, very weakly developed carina is present on the centrum anterior to the condyle. In anterior view, the cotyle is oval and is slightly
wider than high. The neural canal is approximately the same height as the cotyle. The zygosphene is slightly wider than the cotyle. The left prezygapophyseal facet (the right is broken off) is almost horizontal. A very small nubbin is present below the prezygapophysis, forming a rudimentary process. Small paracotylar foramina are present.

In dorsal view, the prezygapophyseal facet is shaped like a parallelogram with rounded corners, and it is about twice as long as it is wide. The median lobe of the zygosphene is moderately developed. A median notch is present on the posterior border of the neural arch. The apex of the small neural spine is broken off; the remaining base is circular. In lateral view, the neural spine is restricted to the posterior third of the neural arch. It rises from the neural arch relatively abruptly, with a slight elevation anterior to the major ascending slope. A lateral foramen is present on each side postero-ventral to the posterior margins of the prezygapophyses. On the left side, which is the better preserved, the diapophysis is abraded. The remaining base is bilobate, with a slight waist between the upper and lower lobes. In posterior view, the condyle is oval and well rounded, with slight abrasion on the ventral margin. It faces posteriad. The neural canal is highly arched and the lateral walls form a circular margin. The zygantra are deep.

Discussion. — Referral to *Dunnophis* is based on the narrow centrum with bordering grooves, the weak hemal keel, the short posteriorly situated neural spine, the presence of a posterior notch in the neural arch, and elongated prezygapophyseal facets with rudimentary accessory process, as discussed by Hecht (1959, p. 145) and Rage (1984, p. 28). Among previously described species of *Dunnophis*, the Big Bend
Figure 37. *Dunnophis cf. D. microechinis*. LSUMG V-866, partial vertebra, in:

A. anterior; B. posterior; C. left lateral;
D. right lateral; E. dorsal; and F. ventral views.
specimens most closely resemble *D. microechinis* Hecht, 1959, from the Bridgerian (middle Eocene) of Wyoming. The Big Bend form differs from specimens described by Hecht (1959, pp. 144-146, Pl. 56) in being relatively wider in overall proportions, in having a faint carina on the posterior portion of the centrum, and a slightly wider median lobe on the zygosphene. Also, the ventrolateral grooves do not quite extend to the condyle. Specimen V-866 exhibits a rudimentary accessory process on the prezygapophysis, but according to Hecht (1959, p. 146), one specimen from Wyoming has this feature. The differences between the Paleocene specimens and Eocene *Dunnophis microechinis* are not great enough to justify specific distinction at this time. The Paleocene specimens are relatively shorter, but as Hecht (1959, p. 145) recovered a relatively small sample (five specimens), the extent of variation in this character is unknown. Specimens of *Dunnophis matronense*, an Eocene species from France, have vertebrae with width approximately equal to length, as illustrated by Rage (1984, Fig. 17B).

Order CROCODILIA

Suborder MESOSUCHIA

Family GONIOPHOLIDAE

Goniopholidae indet.

Figure 38

*Referred specimen.*—LSUMB V-1202, scute fragment.

*Locality.*—Running Lizard (VL-113).

*Distribution.*—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

*Description.*—V-1202 is a fragment of a large, flat scute,
possibly a ventral scute (Langston, 1985, pers. comm.). The surface is worn and abraded, so that the ridges separating the subcircular pits are flat. The pits have concave rather than straight sides.

Discussion.—The pitting of the referred scute is similar to that of TMM 40956, from the Comanche Series of Texas, which was referred to the Goniopholidae by Langston (1974, p. 84). The pits in V-1202 are generally more circular.

![Image of scute fragment](x1)

Figure 38. Goniopholid scute fragment. LSUMG V-1202.

Suborder EUSUCHIA

Family CROCODYLIDAE

Genus Brachychampsia
cf. Brachychampsia sp. indet.

Figure 39

Referred specimens.—LSUMG V-787, V-788, V-868, V-907, V-944, V-1152, V-1301, V-1512, V-1540; isolated teeth.

Localities.—Glenn Eleven (VL-107), Dogie (VL-108), Tom's Top (VL-111), Maximound (VL-112), Running Lizard (VL-113), and Snail's Place (VL-144).

Distribution.—Upper Aguja Formation and Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Maastrichtian and Puercan.
**Description.**—The teeth are relatively low crowned and bulbous, with slightly bulging sides. The base of the crown is smooth, but the upper surface is covered with irregular, relatively coarse wrinkles that frequently anastomose. Smaller teeth tend to have proportionally fewer wrinkles; this may reflect ontogenetic change. An irregular longitudinal crest is present. Occasionally an anteroposteriorly oriented depression or groove is seen on the upper crown adjacent to this crest on unworn specimens.

**Discussion.**—Tentative referral to *Brachychampsia* is based on the relatively heavy wrinkling of the crowns, as described by Estes (1964, p. 142). The genus is reported from Late Cretaceous localities in Alberta, Montana, Wyoming, Colorado, and New Mexico (*ibid.*), but at Big Bend it appears to be present in the early Paleocene as well.

![Diagram of teeth](image)

**Figure 39.**  *cf. Brachychampsia* sp. indet. Isolated teeth.

A,B. LSUMG V-944a; occlusal and lateral views.
C,D. LSUMG V-944b; occlusal and lateral views.
E. LSUMG V-868a; occlusal view.
Crocodilia indet.

Morphotype A

Figure 40A

Referred specimens.--LSUMG V-784, V-787, V-914, V-943, V-1104, V-1153, V-1229, V-1254, V-1304, V-1511, V-1542; many isolated teeth.

Localities.--Glenn Eleven (VL-107), Dogie (VL-108), Hot White (VL-109), Tom's Top (VL-111), Maximound (VL-112), Running Lizard (VL-113), Middle Peak (VL-134), Snail's Place (VL-144), and Alligator Alley (VL-148).

Distribution.--Upper Aguja Formation, Javelina and Black Peaks Members, Tornillo Formation, Big Bend National Park, Texas. Maastrichtian to Torrejonian (middle Paleocene).

Description.--Tooth shape ranges from relatively tall with circular cross section to low with oval or reniform cross section. Anterior and posterior crests are present, which have fine oblique striae. The tooth crown is generally curved slightly laterad so that one side is convex in anteroposterior view. Weak vertical ridges are present near the base of the crown; these ridges extend farther toward the apex of the tooth on the convex side. Very fine wrinkles are present on the upper portion of the crown.

Morphotype B

Figure 40B

Referred specimen.--LSUMG V-893; isolated tooth.

Locality.--Dogie (VL-108).

Distribution.--Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).
Description.--The tooth is recurved and transversely compressed, with a lenticular cross section. The apex of the tooth is tilted only very slightly to one side, so that the tooth is basically erect, but recurved. There are anteroposterior crests with fine oblique striae. The enamel is covered with very fine, short wrinkles. No other ridges are visible, but the base of the crown was removed by breakage.

Morphotype C

Figure 40C

Referred specimen.--LSUMG V-1374; several isolated teeth.

Locality.--Running Lizard (VL-113).

Distribution.--Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.--The teeth are relatively low crowned and bulbous. In cross section the teeth are broadly lenticular to almost circular. Anteroposterior ridges with oblique striae are present, but the enamel is otherwise smooth.

Morphotype D

Figure 40D

Referred specimen.--LSUMG V-785; several isolated teeth.

Locality.--Dogie (VL-108).

Distribution.--Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

Description.--The teeth are large, stout, and circular in cross section. The apices of the crowns lean slightly to one side. Anterior and posterior crests are present, and the sides are covered with vertical wrinkles. These are fine and anastomosing at the top; larger and nonanastomosing at the base.
Figure 40. Teeth of indeterminate crocodiles.

A. LSUMG V-943a
B. LSUMG V-893
C. LSUMG V-1374
D. LSUMG V-785a (scale=10 mm. for D only)
E. LSUMG V-1302a
Morphotype E

Figure 40E

Referred specimen.—LSUMG V-1302; isolated teeth.

Locality.—Running Lizard (VL-113).

Distribution.—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.—The teeth are erect and only slightly recurved. Anterior and posterior crests are present. Strong, irregularly placed vertical ribs are present on both sides of the teeth.

Order SAURISCHIA

Suborder THEROPODA

Infraorder DEINONYCHOSAURIS

Family DROMAEOSAURIDAE

Dromaeosauridae indet.

Figure 41, Table 8

Referred specimens.—LSUMG V-1307, V-1308, V-1377; isolated teeth.

Locality.—Running Lizard (VL-113).

Distribution.—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.—The teeth are compressed laterally with lenticular cross sections. They are posteriorly recurved. Well-developed serrations are present on the entire posterior edge; smaller serrations are present on the upper portion of the anterior edge. A translucent keel is present on the lower portion of the anterior margin. The larger teeth, V-1307 and V-1308, may be from the same individual, as they have the same preservation. Both have 10 serrations per 2 mm. The smallest
tooth, V-1377, has the same morphology, with slightly finer serrations (12 per 2 mm.), but it is differently preserved.

**Discussion.**—Referral to the Dromaeosauridae is based on resemblance to the teeth of *Dromaeosaurus* described by Sahni (1972, p. 359). Dromaeosaurids are known from other Maastrichtian localities in North America (Carpenter, 1982). The smaller specimen, V-1377, probably represents a juvenile (Carpenter, 1982).

Table 8. Measurements of indeterminate dromaeosaurid teeth.

<table>
<thead>
<tr>
<th>LSUMG Specimen No.</th>
<th>L</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-1307</td>
<td>4.2</td>
<td>7.1</td>
</tr>
<tr>
<td>V-1308</td>
<td>4.2</td>
<td>est.8.5</td>
</tr>
<tr>
<td>V-1377</td>
<td>2.8</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Figure 41. Dromaeosauridae indet. teeth.

A-C. LSUMG V-1307; lateral, anterior, and basal views.
D-F. LSUMG V-1308; lateral, posterior, and lateral views.
G-I. LSUMG V-1377; lateral, anterior, and lateral views.
Family SAURORNITHOIDIDAE

Genus Paronychodon Cope, 1876

Paronychodon lacustris Cope, 1876

Figure 42


Referred specimen. -- LSUMG V-1310; partial tooth.

Locality. -- Running Lizard (VL-113), Maastrichtian.

Distribution. -- Judith River and Hell Creek Formations, Montana; Lance Formation, Wyoming; upper Aguja Formation, Big Bend National Park, Texas. Campanian and Maastrichtian.

Description. -- L=3.45+, H=7.55+. The tooth is strongly laterally compressed, with one side planar and covered by long ridges that parallel the edges of the crown. The ridges apparently radiate from the apex, which is broken off. The base is also damaged, but the anterior margin of the tooth shows an angulation near the lower part of the tooth.

Discussion. -- Referral to Paronychodon lacustris is based on the laterally compressed condition, one planar face, the basal angulation, and the radiating ridges. The specimen is very similar to others referred to this species by Carpenter (1982, p. 130) and Sahni (1972, p. 360).
Paronychodon lacustris. LSUMG V-1310, partial tooth.
A. ?External view; B. ?Internal view; C. posterior view.

Genus Saurornithoides Osborn, 1924

Saurornithoides sp. indet.

Figure 43

Referred specimen.--LSUMG V-1309; isolated tooth.

Locality.--Running Lizard (VL-113).

Distribution.--Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.--L=1.9, est. H=2.3. The tooth is compressed laterally and recurved. Posterior serrations are well developed, but no anterior serrations are present. A translucent keel extends down the anterior surface of the tooth almost to the base. The posterior serrations are tilted slightly upward, and there are 14 serrations/2 mm., or 35/5 mm.
Discussion.—Referral to *Saurornithoides* is based on the small size, recurved compressed shape, well developed posterior serrations, and lack of anterior serrations. The serrations are relatively finer than in *S. Junior* Barsbold 1974 and *S. mongoliensis* Osborn 1924 (Barsbold, 1974, p. 14). The Big Bend specimen may be a juvenile of *S. inequalis* (Sternberg) 1932, a North American species.

Figure 43. *Saurornithoides* sp. indet. LSUMG V-1309; isolated tooth.

A. lateral view; B. anterior view; C. basal view.
Genus *Pectinodon* Carpenter, 1982

cf. *Pectinodon* sp. indet.

Figure 44

**Referred specimen.**—LSUMG V-1335; partial tooth.

**Locality.**—Running Lizard (VL-113).

**Distribution.**—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

**Description.**—L=1.62+; H=2.36+. The tooth is compressed laterally, and strongly recurved. The upper portion of the tooth is flexed slightly to one side. The tip is broken off. Large serrations with translucent edges are present on the posterior margin. These serrations project posteriad, and there are six or seven serrations present per 2 mm. The serrations are largest in the middle of the preserved posterior edge. Very faint worn serrations are present on the upper portion of the anterior margin of the tooth. A weak, opaque keel extends a short distance below these anterior serrations.

**Discussion.**—Tentative referral to *Pectinodon* is based on resemblance to *P. bakkeri* Carpenter, 1982. The Big Bend specimen exhibits large posterior serrations perpendicular to the axis of the tooth. The Big Bend specimen differs from *P. bakkeri* as described by Carpenter (1982, p. 129) in having very small serrations on the upper anterior margin. The small size of V-1355 indicates it probably represents a juvenile (Carpenter, 1982).
Figure 44. cf. *Pectinodon*. LSUMG V-1355; partial tooth, in:

A. lateral; B. anterior; and C. basal views.

Infraorder CARNOSAURIA

Morphotype A

Figure 45A

Referred specimen.—LSUMG V-1375; partial tooth.

Locality.—Running Lizard (VL-113).

Distribution.—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.—L=4.0+, est. H=7. The tooth is not laterally compressed. It is oval in cross section, and very slightly recurved. Small serrations (14/2 mm.) are present on the posterior margin. No serrations are present on the anterior margin; a translucent keel is present that descends the anterior margin, diverging toward one side near the base.

Discussion.—The unequal division of the tooth crown by the anterior margin is an advanced carnosaur character, according to
Steel (1970, p. 37). The Big Bend specimen is similar in morphology to the teeth of *Dryptosaurus incrassatus*, as illustrated by Lambe (1904, Pl. VI). It differs in lacking anterior serrations and in its small size. The small size indicates it may represent a juvenile (Carpenter, 1982).

Morphotype B

Figure 45B

*Referred specimen.* --LSUMG V-1313; partial tooth.

*Locality.* --Running Lizard (VL-113).

*Distribution.* --Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

*Description.* --L=10.31+, H=13.42+. The specimen preserves the upper portion of a relatively large adult tooth. Serrations are present on both anterior and posterior margins, and they are subequal in size on both margins (12 serrations/5 mm.). The fragment is lenticular in cross section, and it is symmetrically divided by the anterior and posterior serrated edges. The tooth is evenly convex.

Morphotype C

Figure 45C

*Referred specimen.* --LSUMG V-1312; tooth fragment.

*Locality.* --Running Lizard (VL-113).

*Distribution.* --Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

*Description.* --This fragment preserves a portion of the serrated edge of a large carnosaur tooth. The scrap has 8 serrations/5 mm.

*Discussion.* --This tooth has serrations of appropriate size for a very large carnosaur such as *Tyrannosaurus*. The locality from which it
was recovered is considered to be Maastrichtian in age. *Tyrannosaurus* remains have been recovered from other areas in Big Bend National Park, from levels approximately 110 meters higher stratigraphically (Lawson, 1976).

Figure 45. Carnosaur teeth.

A. Morphotype A. LSUMG V-1375; lateral, anterior, and occlusal views.
B. Morphotype B. LSUMG V-1313; lateral and occlusal views
C. Morphotype C. LSUMG V-1312; lateral view.
Carnosauria incertae sedis

Figure 46

Referred specimen.—LSUMG V-1226; right femur, missing head.

Locality.—Port South (VL-149).

Distribution.—Uppermost Aguja Formation or lowermost Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Maastrichtian.

Description.—L=1080+, midshaft D=180; length of fourth trochanter=310; width across condyles=290. The shaft is straight and squared in cross section. The medial condyle is larger than the lateral condyle. The lateral condyle extends slightly farther distally. The fourth trochanter, which is the only trochanter preserved, is large and somewhat pendant. Its proximal end curves smoothly back to the level of the shaft. Muscle attachment scars are prominent on the ventral borders of the condyles, the medial side of the trochanter, the distolateral side of the shaft, and the distal end of the dorsal side of the shaft, proximal to the condyles.

Discussion.—The specimen is about the same size as the femur of Tyrannosaurus (Osborn, 1906, Fig. 9), but because the proximal end of the fourth trochanter does not extend to the head, it cannot be assigned to a member of the Tyrannosauridae (Russell, 1970, p. 2).

Order ORNITHISCHIA

Suborder ORNITHOPODA

Family HADROSAURIDAE

Figure 47

Referred specimen.—LSUMG V-1315, partial tooth with root; V-1318,
Figure 46. Non-tyrannosaurid carnosaur femur. LSUMG V-1226.
Scale=100 mm.
A. posterior view; B. medial view; C. distal view.
V-1319, numerous isolated teeth.

**Locality.**—Running Lizard (VL-113).

**Distribution.**—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

**Description.**—The specimens can be roughly divided on the basis of size into two groups. Smaller teeth generally are prismatic, with short roots and short, heavily worn crowns. Wear facets are polygonal, with varying shapes depending on position in the tooth battery. An additional wear facet is present on many specimens extending basally on the median external ridge. A basal cavity is frequently present.

A relatively unworn tip of a larger tooth, V-1318a, exhibits a narrow, lanceolate shape with a strong median ridge and large, rounded lateral denticles. V-1315, which preserves the base of the enamel as well as a large portion of the root, also exhibits a narrow lanceolate shape with diverging enamel borders indicating a rhombic enamel surface.

**Discussion.**—The smaller teeth are comparable in size to those considered to represent babies by Carpenter (1982, p. 131). This is the most common type of dinosaur tooth found at this locality.

Hadrosaurs reported from Big Bend (Davies, 1983) include *Kritosaurus* and a second unidentified genus from the Aguja Formation (upper Campanian portion of the section), and cf. *Edmontosaurus* from the Javelina Member of the Tornillo Formation (Maastrichtian). The level of Running Lizard is stratigraphically intermediate between these levels. The larger teeth from Running Lizard appear to be slightly wider than that of *Kritosaurus* illustrated by Steel (1969, p. 21). The hadrosaurs at Running Lizard may be referable to *Edmontosaurus*. 
Figure 47. Hadrosauridae indet. teeth.

