

Paleontology, Taphonomy, and
Stratigraphy of the
Browns Park Formation
(Oligocene and Miocene)
Near Maybell, Moffat County, Colorado

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1358



Paleontology, Taphonomy, and Stratigraphy of the Browns Park Formation (Oligocene and Miocene) Near Maybell, Moffat County, Colorado

By JAMES G. HONEY and GLEN A. IZETT

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1358

*Descriptions of fossil mammals from the Browns
Park Formation in northwestern Colorado,
with a discussion of the stratigraphy of the
formation and the burial mechanics of the fossils*



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PALEONTOLOGY, TAPHONOMY, AND STRATIGRAPHY OF THE BROWNS PARK FORMATION (OLIGOCENE AND MIOCENE) NEAR MAYBELL, MOFFAT COUNTY, COLORADO

By JAMES G. HONEY and GLEN A. IZETT

ABSTRACT

Fossils from four sites in the sparsely fossiliferous Browns Park Formation provide a new record of mammalian life in the middle Miocene in northwestern Colorado. The Browns Park fossils allow faunal dating of the upper part of the formation in the Maybell, Colo. area. Measurements of the orientation, relative abundance, and preservation of the fossil mammal bones at one locality indicate that the bones were not subjected to water currents before burial. The fracturing, destruction, and random orientation of the bones were probably caused mainly by intense carnivore activity; weathering may also have contributed to the bone destruction.

The Browns Park Formation crops out extensively in northwestern Colorado, and locally is more than 555 m thick near the town of Maybell. In the area we studied, which is southwest of Maybell, the formation is composed primarily of sandstone that contains a layer of conglomerate and conglomeratic sandstone about 9 m thick at its base. Pebbles and cobbles in the conglomerate were derived from adjacent topographic highs or from more distant sources. The overlying sandstone comprises three informal units. A white, crossbedded sandstone is the most widely exposed; the dip of its large-scale, high-angle sets indicates that it was deposited by winds blowing from the southwest. A white, parallel-bedded sandstone lacks eolian cross-strata. A tan, parallel-bedded silty and clayey sandstone contains some mudstone and is probably of fluvial origin. The distribution of the basal conglomerate and the white, crossbedded sandstone suggests that the Browns Park Formation, at least in the Maybell area, was deposited in late Oligocene and Miocene time by the ancestral Yampa River flowing west from the northern Park Range in Colorado. Volcanic ash beds as thick as 3 m occur locally in the formation and range in age from 23.3 ± 3.7 m.y. near the base of the formation to 11.3 ± 0.8 m.y. near the highest preserved parts of the formation.

Despite its thickness and extent, the Browns Park Formation contains few fossils. In Colorado, only small collections from two localities had been reported before our study. In 1972, we discovered fossil mammals at four localities, comprising two local faunas, west of Maybell. The older local fauna, which we name the Cross Mountain local fauna (locality D857), is early to late Hemingfordian in age and contains the horse, *Parahippus* cf. *P. leonensis*, and the camel, *Blickomylus galushai*. The younger local fauna, which we name the Cedar Springs Draw local fauna (locs. D854, D855, D856), is late Barstovian to early Clarendonian in age. It contains the following fossil mammals:

the dog, *Tomarctus* cf. *T. paula*
the horse, *Megahippus* sp.
the camel, cf. *Protolabis*
the camel, *Michenia* sp.

the camel, *Procamelus* sp. or *Aepycamelus* sp.
a camel, genus and species indeterminate
an antilocaprid, *Meryceros warreni*
an antilocaprid, *Meryceros* sp.
an antilocaprid, genus and species indeterminate

The Cedar Springs Draw local fauna most closely resembles a largely undescribed late Barstovian to possibly early Clarendonian fauna from the Pojoaque Member of Galusha and Blick (1971) in the Tesuque Formation near Espanola, N. Mex. A volcanic ash in the Browns Park Formation that projects to the stratigraphic level of locality D855 has a fission-track age of 11.3 ± 0.8 m.y. This age is latest Barstovian or early Clarendonian.

No generic similarity exists between the assemblages found in the Browns Park Formation at the Cross Mountain and Cedar Springs Draw local faunas of the Maybell area and Peterson's Douglas Mountain fauna of the Browns Park Formation farther northwest in Colorado; accordingly, comparisons among the faunas cannot be made. The Douglas Mountain fauna is difficult to date precisely owing to the small number of genera, but the fauna is considered to be of late Barstovian age.

INTRODUCTION

BACKGROUND

The Browns Park Formation was deposited in north-west Colorado, northeast Utah, and south-central Wyoming during latest Oligocene and Miocene time. The formation is as much as 600 m thick. Isotopic ages (Izett, 1975, p. 186) determined on minerals from volcanic ash beds interlayered in the formation range from about 26 m.y. near the base of the formation to about 9 m.y. in the highest preserved parts of the formation. The Oligocene and Miocene time boundary, as used herein, is 23.7 m.y. based on a recent estimate made by Berggren and others (1985, p. 1409).

Fossils are rare in the Browns Park Formation, despite its extent and thickness. Previous discoveries of fossil vertebrates in the formation in Colorado have been reported from only two localities—one of unrecorded stratigraphic position and another from the

middle part of the formation (Peterson, 1924, 1928). At both localities the fossil collections are small. In 1972, we discovered fossil vertebrates in the upper part of the formation at several localities west of Maybell, Colo. These fossils provide a significant record of mammalian life in northwest Colorado in medial Miocene time and allow faunal dating of the upper part of the formation in the Maybell area.

PURPOSE

The primary purpose of this paper is to describe the fossil mammals we collected from the Browns Park Formation between Maybell and Elk Springs, Colo. A second purpose is to compare the Browns Park fossil assemblages with other North American fossil mammal assemblages, thereby temporally placing the Browns Park fossils within the biochronological framework of North American land mammal ages. A third purpose is to propose a mechanism for burial (taphonomy) of the fossils. Brief descriptions of the rocks of the Browns Park Formation in the study area are included.

LOCATION

Most exposures of the Browns Park Formation studied, and all the fossil localities discussed in this report are between 40 and 63 km west of Craig, Colo. The area studied is in the northern half of the Citadel Plateau 15-minute quadrangle, and in the northeast part of the Elk Springs 15-minute quadrangle (fig. 1). The study area for the purpose of this report includes exposures of Browns Park Formation from Juniper Mountain on the east to locality D857 on the west, and from the town of Maybell on the north (located just outside the Citadel Plateau quadrangle), to the southernmost limit of Browns Park exposures in the Citadel Plateau quadrangle.

Access to the northern part of the study area is by U.S. Highway 40, which connects Craig, Maybell, and Elk Springs, Colo. The Deception Creek road, which connects Maybell with Meeker, Colo., extends along the eastern margin of the study area. The Cedar Springs Draw road, which runs south from U.S. Highway 40 and connects with the Deception Creek road, crosses the western part of the study area. Numerous unimproved dirt roads provide easy access to other points within the study area. Many exposures of Browns Park Formation were studied along U.S. Highway 40 between Craig and Elk Springs, Colo., a distance of about 69 km.

PREVIOUS INVESTIGATIONS

The Browns Park Formation was named by Powell (1876) for outcrops of upper Cenozoic rocks exposed along the Green River in Browns Park in western Colorado and eastern Utah. Numerous geologists since Powell have studied the Browns Park Formation, and a thorough discussion of the older studies can be found in Buffler (1967, p. 9).

Several studies have been made of the Browns Park Formation in northwestern Colorado. Winkler (1970) described a white, sandstone unit near Maybell and concluded that it is of eolian origin. Izett and others (1970) determined an isotopic age of 24.8 ± 0.8 m.y. for the lower part of the Browns Park Formation along the Little Snake River. Later, Izett (1975) reported a 9.1 ± 1.0 m.y. isotopic age for the upper part of the formation west of the Little Snake River in sec. 21, T. 9 N., R. 101 W., Moffat Co., Colo., and briefly discussed folding and faulting in the Browns Park Formation in northwest Colorado. Grutt and Whalen (1955), Bergin and Chisholm (1956), and Lewis (1977), discussed uranium mineralization in the Browns Park Formation in the Maybell-Lay area. Luft and Thoen (1981) measured a number of partial stratigraphic sections in the Browns Park Formation in Moffat County, Colo. Mapping by Sears (1924b), Hancock (1925), Bergin (1959), Dyni (1968), McKay (1974), McKay and Bergin (1974), Brownfield and Anderson (1979), Brownfield and Prost (1979), Rowley and others (1979), Reheis (1981), and Izett and others (1985) delineated the distribution of the Browns Park Formation in northwest Colorado.