A-C. LSUMG V-1315, adult tooth with root; external, lateral, and occlusal views.
D. LSUMG V-1318a, apex of adult tooth; external view.
E-H. LSUMG V-1319a, juvenile tooth; occlusal, basal, internal, and external views.
Suborder ANKYLOSAURIA

Family ANKYLOSAURIDAE

Genus Euoplocephalus Lambe, 1910

cf. Euoplocephalus sp.

Figure 48

Referred specimen.—LSUMG V-1305; isolated tooth.

Locality.—Running Lizard (VL-113).

Distribution.—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.—L=3.92, W=2.01. The crown is slightly larger than the root, which is oval in cross section. The major diameter of the root is 2.32 mm. The tooth is triangular in lateral view. The apex is worn, and a large wear facet has reduced one side (?internal) to a steep planar surface that extends to the base of the crown. The apex of the crown lies slightly posterior to the midline. The anterior margin has four serrations that increase gradually in size as they ascend the slope. The lower two serrations have obliquely oriented crests and accessory lateral denticles. The remaining serrations have antero-posteriorly oriented crests. The posterior margin of the tooth has five serrations. On anterior and posterior ends of the crown, the serrated margin curves toward one side near the base of the crown. Both the crown and the serrations are swollen. Cingulum development is restricted to faint irregular ridges at the base of the serrated margins. Shallow fluting is visible on the unworn side, extending downward about one-third of the distance to the base of the crown.
Discussion.—Referral to the Ankylosauridae is based on the leaf-shaped crown with large serrations and the small size of the crown relative to the root. The Nodosauridae have teeth with larger crowns relative to root size, according to Coombs (1978, p. 151). Tentative referral to Euoplocephalus is based on overall resemblance to the tooth referred to Stereoccephalus tutus (=Euoplocephalus tutus) by Lambe (1902, p. 57). The Big Bend ankylosaurid tooth differs from previously described teeth of Euoplocephalus in having accessory denticles on some of the serrations, and in being relatively more swollen at the base. In these respects it resembles the teeth of Ankylosaurus magniventris as illustrated by Brown (1908, p. 191) and Carpenter (1982, p. 128). The Big Bend tooth does not appear to be as conical, however. The small size of V-1305 indicates it may represent a juvenile; it is only slightly larger than a tooth referred to Ankylosaurus as a baby by Carpenter (1982, p. 131). V-1305 is the first ankylosaurid specimen to be recovered from Big Bend deposits.
Figure 48. cf. Euoplocephalus sp. LSUMG V-1305; tooth, in:

D. ?posterior  E. occlusal; and F. basal views.
?Ankylosauridae incertae sedis

Figure 49

Referred specimen.--LSUMG V-1334, isolated tooth with apex broken off.

Locality.--Running Lizard (VL-113).

Distribution.--Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.--L=2.73, W=1.60. The crown has an oval cross section. The crown is relatively small, apparently only slightly wider and longer than the root, which is broken off. Five serrations are preserved on each of the anterior and posterior margins. The serrations are slightly larger on one end. They are simple, with anteroposterior crests, and are slightly swollen. The serrations are oriented perpendicular to the slope of the tooth margins. In anteroposterior view, the tip of the crown curves slightly to one side; on that side the base of the crown is swollen, with a small round wear facet visible at the level of the lowest serration. The sides of the crown adjacent to the serrations are slightly concave, becoming convex at midlength. The enamel is smooth, and no cingula are present.

Discussion.--Tentative referral to the Ankylosauria is based on the simple structure of the tooth and the relatively small crown. The specimen resembles teeth of Pinacosaurus Gilmore, 1933, from the Djadochta Formation of Mongolia, in lacking cingula.
Figure 49. *Ankylosauridae incertae sedis;* LSUMG V-1334, partial tooth, in:

D. ?anterior  E. occlusal; and F. basal views.
Suborder CERATOPSIA
Family CERATOPSIDAE
Ceratopsidae indet.

Figure 50

Referred specimen.--LSUMG V-1373; tooth fragment.

Locality.--Running Lizard (VL-113).

Distribution.--Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian.

Description.--The specimen preserves the upper portion of an adult tooth. The apex is broken off. The fragment is pyramidal, with four ridges descending from the apex. Three are denticulate. The denticles are relatively small and complex. Fluting is present on the sides of the two lateral ridges.

Discussion.--Referral to the Ceratopsidae is based on the pyramidal shape of the tooth crown, the large external ridge, lateral fluting, and size. Teeth of other ornithischians do not have the pyramidal apex seen in this specimen. The specimen is included here in order to document the presence of ceratopsians at this locality and stratigraphic level. The fossil may represent Torosaurus, which has been reported from the Javelina Member of the Tornillo Formation by Lawson (1976).
Figure 50. Ceratopsidae indet. LSUNG V-1373, tooth fragment.

A. Occlusal view; B. external view; C. internal view.
Class MAMMALIA

Order MULTITUBERCULATA

Suborder PTILODONTOIDEA

Family PTILODONTIDAE

Genus Ptilodus Cope, 1881

Ptilodus mediaevus Cope, 1881

Figure 51 A,B

Ptilodus mediaevus Schiebout, 1974, p. 9 (in part), Fig. 12 e, g.

Referred specimens.—TMM 40147-43, RM\textsuperscript{b} fragment; 40147-42, left mandible fragment with \(P_{3}-M_{1}\); 40147-47, \(LM_{1}\).

Locality.—TMM 40147 (T2) = Alligator Alley (VL-148). Torrejonian.

Distribution.—Nacimiento Formation, San Juan Basin, New Mexico; Fort Union Formation, Washakie Basin, Wyoming; Joe's Valley Member, North Horn Formation, Utah; Lower Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Torrejonian.

Description.—See Schiebout (1974, p. 9) for descriptions of referred specimens, except TMM 40147-43. This is a fragment of RM\textsuperscript{b} that preserves the anterolingual corner. The fragment is 2.8 mm. long and 2.0 mm. wide; it has 4½ cusps in the lingual row, and remnants of the second and third medial cusps. The lingual margin is slightly concave in occlusal view opposite the fourth cusp; its outline corresponds very closely to that of AMNH 3033 from the San Juan Basin.

Discussion.—Schiebout (1974) grouped all of the then known
specimens of *Ptilodus* from Big Bend in one species, *P. mediaevus*. Since that time, additional studies have been made that have greatly contributed to the concept of the genus and its included species. Rigby (1980) examined a large sample of *P. mediaevus* from the Swain Quarry of Wyoming and synonymized *P. ferronensis* Gazin, 1941, with *P. mediaevus*. Krause (1977) had previously described a new species, *P. kummae*, from the Tiffanian Roche Perce local fauna of the Ravenscrag Formation of Canada. Schiebout (1974, p. 10) indicated a range extension into the Tiffanian for *P. mediaevus*, but Krause (1977, p. 9) commented that this was based on inconclusive evidence, and that the three Torrejonian species of *Ptilodus* (*P. mediaevus*, *P. montanus*, and *P. wyomingensis*) are "remarkably similar to one another." Rigby (1980, p. 52) noted that specimens corresponding to the types of each of these species could be found in the large Swain Quarry sample, but did not synonymize them pending further study.

Specimens from Big Bend that are definitely referable to *P. mediaevus* have been recovered only from TMM locality 40147. These correspond in morphology, size, and cuspation to *P. mediaevus* as described by Rigby (1980). TMM 40147-45 and 40147-46, M₂'s, are here referred to *P. douglassi* because they are outside the size range of the large Swain Quarry sample for *P. mediaevus* (Rigby, 1980, p. 49). Other specimens previously referred to *P. mediaevus* by Schiebout (1974) include those from Joe's Bonebed, a late Tiffanian locality much higher in the section, and those from TMM locality 41274, C-Con. Specimen TMM 41274-4 is listed in error on p. 52 (Schiebout, 1974) as being from locality 41217. The specimens from Joe's Bonebed may belong
to *P. kummae*. The anterior profile of TMM 41365-445, an $\text{M}_b$, curves markedly posteriorly below the first serration, and the anteroexternal lobe of TMM 41365-62, an $\text{M}_b$, lacks definite cusps, as described for *P. kummae* by Krause (1977). Specimens from C-Con (TMM 41274) do not include elements that enable specific designation, and are slightly larger than specimens from the Swain Quarry sample (Rigby, 1980), so they are here assigned to *Ptilodus* sp. indet. (see below) pending recovery of better material. This reassessment of Big Bend *Ptilodus mediaevus* means that there are now no Tiffanian records for the species.

*Ptilodus* sp. indet.

Figure 51 C-J

*Ptilodus mediaevus* Schiebout, 1974 (in part), p. 9, Fig. 12b.

**Referred specimens.**—TMM 41274-4, $\text{LM}_1$; and six unnumbered TMM specimens, including $\text{LP}^2$, $\text{RM}_b$ fragment, $\text{RM}_2$, $\text{LM}_2$, and two $\text{RI}_1$'s.

**Locality.**—C-Con (VL-122=TMM 41274).

**Distribution.**—Lower Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Early Tiffanian.

**Description.**—$\text{LP}^2$: $L=2.65$, $W=2.18$. The crown is oblong in occlusal view, with concave labial and lingual margins. Four cusps are present; the lingual cusps are larger and higher than the labial cusps. The anterolabial cusp has an oblique crest, while crests on the remaining cusps are oriented more parallel to the midline. All cusps have additional wrinkles.

$\text{M}^b$: $L=3.50+$, $W=2.23+$. This specimen is the posterior portion of a $\text{Lm}^b$. The wear pattern on the crown indicates at least four cusps...
were present in the posterior half of the lingual cusp row.

M¹: This tooth has been previously described and illustrated by Schiebout (1974, p. 9).

M²: Dimensions of one specimen: L=3.09, W=2.75; the second specimen L=3.25, W=3.05+. Both specimens are slightly damaged, but each has one low cusp in the labial cusp row and three large cusps in the medial row. The lingual cusp row apparently had four cusps. The anterior margin is concave in occlusal view.

I₁: Both specimens have smoothly tapering crowns with a mesial ridge. In anterior view there is a flexure about two-thirds of the distance from tip to root.

Discussion.—The referred P² differs from P² of P. mediaevus in being relatively longer, but not as long as P² of P. kummae as described by Krause (1977). The referred M²'s are slightly larger than specimens of P. mediaevus from the Swain Quarry. Specific determination awaits the recovery of more definitive material.
Figure 51. *Ptilodus mediaevus* and *Ptilodus* sp. indet.

A,B. *P. mediaevus*. TMM 40147-43, RM² fragment; occlusal and lingual views.

C-J. *P. sp. indet.* unnumbered TMM specimens

C. RM² fragment; D. LP²; E. RM²; F. LM²; occlusal views

G,H. RI₁; I,J. RI₁; mesial and anterior views
Ptilodus douglassi Simpson, 1935

Figure 52


cf. Mimetodon douglassi (Simpson). Wilson, 1967, p. 159, Fig. 107.
Neoplagiaulax douglassi (Simpson). Sloan, in Schiebout, 1974, p. 12,
Fig. 14a,b.


Referred specimens. — TMM 40147-6 (=40147-15), RMb; 40147-38, RMb;
40147-68, anterior half, RMb; 40147-45, RMb; 40147-46, RMb;
LSUMG V-1256, anterior half, RMb.

TMM 40147-15, illustrated in Wilson (1967, p. 159, Figure 107),
is apparently the same specimen figured as 40147-6 on p. 54, Figure 14a
by Schiebout (1974). The number currently on the specimen is TMM
40147-6. Also, TMM 40147-66, anterior half of RMb (Schiebout, 1974,
p. 12) is missing, but a similar specimen, 40147-68, is present. This
may be the same specimen, with the number changed due to a typographic-
al error.

Locality. — Middle Peak (VL-134=TMM 40147). Torrejonian.

Distribution. — Upper Lebo Formation, Montana; lower Black Peaks
Member, Tornillo Formation, Big Bend National Park, Texas.
Torrejonian.

Description. — Mb: Remeasurement of TMM 40147-6 after repairs
yielded a length of 6.19+ mm. This is the most complete specimen; it
has 10 serrations, plus a remnant of the base of another serration.
The exodaenodont lobe is preserved on TMM 40147-68; it is relatively
smaller than in *P. mediaevus*. All the referred $M_b$'s have a smoothly convex anterior profile and the flaring crown over the exodaenodont lobe characteristic of the genus. LSUMG V-1256 is anomalous in having tiny accessory cuspules on the serrate crest between all of the ridge-bearing serrations except for between the first and second.

$M_2$: These specimens have been previously described and illustrated by Schiebout (1974), who considered them to belong to *P. mediaevus*. They are, however, 15% smaller than the smallest $M_2$'s reported from the large Swain Quarry sample by Rigby (1980, p. 49), and on the basis of size are here referred to *P. douglassi*.

Figure 52. *Ptilodus douglassi*.

A. TMM 40147-68, $RM_b$; labial view.
B. LSUMG V-1256, $RM_b$; labial view.
Ptilodus torridus n. sp.

Figures 53, 54, 55 Plate 11 Table 9

Type.—LSUMG V-810, isolated RM₁.

Refereed specimens.—LSUMG V-808, LP¹; V-823 and V-824, dP²'s; V-831, anterior half of RM₁; V-878, V-801, and V-1558, LI₁'s; V-887, RM₂; V-807, anterior half of LM₂; V-809, anterior crest of RM₂; V-872, labial half of LM₂.

Locality.—Dogie (VL-108).

Distribution.—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Puercan.

Etymology.—Latin; parched or arid, with reference to present conditions at the locality.

Diagnosis.—M₁ L=3.0, W=1.7; cusp formula 5:3, with fewer lingual cusps than in Ptilodus mediaevus, which has cusp formula 5-6:4-5 (Rigby, 1980). M₂ approximately the same size as in P. mediaevus, with 12 serrations, but with lateral profile slightly lower anteriorly. M₂ 30% longer than in P. tsosiensis from the Puercan of the San Juan Basin (Sloan, 1981), and in P. cf. P. tsosiensis from the Puercan of Saskatchewan (Jognston and Fox, 1984).

Description.—P₁. The referred specimen is triangular in occlusal view. The enamel is missing from much of the tooth crown, but three large cusps may be discerned; one anterior and two posterior. The crest on the posterolingual cusp is oriented perpendicular to the crest on the posterolabial cusp.

dP². Each specimen has five cusps; the apices of the anterior four form a square in occlusal view, but the cusps of the inferred
Figure 53. *Ptilodus torridus* n. sp. $M_1$, $M_b$.

A,B. LSUMG V-810 (type) $RM_1$; occlusal and anterior views.
C,D. LSUMG V-887, $RM_b$; labial and lingual views.
E. LSUMG V-807, partial $LM_b$; labial view.
internal row are higher. A smaller, transversely oriented cusp is situated on the posterior midline. All cusps have wrinkled crests.

\(M^1\). V-831 is a worn anterior fragment that preserves the remnants of four labial and four medial cusps. A cingulum extends along the lingual margin anteriorly from a small cusp lingual to the fourth medial cusp, and a very short cingulum is present at the labial base of the first labial cusp.

\(I^1\). The lower incisors are evenly curved and tapering, with a distinct ridge along the ventral internal margin of the distal portion. A buttress is also present mesial and dorsal to this ridge, producing an angulation on the root cross section. Enamel covers the distal two-thirds of the tooth, except for the worn occlusal surface.

\(M_b\). The most complete specimen (V-887) was pieced together from three fragments, allowing determination of size, cuspation, and dorsal lateral outline. Twelve serrations are present; these have narrow crests anteriorly, but posteriorly the serrations become broader and more gently rounded. The roof of the anterobasal concavity is preserved; the distance from the top of the concavity to the first serration is 3.72, or 48% of the length of the tooth. Twelve ridges are present on both the labial and lingual sides of the tooth, as well as several additional very short ridges on the posterior sides of the tooth. The lateral ridges from the first serration descend anteroven­trally to merge with the ridges from the second serration; posterior ridges are generally parallel and gently convex anteriorly. A medial ridge descends from the first serration about one-third of the distance to the anterobasal concavity. A broad, worn posterolabial shelf is
Figure 54. *Ptilodus torridus* n. sp. assorted teeth.

A. LSUMG V-810 (type) RM₁; occlusal view.
B. LSUMG V-808, LP₁; occlusal view.
C, D. LSUMG V-824, dP₂; occlusal and lateral views.
E. LSUMG V-831, anterior half of RM₁; occlusal view.
F. LSUMG V-872, labial half of LM₂; occlusal view.
G-J. LSUMG V-878, L1₁; basal, mesial, lateral, and dorsal views.
present. The exodaenodont lobe is only moderately developed on V-807, the only specimen preserving this feature. The lateral profile is moderately high, with a steeply ascending anterior margin that is variably slightly convex or sinuous, a moderately arched middle portion, and a gently descending posterior portion.

M\textsubscript{1}. The type specimen is oblong with a blunt anterior outline and becomes slightly wider posteriorly. The length-to-width ratio is 1.8. The lingual cusp row contains three cusps. The anterior cusp is conical-pyramidal, the second is slightly larger and subcrescentic, and the posterior cusp is equally tall but elongate. Of the five labial cusps, the first two are well separated, the second and third less so, and the fourth and fifth poorly separated by a shallow depression. The anterior cusp is conical, and the posterior cusps are pyramidal to subcrescentic. The tooth has two roots; the anterolabial margin of the crown overhangs the root and a shallow vertical depression is present on the lower crown and upper root surfaces. The medial longitudinal groove between the cusp rows is continuous, but not absolutely straight; medial buttresses on both labial and lingual cusps cause the groove to be displaced laterally as it passes. All cusps have at least two ridges descending their medial faces; short anterior crests and longer posterior crests that curve posteriorly and occasionally ramify. The posterior ridges descend from the labial cusps to almost link with anterior ridges from lingual cusps, and vice versa. The cusp rows are linked posteriorly by a strong ridge that descends from the posterolingual cusp obliquely to the posterior base of the posterolabial cusp. A weak ridge is present on the
Plate 11. *Ptilodus torridus* n. sp.

A. LSUMG V-810; RM₁ (type), occlusal view (stereopair)

B. LSUMG V-887, RMₜ, labial view.
anterior of the tooth. The external sides of the crown are smooth.

M₂. The referred labial fragment has four cusps; the first is weakly separated, but the posterior cusps are poorly distinguished. Crests descend the medial faces to produce posteriorly oriented buttresses, with frequent ramifications and occasional anastomoses.

Discussion. -- The type M₁ is referred to Ptilodus on the basis of size, occlusal outline, and morphologic resemblance to M₁ of Ptilodus mediaevus. Ptilodontid M₃'s found at the locality are the only fossils recovered of a size appropriate for this M₁, and the preservation is very similar. Morphologic resemblances between V-810 and M₁ of P. mediaevus include: occlusal outline with a blunt anterior; slightly diverging cusp rows; subcrescentic cusp development; and disposition of medial buttresses of cusps with posteriorly directed ridges tending to link with anterior buttresses from slightly posteriorly positioned opposing cusps.

The type of P. torridus differs from M₁ of several other genera including species having an M₁ of similar oblong, blunt aspect. M₁ of Pentacosmodon, which has a similar low cusp formula (4:3), differs in being smaller and in lacking the complex internal crests; length-to-width ratio, however, is the same (1.8), although the tooth is of uniform width throughout (Jepsen, 1940, p. 323-4, Pl. V.). M₁ of Neoliotomus conventus is also similar in outline, but much larger. As illustrated by Krause (1980, p. 1177), the alternating cusps have similar posteriorly directed buttresses, but the posterior ridge from the penultimate lingual cusp is much longer, extending to the second cusp posterior to it in the labial cusp row. Neoliotomus conventus is
much more derived than *Ptilodus torridus* in this respect. *Mesodma ambiguа* also has an $M_1$ with oblong anterior outline and slightly diverging cusp rows, but with a higher cusp formula (7:5). The labial cusps appear to increase in height posteriorly (Jepsen, 1940, Pl. I) to a greater degree than in V-810, and the cusps are more crescentic. $M_1$ of *M. ambiguа* is smaller than V-810, and it has a higher L/W ratio (2.0).

The referred $M_b$'s were first thought to represent *P. mediaevus*, but detailed comparison of camera lucida outlines (Fig. 55A) with those provided by Rigby (1980, p. 50), derived from the very large Swain Quarry sample, show that $M_b$ of *P. torridus* is slightly lower anteriorly and apparently has a smaller exodaenodont lobe (orientation of this feature is less certain, being determined from a partial specimen). The overall outline more closely resembles that of the much smaller *P. tsosiensis* Sloan, 1981, from the Puercan of the San Juan Basin (Fig. 55B).

The ratio of $M_b$ to $M_1$ for *P. torridus* is 2.56, using measurements of isolated teeth. This is the largest ratio reported for *Ptilodus*, other ratios being as follows:

- **P. mediaevus**: 2.32 (AMNH 3021)
- **P. montanus**: 2.30 (Granger and Simpson, 1929)
- **P. wyomingensis**: 2.10 (Jepsen, 1940)
- **P. kummae**: 2.05 (Krause, 1977)
- **P. douglassi**: 1.76 (Krause, 1977)

The lateral profile of the $M_b$ of *P. torridus* is intermediate between those of *P. tsosiensis* and *P. mediaevus*. The features of the
Figure 55. Comparisons of $M_b$ profiles of Ptilodus *torridus* n. sp.

A. *P. mediaevus* from Swain Quarry (Rigby, 1980, p. 50)

B. *P. tsosiensis* from Tsosie (AMNH 59800 cast).
type are primitive, but cannot be compared yet with the $M_1$ of
P. tsosiensis because $M_1$ for this species has not been described.

Table 9. Measurements of teeth of Ptilodus torridus n. sp.

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<th>LSUMG Specimen Number</th>
<th>Element</th>
<th>Length</th>
<th>Width</th>
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<td>2.23</td>
</tr>
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<td>dP\textsuperscript{2}</td>
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<td>----</td>
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<tr>
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<td>----</td>
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<tr>
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<td>$M_1$</td>
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<tr>
<td>V-872</td>
<td>$M_2$</td>
<td>2.03</td>
<td>----</td>
</tr>
</tbody>
</table>

Family NEOPLAGIAULACIDAE

Genus Parectypodus Jepsen, 1930

Parectypodus sinclairi (Simpson, 1935)


Sys. Zool. 15(4):270, Fig. 5.


Parectypodus sloani Schiebout, 1974, p. 11 (in part), Fig. 13 f,g,h,k,l.

Mesodma sp. Schiebout, 1974, p. 13, Fig.14c.

Referred specimens.—TMM 40147-67, $P^2$; 40147-36, $LM_b$; 40147-37, $RM_b$; 40147-41, $LM_b$; 40147-35, anterior and posterior fragments of $LM_b$'s; 40147-40, anterior half of $RM_b$; 40147-39, lingual half of $LM_b$;
40147-74, \( \text{RM}_2 \).

**Locality.**—TMM 40147; T2.

**Distribution.**—Lower Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Torrejonian.


**Discussion.**—These specimens were assigned to several different taxa by Schiebout (1974). The upper premolar and \( \text{M}_b \)'s were grouped with *Parectypodus sloani* Schiebout, 1974, the type of which is from Joe's Bonebed, a late Tiffanian locality. On re-examination of the material from Joe's Bonebed, more than one taxon was found to be represented. Also, no \( \text{M}_b \)'s from Joe's Bonebed have been recovered that correspond to the \( \text{M}_b \)'s from TMM 40147. No complete \( \text{M}_b \)'s from TMM 40147 have been found; the anterior and posterior portions of TMM 40147-35 did not appear to match, so they were separated, cleaned, and examined under the microscope. In details such as enamel thickness, broken borders, and preservation, they do not match. TMM 40147-40, an anterior fragment of a \( \text{RM}_b \), was questionably assigned to *Ectypodus musculus* by Schiebout (1974, p. 10). This specimen corresponds well in size and lateral outline to \( \text{M}_b \) of *Parectypodus sinclairi*. The \( \text{M}_2 \), 40147-74, is of appropriate size and cusp formula as described for *P. sinclairi* by Simpson (1937, p. 98). This tooth, which was assigned to *Mesodma* sp. by Schiebout (1974, p. 13), is intermediate in size between \( \text{M}_2 \) of *Mesodma* sp. P and *Mimetodon silberlingi* as described by Krause (1977, pp. 21, 25).

As TMM 40147 is now considered to be Torrejonian rather than Tiffanian in age, the *Parectypodus* specimens from this locality are grouped with *P. sinclairi*, a known Torrejonian form to which they
show close similarity. Schiebout (1974, p. 11) noted the resemblance of the referred M\textsubscript{b} to those of P. sinclairi.

**Genus Mesodma Jepsen, 1940**

**Mesodma thompsoni** Clemens, 1963

**Figure 56**

Referred specimens.—LSUMG V-880, LM\textsuperscript{2}; V-811, LM\textsubscript{b}; V-885, anterior half of RM\textsubscript{b}; V-1563, RM\textsubscript{b} fragment; V-876, LM\textsubscript{2}.


Distribution.—Lance Formation, Wyoming; Hell Creek Formation, Montana; upper Edmonton Formation, Alberta; Nacimiento Formation, New Mexico; upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas; Lancian and Puercan.

Description.—M\textsuperscript{3}: L=1.67, W=1.61, cusp formula 1:3:4. The anterior margin of the tooth is straight. The labial cusp is low and elongated. The anterior medial cusp is pyramidal; the second and third are crescentic. The medial cusps are both larger and taller than the lingual cusps, and are grooved on the sides.

M\textsubscript{b}: None of the referred specimens is complete. V-885 preserves the posterior root and all of the serrations; L=3.40+, est. L=3.5. Twelve serrations are present on the low, arcuate crest; the slope anterior to the first serration is convex. Labial and lingual ridges from the first two serrations are short, and approach the ridge from the third serration. Ridges from serrations 3 through 8 are longer and are gently convex anteriorly. The ridges from the 9th serration are shorter and straight, and labial ridges from the 10th and 11th serrations are very short, directed parallel to the
Figure 56. *Mesodma thompsoni*

A. LSUMG V-880, LM$^2$; occlusal view
B. LSUMG V-876, LM$^2$; occlusal view
C, D. LSUMG V-881, LM$^2$; labial and lingual views
E. LSUMG V-885, RM$^3$; labial view
F. LSUMG V-1563, RM$^3$; labial view
other labial ridges. Very short, ventrally directed ridges are present lingually on the posterior two serrations. V-885 and V-1563 are fragments that show the anterolabial portion of $M_b$. The exodaenodont lobe is moderately large, and an anterobasal cavity is present.

$M_2$: $L=1.61$, $W=1.32$, cusp formula 4:2. The tooth is moderately worn, but the wear pattern in the labial cusp row indicates that four cusps are probably present. The medial sides of the cusps in both rows are grooved.

Discussion.—Referral to Mesodma thompsoni is based on the size of the specimens and the relatively low profile of the referred $M_b$'s, as described by Clemens (1963, p. 39). The lateral outline of V-811 particularly resembles that of $M. thompsoni$ from the San Juan Basin (Sloan, 1981, p. 39). The $M_b$'s from Big Bend differ from those of $M. thompsoni$ from the Lance Formation in having more sloping profiles anterior to the first serration and slightly smaller anterobasal concavities. In these respects they also resemble Puercan specimens of $M. thompsoni$ from the San Juan Basin.

Ptilodontoidae indeterminate

Referred specimen.—LSUMG V-1325, partial incisor.

Locality.—Running Lizard (VL-108).

Distribution.—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian (Lancian).

Description.—The maximum basal diameter is 1.15 mm. A ridge runs from the worn tip posteriorly along the external margin, dissipating near midlength. The base is broad, with a distinct squared
butress on the proximal mesial side.

Discussion.—The tooth is relatively short for a ptilodontoid lower incisor. It may be an upper incisor; it has proportions similar to those of I$^2$ of Ectypodus tardus as illustrated by Krause (1982, p. 277). The posterior buttress results in a cross section very similar to that of I$_1$'s from other localities that have been referred to Ptilodus.

Figure 57. Indeterminate ptilodontoid incisor. LSUMG V-1325
A. mesial view; B. proximal view.

Suborder TAENIOLABIDOIDEA
Family EUCOSMODONTIDAE
Genus Stygimys Sloan and Van Valen, 1965
Stygimys gratus (Jepsen, 1930)

Figure 58

Eucosmodon gratus Jepsen, 1930, p. 499.

Referred specimen.—LSUMG V-1501, anterior half of LM$_1$.
Locality.—Snail's Place (VL-144).
Distribution.—Mantua Lentil, Polecat Bench Formation, Wyoming;
Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Puercan (early Paleocene).

**Description.**—L=2.26+, W=2.03. The specimen is an unworn anterior fragment that preserves three labial cusps and three and one-half lingual cusps on a broken crown. The cusps are simple; the anterior cusps of both rows are conical, and the more posterior cusps are subcrescentic. The lingual cusps are relatively narrower and taller than the labial cusps. In both cusp rows, cusps increase in size and height posteriorly. In occlusal view, the anterior of the tooth tapers to a smoothly rounded point. A tiny cuspule is present on the anterior margin lingual to the midline. The only ridges present are short and weak; one is situated on the lingual side of the first lingual cusp, and others appear on the backward-tilted posterior sides of the larger posterior cusps.

**Discussion.**—Referral to *Stygimys* is based on size and simple cusp morphology. Referral to *S. gratus* is based on the similarity of the anterior outline to that of the specimen described by Jepsen (1940, p. 274), as well as size. V-1501 is slightly wider at mid-length, and would have been still wider at the posterior end. This specimen also differs from the M1 described by Jepsen in having an anterior cuspule that is slightly lingual to the midline, rather than labial.
Figure 58. *Stygimyss gratii*. LSUMG V-1501, anterior half of LM$_1$.

A. occlusal view  
B. anterior view  
C. lingual view  
D. labial view
Stygimys vastus n. sp.

Figure 59

Type. — TMM 41400-12; LM_b.

Referred specimens. — LSUMG V-962, partial LI¹; TMM 41400-15, P¹.

Locality. — Tom's Top (VL-111 = TMM 41400).

Distribution. — Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

Etymology. — Latin vastus, desert or waste, referring to the badlands near Dawson Creek.

Diagnosis. — A medium-sized eucosmodontid with M_b having 9 serrations, arcuate anteriorly convex labial ridges, and a convex anterior profile with an obtuse angle midway between the first serration and the anterior base of the crown. In comparison with S. kuszmauli, the lateral profile of M_b is relatively lower anteriorly and the labial ridges are more arcuate and less steeply inclined. Compared with S. camptorhiza, the anterior profile is more convex and angulated, rather than straight, and the labial ridges are more arcuate; the exodaenodont lobe is smaller. Compared to S. gratus, the labial ridges are more arcuate and longer, and the exodaenodont lobe is smaller. These species, which are about the same size as S. vastus, also have more serrations on M_b (10 in S. camptorhiza, 11 in S. kuszmauli and S. gratus).

Description. — I¹: D=1.11. V-962 preserves the lateral half of the crown, which is evenly curved and has wrinkled enamel. The posterobasal cusp is small and not well separated from the main bulk of the crown.
$P_1^1$: $D=1.33$. The tooth is single rooted, with wrinkled enamel, and has three cusps evenly spaced on the crown, which is circular in cross section. No interdental wear facets are visible on the sides of the tooth.

$M_b$: $L=4.67$, $W=1.51$. The tooth is of relatively constant width throughout its length. It has 9 serrations, with the posterior two very poorly distinguished. The serrations become wider posteriorly, with the exception of the last serration. In lateral view the outline of the tooth is J-shaped, with a straight posterior margin and a convex anterior margin. The first serration has very short labial and lingual ridges, as well as an anterior ridge that reaches about a third of the distance to the anterior base of the crown and then angles ventrolingually for another third of the distance, until it ends on the anterolingual face above a shallow, flat lingual basal concavity. This concavity is not lined with enamel. The anterior profile below the first serration is angulated, with a distinct change in slope from the steep lower portion to the upper, less inclined portion. Serrations 2 through 5 have long, anteriorly convex labial ridges that are slightly irregular and wavy; the labial ridge from the 6th serration is shorter and the labial ridge from the 7th serration is extremely short. Serrations 2 through 6 also have shorter, irregular lingual ridges, but the posterior three serrations lack lingual ridges. A strong posterolabial shelf that may have borne cusps is present; the wear surface is trilobate. The apices of the posterior three serrations are worn. The base of the anterior root is abraded, but it appears to have been circular in cross section. The smaller posterior root is
anteroposteriorly elongate. An interradicular crest is present that
is larger near the anterior root.

Discussion.—Referral to Stygimys is based on the J-shaped
lateral profile of $M_b$ (Sloan and Van Valen, 1965, p. 223). Association
of the bicuspid upper incisor and single-rooted premolar is based
on size, preservation, and appearance of the enamel. Apical rather
than shear wear on the posterior serrations of $M_b$ also favors the
association of this form with eucosmodontids. $M_b$ of *S. vastus* also
shows some resemblance in its low outline to $M_b$ of *Xyronomys* Rigby,
1980, but differs in having an arcuate, relatively longer anterior
slope rather than a short vertical slope. Lateral outlines of this
specimen (TMM 41400-12) were compared to those of *S. kuszmauli*
(UALP 11837), *S. camptorhiza* (Johnston and Fox, 1984, Pl.3), and
*S. gratus* (Jepsen, 1940, Pl. 1). *Stygimys vastus* is relatively
underived compared to other described species of *Stygimys* in having
fewer serrations and a small posterobasal cusp on $I^1$; in these
respects it approaches *Nemegtbaatar*, which has 6-7 serrations and
lacks a posterobasal cusp on $I^1$ (Kielan-Jaworowska, 1974, p. 37).
Figure 59. *Stygimys vastus* n. sp.

A. LSUMG V-962, L1<sub>1</sub>; lateral view.
B,C. TMM 41400-15, P<sub>1</sub>; occlusal and lateral views.
D,E. TMM 41400-12, LMc<sub>b</sub> (type); labial and lingual views.
Eucosmodontidae indet.

Referred specimens.—LSUMG V-1328, LI₁ fragment; V-1356, RI₁ fragment.

Locality.—Running Lizard (VL-113).

Distribution.—Upper Aguja Formation, Big Bend National Park, Texas, Maastrichtian.

Description.—Maximum basal diameters are for V-1328, 1.25 mm; for V-1356, 1.20 mm. The two lower incisor fragments have flat medial and convex lateral surfaces, with enamel restricted to the anterior half of the tooth. In proximal view the outlines of the two fragments differ; that of V-1328 is relatively narrow, while that of V-1356 is broad.

Discussion.—Referral to the family Eucosmodontidae (Jepsen, 1940) is based on the lateral compression of the incisors. The specimens may represent two different taxa. The relative proportions of V-1328 resemble those of Eucosmodon, but it is much smaller than previously reported Eucosmodon incisors. V-1356 is relatively less compressed than in known eucosmodontid incisors.
Figure 60. Eucosmodontidae indet. lower incisor fragments.

A-C. LSUMG V-1328, LI\(_1\) fragment; in mesial, lateral, and proximal views.
D-F. LSUMG V-1356, RI\(_1\) fragment; in proximal, mesial, and lateral views.

Suborder INCERTAE SEDIS

Family CIMOLOMYIDAE

Genus *Jas* n. g.

*Type.* — *Jas tejana* n. sp.

*Etymology.* — An acronym in honor of Judith A. Schiebout.

*Diagnosis.* — As for the type and only known species.

*Jas tejana* n. sp.

Figure 61

*Type.* — LSUMG V-1324, LM\(_b\).

*Referred specimen.* — LSUMG V-1322, RI\(_1\).*
Locality.—Running Lizard (VL-113).

Distribution.—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian (Lancian).

Etymology.—Spanish for a female Texan.

Diagnosis.—A medium-sized multituberculate with an \( M^b \) cusp formula of \( 0? : 7 + b : l \). \( M^b \) broad, with a long, high median cusp row, penultimate cusp highest, posterior slope steep and straight. Postero-basal cusp and strong posterolingual cusp present, enamel wrinkled. Anterolabial lobe lacks definite cusps. It differs from the \( M^b \) in Cimolomys in being relatively broader, with a higher crown. It differs from the \( M^b \) in Essonodon in having a lower crown, smaller anterolabial lobe, and trapezoidal outline. It differs from the \( M^b \) in Meniscoessus in lacking strong anterolabial cusps and in having the penultimate cusp highest on the median cusp row. It differs from \( M^b \) in Neoplagiaulax in being wider, lacking anterolabial cusps, and in having a well developed posterobasal cusp and sculptured enamel.