Peterson (1924) described Browns Park fossils found near Sunbeam, Colo., and other fossils found a short distance farther west along Sand Wash. Later (1928) he described fossils collected from north of Douglas Mountain near Greystone, Colo. McGrew (1951, p. 55-56), Skinner (1968), and Frick and Taylor (1968) reexamined some of Peterson's Browns Park fossils; McGrew also reported on a small fauna from rocks near Saratoga, Wyo. that he assigned to the Browns Park Formation. An undescribed collection of Browns Park fossil mammals collected near Peterson's Douglas Mountain locality is in the Frick collection of the American Museum of Natural History.

ABBREVIATIONS

The following abbreviations are used in this report:
Institutions

AMNH—Department of Vertebrate Paleontology,
American Museum of Natural History

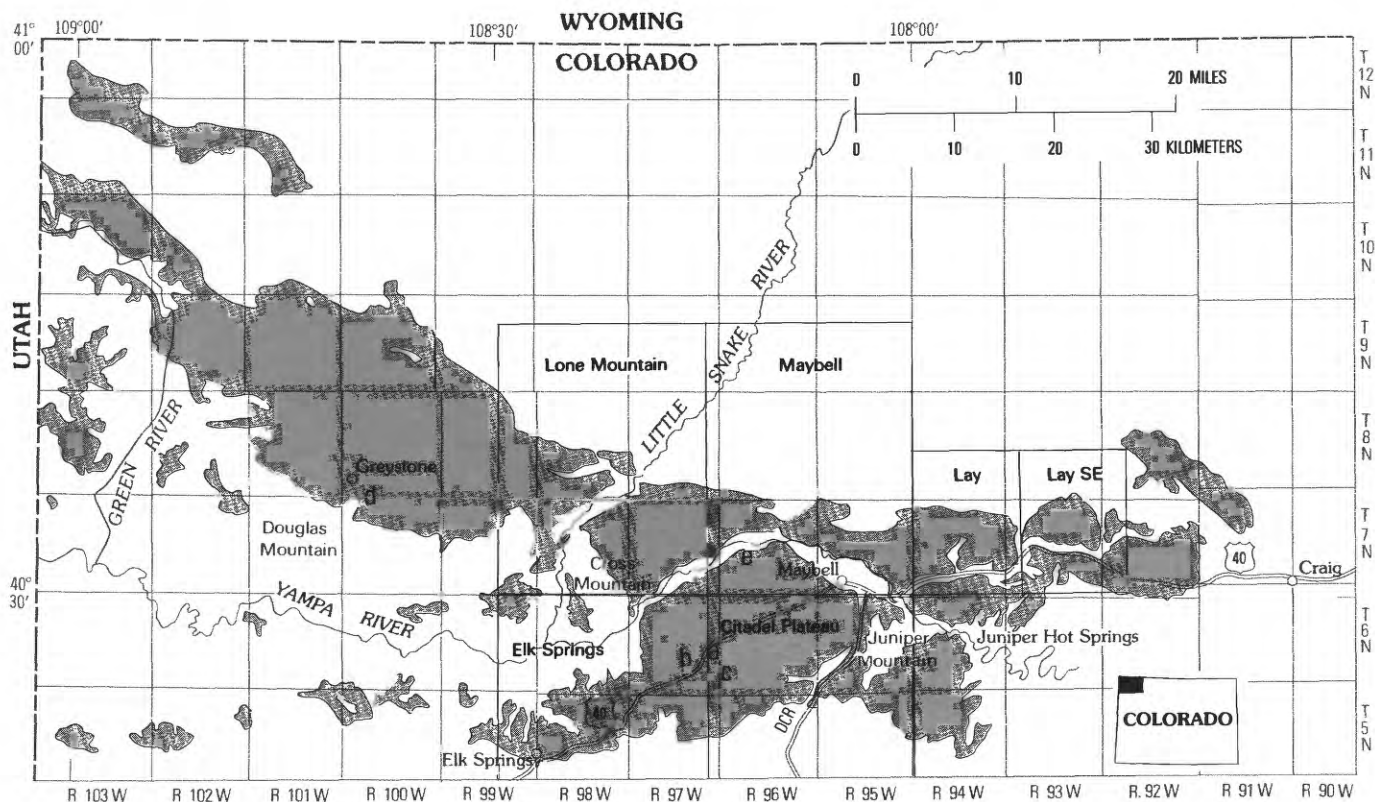


FIGURE 1.—Distribution of the Browns Park Formation (pattered area) in northwest Colorado and location of the Citadel Plateau, Elk Springs, Lone Mountain, and Maybell 15-minute quadrangles, and the Lay and Lay SE 7½-minute quadrangles. Letters designate fossil localities: a, D854; b, D857; c, D855 and D856 of this report; d, Peterson's Weller Ranch locality near Douglas Mountain; e, Peterson's Sunbeam locality near Maybell. DCR, Deception Creek road. Distribution of Browns Park Formation modified from Tweto (1979).

BEG—University of Texas, Bureau of Economic Geology

LACM-CIT—formerly the California Institute of Technology; the collection is now at the Los Angeles County Museum

D854, D855, D856, D857—U.S. Geological Survey vertebrate locality numbers, Denver register

ESP—Field designation on some specimens in the AMNH

F:AM—Frick American Mammals, Department of Vertebrate Paleontology, American Museum of Natural History

FGS—Florida Geological Survey

UNSM—Nebraska State Museum

UALP—University of Arizona, Laboratory of Paleontology

UCMP—University of California, Museum of Paleontology, Berkeley

USNM—U.S. National Museum

Anatomy

C—canine

d—deciduous, as in dI, deciduous incisor

I—incisor

L—left

M—molar

P—premolar

R—right

Measurements and statistics

AP—anteroposterior measurement

EF—expected frequency

n—sample size

OF—observed frequency

O.R.—observed range

TR—transverse measurement

\bar{X} —mean

m.y.—million years

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This paper resulted from a study undertaken as part of a U.S. Geological Survey mapping program

conducted by G. A. Izett, J. G. Honey, and M. E. Brownfield in the Citadel Plateau 15-minute quadrangle, Moffat County, Colo. Fossil and stratigraphic data were collected in the summers of 1972 and 1973 and during one short trip to the area in the summer of 1975.

We appreciate advice and criticism concerning the mammalian paleontology given by E. H. Lindsay and G. G. Simpson (deceased) of the University of Arizona. L. L. Jacobs, L. H. Taylor, L. J. Flynn, and J. Baskin, all formerly of the University of Arizona, aided with quarrying at the University of Arizona's locality 7498 (discussed in this report). We owe special thanks to R. H. Tedford, B. E. Taylor, and M. F. Skinner of the American Museum of Natural History for allowing us to examine specimens in their care, for the loan of fossils, and for information concerning the fossils. We thank C. B. Schultz and L. G. Tanner of the University of Nebraska for showing us fossils in their care. M. E. Brownfield of the U.S. Geological Survey helped us collect fossils on several occasions.

STRATIGRAPHY OF THE BROWNS PARK FORMATION

DISTRIBUTION

The Browns Park Formation is extensively exposed in northwest Colorado and eastern Utah, and other sandstone outcrops in southern Wyoming have been correlated with the formation. The formation crops out in a continuous west-trending belt from an area just west of Craig, Colo., to its type area in Browns Park, which straddles the Utah-Colorado state line, a distance of about 136 km (Hansen, 1965, p. 115). In this belt the Browns Park Formation was deposited in a paleovalley cut on the Uinta Mountain arch, which was formed more than 26 m.y. ago (Izett, 1975, p. 189). Rocks referred to the Browns Park Formation are mapped on the north and south flanks of the Uinta Mountains, Utah, on the west flank of the Sierra Madre and Park Range in Colorado and Wyoming, on the White River Plateau in Colorado, and in the Poison Basin area, Wyoming (Izett, 1975, p. 184-185).

PHYSICAL CHARACTERISTICS AND OUTCROP PATTERN

The sandstone of the Browns Park Formation erodes easily and is poorly exposed in the Maybell, Colo. area. The formation forms a blanketlike deposit of low relief in the northwest quarter of the Citadel Plateau quadrangle. The formation generally lies near the

surface beneath a soil, but in many places it is covered by Pleistocene and Holocene eolian deposits, as south of Maybell, or by alluvial deposits, as along the Yampa River. At lower elevations, the formation is covered by grass and sage; at higher elevations, the formation is covered by shrubs and pinyon pine. The best exposures are in roadcuts, along arroyos, and occasionally, on steep slopes. The Browns Park forms some cliffs along the Yampa River between Juniper and Cross Mountains, and a small area of badlands on the west flank of Juniper Mountain. We examined all outcrops within the Citadel Plateau quadrangle, and numerous others outside the study area.

GEOLOGIC SETTING AND CONTACT RELATIONS

The study area includes the southern half of the west-trending depositional basin of the Browns Park Formation. The deepest part of the depositional basin is probably north of the study area, near Maybell, Colo., where more than 555 m of Browns Park have been drilled (S. J. Luft, written commun., 1980); the greatest thicknesses in the Citadel Plateau quadrangle, within the study area, are 510 m at the Texaco No. 1 State-K well in the NW1/4SE1/4 sec. 16, T. 6 N., R. 96 W., and 533 m at a core hole near this well. In the northeast corner of the Citadel Plateau quadrangle, the Browns Park paleovalley is split by the Juniper Mountain uplift, which exposes Precambrian and Paleozoic rocks surrounded by sandstone outcrops of the Browns Park Formation. To the west, the Browns Park Formation extends uninterrupted north and south of the Cross Mountain anticline.

The Browns Park Formation unconformably overlies all older formations and rests on rocks ranging in age from Precambrian to middle Eocene. Along the southern edge of the depositional basin, the Browns Park overlaps Mesozoic rocks, and farther west lies against the upturned edges of Cretaceous and Eocene strata. At the Texaco No. 1 State-K well, in the northwest part of the Citadel Plateau quadrangle, the Browns Park rests on Cretaceous Mancos Shale.

The Browns Park Formation within the study area is mostly flat lying. Along the southern edge of the Browns Park depositional basin, however, bedding dips from about 5° to 30° to the north, and along the northern edge of the depositional basin the rocks locally dip 30° to the south (McKay and Bergin, 1974). Post-Browns Park faulting has considerably steepened the southerly dips along the northern edge of the basin (Sears, 1924a, p. 288).

A few small normal faults with throws generally less than 50 m locally cut the Browns Park in the Citadel

Plateau quadrangle. Larger unseen faults may cut the formation in the study area, but because much of the formation is covered by surficial deposits their locations and throws are unknown.

LITHOLOGY AND SEDIMENTARY STRUCTURES

BASAL CONGLOMERATE UNIT

At surface exposures and in boreholes, the base of the Browns Park Formation commonly consists of a conglomerate or conglomeratic sandstone unit with clasts derived both from local bedrock and from distant source-rock areas. Just east of the Citadel Plateau quadrangle, near Juniper Hot Springs, Colo., the basal conglomerate consists of well-rounded pebbles and cobbles of Precambrian rocks composed of schist, gneiss, coarse- to fine-grained granite, white and reddish quartzite, and white and reddish vein quartz (Hancock, 1925, p. 24). This may be the same conglomerate containing varicolored pebbles that was mentioned by Sears (1924a, p. 285) as being north of the Yampa River upstream from Juniper Canyon. South of Juniper Hot Springs, Reheis (1981) also reported igneous and metamorphic cobbles in the basal sandstone of the Browns Park. Presumably, all these pebbles and cobbles were derived from outcrops of Precambrian rocks in the Park Range east of Steamboat Springs, Colo. (Izett, 1975, p. 203). Along the south flank of Juniper Mountain in the northeast quarter of the Citadel Plateau quadrangle, the basal conglomerate unit contains quartzite boulders as much as 0.9 m in diameter of the Middle Proterozoic Uinta Mountain Group, perhaps locally derived from outcrops at Juniper Mountain. At surface exposures throughout much of the western part of the Citadel Plateau quadrangle (for example, in sec. 18, T. 5 N., R. 96 W.), the basal unit of the Browns Park consists chiefly of conglomerate and conglomeratic sandstone containing clasts of quartzite from the Middle Proterozoic Uinta Mountain Group, Paleozoic carbonate rocks, and chert, the last possibly of Paleozoic age. No igneous or high-grade metamorphic clasts were seen. However, in the Pan-American Petroleum No. 1 George Norvell well, in the NE1/4 sec. 3, T. 5 N., R. 96 W., igneous rock fragments were recorded in the basal conglomeratic unit. North and northwest of the Citadel Plateau quadrangle, in the parts of the Maybell and Lone Mountain quadrangles east of the Little Snake River, the basal conglomerate unit also contains pebbles of mafic and felsic igneous and metamorphic rocks, quartzite, chert, and quartz (Sears, 1924b, p. 295; McKay, 1974; McKay and Bergin, 1974). West of the Little Snake River, in Colorado, the conglomerate consists only of

red quartzite from the Uinta Mountain Group and some gray Paleozoic carbonate rock and chert. In the Elk Springs quadrangle west of the Citadel Plateau quadrangle, Dyni (1968) noted only carbonate and chert cobble conglomerate and red conglomeratic sandstone in the basal part of the Browns Park; these clasts were probably locally derived from outcrops on Cross and Juniper Mountains and the eastern Uinta Mountains. In the Park Range to the east, Crews (1963, p. 66) and Buffler (1967, p. 24) reported granite and high-grade metamorphic rocks in the basal conglomerate of the Browns Park Formation.

WHITE, CROSSBEDDED SANDSTONE UNIT

White, crossbedded sandstone in the Browns Park Formation is widely distributed in northwest Colorado, and is locally well exposed in the Maybell area. In most areas, poor exposures make it impossible to determine the precise distribution of these rocks, but topographic expression and weathering characteristics suggest that the unit occurs at the surface over the entire area west of the Deception Creek road and north of T. 5 N. (except for a small area of Pleistocene and Holocene dunes in the northeast corner of this area). Rocks of this unit apparently blanket large areas to the north and west of the Citadel Plateau quadrangle in the Maybell, Lone Mountain, and Elk Springs quadrangles, and they extend eastward nearly to Craig, Colo.

This unit consists of gray to white quartzose sandstone that locally contains some interbedded volcanic ash beds and tuffaceous sandstone. The quartzose sandstone is fine to medium grained, well sorted, and the grains are subrounded to rounded and generally frosted. The sandstone contains more than 90 percent quartz grains, with black opaque mineral grains and dark lithic grains composing the remainder. Calcite locally cements this sandstone, which then forms resistant ledges. Beds of the white, crossbedded sandstone unit usually show high-angle cross-stratification, as in roadcuts along U.S. Highway 40 (fig. 2) and in cliffs along the Yampa River north of Maybell. Low-angle bounding surfaces commonly separate individual sets of high-angle cross-strata. Horizontal lamination is also present, as at fossil quarry D856. The white, crossbedded sandstones are generally friable, and in a few places have been a sediment source for active or recently stabilized dunes.

We examined crossbedding in the white, crossbedded sandstone unit to determine the transport direction of the sand grains. Crossbedding is best seen in roadcuts, and consists mainly of wedge-planar and tabular-planar (McKee, 1979, fig. 137) sets, which are medium to large scale, and straight to concave upward. These large-scale cross-strata were observed in roadcuts from Craig west



FIGURE 2.—View of roadcut exposure at locality D854 along U. S. Highway 40, at the west edge of the Citadel Plateau 15-minute quadrangle, Moffat County, Colo., showing large-scale, cross-stratified sandstone in the upper part of the Browns Park Formation. Person at center of photograph shows scale.

to Elk Springs, Colo. Dips recorded at these roadcuts generally range from 2° to 34° , with most high-angle dips clustering between 24° and 29° . Dips greater than 30° in crossbedded sandstone of the Browns Park also were noted by Buffler (1967, p. 43) in the Elkhead region east of Craig, Colo.

The large-scale, high-angle, tabular- and wedge-planar sets in the Browns Park Formation are foresets formed on the slip faces of dunes. The large size and high angle of the individual sets, the low-angle bounding surfaces between some of the sets (McKee, 1979, p. 89), and the lack of coarse-grained channel-lag deposits suggest that the sandstone was deposited by eolian processes. A sample of medium-grained, well-sorted sandstone, with grains subrounded and frosted, was taken from foresets at roadcut locality D854. Most of the sandstone at D854 is not cemented by calcite, and the frosting of the grains probably was caused by abrasion during transport rather than by dissolution of grains by intrastratal solutions.