Description.—1:\(^1\): The tooth has a diameter of 1.67 at the base of the crown. As in other cimolomyids, it has two distinct cusps. The posterior, smaller cusp is located at the end of a large wear facet extending mesially from the tip of the large anterior cusp. The enamel is faintly wrinkled and grooved. There is a distinct ridge on the posterolateral side of the large cusp, running from the anterolateral margin mesially toward the base of the smaller cusp. At the base of the smaller cusp the ridge broadens and divides, one branch continuing to join the base of the cusp, while the other dissipates onto the main body of the tooth. The smaller cusp is only slightly worn; the tip of the large cusp is removed by wear, but it is
possible that more than one cusp was present on its apex. The lateral edge of the wear facet is undulatory due to the presence of a broad lateral flexure that may have continued to a separation into cusps at the tip.

\[M^b: L=2.81, W=1.28.\] The tooth is broad and trapezoidal in occlusal view, with the base of the trapezoid lingual. The median cusp row begins with a very small cusp, and it increases in height regularly until the penultimate main cusp; this cusp is not well separated from the last cusp, which is slightly lower. Seven cusps are present, counting the initial small cusp. These are followed by a separate cusp situated at the base of the steep, straight posterior crest, which turns lingually just before reaching the basal cusp. A low cingulum connects the posterior basal cusp to a larger postero-lingual cusp, which is separated from the main body of the tooth by a V-shaped valley. Distinct grooves and ridges sculpture the postero-lingual face of the tooth. Two pits are also present, a shallow one anterior to the posterobasal cusp, and a deeper pit on the cingulum connecting the basal cusp to the posterolinguinal cusp. A slight hump is present on the ridge ascending the posterolinguinal face anterior to the posterolinguinal cusp. No distinct cusps are present on the anterolabial corner of the tooth; however, a semicircular ridge is present in this area overhanging a circular cavity. The ridge may represent the base of a cusp, but it shows no breakage. The anterior base of the crown protrudes over the root slightly. The roots are elliptical in cross section, with the long axes of the ellipses transversely oriented. No interradicular crest is present.
Figure 61. *Jas tejana* n. g., n. sp.

A-C. LSUMG V-1324 (type) Lm\(^b\); occlusal, lingual, and labial views.

D,E. LSUMG V-1327, R1\(^1\); mesial and lateral views.
Discussion.—Referral to the Cimolomyidae is based on the high, broad $M^b$ similar to that of *Meniscoessus*, the enamel sculpturing, and the bicuspid $i^1$. Association of the two referred specimens is based on size, appearance of the enamel, and marked similarity of preservation (at a locality that displays wide variation in preservation). Ratios of incisor diameter to $M^b$ length in previously described cimolomyids (Archibald, 1982; Clemens, 1963; Sahni, 1972) are rather variable. The referred incisor is approximately the same size as that referred to *Meniscoessus major* by Sahni (1972, p. 373).

*Jas tejana* exhibits $M^b$ morphology intermediate between that shown by species of *Cimolomys* and *Meniscoessus*, and yet it lacks the anterolabial cusps seen in those genera. Like *Cimolomys*, *Jas* has $M^b$ with a relatively long medial cusp row, but in *Jas tejana* the occlusal outline is relatively broad, and the medial cusp row is very high posteriorly, as in *Meniscoessus borealis*. The lateral profile of $M^b$ of *Jas tejana* is similar to that seen in $M^b$ of neoplagiaulacids, particularly *Neoplagiaulax*, but the enamel sculpturing is entirely different, and the posterolinguinal cusp is much stronger. Earlier (Campanian) species of *Meniscoessus* have lower $M^b$ profiles (Fox, 1971), but the $M^b$ of *Jas tejana* appears to most closely resemble that of *Cimolomys* ssp. A and B of Fox (1971, pp. 930, 932). *Jas tejana* differs from these forms in that the $M^b$ of *Jas* is smaller and relatively broader and higher. I consider the resemblance of the lateral profile of $M^b$ of *Jas tejana* to that of *Neoplagiaulax* to be convergent.
Genus *Meniscoessus* Cope, 1882

? *Meniscoessus* sp. indet.

Figure 62

**Referred specimen.**—LSUMG V-1323; RI1.

**Locality.**—Running Lizard (VL-113).

**Distribution.**—Upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian (Lancian).

**Description.**—The maximum diameter at the base of the tooth is approximately 2.5 mm. The tooth has a broad larger cusp with a moderately convex external profile, and a smaller basal cusp. The enamel is extensively worn, resulting in a large ventral wear facet that extends onto the smaller cusp. The enamel is strongly ridged and rugose. Three longitudinal ridges extend posteriad from the tip onto the dorsolateral surface. A smaller ridge is present extending from the smaller cusp across the valley between the cusps.

**Discussion.**—V-1323 is larger, more rugose, and of different preservation than the incisor referred to *Jas tejana* (see above). It also lacks the bifurcating ridge seen in that specimen, and it is less strongly curved. The overall shape of this specimen resembles that of specimens referred to *Meniscoessus robustus* by Clemens (1963, p. 90) and to *M. major* by Sahni (1972, p. 374). Fox (1980, p. 1481) did not refer incisors to *M. major* because incisors associated with diagnostic teeth had not been found; however, strong similarity in curvature and ridge development is here considered adequate to justify a tentative identification. This specimen is intermediate in size between incisors referred to *M. major* by Sahni (1972) and to *M. robustus* by Clemens (1963).
Figure 62. ? Meniscoessus sp. indet. LSUMG V-1323, R1 fragment, in:

A. lateral; B. mesial; C. anterior, and
D. posterior views.
Suborder INCERTAE SEDIS

Family VIRIDOMYIDAE new family

Included genus.—Viridomys Fox, 1971.

Diagnosis.—Multituberculates with upper premolars having tall, narrow crowns with only one row of cusps; no anterolabial cusps on M^b.

Distribution.—Upper Milk River Formation, Alberta; upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Aquilan (early Campanian) and Puercan (early Paleocene).

Genus Viridomys Fox, 1971

Viridomys bovorbus n. sp.

Figures 63, 64, 65 Plates 12, 13 Table 10

Type.—LSUMG V-818; anterior half of LM^b.

Referred specimens.—LSUMG V-814, RI^x; V-816, V-817, V-1565, anterior upper premolars; V-821, posterolabial fragment of LM^b.

Locality.—Dogie (VL-108).

Etymology.—Latin bos, cow, and orbus, orphan; from the name of the type locality, dogie, a vernacular term meaning a calf that has lost its mother.

Distribution.—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

Diagnosis.—M^b slightly larger than that of V. orbatus Fox, 1971, with anterior slope below the first median cusp having an angular rather than gently convex profile as in V. orbatus. Anterior upper premolars bicuspid.
Description. -- I X: V-814, an isolated right upper incisor, is tentatively referred on the basis of size and preservation. The tooth and its root are oval in cross section, with the root set at an angle to the crown. The slightly recurved crown is symmetrically divided by anterior and posterior crests that extend from the apex to approximately half the crown height. The posterior crest is linked by a break in slope to a short crest near the base of the crown; this forms a very slight basal bulge or heel. A small wear facet is present on the medial side of the apex of the crown, which appears to have been unicuspid.

P X: The three referred specimens have high, longitudinally compressed crowns that are oblong in occlusal view; each bears two small cusps of unequal height carried high on the crown. A weak longitudinal crest is present extending from near the apex of the cusp at one end, across the narrow groove between the cusp apices, and up the crown a short distance from the apex of the second cusp. In addition, very short lateral crests, which are little more than wrinkles, extend both labially and lingually from the cusp apices. The bases of the cusps are connate, resulting in a pinched-off appearance of the cusps.

V-1565 is an unworn, probably unerupted, enamel cap preserving most of the crown. The two cusps are situated at midlength, giving the tooth a more balanced triangular aspect in lateral view than is the case with the other referred specimens. The crown of V-1565 is also higher.

V-816 and V-817 are similar in that their occlusal outline is relatively wider than that of V-1565, and the two cusps are situated slightly off-center longitudinally, with a steep, straight or slightly
Figure 63. *Viridomys bovorbatus* n. sp.

A-E. LSUMG V-818 (type) LM\(^b\); labial, anterior, lingual, occlusal, and anterobasal-oblique views.

F-I LSUMG V-814, RI\(^x\); basal, medial, posterior, and lateral views.

J. LSUMG V-821, LM, fragment; labial view.

Figure 64. *Viridomys bovorbatus* n. sp. upper premolars.

A-E. LSUMG V-1565: A. occlusal; B,D. lateral; C,E. sagittal.
convex slope on one end rising to the shorter cusp, and a less steep, slightly concave slope on the other end descending from the taller cusp. On V-817 the taller cusp is broken off, but the diameter of the broken stump indicates a cusp of larger size than the remaining cusp. On the end of the larger cusp, the crown of V-816 has a basal concavity; this is a shallow arched area lined with enamel. This end of V-817 is damaged, but no indication of such a concavity is present; therefore, it is inferred that V-816 and V-817 represent different teeth in the series.

V-816 is also an unworn enamel cap that preserves the entire crown. It has a slight waist in occlusal view. The highest cusp is at mid-length; the lower second cusp is slightly smaller. In longitudinal view, the cusp apices appear to lean slightly to one side, possibly indicating this is the labial side, as in M\(^b\). The outline in this view is an isosceles triangle. At the base of the crown is a flattened depression that has a slight shoulder above it on the lingual side. No wear facets are present.

V-817 preserves the crown and one root; a second root was present but was broken off. The remnant of a weak intraradicular crest is present on the remaining root. Two wear facets are present; one is vertical, located near the base of the enamel on the end with the steeper slope, the other is off center on the shoulder of the shallow slope at the other end of the tooth, oriented facing downwards (from the root). This indicates that the tooth may have fit underneath the anterior (or posterior) margin of a tooth such as V-818, M\(^b\). The apices of the cusps lean slightly to one side as in V-818 and V-816;
this may be the labial side. However, the lobe at the base of the crown on the presumed labial side is weaker than that on the lingual side in this interpretation, contrary to the condition in $M^b$.

$M^b$: V-818 (type) has a high, laterally compressed crown with steep lateral walls, planar on the lingual side and slightly concave on the labial side. A strong anterolabial lobe that lacks cusps is present at the base of the crown; the anterolingual lobe is somewhat weaker. The cusps of the median (and only) cusp row are situated high on the crown; they increase in both size and height posteriorly, and are separated by very shallow grooves. A median ridge connects the cusps and extends about halfway up the anterior slope, bulging slightly above the point at which the lateral outline makes a gentle angulation back toward the root. There is a V-shaped depression on the anterior base of the crown that extends into a narrow groove on the root; this root has a vertically divided appearance both anteriorly and posteriorly. A small interradicular crest is present. In addition to a large lingual wear facet, the cusp apices have small lingual-oblique wear facets and tiny, circular labial-posterior wear facets. At the anterior base of the crown, underneath the overhanging anterior slope, two small wear facets are present, indicating interdental abrasion with $P^3$ (Figure 63E). The posterolingual face near the broken edge shows no evidence of the swelling of possible posterolingual cusps.

$M^b$: V-821 is referred on the basis of size and preservation. The fragment preserves the posterolabial enameled surface, but no serrations, and a large portion of the root. This root is the same size as the anterior root of the type $M^b$. Seven ridges are present. The
anterior two ridges are gently convex anteriorly and appear to be oriented toward serrations. The third ridge is straight and is joined at its dorsal termination by the dorsal termination of the fourth ridge, which is concave anteriorly. The fifth and sixth ridges are short, concave anteriorly, and are joined by two anastomoses. The seventh ridge is very short and is directed posteroventrally. Posterior to the ridges, a facet is present from which wear has removed the enamel and left the dentine exposed in a lobate pattern. This worn area has a central dorsal salient that indicates a cuspule may have been present. The posterior junction of this possibly cuspidate ridge with the median row of serrations is not preserved. In addition to wear on the posterolabial ridge, wear is also visible on the seven ridges and anastomoses.

Discussion.—Comparison of the lateral outline of V-818 with the type of V. orbatus, aligned on the five cusps (Figure 65A) shows that the outlines match well with respect to the cusps, but the posterolingual border of V-818 where it is broken does not show any evidence of swelling for a posterolingual talon such as is seen in the type of V orbatus. In addition, the base of the crown of V-818 is directed upwards at the break, and the anterior root of V-818 is slightly larger than that of the type of V. orbatus. For these reasons, the orientation of Figure 65B is preferred, from which it is inferred that the length of the whole tooth was approximately 4.4 mm., and at least six medial cusps were probably present.

The referred specimens are associated on the basis of size, preservation, and for the premolars, the presence of a single row of cusps
Figure 65. Comparison of lateral outlines of V-818 (heavy line) and the type of Viridomys orbatus (Fox, 1971, Figure 8a), drawn to the same scale.

A. Cusps aligned; B. Centers of base of crown aligned.

of a morphology similar to that of the type. The anterior face of V-818 bears a groove resembling that seen in triconodont molars; however, the close resemblance of this tooth to the type of Viridomys orbatus Fox, 1971, which is a complete tooth differing from most multituberculate M^b's in only two features (high anterior cusp and lack of anterolabial cusps), as well as the presence of referred anterior premolars differing from other multituberculate premolars only in having one rather than two cusp rows, favors assignment to the order Multituberculata. The referred teeth lack anteroventrally directed ridges from serrations such as are seen in lower premolars of other multituberculates, including plagiaulacids (Hahn, 1971). In addition, the referred fragment of M^b, which is of appropriate size and preservation, and the multituberculate-like upper incisor support this interpretation. No cingula are present on the referred premolars as would be expected in teeth of triconodonts (Simpson, 1929, p. 151).
Plate 12. *Viridomys bovorbatus* n. sp. LSUMG V-818 (type), LM^b^.

A. Occlusal view (stereopair);
B. labial view; C. lingual view; D. anterior view; and
E. posterior view.
Plate 13. *Viridomys bovorbatus* n. sp. upper premolars.

A,B. LSUMG V-1565; A. lateral view; B. occlusal view (stereopair);
C,D. LSUMG V-816; C. lateral view; D. occlusal view (stereopair);
E,F. LSUMG V-817; E. lateral view; F. occlusal view (stereopair).
Fox (1969) reported the presence of a triconodont in the same fauna that yielded *Viridomys orbatus*; *Alticonodon lindoei* has molars that have high, narrow crowns with a single cusp row, but cingulids are present and the cusps have much stronger ribs, lacking crests. Pending the discovery of definitely associated lower molars, the Viridomyidae are assigned to the Multituberculata.

Fox (1971) recognized *Viridomys* as a distinct genus (family and suborder uncertain) on the basis of the single median cusp row on $M^b$ ($P^4$), with anterolabial cusps lacking. The recovery of anterior premolars referable to this genus requires recognition at the familial level. Another multituberculate having anterior premolars with a single row of cusps is *Boffiuss splendidus* Vianey-Liaud, 1979, from the Montian of Belgium. *Boffiuss* differs from *Viridomys* in having a very broad premolar, and the $M^b$ of *Boffiuss* has three rows of cusps on the anterior portion.

Hahn (1971, p. 21) reported a bicuspid $P^1$ of an "otherwise unknown" taxon from the Guimarota coal pit of Portugal (Late Jurassic). This tooth has one large root, and may have been a canine (Hahn, 1971, p. 22). As illustrated (Hahn, 1971, Fig. 16a), the Guimarota bicuspid tooth is similar in occlusal outline to V-816 and V-817, but it is egg-shaped rather than elliptical. The height of the crown is not mentioned, and the cusps of the Guimarota tooth appear to have had more sculpturing.

Carlson and Krause (1985) have noted that the enamel ultrastructure of *Viridomys orbatus* differs from that seen in other non-plagiaulacoid multituberculates. SEM analysis of specimens referred
to *Viridomys bovorbatus* will contribute to the analysis of this problem. It is possible that the Viridomyidae cannot be included in any described suborder of multituberculates.

Table 10. Measurements of teeth of *Viridomys bovorbatus* n. sp.

<table>
<thead>
<tr>
<th>LSUMG Specimen Number</th>
<th>Element</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-814</td>
<td>I^x</td>
<td>1.20</td>
<td>1.05</td>
</tr>
<tr>
<td>V-816</td>
<td>P^x</td>
<td>1.77</td>
<td>1.27</td>
</tr>
<tr>
<td>V-817</td>
<td>P^x</td>
<td>1.71</td>
<td>1.02</td>
</tr>
<tr>
<td>V-1565</td>
<td>P^x</td>
<td>1.7-</td>
<td>----</td>
</tr>
<tr>
<td>V-818 (type)</td>
<td>partial M^b</td>
<td>est. 4.4 (2.38+)</td>
<td>1.42</td>
</tr>
<tr>
<td>V-821</td>
<td>M_b fragment</td>
<td>2.27+</td>
<td>----</td>
</tr>
</tbody>
</table>
Theria indeterminate

Figure 66

Referred specimen.—LSUMG V-802; distal right humerus.

Locality.—Dogie (VL-108).

Distribution.—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

Description.—V-802 preserves the major features of the distal humerus. The width of the specimen is 11.2 mm. The entepicondyle is an elongate medial protuberance. The ulnar condyle is a distinct ridge with a gently convex lateral profile and a steep, concave medial slope. A broad trochlea separates this ridge from the capitulum, of which only the margin is preserved. Neither an intercondylar ridge nor a groove are present on the trochlea. In posterodorsal view, two fossae are visible; one is proximal and medial to the ulnar condyle, the other proximal and slightly lateral. This second fossa contains a small foramen within its depression. Also, a perforation, or ectepicondylar foramen, is indicated on the broken margin above the trochlea by the presence of a small area of periosteum that is continuous to the ventral side. The entepicondylar foramen is moderately large and has an oval outline.

Discussion.—In distal view, the morphology of this specimen agrees well with that shown by Jenkins (1973, p. 297, Pl. 1) for a therian (i.e., non-multituberculate) humerus, having trochlear rather than concylar articulation. V-802 is approximately twice the size of the specimen figured by Jenkins. Although the specimen has features indicating therian articulation, it retains an ectepicondylar foramen.
similar to that present in the humerus of a multituberculate (Clemens and Kielan-Jaworowska, 1979, Fig. 6-4).

Figure 66. Therian distal right humerus. LSUMG V-802, in:

A. anteroventral; B. medial; C. posterodorsal;
D. lateral; and E. distal views.
Order MARSUPIALIA

Family DIDELPHIDAE

Genus Alphadon Simpson, 1927

Alphadon marshi Simpson, 1927

Figure 67

Referred specimen. --LSUMG V-1326; LM anterolabial fragment.

Locality. --Running Lizard (VL-113). Lancian.

Distribution. --Lance Formation, Wyoming; Hell Creek Formation, Montana; upper Edmonton Formation, Alberta; Fruitland and Kirtland Formations, New Mexico; upper Aguja Formation, Big Bend National Park, Texas. Maastrichtian (Edmontonian and Lancian).

Description. --V-1326 preserves the anterolabial half of the paracone and stylar cusps A and B. The fragment is worn, but the remaining cusp bases indicate that B was larger than A, and connected by a strong ridge to the paracone. Cusp A is longer than wide, B is triangular, and the remaining portion of the paracone is conical, with a slightly convex labial slope. Posterolinguall to cusp B, a low rounded ridge descends toward the center of the stylar shelf, which is broken off. A sharper, slightly worn ridge descends linguall from cusp A. Using the centers of the worn cusp apices for end points, the distance from A to B is 0.71, and from B to the paracone is 1.09.

Discussion. --Referral to Alphadon is based on the morphological resemblance of the fragment to the teeth of A. marshi described by Clemens (1966). The size and proportions of the preserved cusps are very close to those of UCMP 52450 (Clemens, 1966, p. 7, Fig. 5). The labial base of the paracone in V-1326 is slightly convex, but the curvature of the borders of the worn apex of the paracone indicates
that the labial side is less convex than the lingual side. V-1326 differs from the upper molars of Pediomys Marsh, 1889, in having a well-developed stylar cusp B, and from Glasbius Clemens, 1966, in that stylar cusp B is not bulbous. Didelphodon Marsh, 1889, has a relatively larger cusp B and lacks the high ridge connecting cusp B to the paracone. Eodelphis Matthew, 1916, has a relatively larger cusp B and, as illustrated by Fox (1981, p. 355), has a lower crista connecting cusp B to the paracone. In Albertatherium Fox, 1971, the labial crista extends from the paracone toward cusp A or the notch between A and B (Fox, 1971, p. 150). Aquiladelphis Fox, 1971, has two cusps B rather than one (Fox, 1971, p. 155). V-1326 differs from the early Tertiary genera Thylacodon, Peradectes, and Peratherium in having larger stylar cusps.

Referral to Alphadon marshi is based on size. Smaller forms include A. creber Fox, 1971, A. wilsoni Lillegraven, 1969, A. lulli Clemens, 1966, and A. halleyi Sahni, 1972. Larger forms include A. praesagus Sahni, 1972, and A. rhaister Clemens, 1966; this latter form also has a more bulbous cusp B.

Figure 67. Alphadon marshi; LSUMG V-1326, LH anterolabial fragment, in occlusal view.
Genus **Peratherium** Aymard, 1850

**Peratherium** sp.

**Figure 68**

**Referred specimens.**—LSUMG V-895, RM*\(^X\) fragment; V-705, LM*\(^x\).

**Locality.**—Dogie (VL-108).

**Distribution.**—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

**Description.**—**M*\(^x\):** The specimen is a posterolabial fragment preserving the metacone and the stylar shelf labial to the metacone. The fragment is 1.35 mm. long, 1.09 mm. wide. The metacone is conical, slightly flattened labially. The premetacrista is directed anterolabially, but its labial terminus is not preserved. Stylar cusps C and D are present; D is slightly higher than C, and C is doubled. Low ridges extend from both C and D toward the metacone. Cusp E is absent on the posteriorly projecting stylar shelf. The ectoflexus is very weak.

**M*\(^x\):** L=1.73, AW=1.00, PW=0.99. The crown of the tooth is little worn, but the apices of the protoconid and hypoconid are broken off. The trigonid is relatively high, with the triangular protoconid the largest and tallest cusp. The slightly lower metaconid is more conical and the paraconid projects anterolingually. An anterior cingulid is present. A carnassial notch is present between protoconid and paraconid, but the notch between protoconid and metaconid is not as strongly developed. The talonid is almost as long as the trigonid; the hypoconid is the largest cusp, but its height is unknown. The entoconid is opposite the hypoconid, anteroposteriorly elongate, and
tall. The hypoconulid is posterolinguial in position, close to the entoconid, but separated from it by a moderately deep notch. Entoconid and hypoconulid do not share a common internal wall. The talonid basin is closed by a low ridge anterior to the entoconid. The talonid basin is deep, with its deepest point just internal to the entoconid. A shelf descends posterolabially from the hypoconulid. The cristid obliqua intersects the posterior trigonid wall below the protoconid, labial to the notch in the protolophid.

Discussion.—Referral to *Peratherium* is based on resemblance to *P. innominatum*. The referred specimens exhibit the following characters associated with the Tribe Didelphini, of which *Peratherium* is a member: dilambdodont upper molar with relatively strong stylar cusps; lower molar with tall entoconid, lower, proximal and posterior hypoconulid and a relatively deep entoconid notch. The relatively tall trigonid of V-705 resembles that of *P. innominatum* Simpson, 1928, and it is close in size to that species. V-895 also has a doubled stylar cusp C, as in specimens described by Krishtalka and Stucky (1984, p. 37). In comparison with their illustrations of *P. innominatum*, however, the Paleocene Big Bend specimens exhibit some differences; the trigonid is slightly wider than the talonid, and the entoconid is more elongate, with a slightly less distinct notch separating it from the hypoconulid. The upper molar fragment is slightly less dilambdodont. Compared to a cast of the type of the Puercan form *Thylacodon pusillus*, V-705 is much smaller, and the deepest part of the talonid basin is more lingual. The appearance of the entoconid is very similar. The referred specimens probably represent a new
species, but actual comparison with specimens of *P. innominatum* is needed for better characterization. *Peratherium* has previously been considered to have first appeared in the early Eocene (Krishtalka and Stucky, 1984).

Figure 68. *Peratherium* sp.

A,B. LSUMG V-895, posterolabial fragment of RM¹; occlusal and labial views.
C-G. LSUMG V-705, LM; occlusal, anterior, lingual, labial, and posterior views.
Order CIMOLESTA

Family PALAEORYCTIDAE

Genus *Gelastops* Simpson, 1935

*Gelastops* sp.

Figure 69

**Referred specimens.**—LSUMG V-708, LP³; V-841, partial RM².

**Locality.**—Dogie (VL-108).

**Distribution.**—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

**Description.**—P³: L=1.95, W=1.39. The tooth is triangular in occlusal view, with a tall paracone and small lower, connate metacone. The bases of three roots are visible. A low notch is present between the metacone and the metastyle, the crest of which is slightly oblique to the paracone and metacone. A parastyle was present, but most of it has been removed by wear. A small protocone is situated low on the lingual margin, slightly anterior to the midline. Very short cristae are present anterior and posterior to the protocone, and short cingula are present posterior to the parastyle, and anterior to the metastyle, on the labial margin. Posterolingual wear facets are developed on the paracone, metacone, and metastyle.

M²: L=2.31+, PW=4.50. V-841 preserves the paracone, parastyle, and lingual portion of the tooth. Paracne and protocone are subequal in size and height; the protocone is compressed and the posterior height of the enamel below the slightly worn apex is 1.77. A paraconule and smaller metaconule are present; both lack internal wings. No lingual cingula are present. The lingual base of the metacone is present, and its size indicates that this cusp was slightly smaller.
than the paracone. The bases of paracone and metacone are connate. The parastyle projects anteriorly and is relatively low, and it is connected by a ridge to the paracone. A lingual ridge descends from the parastyle toward the lingual cingulum; a possible intersection with this cingulum is obscured by breakage. A labial cingulum is present. The stylar shelf is relatively narrow and has a weak ectoflexus.

**Discussion.**—This animal was approximately the same size as *Cimolestes simpsoni*, but its teeth had much lower crowns. Referral to *Gelastops* is based on lower crown height, relative reduction of cuspules, and the narrow stylar shelf. It differs from previously described species of *Gelastops* (Simpson, 1937; Rigby, 1980) in its smaller size and in having a less well developed parastyle on the molars. In this respect it is more like *Cimolestes* and *Procerberus*. The referred $P^3$ is similar in outline to $P^3$ of *Procerberus formicarum* as illustrated by Lillegraven (1969, p. 62), but it differs in having a distinct posterior accessory blade, as in *Cimolestes*. This form is also close to *Acmeodon*, but the lingual protocone of $M^2$ is curved rather than straight (Van Valen, 1966). The $M^2$ is neither as wide nor as compressed as in *Palaeoryctes*, and it has a much narrower stylar shelf. *Gelastops* sp. is intermediate in morphology between *Cimolestes* and *Gelastops parcus* of Torrejonian age, but the relatively low crown of its $M^2$ more closely resembles the condition seen in *Gelastops*. Although the referred specimens probably represent a new species, formal description awaits the recovery of more complete material.
Figure 69. *Gelastops* sp.

A-D. LSUMG V-708, LP³; occlusal, basal, labial, and posterolingual views.

E,F. LSUMG V-841, partial RM²; occlusal and anterior views.
Order PANTOLESTA

Family PANTOLESTIDAE

Genus Paleotomus Van Valen, 1967

Paleotomus senior (Simpson, 1937)

Paleosinopa senior Simpson, 1937.


Referred specimen.—TMM 41274-X, unnumbered LM₂.

Locality.—C-Con (VL-122=TMM 41274).

Distribution.—Scarritt and Douglass Quarries, Melville Formation, Crazy Mountain Basin, Montana; Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Early Tiffanian.

Description.—L=4.77, AW=3.72, PW=3.30. The specimen is moderately worn and broken. The trigonid is elevated, with the protoconid larger and although worn, slightly taller than the metaconid. The paraconid is smaller and is situated lingual to the midline, close to the metaconid; its apex is broken off. The paracristid descends the anterior slope of the protoconid and bends abruptly toward the paraconid. No carnassial notches are visible on the worn trigonid cristids. An anterolabial cingulid is present, sloping downward from the paraconid.

Discussion.—Referral to Paleotomus senior is based on resemblance in size and morphology to the M₂ of a dentary described by Krause and Gingerich (1983, p. 169). The trigonid of the Big Bend specimen is less elevated, but it is considerably more worn. The talonid also appears to be relatively wider, but the entoconid and hypoconulid
placement is similar to that displayed by the $M_2$ of \textit{Paleotomus milleri} from Swain Quarry (Rigby, 1980, p. 161).

Figure 70. \textit{Paleotomus senior}, TMM 41274-X, broken $LM_2$, in:

A. occlusal; B. anterior; C. labial; and
D. lingual views.
Order CARNIVORA
Family DIDYMICTIDAE
Genus Protictis (Matthew, 1937)
Subgenus Bryanictis MacIntyre, 1966

Protictis (Bryanictis) terlinguae n. sp.

Figures 71, 72

Type.—TMM 41400-10; LP$_4$.

Referred specimens.—LSUMG V-709, LP$^3$; V-960, RP$_2$.

Localities.—Tom's Top (VL-111=TMM 41400) and Dogie (VL-111).

Distribution.—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

Etymology.—Named for Terlingua Creek, near the type locality (Tom's Top).

Diagnosis.—P$_4$ with no metaconid [metaconid present in Protictis (Bryanictis) vanvaleni]; slightly smaller than in P. (Bryanictis) microlestes, and with erect main cusp that is little recurved. Anterior accessory cusp relatively small and only slightly taller than first posterior accessory cusp; posterior of tooth relatively narrow, with posterior margin oblique rather than perpendicular to the labial margin. Referred P$^3$ lacks distinct protocone, has distinct metacone set obliquely to paracone and separated from the paracone by a notch.

Description.—P$^3$:L=2.97, W=1.79. The tooth is triangular in occlusal view, with a tall, central paracone and a low, oblique metacone separated from the paracone by a notch. A low parastyle is present, as well as a very reduced metastyle. A protocone does not appear to have been present, although the lingual corner of the tooth is slightly
Figure 71. *Protictis (Bryanictis) terlinguae*. LSUMG V-709, LP³, in:

A. occlusal; B. basal; C. labial; and D. lingual views.

damaged. The tooth probably had three roots; the bases of two are distinct, and a circular raised area is present below the lingual corner, incompletely set off from the posterior root. The cingulum is reduced labial to the paracone. Anterior and posterior lingual cingula are present.

P₂: L=2.38, W=0.87. The tooth is laterally compressed, with the main cusp anterior to the midline and slightly recurved. A rudimentary basal cuspule is present anterior to the main cusp, and a single talonid cusp is present on the posterior midline.

P₄: L=3.68, AW=1.42, PW=1.65. The type is an elongate triangle in occlusal view, with an oblique posterior margin. The three anterior
Figure 72. *Protictis (Bryanictis) terlinguae* lower premolars.

A-E. LSUMG V-960, RP₂, in: lingual, labial, anterior, posterior, and occlusal views;
F-J TMM 41400-10 (type) LP₄, in: occlusal, labial, lingual, anterior, and posterior views.
cusps are laterally compressed. The main cusp is erect and leaf-shaped in lateral view; it is separated from the anterior and first posterior accessory cusps by carnassial notches. The anterior accessory cusp is only slightly taller than the first posterior accessory cusp. The second posterior accessory cusp is set at the posterolingual corner of the tooth. It is linked to the first posterior accessory cusp by a short ridge with a V-shaped valley. A lingual cingulid extends from the second posterior accessory cusp anteriorly around the margin of the talonid basin to the posterior base of the main cusp, where it dissipates onto a curved slope leading to the apex of the main cusp. A second, labial cingulid extends a short distance anteriorly from the second posterior accessory cusp toward the posterolabial corner of the tooth. A very short anterior cingulid is present at the anterolabial base of the tooth below the anterior carnassial notch.

Discussion.—Referral to Protictis (Bryanictis) is based on the presence in the type of the following features: enlarged shearing anterior accessory cusp; expansion and basining of the lingual talonid; lateral compression of the cusps; and alignment of the principal cusps in a straight anteroposterior line on the buccal tooth margin, which is straight. These features are discussed by Flynn and Galiana (1982) in their revision of Early Tertiary Carnivora, in which they refer Protictis to a new family, the Didymictidae, rather than to the Miacidae as in MacIntyre (1966). The type of Protictis (Bryanictis) terlinguae is less derived than the previously described species in that the anterior accessory cusp is smaller and slightly lower, the
main cusps are less buccal, the talonid is narrower, and the main cusp is more erect.

Order INSECTIVORA

Family MIXODECTIDAE

Genus Mixodectes Cope, 1883

Mixodectes malaris (Cope, 1883) Matthew, 1937

Figure 73

Indrodon malaris Cope, 1883.

Mixodectes malaris (Cope). Matthew, 1937.

Referred specimens.—LSUMG V-924, posterior half of LM³; V-928, posterior half of LM²; TMM 40147-60, partial LM₂.

Localities.—Tom's Top (VL-111=TMM 41400), late Puercan; T2 (TMM 40147), Torrejonian.

Distribution.—Nacimiento Formation, San Juan Basin, New Mexico; Fort Union Formation, Washakie Basin, Wyoming; upper Javelina and lower Black Peaks Members, Tornillo Formation, Big Bend National Park, Texas. Late Puercan and Torrejonian (early and middle Paleocene).

Description.—Upper molars: The referred specimens from Tom's Top are fragmentary. V-924 preserves the major portion posterior to the paracone, and V-928 preserves the posterior half. The posterior width of V-928 is 4.31 mm., and that of V-924 is 3.73 mm. Both specimens have a mesostyle and an ectocingulum. Broad wear surfaces are present on the centrocristae, which are straight anteroposteriorly, and on the referred M² the wear surface extends labially to encompass the mesostyle. The metastylar area of V-924 is broken, but on V-928 a metastyle is present. Metaconule cristae are well developed. V-928
has a distinct low hypocone, but this feature is not present on V-924.

\[ M_2: L = 3.64, W = 2.48. \]  The crown of the specimen leans slightly anteriorly, and moderately lingually. The protoconid is moderately tall and has two shallow valleys descending its lingual side; one extends anterolingually posterior to the paraconid shelf, and the other extends posterolingually toward the metaconid. The paraconid is a low shelf without a distinct cusp. The metaconid is broken, but the size and elevation of the broken base indicate that it was undoubtedly larger and higher than the protoconid. A precingulid is present extending from a point anteroventral to the protoconid lingually to a point just below the lingual margin of the paraconid shelf. A tiny cuspule is present on its labial end.

The talonid is wider than the trigonid, but exact measurements cannot be determined because of breakage. It has a large, tall entoconid that lacks an anterior crest, but it has a strong posterolabial crest. The cristid obliqua meets the posterior trigonid wall at a point labial to the midline; a distinct mesoconid is developed on the cristid obliqua near this junction. A large shear wear facet is present on the remaining posterior trigonid wall.

**Discussion.**—Referral to *Mixodectes malaris* is based on size and morphologic resemblance to specimens from the San Juan Basin. Hypocone development is of particular value in making generic assignment; the hypocone of the referred \( M^2 \) is larger than that seen in *Elpidophorus* and smaller than in *Eudaemonema*, as discussed by Szalay (1969). The appearance of this form at Tom's Top, which is considered to be late Puercan in age, represents a chronological range extension to a time earlier than Torrejonian.
Figure 73. *Mixodectes malaris.*

A. LSUMG V-928, posterior half of LM³, occlusal view;
B. LSUMG V-924, posterior half of LM³, occlusal view;
C-G. TMM 40147-60, partial LM², in: occlusal, anterior, posterior, labial, and lingual views.
Order ?PRIMATES

Family MICROSYOPIDAE

Genus Palaechthon Gidley, 1923

Palaechthon nacimenti Wilson and Szalay, 1972

Figure 74

Referred specimens.—LSUMG V-921, RP$^4$; TMM 41400-17, LM$^2$; LSUMG V-923, RM$^3$.

Locality.—Tom's Top (VL-111=TMM 41400). Late Puercan.

Distribution.—Nacimiento Formation, San Juan Basin, New Mexico; upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan and Torrejonian.

Description.—P$^4$: L=2.18, W=2.41. The tooth is moderately swollen, with a distinct conical parastyle. The metacone merges with the posterior base of the paracone, and the metacone is no more than a shelf formed by the junction of the labial and posterior cingula. The posterior cingulum rises toward the protocone at its lingual end, and is linked to the apex of the protocone by a worn ridge. The anterior cingulum is very short, linking the anterolabial base of the protocone to the parastyle; a short curved ridge links its midpoint to the base of the paracone.