Winkler (1970, p. 48) also suggested an eolian origin for the crossbedded sandstone unit of the Browns Park in the Maybell area. Earlier, Bradley (1936, p. 182) thought that the Browns Park Formation west of Craig, Colo. and north of the Citadel Plateau quadrangle was in part eolian in origin. In addition, Chisholm (1963, p. 353) suggested that parts of the Browns Park Formation in northwestern Colorado and south-central Wyoming are eolian, and Buffler (1967, p. 60) suggested an eolian origin for his white sandstone facies of the Browns Park Formation in the Elkhead Mountains east of Craig, Colo.

The transport direction of the white, crossbedded sandstone was determined by 191 dip direction measurements taken on cross-strata along the 69-km stretch of highway between Craig and Elk Springs, Colo. Dip measurements taken from both high- and low-angle sets indicate an average transport direction of about $N. 45^{\circ}E.$ (fig. 3A). Laminae dipping less than 15° might have been deposited on the backs and sides of dunes,

so a second average was calculated from the 135 dip measurements that were greater than 15° . The transport direction calculated was N. 47° E., nearly the same as before (fig. 3B). Chisholm and others (1961, p. 84) obtained a south-to-north sediment transport direction for the Browns Park Formation, derived from more than 600 measurements made over a wide area. In the Elkhead region, Buffler (1967, fig. 10) obtained a bimodal distribution of dip maxima based on 250 bedding measurements in his white sandstone facies of the Browns Park Formation. His dip directions are also spread over a range of nearly 180° , but the mean of the measurements demonstrates a southwest to northeast transport direction, as in the area west of Craig, Colo.

Figure 3 is interpreted to indicate a unimodal wind regime. Both diagrams show the dominant northeast direction of sand transport; 87 percent of all the dips are within a 140° arc in fig. 3A, and 93 percent of the high-angle dips (fig. 3B) are within the same arc. These dip direction distributions are similar to those reported for some barchan and dome dunes (Glennie, 1970, figs. 82 and 83; Ahlbrandt and Fryberger, 1980, p. 8; McKee, 1966, table IV). Parabolic dunes have a wide distribution (180° – 270°) of dip directions which may be strongly bimodal or trimodal (Ahlbrandt and Andrews, 1978,

fig. 5; McKee and Bigarella, 1979, fig. 78; McKee, 1979, p. 195). The dip directions shown in figures 3A and 3B show no strong bimodality, but this may be partly because most of the dip readings were taken in an east-west section along Highway 40, where roadcuts gave the best exposures of crossbedding. Sample bias may thus have increased the number of measurements taken of high-angle strata dipping parallel to the highway and decreased the number of measurements taken on strata dipping normal to the highway. The spread of Browns Park dip directions is wider than that reported for transverse dunes (Ahlbrandt and Fryberger, 1980, fig. 6). The distribution of dip directions also does not correspond to expected distributions for linear (seif) dunes, which should have two clusters of dips opposite one another (McKee and Tibbitts, 1964; McKee, 1979), or dunes formed from scattered wind directions (star and reversing), in which a significant number of high-angle dips should be opposite the main northeast transport direction (McKee, 1966; McKee and Bigarella, 1979).

Stratigraphic sections were measured at fossil sites D855 and D856 in the white, crossbedded sandstone unit. Locality D855 is stratigraphically 15 m below locality D856. The following stratigraphic section shows the lithology at locality D855:

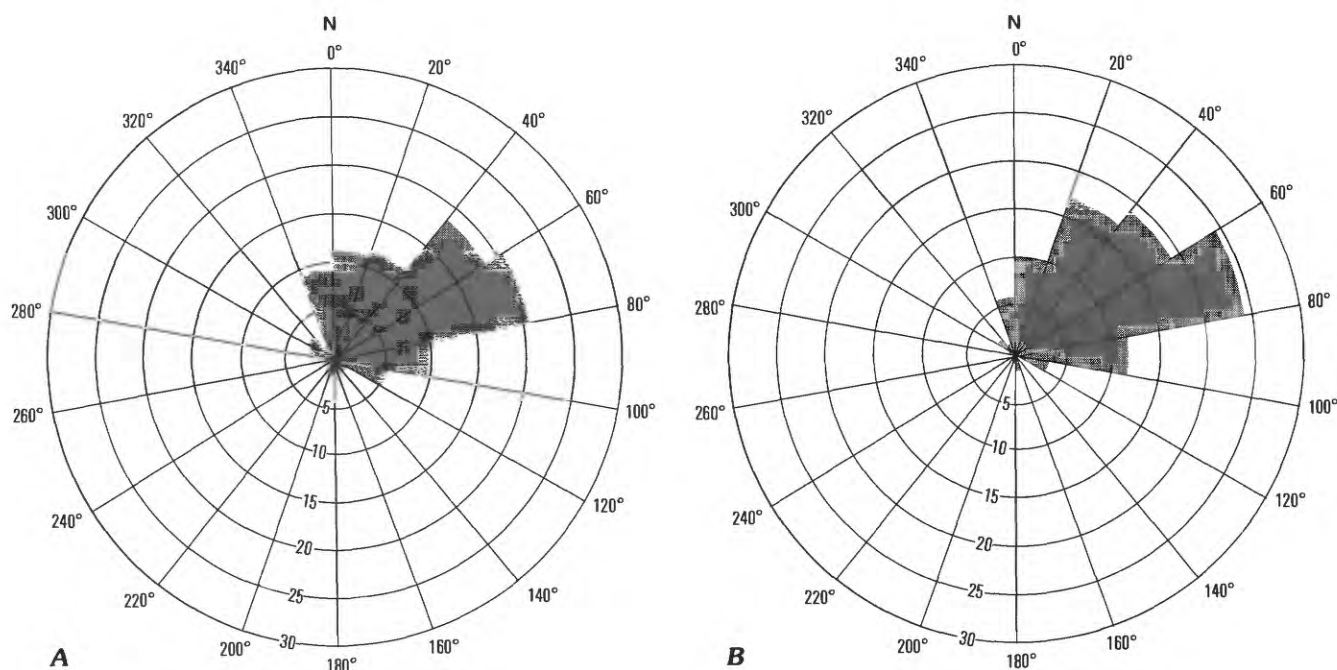


FIGURE 3.—Rose diagrams of dip direction measurements of the white, crossbedded sandstone unit of the Browns Park Formation in roadcuts along U.S. Highway 40 west of Craig, Colo. Concentric circles and associated values represent percent of total number of observations. Numbers on periphery of each circle show dip direction. A, plot of 191 dip directions. B, plot of 135 dip directions (dips equal to or greater than 15°).

Section of the Browns Park Formation (top to bottom) exposed on northwest slope of a ridge in the NE1/4 sec. 36, T. 6 N., R. 97 W., Moffat County, Colorado

	Thickness	
	Meters	Feet
Sandstone, quartzose, in part tuffaceous, very fine grained to fine-grained, well-sorted, grains frosted; less than 1 percent dark lithic fragments. Alternating resistant and nonresistant layers about 6.4 cm thick; resistant layers calcareous. Vertebrate fossils found beneath a thin calcareous mudstone at top of unit (D855)	1.07	3.5
Tuff and tuffaceous sandstone, white, thinly laminated, highly calcareous	0.76	2.5
Volcanic ash, blue-gray, vitric, very finely laminated	0.15	0.5
Sandstone and tuffaceous sandstone, very fine grained to fine-grained, highly calcareous; individual laminae 0.10–0.51 cm thick; more tuffaceous parts weather as resistant white laminae	1.22	4.0
Tuffaceous sandstone and tuff, gray at bottom of unit and white at top; no calcite cement; individual laminae 0.10–0.51 cm thick	0.15	0.5
Quartzose sandstone, tan, very fine grained, moderately well sorted; individual laminae 0.10–0.30 cm thick	0.15	0.5
Bottom of exposure	0.15	0.5
Total thickness of section	3.50	11.5

At locality D856 the 1-m-thick unit contains four non-crossbedded layers. The only stratification observed was in the fossiliferous layer, where thin, horizontal laminae 3.8 cm thick were seen. Each of the four layers is composed of fine-grained quartzose sandstone; the individual grains are subrounded to rounded and well sorted. Larger grains tend to be more rounded than smaller grains. The quartz grains are frosted and are cemented by calcite. Many short, white, noncalcareous stringers, interpreted as root casts, are present in several of the layers. No sedimentary structures other than the horizontal lamination and white stringers were observed. The following measured section shows the lithology at locality D856:

Measured section of the Browns Park Formation (top to bottom) exposed near top of a west-facing slope of a hill (1981 m) in the NW1/4 sec. 31, T. 6 N., R. 96 W., Moffat County, Colorado