M$^2$: L=2.13, AW=3.41, PW=3.13. This tooth has poorly preserved surface enamel, the result of etching. It is much wider than long. The stylar shelf is very narrow, and has a slight ectoflexus. The anterior cingulum is long; the posterior cingulum extends lingually to the indistinct, small hypocone, which is linked to the protocone apex by a worn ridge (Nannopithex fold).
M₃: L=2.55, AW=1.42, PW=1.46. This specimen was found in two fragments, the trigonid and talonid having been recovered separately from screen washing. Under high magnification (X60), a small crescentic area of contact was matched to unite the two fragments. The trigonid is relatively low; the metaconid is the largest and highest cusp. The protoconid is slightly anterior and labial to the metaconid; it is the same height as the hypoconulid in lateral view. The small paraconid is anterior and slightly labial to the metaconid and separated from it. The paraconid projects slightly anteriorly and is linked to the anterior face of the protoconid by the transverse paralophid. The paralophid makes a right angle turn to ascend the anterior face of the protoconid. A narrow, transverse trigonid valley is present posterior to the paralophid, and a second, circular valley is present between the protoconid and metaconid. This valley is separated from the anterior valley by medial buttresses of the protoconid and metaconid, and from the posterior wall of the trigonid by the protolophid, which forms a low notch. A worn anterior cingulid extends onto the labial face of the protoconid.

The talonid is relatively long; the conical hypoconid is subequal in size to the transversely compressed, slightly lingually positioned hypoconulid. They are linked by a strong ridge that has a postero-labial concavity below it. The entoconid is slightly posterior to the hypoconid. The entoconid has a high short ridge connecting it to the hypoconulid, and a lower ridge descending anteriorly to the area of breakage. An extension is present on the lower posterior wall of the metaconid, indicating that the talonid basin may have been closed.
Figure 74. *Palaechthon nacimienti*.

A. LSUMG V-921, RP^4_; occlusal view;  
B. TMM 41400-17, LM^3_; occlusal view;  
C-F. LSUMG V-923, RM^3_; occlusal, anterior, lingual, and labial views.
The cristid obliqua is strong and high, and intersects the posterior
trigonid wall beneath the protoconid, slightly labial to the bottom
of the notch in the protolophid. A swollen area is present anterior
to the hypoconid on the cristid obliqua. The talonid basin is deep
and wide, and accessory ridges and wrinkles are present on the
lingual slope of the hypoconid.

Discussion.—Referral to Palaechthon is based on similarity to
P. alticuspis, the genotype, as illustrated by Simpson (1955, Pl. 34).
Referral to P. nacimienti is based on the less lingual position of
the paraconid and the less expanded hypoconulid on the referred M$_3$,
which closely resembles M$_3$ of specimens illustrated by Wilson and
Szalay (1972). The referred M$^2$ is slightly smaller than in specimens
from the San Juan Basin (Wilson and Szalay, 1972, p. 7), and inter­
mediate in size between their P. nacimienti and P. alticuspis;
however, considering the wide size range in the molars of
P. problematicus reported by Rigby (1980, p. 96), TMM 41400-17 is
here considered to be a smaller individual of the same taxon as the
referred P$^4$ and M$_3$.

Palaechthon cf. P. woodi Gazin, 1971
Figure 75

Navajovius kohlhaasae Matthew and Granger, 1921. Schiebout, 1974,
p. 15 (in part), p. 55, Fig. 15e.

Referred specimen.—TMM 40147-62, left maxilla fragment with M$^2$.

Locality.—T2 (TMM 40147). Torrejonian.

Distribution.—Shotgun and Bangtail local faunas, Fort Union
Formation, Wyoming and Montana; Nacimiento Formation, San Juan Basin,
New Mexico; lower Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Torrejonian and earliest Tiffanian.

**Description.**—L=1.46, W=2.13. This specimen was described and illustrated by Schiebout (1974, pp. 16, 55; Fig. 15e). Re-examination has disclosed additional features. The orientation of the posterior alveolus preserved in the maxilla fragment indicates that the missing posterior tooth had a reduced posterior margin and was thus an $M^3$, implying that the preserved tooth is indeed an $M^2$. On this tooth, *contra* Schiebout (1974, p. 16) a short crest (*Nannopithex fold*) is present linking the hypocone to the posterior slope of the protocone. A short postparacrista is present, as well as a weak ridge descending from the metaconule to the labial end of the postcingulum. The protocone leans slightly anteriorly and there is a wear facet on its posterior slope extending to the short anterior crest from the hypocone.

**Discussion.**—The proportions of this specimen resemble those of *Palaechthon* rather than *Navajovius*. As illustrated by Simpson (1936, p. 14) and Szalay (1969, Pl. 31), the $M^2$ of *Navajovius* is relatively longer and has a more lingual hypocone. Also, the protocone in TMM 40147-62 leans somewhat more anteriorly and the posterior margin of the tooth is concave. The paracone and metacone are more labially situated than in *Navajovius*, the conules are weaker, and the anterior cingulum is shorter. This specimen is slightly smaller than the upper molar ($M^1$ or $M^2$) provisionally referred to *P. woodi* by Gingerich *et al.* (1983, p. 964), which as illustrated appears to lack a hypocone. The presence of *P. woodi* in southern faunas (the San Juan Basin of New Mexico) has been documented by Wood *et al.* (1979).
Figure 75. *Palaechthon cf. P. woodi*. TMM 40147-62, left maxilla fragment with \( N^2 \).

A. occlusal view; B. lingual view.

Order **CONDYLARTHRA**

Family **ARCTOCYONIDAE**

Genus *Prothryptacodon* Simpson, 1935

*Prothryptacodon* sp.

Figure 76

**Referred specimen.**—TMM 40147-28, RM.<sub>3</sub>.

**Locality.**—T2 (TMM 40147).

**Distribution.**—Lower Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Torrejonian.

**Description.**—L=4.08, AW=PW=2.55. The tooth is elliptical in occlusal view. The trigonid is moderately elevated above the talonid. The protoconid is the largest trigonid cusp, and it is subequal in height to the smaller metaconid. The paraconid is high, transversely elongated, and is situated anterior and slightly labial to the
Figure 76. Prothryptacodon sp. TMM 40147-28, RM₃, in:
A. occlusal; B. anterior; C. labial; and D. lingual views.

Discussion.—Referral to Prothryptacodon is based on the relative height of the trigonid. Simpson (1937, p. 195) stated that this genus
has only one inner talonid cusp (entoconid) rather than two as in *Thryptacodon*; the Big Bend form has cuspules near the paraconid, entoconid, and hypoconulid, but I consider the high trigonid to have more weight in taxonomic placement. TMM 40147-28 differs from previously described species of *Prothryptacodon* in having a reduced metaconid and hypoconulid, and a longer, wider talonid. In occlusal view the tooth resembles early Tiffanian *Thryptacodon* cf. *T. demari* as illustrated by Krause and Gingerich (1983), but the trigonid of TMM 40147-28 is relatively higher. This specimen is approximately the same size as *M₃* of *Prothryptacodon albertensis*, but it differs from the latter in having a less prominent hypoconulid and in possessing accessory cuspules. TMM 40147-28 is the right size for *M₃* of *P. ambigua* (Van Valen, 1967), but anterior molars of *P. ambigua* lack accessory cuspules (*M₃* is unknown).

Genus *Eoconodon* Matthew and Granger, 1921

*Eoconodon* coryphaeus (Cope, 1885)

*Triisodon heilprinianus* Cope, 1882. Van Valen (1978, p. 58) noted that this is not the senior synonym because the specimen associated with the name was later identified as *Conoryctes*.

*Sarcothraustes coryphaeus* Cope, 1885.


Referred specimens.—LSUMG V-1156, RM₁ or M² lingual fragment; V-1157, LM₁ or M₂ trigonid fragment; V-1158, left dentary fragments with tooth roots; V-1151, right proximal radius; V-1159, right femur head.

Distribution.—Nacimiento Formation, San Juan Basin, New Mexico; upper Javelina Formation, Tornillo Formation, Big Bend National Park, Texas. Puercan.

Description.—$M^1$ or $M^2$: $L=11.72+$. V-1156 preserves a massive protocone with a squared lingual outline and a steep lingual slope, and a small but distinct hypocone situated at the lingual end of a strong posterior cingulum. A shorter anterior cingulum is also present. The enamel is relatively smooth, with a few short, weak wrinkles. The base of the crown lingual to the protocone is indented in a small area that appears to have been damaged. The crown is worn; an expansion on the preprotocrista indicates the paraconule was moderately strong, but the size of the metaconule cannot be determined. A short extension of the worn area labial to the position of the metaconule indicates that the metaconule may have had an anterior crista. The worn postmetaconulecrista descends to the posterolabial corner of the fragment.

$M_1$ or $M_2$: V-1157 is a fragment 8.61 mm. long that preserves most of the protoconid and the metaconid. The enamel is faintly wrinkled. The protoconid is larger than the metaconid, and connate with it. The wear surfaces truncating the apices of the cusps are slightly angulated. A short groove descends the anterior face between the two cusps, and a worn remnant of the preprotocristid descends from the protoconid. The posterior face of the protoconid is bevelled by a large shear wear facet. A short fold descends from the posterior margin of the metaconid to intersect with a narrow oblique wear facet.
Figure 77. *Eoconodon coryphaeus* molar fragments.

A-C. LSUMG V-1156, lingual half of RM\(^1\) or M\(^2\); occlusal, posterior, and anterior views.

D-F. LSUMG V-1157, partial trigonid of LM\(_1\) or M\(_2\); occlusal, anterior, and lingual views.
extending posterolingually from the lingual margin of the protoconid, but there is no indication of a medial cristid descending the posterior trigonid wall as in Triisodon.

Dentary: V-1158 consists of three fragments of the left dentary, including anterior, intermediate, and posterior sections. The anterior fragment is 40 mm. long; it preserves a remnant of the symphysis and five tooth roots, as well as a portion of the alveolus for an anterior root. The alveolus and the most anterior root are small and labial to the midline; the remaining roots are on the midline. The second root is oval in shape, situated directly anterior and close to the large third root, which is reniform and concave posteriorly. The third root is long; its base is visible on the broken internal surface of the fragment. The equally large fourth root is concave both anteriorly and posteriorly. The fifth root is only partially preserved, but was apparently large, as the remnant is 13 mm. long. Two foramina are visible on the labial side of the fragment. The smaller one is situated immediately below the remnant of the alveolus on the anterior margin, while the larger second foramen is situated below the third root a little more than half its height above the ventral margin of the fragment. The 35 mm.-long intermediate fragment does not preserve any tooth roots. The posterior fragment preserves the remnant of a root, presumably the posterior root of M₃. The depth of the jaw at this point is 46 mm. The ascending ramus has a strong labial crest. The mental foramen is visible in all three fragments, and no indications of unerupted teeth are seen.

Radius: V-1151 has a shallowly concave head which is 25.14 mm. wide. The head is reniform in proximal view with a shallow fovea.
Figure 78. Eoconodon coryphaeus. Scale=10 mm.

A-C. LSUMG V-1158, left dentary fragments; lingual, labial, and dorsal views.
D,E. LSUMG V-1151, right proximal radius; proximal and posterior views.
F. LSUMG V-1159, right femur head; medial view.
The rim of the head is broken posteriorly, but preserves a wide, shallow vertical facet. The shaft is 12.34 mm. in diameter. The radial tuberosity is medial relative to its position in the radius of the dog.

Femur: V-1159 is 36 mm. in diameter. A small circular medial concavity (fossa capitalis) is present.

Discussion.--These specimens are associated on the basis of size and preservation. Referral to Eoconodon is based on the presence of a distinct hypocone on the upper molar fragment, and the squared lingual outline. The lower molar fragment does not exhibit the medial crest descending the posterior trigonid wall seen in Triisodon, and the relatively small metaconid precludes assignment to Goniacodon.

In Triisodon quivirensis, a cast of which was available for comparison, the posterior foramen of the dentary is between P₃ and P₄. Assuming V-1158 represents a similar form, roots 4 and 5 may be the roots for P₄, and roots 2 and 3 the roots for P₃. P₂ of Eoconodon coryphaeus has two roots according to Matthew (1937, p. 81), probably corresponding to root 1 and the alveolus anterior to it. In Triisodon quivirensis the anterior foramen is immediately posterior to the canine; in V-1158 it is below the anterior alveolus. The position of the remnant of the symphysis compares well to that seen in T. quivirensis; the specimen of Eoconodon illustrated by Matthew (1937, Pl. XII) is inadequate for determining details of the anterior lower dentition. Matthew (1937, p. 81) stated that the dentition of Eoconodon was unreduced, but the lateral displacement of the anterior roots as well as the position of the symphysis and anterior foramen indicate that V-1158 may have lacked P₁.
Referral to *Eoconodon coryphaeus* is based on size; while this specimen represents an individual slightly larger than those from the San Juan Basin, Matthew (1937, p. 83) stated that individual variation in specimens from the San Juan Basin is considerable, and may be due to sexual differences.

**Eoconodon sp.**

Figure 79

**Referred specimen.**—LSUMG V-704, LN³.

**Locality.**—Dogie (VL-108).

**Distribution.**—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan (early Paleocene).

**Description.**—L=4.71, AW=7.30, PW=5.81. The tooth is triangular in occlusal view, with rounded margins. The protocone is the largest cusp; it is subequal in height to the slightly smaller paracone. The protocone has a steep lingual slope. The metacone is reduced. The paraconule is distinct and lacks a posterior crista. The metaconule is vestigial. The postmetaconulecrista is linked to the labial cingulum by a weak connection posterior to the very short postmetacrista. The labial cingulum is reduced labial to the metacone, but very strong labial to the paracone; a notch, which may be due to breakage, is present on the labial cingulum posterolabial to the moderately strong parastyle. The parastyle is linked to the paraconule by a strong preparaconulecrista. A lingual cingulum is present that extends from the junction with the preparaconulecrista around the lingual base of the protocone, where it is weakened, to a point posterolinguinal to the preparacrista. The enamel is wrinkled.
Discussion.--Referral to Eoconodon is based on the lingual position and steep lingual slope of the protocone, the reduced metacone, vestigial metaconule, and strong lingual cingulum. The rounded outline of the tooth most resembles that of the \( M^3 \) of the much larger species *E. coryphaeus*. The \( M^3 \) of *Eoconodon* sp. Johnston and Fox, 1984, which is approximately the same size, is more angular with a narrower lingual margin and straighter anterior and posterior borders. V-704 is of appropriate size to occlude with the type \( M_3 \) of *E. nidhoggi* Van Valen, 1978, and has similarly wrinkled enamel; however, Van Valen (1978, p. 58) stated that upper molars of this form are "very transverse," and he did not illustrate the \( M^3 \). V-704 does not appear to be particularly "transverse." In comparison with UALP specimens of *E. gaudrianus* from the San Juan Basin, V-704 is smaller and has more wrinkled enamel.

![Figure 79. *Eoconodon* sp. LSUMG V-704, \( M^3 \); occlusal view.](image-url)
Family PERIPTYCHIDAE
Genus Periptychus Cope, 1881

Periptychus carinidens Cope, 1881

Figure 80

Periptychus carinidens Cope. Wilson, 1967, p. 160, Fig. 110.

Periptychus superstes Matthew, 1935. Schiebout, 1974, p. 31 in part (not P. superstes Matthew), p. 65, Fig. 25a.

Referred specimens.—TMM 40147-1, LP1; 40147-4, RP4; 40147-17, maxilla fragment with RM1-2, mandible fragment with LM2, and alveoli for M3; 41274-1, RP4.

Localities.—T2 (TMM 40147), Torrejonian, and C-Con (VL-122=TMM 41274), early Tiffanian.

Distribution.—Nacimiento Formation, San Juan Basin, New Mexico; Fort Union Formation, Washakie Basin, Wyoming; lower Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Early Torrejonian (Tomida, 1981) to early Tiffanian (this paper).

Description.—P4; L=11.2+, W=10.9+. TMM 40147-4 preserves the lingual two-thirds of the crown and labial base. As mentioned by Schiebout (1974, p. 31), the crescentic protocone is worn, but the shape of the worn surface indicates that a cuspule was probably present anterior to the protocone.

M1, M2: These teeth have been previously described and illustrated (Wilson, 1967; Schiebout, 1974).

P1: L=6.54, W=4.63. The crown of TMM 40147-1 has distinct vertical ridges on its labial side. The principal cusp is erect, with an anterior crest descending to a short, low anterior cingulid, and a
posterior crest descending to a short lingually situated heel. The
tooth has only one root.

\( P_4: \ L=13.32, \ W=10.54. \) TMM 41274-1 has been described
previously (Schiebout, 1974, p. 31). Additional repairs to this
specimen have added several fragments that enable better measurements
to be made. The tooth has suffered postmortem distortion and breakage,
but it exhibits a distinct, long anterior cingulid extending from the
base of the paraconid to the anterolabial corner of the tooth. Crests
descend the anterior and posterior slopes of the protoconid; the
posterior crest leads to the lingual margin of a broad talonid. The
anterior width is slightly exaggerated due to distortion.

\( M_2: \ L=10.16, \ W=8.30. \) TMM 40147-17 includes a dentary fragment
with a damaged left \( M_2 \) preserving the protoconid, obliconid, and
talonid. The cristid obliqua extends lingually from the hypoconid to
intersect near the hypoconid with a cristid running anterolabially
from the hypoconulid. Vertical ridges are present, with the enamel
in general being moderately wrinkled. The dentary posterior to this
tooth preserves the alveoli and the remnants of the root of \( M_3 \). The
posterior alveolus tapers posteriorly. The alveolar space is 12.3 mm.
long, allowing for a tooth with this maximum length if the posterior
root were vertical (it frequently projects posteriorly).

Discussion.--Schiebout (1974, p. 31) assigned all periptychid
remains from Big Bend to one species, \textit{P. superstes} Matthew, 1935,
primarily on the basis of size. \textit{Periptychus superstes} is present at
Ray's Bonebed on western Tornillo Flat, but the specimens discussed
here are considered to be closely comparable to \textit{P. carinidens} Cope,
1881, on the basis of both morphology and size. All of these
Figure 80. *Periptychus carinidens*.

A-C. TMM 40147-1, LP₁; occlusal, labial, and lingual views.

D-F TMM 40147-17: D. LP₄ occlusal view;
E,F. LM₄; occlusal and labial views.

G. TMM 41274-1, broken RP₄, occlusal view.
specimens are within the size range of described specimens of *P. carinidens* (Matthew, 1937; Simpson, 1959; Rigby, 1980; Tomida, 1981). Morphological characters favoring assignment to *P. carinidens* include: width and cingulid development of the $P_4$; and disposition of talonid cristids on the $M_2$. *Periptychus superstes* is derived relative to *P. carinidens* in that on the $M_2$ a cristid runs directly anteriorly from the hypoconulid to intersect with the cristid obliqua at a more anterior point, thus forming a strong anteroposterior crest. In *P. carinidens* this cristid angles toward the hypoconid, joining the cristid obliqua near the hypoconid. In addition, the length of the space for the $M_3$ on TMM 40147-17 indicates a tooth with a length more appropriate for *P. carinidens* than the relatively long $M_3$ of *P. superstes* (Simpson, 1935, p. 26). For these reasons the specimens from the lower Black Peaks Member are referred to *P. carinidens*, following Wilson (1967). Figure 80 shows specimens not illustrated previously.

Genus *Carsioptychus* Simpson, 1936

*Carsioptychus coarctatus* (Cope, 1883)

Figure 81

*Periptychus coarctatus* Cope, 1883, p. 168.


Referred specimens.—LSUMG V-888, RM$_3$; V-873, R dentary fragment with $M_x$ trigonid fragment; V-1554, RM$_x$ talonid fragment.

Locality.—Dogie (VL-108); late Puercan.

Distribution.—Nacimiento Formation, San Juan Basin, New Mexico;
upper Javelin Member, Tornillo Formation, Big Bend National Park, Texas. Puercan.

Description.—M₃: L=11.86, W=8.08. V-888 is a moderately worn tooth with a wide, rounded trigonid and narrower, tapering talonid. The protoconid is the largest cusp; the metaconid is situated posterolingual to the protoconid, and the smaller paraconid, which projects slightly anteriorly, is anterolabial to the metaconid. The trigonid basin is constricted, as the swollen bases of the trigonid cusps are closely appressed. The talonid is slightly longer than the trigonid; the apices of its cusps are well separated. The hypoconid and entoconid are opposite each other, and the hypoconulid is located slightly lingual to the midline. The hypoconulid is large and it is elevated so that its worn occlusal surface is as high as the worn surfaces of the trigonid cusps. This elevation is paralleled by the lingual base of the enamel, which is higher beneath the hypoconulid. Accessory cusps are developed at the following points: behind the metaconid, where a distinct metastylid is situated at the base of the postmetacristid; posterior to the entoconid, where a cusp is situated posterolingual to a gap separating entoconid and hypoconulid; and mid-labially, where a low, worn cusp is present at the labial base of the talonid notch. Cuspules are also present posterior to the hypoconid and lingual to the paraconid. The protocristid angles posteriorly to meet the anterior extension of the cristid obliqua. An obliconid is not present at this point. The enamel of the talonid basin is smooth and uncomplicated, as is that in the low valley between the hypoconid and the mediolabial accessory cusp. A cristid extends posteriorly from the entoconid toward the hypoconulid, but it
is separated from the anterolingual cristid that extends from the hypoconulid by a small gap. Another cristid from the hypoconulid extends anterolabially to the hypoconid. The anterior cingulid is very short; the labial cingulid is well developed, extending from the talonid notch around the base of the hypoconid to the base of the hypoconulid. There is no posterior cingulid. Vertical ridges are present on the labial side of the protoconid and the lingual slopes of the hypoconulid.

\[ M^x \text{ V-873 preserves the anterior root and most of a worn trigonid. The labial side of the protoconid has vertical ridges, and a labial cuspule is present at the broken edge behind the protoconid. The width of the base of the crown is 8.0 mm. V-1554 preserves the hypoconid and part of the hypoconulid, as well as the cristid obliqua, which shows no indication of an obliconid at its anterior end. An ectocingulid is present, as well as a mediolabial cuspule. Vertical ridges are present on the external sides of the hypoconid.} \]

Discussion.---Referral to Carsioptychus coarctatus is based on close similarity in size and morphology to specimens from the San Juan Basin (Matthew, 1937). The species has a checkered nomenclatural history. Originally considered a species of Periptychus (Cope, 1883), coarctatus was designated the type species of Plagioptychus by Matthew (ex MS, in Simpson, 1936, p. 9). As this name was preoccupied, it was soon replaced by Carsioptychus (Simpson, 1936, p. 234, in Matthew, 1937, p. 365). Matthew (1937, p. 122) listed Plagioptychus as a subgenus of Periptychus, but editorial notes in this same publication (Matthew, 1937, p. 365) noted the change to Carsioptychus.
Figure 81. Carsioptychus coarctatus.

A-E. LSUMG V-888, RM; occlusal, lingual, anterior, posterior and labial views.

F,G. LSUMG V-873, dentary fragment with RM trigonid fragment; occlusal and labial views.

H. LSUMG V-1554, RM talonid fragment; occlusal view.
Van Valen (1978, p. 62) synonymized the two described species from the San Juan Basin, *Plagioptychus matthewi* Simpson, 1936, and *Carsioptychus coarctatus* (Cope, 1883), and agreed with Matthew (1937, p. 122) that *Carsioptychus* "is best treated as a subgenus."

Van Valen (1978, p. 69) noted that the species *C. coarctatus* occurs in both Puercan fossil levels of the San Juan Basin, whereas Simpson (1936, p. 10) described *P. matthewi* as being found only in the upper, *Taeniolabis*, level. Available locality information for specimens of *C. coarctatus* at the University of Arizona Laboratory of Paleontology shows recovery limited to the lower, *Ectoconus*, level (*Hemithlaeus* level of Van Valen, 1978). Van Valen (1978, p. 69) did not elaborate on the reasons for his conclusions.

*Carsioptychus* differs from *Periptychus* in the following features:

1) premolars and molars wider; 2) $P_4^4$ distinctly skewed posteriorly; 3) hypoconulid and hypoconid in lower molars linked directly by a cristid; 4) obliconid absent or poorly developed; 5) relatively small paraconid. *Periptychus* has narrower molars, an erect $P_4^4$, an anterior cristid from the hypoconulid linked with the cristid obliqua rather than with the hypoconid, obliconids present, and larger paraconid.

Gaxin (1941) described two periptychids from Utah: a smaller form from the Wagonroad locality named *Carsioptychus hamaxitus*, and a larger, Dragon form named *Periptychus gilmorei*. He considered these as showing intermediate stages in *Periptychus* from the Puercan to Torrejonian forms of the San Juan Basin. *Periptychus gilmorei*, however, lacks the hypoconulid-cristid obliqua linkage here considered
a Periptychus character, and has more transverse cheek teeth, as well as a skewed $P_4^4$ and a weak obliconid. It is here considered a species of Carsioptychus.

Previous authors (Matthew, 1937; Gazin, 1941; Van Valen, 1978) have apparently interpreted the skewed nature of the Carsioptychus $P_4^4$ as being the primitive state, but this is not clarified by Van Valen's interpretation of the phyletic position of Maiorana (Van Valen, 1978, p. 67), his presumed primitive peryptychine, which has an erect $P_4^4$. The polarity of this character is therefore ambiguous. I consider the apomorphous state of the cristid obliqua-hypoconulid link in Periptychus, combined with an erect $P_4^4$, narrower cheek teeth, larger paraconids, and persistent obliconids to be of generic significance. Carsioptychus as presently known includes the following species: C. coarctatus, C. matthewi, C. hamaxitus, and C. gilmorei.

Genus Haploconus Cope, 1882

Haploconus inopinatus Gazin, 1939

Figure 82

Referred specimens.—LSUMG V-710, partial RM$^1$; V-711, partial RM$^2$; V-835, LM$^1$ trigonid.

Locality.—Dogie (VL-108). Late Puercan.

Distribution.—North Horn Formation, Joe's Valley Member, Utah; upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan and early Torrejonian.

Description.—The upper molars, which were recovered in picking by Victoria Richardson, lack the stylar shelf area, with fresh breaks. The teeth were probably associated, but separated during removal of
material for screen washing.

\( M^1 \): \( L=3.81+, W=4.57+. \) The length approximates the actual length before breakage. On \( V-710 \), conules are present, and conule cristae do not interrupt the anterior and posterior cingula. A short premetaconulecrista connects the metaconule to the base of the metacone. The area of the postparaconulecrista is worn, so that it is not possible to determine if one was present. The paracone is larger than the metacone. A prominent protostyle is present lingual to the paraconule; the apices of the conules, protocone, protostyle, and hypocone are symmetrically distributed like the spots on a 5-die, with the hypocone slightly larger and higher than the protostyle. An accessory cuspule is present on the posterior cingulum labial to the hypocone.

\( M^2 \): \( L=3.96, W=5.25+. \) On \( V-711 \) the protocone apex is relatively more labial, and the conules are closer to the protocone and slightly less distinct than on \( M^1 \). As on \( M^1 \), the conule cristae are high and do not extend to the anterior or posterior cingula. A crista extends from the protocone to the base of the paracone, and an indistinct ridge extends from the posterolabial side of the metaconule to the anterolingual side of the metacone. The area of the protostyle is broken, so that it cannot be determined if one was present. As on \( M^1 \), an accessory cuspule is present on the postcingulum labial to the hypocone.

\( M_1 \): \( V-835 \) preserves a worn trigonid; the apices of protoconid and metaconid are closely approximated. A worn ridge descends directly anteriorly from the protoconid, and a second, lower, worn ridge
Figure 82. *Haploconus inopinatus*.

A, D, F. LSUMG V-711, partial RM'; occlusal, anterior, and posterior views.

B, C, E LSUMG V-710, partial RM'; occlusal, anterior, and posterior views.

G-J LSUMG V-835, LM, trigonid; occlusal, anterior, lingual, and labial views.
extends from the metaconid to the anterolingual corner of the tooth, which is squared. This second worn area is wider than that in the type of *H. angustus* (AMNH 3477), and it appears that a small paraconid may have been present.

**Discussion.**—Referral to *Haploconus* is based on resemblance to the teeth of the type species, *H. angustus* from the San Juan Basin. The lingual slope of the protocone is relatively reduced, compared to other small anisonchines, and the trigon basins of the upper molars are compressed, and the paraconid of the lower molars is reduced (Rigby, 1981, p. 94). Referral to *H. inopinatus* is based on the development of the protostyle and the relatively more transverse M\(^2\) (Gazin, 1939). The referred upper molars are intermediate in size between *H. elachistus* Gazin, 1941, and *H. inopinatus*; the M\(^2\) is 11% shorter than in the type of *H. inopinatus* (Gazin, 1939, p. 281).

**Family MIOCLAENIDAE**

**Genus Ellipsodon** Scott, 1892

*Ellipsodon priscus* (Simpson, 1936)

Figure 83

*Tiznatzinia priscus* Simpson, 1936, pp. 8, 9.


*Ellipsodon priscus* (Simpson). Cifelli, 1983, p. 34.

Referral specimens.—LSUMG V-875, RP\(^3\); V-706, LM\(^1\); V-701, RM\(^1\).

Locality.—Dogie (VL-108).

Distribution.—Nacimiento Formation, San Juan Basin, New Mexico; upper Javelina Member, Tornillo Formation, Big Bend National Park,
Texas. Puercan.

**Description.** — $P^3$: $L=3.30$, $W=2.48$. This tooth is a rounded equilateral triangle in occlusal view. It has a single large, central cusp that is slightly swollen, a small parastyle, and a tiny posterior cuspule (metastyle?) on the posterior cingulum. The anterior cingulum extends from the anterolabial margin to the lingual corner. The tooth had two roots; the large anterior root is preserved, and is subdivided near the crown and concave internally. The smaller posterior root was broken off near the crown.

$M^1$: $L=3.70$, $W=4.81$. This tooth is a rounded isosceles triangle in occlusal view. The cusps are conical and are moderately swollen. A large paraconule is present abutting the bases of paracone and protocone, but there is no metaconule. The paraconule lacks an anterior crista, but a short postparaconulecrista links the paraconule with the lingual base of the paracone, where it dissipates into a low ridge ascending the paracone. The postprotocrista extends from the protocone to the metacone, where it joins a crista ascending to the apex. The centrocrista extends from the small parastyle across the paracone and metacone to link with the posterior cingulum, which extends lingually to the base of the protocone and turns upward toward its apex. The anterior cingulum extends from the parastyle to the base of the protocone, but rises only slightly. The labial cingulum is reduced; a remnant is present at mid-length.

$M_1$: $L=3.67$, $W=3.12$. The cusps are moderately swollen, tapering smoothly from the base. The trigonid is only slightly higher than the talonid. In occlusal view, the trigonid is narrower anteriorly,
Figure 83. *Ellipsodon priscus*.

A. LSUMG V-875, RP\(^3\); occlusal view.
B-D. LSUMG V-706, LM\(^1\); occlusal, labial, and posterior views.
E-H. LSUMG V-701, RM\(^1\); occlusal, lingual, anterior, and labial views.
tapering smoothly on both labial and lingual margins. The metaconid is slightly larger and taller than the protoconid, and their apices are closely approximated; however, a tiny posterior trigonid basin is present anterior to the V-shaped protolophid. The larger anterior trigonid basin is open anteriorly. The paraconid is small but distinct, situated on the anterior base of the metaconid. The paralophid extends downward to the midline, where a small gap isolates the paraconid. The talonid is of uniform width, as wide as the posterior base of the trigonid. The hypoconid is large, the entoconid small but distinct. They are joined by a posteriorly convex ridge. No hypoconulid is present; the relatively unworn state of the tooth enables this determination to be made. The cristid obliqua extends from the hypoconid a short distance anteriorly, then turns to ascend the posterior trigonid wall toward the metaconid. A tiny remnant of the labial cingulid is represented by a basal cuspule anterolabial to the hypoconid. Lingually, a ridge descends at a low angle from the entoconid to the base of the metaconid, closing off the talonid basin, which is deepest labial to the entoconid. An anterior cingulid is present that extends from a point anterior to the paraconid to the anterolabial corner of the tooth; it has tiny cuspules. No posterior cingulid is present.

Discussion.—Referral to *Ellipsodon* is based on resemblance to the type, *E. inaequidens*, and to species referred by Wilson (1956). The Big Bend specimens display the relatively swollen cusps, appressed protoconid and metaconid, reduced hypoconulid and lingual and small paraconid of the lower molars, as well as having no metaconule on the
The P\textsuperscript{3} is associated on the basis of its small size and its relatively swollen nature. Referral to *E. priscus* is based on the small size and lesser degree of swelling of cusps compared to other species of *Ellipsodon*, as noted by Van Valen (1978, p. 59). The referred M\textsubscript{1} differs from the type of *E. priscus*, AMNH 16403, in having a tapered rather than broad anterior margin, as the anterolingual base of the tooth is less expanded below the paraconid. In this respect V-701 is slightly less derived. The type also has a small posterior cingulid, which is lacking in V-701.

Wilson (1956) did not include *E. priscus* in the genus as he described it, since Simpson (1936) had earlier included it in his new genus *Tiznatzinia*. Van Valen (1978, p. 59) synonymized *Tiznatzinia* with *Promioclaenus*, and erected a new genus, *Bomburia*, for *E. priscus*. The characters Van Valen used to distinguish *Bomburia* (degree of swelling, short talonid, large but uninflated protocone) differ from those of the type species of *Ellipsodon* only in being relatively more primitive, and they are inadequate for generic separation. I therefore follow Cifelli (1985, p. 34) in returning to Matthew's (1937) assignment.
Genus Promioclaenus Trouessart, 1904

Promioclaenus sp.

Figure 84

Referred specimen.—LSUMG V-920, LM^3.

Locality.—Tom's Top (VL-111).

Distribution.—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan.

Description.—L=2.29, W=3.49. The parastylar area and the metacone are broken off. The crown is relatively low; the paracone and protocone are conical and subequal in height. The cusps are slightly swollen—more so than in Promioclaenus wilsoni but much less than in P. acolytus. The protocone is relatively lingual in position, as in P. wilsoni, but it leans slightly anteriorly and has a low, broad posterior ridge linking it to a rudimentary hypocone on the raised lingual terminus of the posterior cingulum. This results in an appearance similar to the "Nannopithec fold" of some primates, as Rigby (1980) noted for Promioclaenus M^3 specimens from Swain Quarry. A strong anterolingual cingulum, which is raised on the lingual end, is also present. A remnant of the labial cingulum is present labial to the paracone; it is moderately large, less developed than in P. wilsoni, but larger than in P. acolytus. Pre- and postparaconule cristae are present, as well as a premetaconulecrista. The postmetaconulecrista is reduced to a vestigial ridge that does not intersect the postcingulum. The conules are well developed. An accessory cuspule is present on the postcingulum labial to the metaconule. The enamel is wrinkled on anterior and posterior external slopes below
the protocristae. The tooth is little worn; apical wear is present on the protocone, paracone, and conules. Shear wear is also present on the anterior of the paraconule and preprotocrista.

Discussion.--V-920 is of appropriate size for Promioclaenus acolytus as described by Rigby (1980, p. 120); however, the tooth is much less swollen than in P. acolytus from the San Juan Basin. In other aspects of its morphology (development of labial cingula, protocone position) it is intermediate between the Puercan P. wilsoni and the Torrejonian P. acolytus. As no anterior molars have been yet recovered, the existence or degree of $M^3$ reduction is unknown.

Figure 84. Promioclaenus sp. LSUMG V-920, $LM^3$; occlusal view.
Genus *Nexus* n. g.

**Type.**—*Nexus plexus* n. sp.

**Etymology.**—Latin *nexus*, binding or entwining, with reference to relationships with other mioclaenids.

**Diagnosis.**—As for the type and only known species.

*Nexus plexus* n. sp.

Figure 85, Table 11

**Type.**—LSUMG V-890; LM².

**Referred specimens.**—LSUMG V-891, LM¹; V-833, LP⁴; V-703, right mandible fragment with erupting M₂; V-839, V-840, RM₂ trigonid fragments; V-881, LM₃.

**Locality.**—Dogie (VL-108).

**Distribution.**—Upper Javelina Member, Tornillo Formation, Big Bend National Park, Texas. Late Puercan.

**Etymology.**—Latin *plexus*, plaited, with reference to the complex morphological linkages with other mioclaenids.

**Diagnosis.**—Mioclaenid of medium size, with molars very low crowned and moderately swollen. Upper molars with the protocone central in position, distinct labial cingula, reduced paraconule, hypocones small and posterior to the protocone. Mesostyle present, situated on centrocrista between paracone and metacone. The P⁴ with small metacone situated near apex of paracone, anteriorly projecting parastyle, and metaconule. Lower molars with low trigonids, small paraconids situated anterior and slightly labial to the metaconid, rugose talonid basins, and medial anterior terminus of cristid obliqua. The M₂ with a postmetacristid, small hypoconulid, and indistinct,
crest-like entoconid. The $M_3$ moderately reduced, with a metastylid, small entoconid, and non-projecting hypoconulid.