	Thickness	
	Meters	Feet
Sandstone, brown; to top of hill; not measured		
Sandstone, grayish-white, slightly green, quartzose, fine-grained, well-sorted; grains subrounded to rounded, frosted, and calcite cemented; root casts present near bottom; becomes broken into balls and grades into brown sandstone above	0.46	1.5
Sandstone, greenish-white, quartzose, fine-grained; dark grains rounded, well sorted, and frosted; less than 1 percent lithic fragments, highly calcareous and indurated; root casts common	0.18	0.58
Sandstone, greenish-gray, quartzose, fine-grained, well-sorted, less than 1 percent lithic fragments; grains subrounded and frosted, calcite cemented; thinly laminated; root casts common; fossil horizon	0.13	0.42

Sandstone, greenish-gray, quartzose, fine-grained, well-sorted, less than 10 percent dark lithic fragments; grains subrounded to rounded, calcite cemented; unit massive; root casts common near top

Base of excavation	0.25	0.83
Total thickness of section	1.02	3.33

The sandstone at locality D856 is probably of eolian origin. Some evidence is inconclusive: the frosting of the grains, for example, could result from either eolian transport or chemical solution. But most of the evidence suggests eolian origin: horizontal sand laminae associated with eolian deposition have been described from modern interdune, sheet sand, and wadi-fill deposits (Ahlbrandt and Fryberger, 1981, and references therein), and from ancient eolian deposits (Adams and Patton, 1979; McKee, 1979, and references therein). No silt or clay interbeds were seen at D856, and visual examination suggests that the sand is nearly as well sorted as in nearby Browns Park dune deposits. Glenie (1970, p. 39 and 106) mentioned and illustrated the occurrence of horizontally laminated, well-sorted sands in both desert wadis and sheet sands. Ahlbrandt and Fryberger (1981, fig. 7) interpreted some horizontally laminated sandstones of the Browns Park Formation near Maybell, Colo., as interdune deposits. Horizontal laminae could have been present in the other layers at locality D856, but may have been destroyed due to bioturbation by plant roots.

Horizontal stratification also occurs in lacustrine deposition, but no lacustrine fossils such as freshwater mollusks or fish were found in the rocks at locality D856. Also, no load structures, mudcracks, or any other features that might have formed in a lacustrine environment were found.

Horizontal stratification may also occur locally due to flood deposition, and may constitute the bulk of a flood deposit (McKee and others, 1967, p. 829). In the Bijou Creek, Colo., flood deposit studied by McKee and others (1967), the sediment was fine- to coarse-grained quartzose sand. In contrast to the sandstone at D856, the sorting usually was only fair; rarely was the sorting good. Williams (1971, p. 35) however, noted that upper flow regime plane beds were the best sorted in the flood deposit he studied. The D856 locality lacks the armored mud balls noted at Bijou Creek. The fine-grained sandstone at D856 would not suggest high water velocities; however, the grain size in flood deposits partially depends on the size of the material available for transport (McKee and others, 1967; Williams, 1971). If the layers at locality D856 are flood deposits, it might be supposed that the fossils represent the larger material transported during the flood. However, the fossils show no evidence of transport in their orientation or

abundance. The field evidence then, suggests that the sandstone at locality D856 is of eolian rather than of fluvial or lacustrine origin.

WHITE, PARALLEL-BEDDED SANDSTONE UNIT

White, parallel-bedded sandstone crops out west of the Deception Creek road in secs. 1, 2, and 11, T. 5 N., R. 96 W., south of Juniper Mountain, and along the north bank of the Yampa River just north of Juniper Mountain. Rocks at these exposures lack the high-angle cross-stratification of the white, crossbedded unit. The parallel-bedded unit is generally highly calcareous, resistant, and laterally continuous. In the study area, white, parallel-bedded sandstone is typically exposed near the base of the Browns Park Formation, and is older than the eolian crossbedded sandstone. South of Juniper Mountain, for example, the Browns Park is only 152 m thick in the Moore and Gilmore No. 1 Seeley well drilled in the NE1/4SE1/4SE1/4, sec. 2, T. 5 N., R. 95 W., and rocks of the white, parallel-bedded unit are exposed near this location. Along the Deception Creek road, white, parallel-bedded sandstone directly overlies Mancos Shale of Cretaceous age. In contrast, rocks of the white, crossbedded unit occur at the surface at the Texaco No. 1 State-K well in the NW1/4SE1/4 sec. 16, T. 6 N., R. 96 W., and are underlain by about 510 m of Browns Park Formation.

TAN SANDSTONE UNIT

Rocks of the tan sandstone unit of the Browns Park crop out on Cedar Knob in secs. 6 and 7, T. 5 N., R. 96 W. These rocks contain more mudstone than do rocks of the white, crossbedded sandstone unit; bedding is generally parallel, and no large-scale, high-angle cross-stratification is present. The measured section that follows gives the general characteristics of rocks of this unit.

Section of the Browns Park Formation (top to bottom) on south side of Cedar Knob in the NE1/4 sec. 7, T. 5 N., R. 96 W., Moffat County, Colorado

	Thickness	
	Meters	Feet
Sandstone, tan, fine-grained, friable; forms slope; fossil turtle found near top of unit	2.8	9.3
Sandstone, grayish-white, calcareous, fine- to medium-grained, poorly sorted with dark lithic fragments, thick to massive bedded; forms top of resistant ledge	0.5	1.5
Mudstone, grayish-white, tuffaceous	0.4	1.2
Volcanic ash, white, vitric, thinly laminated near base, becoming calcareous near top; forms bottom of resistant ledge	0.6	1.8

Mudstone, pinkish-tan, calcareous and indurated; contains root casts	0.8	2.5
Sandstone, pinkish-tan, friable; discontinuous calcareous mudstone ledge near base of unit; 0.4 m resistant but discontinuous calcareous sandstone ledge 1.5 m below top of unit	3.1	10.0
Sandstone, greenish-gray, fine- to coarse-grained, poorly sorted, calcareous; contains coarse, subangular lithic fragments; a few root casts present; forms resistant ledge	0.9	3.0
Sandstone, pinkish-tan, medium-grained, friable; top 0.61 m calcareous and thinly laminated	5.2	17.0
Calcareous mudstone, white at base, becoming darker gray with medium-grained sandstone in upper 15.3 cm; forms resistant ledge	0.3	1.0
Volcanic ash, blue-gray, and tuffaceous sandstone; thinly laminated near base; calcareous near top of unit	1.1	3.7
Sandstone with calcareous interbeds, fine-grained; forms slope except for more resistant interbedded calcareous units	2.4	7.9
Calcareous mudstone, grayish-tan	3.1	10.0
Sandstone, tan, medium-grained, moderately well sorted, subangular, unconsolidated; forms slope at base of hill	1.8	5.9
Total thickness of section	<u>23.0</u>	<u>74.8</u>

Surficial deposits hide the exact stratigraphic relationships between the tan sandstone unit and the white, crossbedded sandstone unit. On Cedar Knob, only rocks of the tan sandstone unit are exposed, and this unit was not recognized elsewhere in the study area. The section measured on Cedar Knob is topographically from about 46 m to more than 61 m above locality D856, and bedding-plane attitudes were nearly horizontal. Cedar Knob may have been faulted up relative to the rest of the Browns Park Formation, as suggested by the gross lithologic similarity of the rocks at Cedar Knob to the rocks exposed nearly 48 km farther west at the northern base of Douglas Mountain. There, Peterson's (1928) fossil locality lies stratigraphically lower in the Browns Park Formation than fossil locality D856. Near Douglas Mountain, Peterson (1928, p. 93) measured 224 m from the base of the Browns Park Formation to the fossil horizon; the total thickness of the Browns Park Formation at locality D856 is unknown, but it is 533 m thick north of D856, in SE1/4 sec. 16, T. 6 N., R. 96 W. If, however, the rocks at Cedar Knob have not been faulted up relative to the rest of the formation, then the tan sandstone unit would be the highest preserved part of the Browns Park Formation. This relationship corresponds to the stratigraphic relations noted by Buffler (1967, p. 46) in the Elkhead region east of Craig, Colo., where he described a Miocene brown sandstone facies overlying an eolian crossbedded white sandstone facies. Buffler assigned an Arikareean to Hemingfordian age to the white sandstone facies, which would make it older than the white, crossbedded unit in the

Maybell area. Buffler's age assignment however, was based only on lithologic similarity of the Miocene rocks of the Steamboat Springs, Colo., area with the Arikareean to Hemingfordian Split Rock Formation (Love, 1961) in central Wyoming.

VOLCANIC ASH

The Browns Park contains lenticular beds of vitric, friable volcanic ash from the base to the highest preserved parts of the formation. The thickness of these beds ranges from several centimeters to several meters. Many of the ash beds are nearly pure in that they contain a high proportion of glass shards, and are not contaminated by sediments. Some of the ash beds are indurated and blocky, probably caused by incipient alteration of the glass shards.

In the eastern part of the Citadel Plateau quadrangle (SW1/4 sec. 10 and SE1/4 sec. 14, T. 5 N., R. 95 W.) one or more white, biotite-bearing ash beds, about 15 cm thick, occur about 9 m above the base of the Browns Park Formation. A gray ash bed 15 cm thick occurs 3.0–3.7 m below this white ash. In sec. 10, T. 5 N., R. 95 W., three white ash beds occur in a 1.4-m-thick interval directly overlying a gray ash. Farther west, in the W1/2 sec. 9 and NE1/4 sec. 10, T. 5 N., R. 96 W., a biotite-bearing white ash occurs about 9 m above the base of the Browns Park, but gray ash beds are apparently missing. In sec. 10, this white ash was dated at 23.3 ± 3.7 m.y. (Izett, 1975, p. 187, table 1), and may correlate with a white, biotitic ash about 30 m above the base of the Browns Park at the Little Snake River, dated at 24.8 ± 0.08 m.y. (Izett and others, 1970, p. C150–C152).

Ash beds that are stratigraphically higher in the Browns Park Formation include two gray volcanic ash beds on a hill in the NW1/4SE1/4 sec. 25, T. 6 N., R. 97 W. These ash beds are in the upper part of the white, crossbedded sandstone unit, and the higher of the two is the same elevation as the D855 quarry. The upper ash is 23 m stratigraphically above the lower ash, and has been dated at 11.3 ± 0.8 m.y. (see Isotopic Age). Two bluish-gray ash beds, presumably of medial Miocene age, occur on the south side of Cedar Knob. These two ashes lie in the tan sandstone unit of the Browns Park Formation, and are about 10 m stratigraphically apart. Izett (1975) reported other volcanic ash beds within the Browns Park Formation elsewhere in northwestern Colorado.

THICKNESS OF THE BROWNS PARK FORMATION

The Browns Park Formation thickens from zero along the southern edge of the Browns Park depositional

trough south of Cedar Knob to more than 555 m near Maybell (S. J. Luft, written comm., 1980). Similar maximum thicknesses were recorded at drill holes located west of the Deception Creek road and north of T. 5 N. South of Juniper Mountain, however, the formation is locally considerably thinner—153 m thick at the Moore and Gilmore No. 1 Seeley well in the NE1/4SE1/4SE1/4 sec. 2, T. 5 N., R. 95 W. In the Elk Springs quadrangle, Dyni (1968) recorded a maximum thickness of about 457 m east of Cross Mountain. In the Maybell quadrangle, McKay and Bergin (1974) recorded a maximum thickness of 488 m. In the Lone Mountain quadrangle, McKay (1974) recorded a similar thickness. To the east of the study area, the maximum thickness of the Browns Park Formation is 259 m in the Lay quadrangle (Brownfield and Prost, 1979) and 274 m in the Lay SE quadrangle (Brownfield and Anderson, 1979). Buffler (1967, p. 38) recorded a maximum thickness of 671 m at Sand Mountain in the Elkhead region east of Craig, Colo. In the type area of the formation in Browns Park, the total thickness of the formation is unknown, owing to lack of subsurface information, but Hansen (1965, p. 127) obtained a partial thickness of 250 m for the formation by measuring surface exposures in the type area, and S. J. Luft (written commun., 1980) reported at least 364 m in the Vermillion Mesa 7½-minute quadrangle, Moffat County, Colo.

In the Citadel Plateau quadrangle, a maximum thickness of about 9 m was measured for the basal conglomerate at surface exposures. In the subsurface, the basal conglomeratic sandstone ranges from less than 6.1 m in the Utah Southern Kingston No. 2 well, in the center of the NW1/4NW1/4 sec. 11, T. 5 N., R. 96 W., to at least 27.4 m in the Moore and Gilmore No. 1 Seeley well.

In the Elk Springs quadrangle, Dyni (1968) recorded an average thickness of 12.2–27.4 m for the basal conglomerate unit and a maximum thickness of 41.1 m. In the Maybell quadrangle, McKay and Bergin (1974) reported a thickness for the basal conglomeratic sandstone of only 0.3–0.9 m, yet farther west, in the Lone Mountain quadrangle, McKay (1974) reported a thickness of as much as 91 m for the basal conglomerate. In the Elkhead region to the east, Buffler (1967, p. 20) reported a similar range of thicknesses—0 to 91 m.

The total thicknesses for the white, crossbedded sandstone unit, the white, parallel-bedded unit, and the tan sandstone unit were not determined in the study area. About 88 m of sandstone separates the base of the eolian sandstone at D854 from the top of the hill at quarry D856, which represents a minimum thickness for the crossbedded sandstone unit—the maximum thickness is probably much greater. At the Texaco No. 1 State-L well, just north of the study area, frosted

quartz grains were present in the Browns Park sandstone down to a depth of at least 168 m. Winkler (1970, p. 50) reported a thickness of about 122 m for the white, crossbedded unit in the Maybell area, but the method of calculating this thickness was not given. Buffler (1967, p. 41) measured more than 183 m of sandstone containing large-scale cross-stratification in his white sandstone facies in the Elkhead region.

On Cedar Knob in the Citadel Plateau quadrangle, about 23 m of tan sandstone unit is exposed, but the total thickness of that unit is probably greater. The thickness of the white, parallel-bedded unit was not determined.

SOURCE AREA AND MODE OF DEPOSITION

As mentioned, the basal conglomerate in the study area is derived from both local and distant sources. Field evidence for derivation of the cobbles in the conglomerate unit from nearby topographic highs is found on the south flank of Juniper Mountain in the NE1/4NE1/4 sec. 34, T. 6 N., R. 95 W., where the base of the Browns Park consists of a fine-grained sandstone containing scattered quartzite boulders of the Middle Proterozoic Uinta Mountain Group. Some of these boulders are 0.9 m in diameter. About 3.2 km southeast of this locality, at the Moore and Gilmore No. 1 Seeley well, at least 27 m of slightly conglomeratic sandstone (but no distinct conglomerate beds) was penetrated at the base of the Browns Park. This conglomeratic sandstone may have been derived from nearby Precambrian and Paleozoic rocks at Juniper Mountain.

Outcrops of Precambrian and Paleozoic rocks at Cross Mountain, Colo., probably contributed more to the basal conglomerate in the Citadel Plateau quadrangle than did similar outcrops at Juniper Mountain. Quartzite pebbles and cobbles of the Uinta Mountain Group are larger and more numerous in the basal conglomerate in the western part of the Citadel Plateau quadrangle, indicating a western source for some of this material. As mentioned, the total thickness of the basal conglomerate increases to the west in the Elk Springs quadrangle, suggesting that the basal conglomerate extended east and south from near Cross Mountain, and formed an alluvial apron of gradually decreasing thickness. The eastern extent of this alluvial apron is unknown, but it probably terminated near Deception Creek, west of the barrier formed by Juniper Mountain. Igneous rock pebbles in the basal conglomerate in Pan American Petroleum No. 1 Norvell well, and the mafic and felsic igneous and high-grade metamorphic pebbles of the basal conglomerate in the Maybell and Lone Mountain quadrangles east of the Little Snake River, were derived from source areas other than the Uinta

Mountains. These pebbles were possibly derived from the northern Park Range, as suggested by Izett (1975, p. 203) for the pebbles at Juniper Hot Springs. This derivation suggests that a west-flowing river—the ancestral Yampa—originated in the Park Range and flowed at least as far west as the Little Snake River during late Oligocene and early Miocene time. The course of the ancestral Yampa west of the Lone Mountain quadrangle is uncertain, as only quartzite, chert, and limestone cobbles in the basal Browns Park conglomeratic unit have been reported west of the Little Snake River (Sears, 1924b; McKay, 1974).