Description.--$P^4$: The tooth is low crowned and moderately bulbous. The parastyle is larger than the metastyle and projects anteriorly. A small metacone is situated high on the posterior slope of the paracone. Anterior and posterior cingula are present but discontinuous around the protocone. The labial cingulum is poorly developed labial to the paracone. A metaconule is present midway between the protocone and the metastyle. A worn preprotocrista descends from the protocone anterolabially, extending almost to the parastyle. The preprotocrista is broad; a paraconule may have been present as the enamel is swollen in this region, but wear and poor preservation obscure this area.

Upper molars: The teeth are very low crowned, with moderately swollen cusps. The protocone is central in occlusal view, with the hypocone situated high on the posterior slope, near the protocone, and connected to the protocone slope by a short crista. The anterolingual cingulum rises slightly toward the protocone; an incipient protostyle is present anterior to the protocone. The paracone and the slightly smaller metacone are linked by a broad centrocrista. A distinct mesostyle is situated between the paracone and metacone; it is slightly more labial on the $M^2$. The parastyle is moderately large and connected by a labial cingulum to the metastyle on the $M^1$; the labial cingulum on the $M^2$ is absent labial to the metacone. Accessory cusps are present on the labial cingulum anterolabial to the metacone and adjacent to the hypocone. The paraconule is reduced; it has an anterior crista that is interrupted on the $M^1$ but continues to
the anterior cingulum on the $M^2$. A short postparaconule crista extends directly labially onto the lingual slope of the paracone. The metaconule is larger than the paraconule; a short premetaconulecrista is present on the $M^1$ but lacking on the $M^2$. No postmetaconulecrista is present. The labial position of the protocone results in a very short postprotocrista, which on the $M^2$ is interrupted by a gap so that the metaconule is isolated. The $M^2$ is narrower posteriorly.

$M_2$: The only complete specimen of this tooth is an erupting $M_2$ that is fractured and posteriorly encased by the mandible, so that exact length has not yet been determined. The tooth has moderately swollen cusps, with the trigonid slightly elevated above the talonid. The trigonid is wider than the exposed talonid. The protoconid and metaconid are subequal in size, with the metaconid slightly higher and expanded anterolingually at the base. The paraconid is small but distinct, and it is situated anterior and slightly labial to the metaconid, merging with its base. The paralophid forms an anterior ledge at the midline. An accessory cuspule is present on all three referred $M_2$'s at the anterolingual base at the lingual end of a cingulid that extends to the anterolabial base of the protoconid. A metacristid is present at the posterior base of the metaconid. The talonid is short and narrower than the trigonid. The hypoconid is large and its unworn apex overhangs lingually. A small, medial hypoconulid is present, and the entoconid is elongate, forming a curved, arched crest without a distinct cusp. A separate accessory cuspule is situated between the entoconid and the hypoconulid. The cristid obliqua meets the posterior trigonid wall at a point slightly lingual to the notch in the
protolophid. The talonid basin is rugose. A basal accessory cusp is present at mid-length labially.

$M_3$: The tooth is similarly low crowned and slightly bulbous; the trigonid is only slightly higher than the talonid. In occlusal view, the anterior margin is smoothly rounded, not lingually expanded, and the posterior margin tapers to a median point. Trigonid features are as in $M_2$, with the additional presence of a small metastylid. The hypoconulid is median but does not project posteriorly; the entoconid is relatively low. Accessory cuspules are present between the entoconid and hypoconulid, and between the hypoconulid and hypoconid. The cristid obliqua intersects the posterior trigonid wall below the notch in the protolophid. Lingual to this point an accessory cristid is present that ascends the posterior trigonid wall toward the protolophid to a point slightly higher than that reached by the cristid obliqua. The talonid basin is rugose; accessory cristids descend from the hypoconid toward the entoconid.

Discussion.—This form shows strong similarities to several previously described mioclaenids, but the combination of characters it displays is distinctive. *Nexus plexus* may be ancestral to *Mioclaenus turgidus*. *Nexus plexus* retains a metacone on $P^4$ and has less inflated crowns and a more lingual terminus of the cristid obliqua. Reduction of the paraconule in *Mioclaenus* is variable; the type (AMNH 3135) has a reduced paraconule, but other referred specimens have unreduced paraconules. *Nexus plexus* may be descended from a species of *Protoselene*; *P. griphus* is very similar, differing in a more lingual protocone, unreduced paraconule, lower and more lingual hypocone,
unreduced entoconid, and $M_2$ lacking anterolingual basal expansion.

The mesostyle in Protoselene is labially situated rather than being between the paracone and metacone.

Table 11. Measurements of teeth of *Nexus plexus* n. g., n. sp.

<table>
<thead>
<tr>
<th>LSUMG Specimen No.</th>
<th>Element</th>
<th>Length</th>
<th>Width or</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Anterior width</td>
</tr>
<tr>
<td>V-833</td>
<td>P$^4$</td>
<td>4.49</td>
<td>5.18</td>
</tr>
<tr>
<td>V-891</td>
<td>M$^1$</td>
<td>4.62</td>
<td>5.91</td>
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<td>M$^2$</td>
<td>4.52</td>
<td>6.32</td>
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<tr>
<td>V-703</td>
<td>M$^2$</td>
<td>4.76</td>
<td>4.29</td>
</tr>
<tr>
<td>V-840</td>
<td>M$^2$</td>
<td>------</td>
<td>4.14</td>
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<tr>
<td>V-839</td>
<td>M$^2$</td>
<td>------</td>
<td>3.55+</td>
</tr>
<tr>
<td>V-881</td>
<td>M$^3$</td>
<td>5.18</td>
<td>3.36</td>
</tr>
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</table>
Figure 85. *Nexus plexus* n. g., n. sp., isolated teeth.

A. LSUMG V-833, LF⁴; occlusal view.
B. LSUMG V-891, LM₁; occlusal view.
C. LSUMG V-890 (type) LM₄; occlusal view.
D,E. LSUMG V-703, RM₂; occlusal and lingual views.
F,G. LSUMG V-881, LM₃; occlusal and lingual views.
Family PHENACODONTIDAE

Genus Tetraclaenodon Scott, 1892

*Tetraclaenodon puercensis* (Cope, 1881)

Figure 86

*Tetraclaenodon puercensis* (Cope). Wilson, 1967, p. 160, Fig. 109.


(in part); p. 62, Fig. 22d.

**Referred specimens.**—TMM 40147-19; Lp⁴, M¹ fragment; maxilla fragment with Lm².

**Locality.**—T2 (TMM 40147).

**Distribution.**—Western North America; middle to early late Paleocene (Torrejonian to early Tiffanian).

**Description.**—Most of these specimens have been described and illustrated previously (Wilson, 1967; Schiebout, 1974). Only fragmentary specimens that contribute no additional information have been since recovered from this locality. Examination of the specimens described earlier has clarified some of the observations reported by Wilson (1967) and Schiebout (1974). The fossils show two types of preservation. The Lp⁴ and Lm¹ fragment are preserved like fossils recovered from the upper level at T2 (= Middle Peak; VL-134). Preservation of the complete Lm² is like fossils from the lower level (Alligator Alley; VL-148). Maxwell et al. (1967, p. 100) lists fossils of *Tetraclaenodon puercensis* from both fossil levels. The Lp⁴ and Lm¹ have interdental wear facets which appear to match, although etching has destroyed part of the facet surfaces. Wilson's (1967, Fig. 109) figure of the P⁴ exaggerated the size of the metacone;
this is better figured in Schiebout (1974, Fig. 22d), but neither illustration shows the small metaconule that is present.

Discussion.—Referral to *Tetraclaenodon* is based on the relative development of the mesostyle in the M₂. Comparison with illustrations of early *Phenacodus*, *P. bisonensis* upper molars from the Douglass Quarry (Krause and Gingerich, 1983, p. 184) and from Bison Basin (Gazin, 1956, Pl. 10) indicates that the mesostyle in the complete molar of TMM 40147-19 is slightly smaller, and the lingual margin of the tooth is less quadrate, as in *Tetraclaenodon*. The dimensions of this tooth are smaller than is reported for *P. bisonensis* upper molars (Krause and Gingerich, 1983, p. 185), but well within the size range for *T. puercensis* reported by West (1976, p. 16). The dimensions of the P⁴ fall on the upper end for length of the range of *T. puercensis* of late Torrejonian age (West, 1976, p. 69).

Figure 86. *Tetraclaenodon puercensis*. TMM 40147-19 in occlusal view.

A. LP⁴  B. LM¹ fragment  C. LM²
Genus *Phenacodus* Cope, 1873

*Phenacodus bisonensis* Gazin, 1956

**Figure 87**


**Referred specimen.** — TMM 41274-3; partial RM_1_.

**Locality.** — C-Con (VL-122=TMM 41274). Early Tiffanian.

**Distribution.** — Fort Union Formation, Wyoming and Montana; Black Peaks Member, Tornillo Formation, Big Bend National Park, Texas. Early Tiffanian.

**Description.** — The specimen preserves all of the talonid cusps as well as the metaconid. The tooth is like *Phenacodus* molars described in many previous publications. There is a small metastylid, an entoconulid, and a tiny cuspule anterior to the entoconulid. Comparison with other *Phenacodus* specimens indicates that from the relative closure of the talonid notch, the specimen is probably an M_1_. Although the crown is broken, measurements \( L=8.78^+, \ PW=7.40^+ \) approach closely the size of the complete tooth, particularly the talonid width.

**Discussion.** — Measurements for this partial specimen were not included by Schiebout (1974, Table 20) or West (1976, pp. 20, 26). The specimen is larger than specimens referred to *P. cf. P. matthewi* from TMM localities 40148 and 41365, which are stratigraphically higher and mid-Tiffanian in age (Rapp et al., 1983, p. 564). The size of TMM 41274-3 agrees well with that of the M_1_ of *P. bisonensis* from the Douglass Quarry (Krause and Gingerich, 1983, p. 185).
Phenacodus primaevus Cope, 1873

Figure 88


Referred specimen.--TMM 41274-2; LM_2.

Locality.--C-Con (VL-122=TMM 41274). Early Tiffanian.

Distribution.--Western North America, Tiffanian to Bridgerian (late Paleocene to middle Eocene).

Description.--L=12.09, AW=10.43, PW=9.47. This specimen agrees in all respects with Phenacodus primaevus. The crown is low and bulbous, the paraconid is almost indiscernable, the entoconulid is small, and the metastylid relatively weak. From the shape of the talonid notch in lingual view, the specimen is an M_2.

Discussion.--This specimen is noted in order to document the presence of the species at C-Con, which is early Tiffanian in age. Phenacodus primaevus occurs here with P. bisonensis (see above). The specimen has not been previously illustrated. Phenacodus primaevus
was designated the senior synonym in combination with *P. grangeri* by Van Valen (1978, p. 58). This form is present in Big Bend deposits of the Black Peaks and Hannold Hill members of the Tornillo Formation.

Figure 88. *Phenacodus primaevus*. TMM 41274-2, LM<sub>2</sub>.

A. occlusal view; B. lingual view; C. labial view.
SUMMARY AND CONCLUSIONS

The most significant result of this study was the discovery of faunas of early Paleocene (Puercan Land Mammal Age of Wood et al., 1941) age in the upper Javelina Member of the Tornillo Formation. The Javelina Member was previously considered to be entirely Cretaceous in age (Maxwell et al., 1967, p. 88). A significant regional disconformity between the Javelina and Black Peaks Members of the Tornillo Formation is apparently not present. The identification of faunas of middle Paleocene (Torrejonian) age in the lower Black Peaks Member and the discovery of faunas of late early Paleocene age (late Puercan) in the upper Javelina Member indicate that erosion at the base of the Black Peaks Member was much less than was earlier thought to be the case (Maxwell et al., 1967, p. 98). This corroborates the work of Lawson (1972), Schiebout (1970, 1974), and Rapp (1982). The presence of faunas of Lancian and Puercan age in the Javelina Member indicates that sedimentation was probably continuous through the Cretaceous/Tertiary transition in some areas of Big Bend National Park.

The discovery of a Maastrichtian locality in the upper Aguja Formation supports Lawson's (1976) contention that the upper Aguja is post-Campanian in age, and that the relatively thick Cretaceous deposits of the lower Javelina Member of the Tornillo Formation were deposited during the latest Cretaceous (Lancian).

Preliminary paleomagnetic zonation indicates that the highest stratigraphic occurrence of dinosaurs in the Javelina Member is within a reversed magnetozone. This result is in agreement with the findings
of Archibald et al. (1982) and Butler and Lindsay (1983) for Cretaceous/Tertiary transitional sediments of New Mexico, Montana, and Alberta.

The presence of a fauna of Puercan age in sediments intruded by mafic igneous activity results in increased precision in dating the early phase of Laramide magmatism in the region. At least part of the mafic magmatism must be post-Puercan in age.

New taxa recognized in this study include the following:

Two new rays: Dasyatis matrix n. sp. and Rhombodus tortus n. sp.

An early scolerophidian snake:

Suffosio praedatrix n. g., n. sp.

A cimolomyid multituberculate:

Jas tejana n. g., n. sp.

A new multituberculate family, the Viridomyidae, represented by Viridomyys bovorbatus n. sp.

A primitive species of Stygimys, Stygimys vastus n. sp.

A new Puercan species of Ptilodus, Ptilodus torridus, n. sp

A new carnivore, Protictis (Bryanictis) terlinguae n. sp.

A Puercan mioclaenid condylarth, Nexus plexus, n. g., n. sp.

In addition, material possibly representing new species of Peratherium, Gelastops, Prothryptacodon, Eoconodon, and Promioclaenus was recovered.
Significant upward chronological range extensions are indicated for the taxa Ptychotrygon slaughteri and Viridomys; from Cenomanian to Maastrichtian, and early Campanian to Paleocene, respectively. My assignment of a late Puercan age to Tom's Top (VL-111) implies that Mixodectes malaris and Palaechthon nacimenti were present in the Big Bend area earlier than in the San Juan Basin. Haploconus inopinatus, previously known from the Torrejonian Dragon Canyon local fauna, appears in the Puercan in Big Bend. Forms found at Big Bend at localities considered to be slightly later than appearances in more northern faunas include Periptychus carinidens and Promioclaenus acolytus from the early Tiffanian locality C-Con (VL-122).

The Puercan faunas at Big Bend bear most resemblance to Puercan faunas of the San Juan Basin of New Mexico, as might be expected from their relative proximity. Some Big Bend forms, however, have not been found in extensive collecting in the San Juan Basin deposits: notably Viridomys, Gelaestops, and Stygimys. The genus Nexus may well be represented among the very large amount of material from the San Juan Basin that is referred to other mioclaenid taxa; however, extensive reevaluation of these fossils must be undertaken to determine if this is the case.

Discovery of new faunas and reevaluation of previously known faunas of Big Bend indicate that the composite Cretaceous/early Tertiary section includes Maastrichtian (Lancian) levels in the upper Aguja Formation; Lancian, Puercan, and possibly early Torrejonian levels in the Javelina Member of the Tornillo Formation; and mid-to late Torrejonian and Tiffanian levels in the Black Peaks Member of the Tornillo Formation. It is probable that future work will yield more
Puercan localities. Also, further exploration of the lower, Cretaceous portion of the Javelina Member is needed to find localities yielding mammalian fossils. Even though the recovery rate is not as high as in more northern localities, significant finds have been made, showing the existence of faunas differing in detail from those of more northern areas. A southern area has been added to the list of North American sites containing faunas spanning the Cretaceous/Tertiary boundary.
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## APPENDIX I

### DAWSON CREEK LITHOLOGIC UNITS

#### A. Section DC-E

<table>
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<th>Thickness (meters)</th>
<th>Qrg</th>
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**Tornillo Formation—Javelina Member:**

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<th>Buff, tan, and gray siltstones with scattered sand lenses and brown concretions. Nodule layer 2 meters above base</th>
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<th>Thickness (meters)</th>
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<th>Gray-buff bentonitic clayey siltstone, with calcareous nodules near top</th>
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**Aguja Formation:**

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### B. Section DC-U

**Chisos Formation**

Alamo Creek Basalt and overlying tuffs

**Tornillo Formation—Javelina Member**

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<td>Reddish-buff mudstones with thin sandstone layers</td>
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<td>W 32</td>
<td>Brownish-gray siltstone with lignite at top</td>
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<td>Yellow-buff silty sandstone with conglomerate containing fossil wood at base</td>
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<td>W 29</td>
<td>Red and light gray clayey siltstones</td>
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<td>W 26</td>
<td>White clayey siltstone with sandy cross-sets, large brown concretions 3 meters above base</td>
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<td>W 25</td>
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<td>Gray and maroon-striped claystone</td>
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<td>W 23</td>
<td>Dark gray claystone with purple-white streaks at top</td>
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<td>White bentonitic silty claystones with intermittent sandstone lenses</td>
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<td>Yellow sandstone with large brown concretions with platy splits</td>
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<td>Gray-buff bentonitic silty claystone with orange specks</td>
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<td>W 17</td>
<td>Maroon silty claystone which weathers whitish; calcareous nodules</td>
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<td>Gray cross-bedded lenticular sandstone</td>
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<td>Light gray-buff siltstone with orange streaks</td>
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<td>Light gray and white bentonitic siltstone with intermittent sand lenses</td>
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W 3  White bentonitic clayey siltstone with brown nodules, white sand lenses, and brownish sandstone rounds 24

W 2  Purple bentonitic claystone 1.2

W 1  Buff-gray bentonitic silty claystone at base of exposure at Dawson Creek 8

248.8
A. **Aguja Formation.**—In the absence of published stratigraphic data, earlier reported vertebrates are grouped and considered as coming from the lower and middle Aguja Formation. This is considered Late Campanian (Judithian) in age (Davies, 1983).

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B. **Tornillo Formation.**—Javelina Member and lower Black Peaks Member.

*Lower vertebrates:* earlier reported dinosaurs are grouped in a single column; fossils of uncertain level are also grouped.

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Mammals: no mammalian fossils have yet been recovered from the Cretaceous portion of the Javelina Member.

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VITA

Barbara Ruth Standhardt was born on July 8, 1941 in Roswell, New Mexico, to Frank Moscow and Edith Wolf Standhardt. Following graduation from Roswell High School, she attended Colorado College in Colorado Springs, Colorado and New Mexico State University in Las Cruces, New Mexico, where in May, 1963 she received the B.S. degree. She later attended the University of New Mexico in Albuquerque, New Mexico and was admitted to the graduate school at the University of Arizona in Tucson, Arizona, where she received the M.S. degree in May, 1980. She has three children.

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Barbara R. Standhardt

Major Field: Geology

Title of Dissertation: Vertebrate Paleontology of the Cretaceous/Tertiary Transition of Big Bend National Park, Texas

Approved:

[Signatures]

Major Professor and Chairman
Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination: April 29, 1986