It is possible that the extensive eolian dunes in the Maybell area were formed from sand deposited along the course of the ancestral Yampa River. Allen (1965, p. 162–163) noted that migrating dunes sometimes form belts along the course of a river and are formed from sand winnowed from channel deposits at times of low water. A sand belt is present today in northeast Colorado along the south side of the South Platte River, and its distribution can be seen on the Geologic Map of Colorado (Tweto, 1979). The white, eolian cross-bedded sandstone of the Browns Park Formation is widespread between Craig and Cross Mountain, Colo., and may reflect the course of the ancestral Yampa. If so, then in Miocene time the Yampa was a west-flowing stream probably following a course similar to its modern course between Craig and Cross Mountain. Bergin and Chisholm (1965, p. 195) had previously suggested a possible Sierra Madre-Park Range origin for their non-tuffaceous sandstone facies of the Browns Park in the Maybell area. Such a source would also indicate westward-flowing streams or a river from the Park Range in Miocene time. Southwest of Cross Mountain, eolian sandstone is also present at Elk Springs, Colo., and (S. J. Luft, written commun., 1980) eolian sandstone also occurs at places northwest of Cross Mountain to the Utah state line. What the relation of these occurrences of eolian sandstone are to the inferred location of the ancestral Yampa is unknown.

VERTEBRATE TAPHONOMY OF THE BROWNS PARK FORMATION

INTRODUCTION

The orientation of the fossil bones at locality D856, the relative abundance of the different bone elements, and the character of bone preservation indicates how the bones were buried and what may have altered them after burial. As stated by Voorhies (1969, p. 2), taphonomy “* * * is concerned with the factors intervening between a living fauna and the fossilization of a

fraction of it. It deals mainly with the post-mortem history of animal remains (especially their decay, transportation, and burial) but also with cause of death."

The bones at locality D856 are mainly disarticulated, fragmentary, and dispersed. Carnivore utilization of a limited food resource, with associated trampling and kicking, best accounts for the observed bone fragmentation and dispersal. Weathering at the time of deposition probably accounts for some of the surface texture observed on the bones. The bones do not appear to have been reworked or transported by water, based on bone abundance and orientation data, including comparisons with a site in Arizona where the bones apparently were deposited by running water. Other possible influences, including sediment compaction, tectonism, and calcite deposition, do not account for the condition and distribution of the bones at locality D856.

ON THE ROLE OF WATER AS A DISPERSIVE AGENT

BONE ORIENTATIONS

Orientation data help determine whether bones were aligned in a current of water. Stream-table experiments

by Voorhies (1969, p. 66) showed that water-transported bones tend to be deposited parallel or transverse to current direction, depending on the type of bone and the depth of water; long bones tend to align transverse to the current in shallow water and parallel to the current in deeper water. Bones that parallel the current direction have their large ends downstream. In his analysis of the Verdigre quarry flood deposit in Nebraska, Voorhies (1969, fig. 9) found two mutually perpendicular directions for the bones which he interpreted as parallel and transverse to the current direction. In the Verdigre deposit, many bones had high angles of plunge, which Voorhies attributed to two factors: rapid burial in a high-energy flood situation, with little chance to return to the more stable horizontal position; imbrication in an upstream direction. At locality D856, the orientation of fossil vertebrate bones was determined in the field and later plotted on a stereonet (fig. 4A). Most bones lie in a horizontal plane, and are represented on the stereo diagram by two points 180 degrees removed from each other on the periphery. A rose diagram constructed from the same data (fig. 4B), showing only the azimuth of each bone, indicates no strong preferred orientations that might be interpreted as parallel and transverse to a current. Most of the bones are near horizontal, and

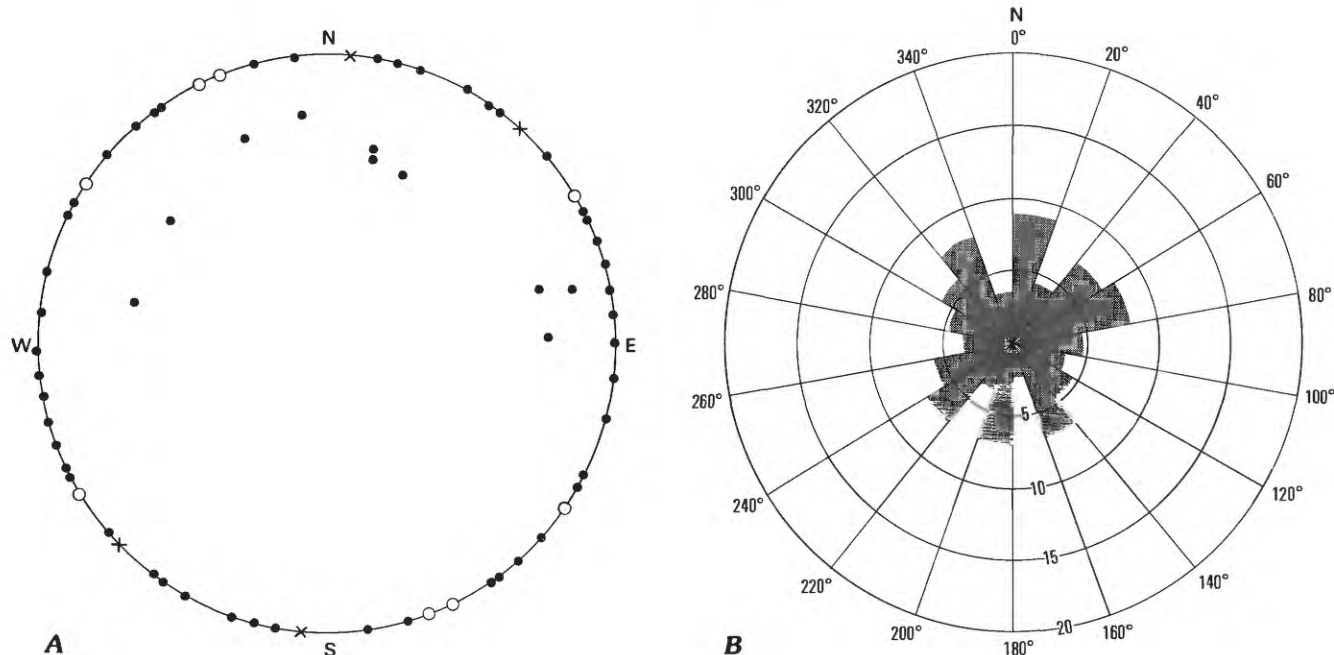


FIGURE 4.—Orientation of fossil mammalian bones from the Browns Park Formation at locality D856 in the Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, Stereographic projection; poles of bones plotted on the lower surface of a stereonet; filled circle, one pole; open circle, two poles at same position; cross, three poles at same position. Observations at periphery of diagram indicate horizontal bones. B, Rose diagram showing azimuths of bones; observed asymmetry results from bones with plunge greater than 0 degrees; values for these bones plot only in one quadrant. Concentric circles and associated values represent percent of total number of observations.

TABLE 1.—*Bones from locality D856 and their distribution into Voorhies Groups*

Group I	Group I/II	Group II	Group II/III	Group III
6 vertebrae 4 ribs	27 phalanges 4 calcanea 6 astragali 7 podials 1 scapula	6 distal humeri 7 proximal radii-ulnae 7 distal radii-ulnae 2 distal tibiae 5 distal metapodials 7 proximal metapodials 1 acetabulum	5 rami and partial rami	1 skull 1 fragment skull 1 mandible

none plunge at high angles. At the time of excavation, large ends were distinguished from small ends on only eight bones. Seven of these bones plunge northeast, with the large ends oriented northeast on five and southwest on two; the eighth bone plunges northwest, with the small end pointed northwest. These few bones indicate a slightly greater tendency for the large ends to be pointed north. The northwest and northeast plunge of the bones suggests that the upstream direction would be to the north if the bones were imbricated. However, only three of the eight bones have the large ends pointed south, which would be in the downstream direction. This suggests that the bones at locality D856 were not acted upon by a current of water.

RELATIVE ABUNDANCE OF BONES

The relative abundance of the different skeletal elements at locality D856 (table 1) provides further information on whether the bones were influenced by water currents. The relative abundances are determined by listing each skeletal element and the number of times it occurs. The bones listed in table 1 are divided into five Voorhies Groups (Behrensmeyer 1975, p. 484) according to their susceptibility to water transport. Voorhies (1969, p. 16) noted that ribs, vertebrae, sacra, and sterna (Group I) tend to be easily removed in a current; others, principally long bones, (Group II) are removed gradually. Rami, skulls, and mandibles (Group II/III, III) form a lag deposit. All three groups are present at locality D856. Group I is underrepresented owing to collecting bias. The observed and expected frequencies of selected skeletal elements are given in table 2. The observed frequencies of most of the long bones are only slightly greater than would be expected if these bones were not transported. On the other hand, the observed frequency of metapodials is slightly less than expected. The observed frequencies of proximal phalanges, calcanea, and astragali are very near the expected values if they had not been transported, whereas the observed frequencies of skulls and mandibles are

slightly less than expected. The sample is small, which has probably caused some slight differences in observed frequencies. For example, the observed frequencies of calcanea and astragali should be the same, but they are slightly different. Similarly, there are 22 complete and partial proximal phalanges preserved, whereas only 5 medial phalanges and no distal phalanges were recognized. The larger size of the proximal phalanges probably has resulted in their better preservation and consequent recognition.

Behrensmeyer (1975, fig. 5) showed that a bone assemblage composed of Groups I, II, and III is an undisturbed concentration. The relative numbers of bones in each group, though, is important for interpretation. At locality D856, the members of Group II are the most abundant, but not disproportionately so. The observed

TABLE 2.—*Observed and expected frequencies of bones from locality D856*

[The number of rami is given the frequency of 1.0; the number of identifiable parts of other bones is then divided by the number of rami. For example, in a complete skeleton there are 1 skull, 2 distal humeri, and 8 proximal phalanges per 2 rami, resulting in expected frequencies of 0.5, 1.0, and 4.0. There were excavated 2 skulls, 6 distal humeri, and 22 proximal phalanges per 5 rami, resulting in observed frequencies of 0.4, 1.2, and 4.4.]

Elements	Observed frequencies	Expected frequencies
Rami-----	1.0	1.0
Skulls-----	0.4	0.5
Mandibles-----	0.2	0.5
Distal humeri-----	1.2	1.0
Proximal radii-ulnae--	1.4	1.0
Distal radii-ulnae---	1.4	1.0
Distal tibiae-----	0.4	1.0
Proximal metapodials--	1.4	2.0
Distal metapodials----	1.4	2.0
Proximal phalanges----	4.4	4.0
Astragali-----	1.2	1.0
Calcanea-----	0.8	1.0

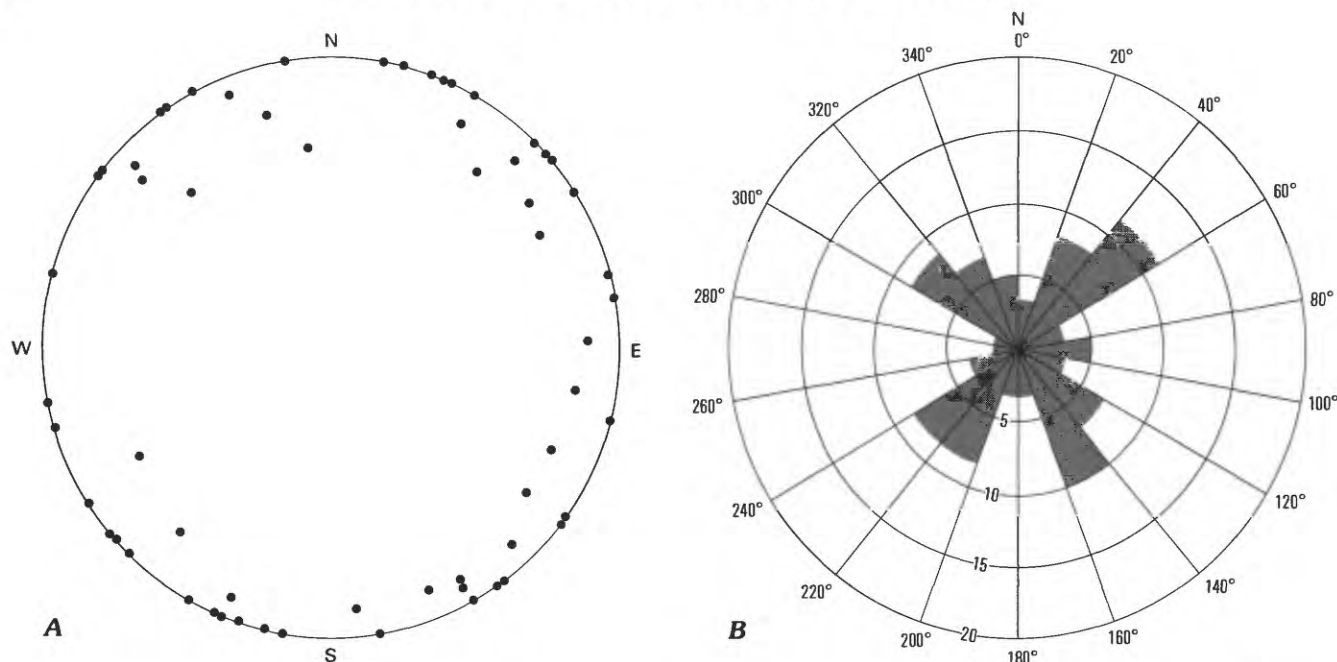


FIGURE 5.—Bone orientations at UALP locality 7498, Yavapai Co., Ariz. *A*, Stereographic projection; poles of bones plotted on lower surface of a stereonet. Each filled circle indicates one pole. Observations on periphery of diagram indicate horizontal bones. *B*, Rose diagram; concentric circles and associated values represent percent of total number of observations.

frequency of mandibles is low because the mandibles easily disassociate into individual rami. The lack of preferred orientation to the bones and the high number of bones in each Voorhies Group (remembering that collecting bias has lowered the number of bones in Group I) indicates that they were not transported by water.

COMPARISONS WITH LOCALITY 7498

The bone orientation and relative abundance data at the Browns Park locality D856 may be usefully compared with similar data collected by J. G. Honey at the UALP (University of Arizona Laboratory of Paleontology) locality 7498, about 15 km south of Prescott, Ariz. Comparison of the two data sets suggests that water currents influenced bone deposition at the UALP locality in contrast to the Browns Park locality. The late Clarendonian UALP bone assemblage is in an area of combined fluvial and eolian sediments of the Milk Creek Formation and is similar to the bone assemblage at locality D856 in that it contains a preponderance of camelid fossils. For details of the stratigraphy and depositional interpretations, see Hook, 1956; Honey, 1977; and Honey and Taylor, 1978. The bone orientations and relative abundances, however, differ significantly between the two deposits.

In the UALP sample, the orientations of the long axes of 42 bones were plotted on a stereonet (fig 5A). About

half of the bone orientations fall on the periphery of the circle, indicating that the bones were deposited horizontally. The rest of the bones have shallow dips, none exceeding 21° . The points tend to cluster in the northeast and northwest sections of the stereonet. The data were replotted as a rose diagram (fig. 5B), which can be compared with the rose diagram for the Browns Park bones (fig. 4B). At the UALP locality the bones form four distinct clusters. The mean of each cluster is within 7° of being 90° removed from its two nearest neighbors. The polarity of 14 of the bones was recorded; the heavy ends of 13 of the bones are distributed almost equally among the northwest, northeast, and southeast clusters.

The tendency for preferred orientations is strong evidence that the UALP bones have been aligned by water currents. Most significant is that the means of the four distinct clusters are within 7° of being 90° removed from each other; that is, the long axes of these bones tend to fall into two mutually perpendicular directions. These directions are interpreted as parallel and transverse to a water current. Generally, on bones parallel to the current direction, the large ends tend to point downstream (Voorhies, 1969); however, the orientations of the UALP bones indicate only that the current probably did not flow southwest.

All skeletal elements from UALP locality 7498 are listed in table 3, which can be compared with table 1

TABLE 3.—Bones from UALP locality 7498, Yavapai County, Arizona, and their distribution into Voorhies Groups

Group I	Group I/II	Group II	Group II/III	Group III
1 patella 1 rib	4 podials	3 distal metapodia 2 proximal metapodia 2 metapodial shafts 3 partial innominates 3 distal tibiae 2 radii-ulnae	23 partial rami	1 skull 1 complete mandible

for the Browns Park (locality D856) bones. A glance reveals the preponderance of ramal fragments (Group II/III) in the sample. Partial palates of at least six individuals were also recovered but are not included in the table because their transport susceptibilities were not examined by Voorhies (1969) or Behrensmeyer (1975). The preponderance of ramal fragments is strikingly illustrated by calculating the observed frequencies of cranial parts relative to the postcranial parts. In a complete skeleton, the number of rami will equal the number of tibiae, or humeri, or metatarsals, or any other paired limb element. The expected frequencies of these elements is therefore equal to one. In camels, there are two indistinguishable proximal (or medial or distal) phalanges per metapodial. Because it is nearly impossible on isolated specimens to tell front from hind phalanges, for practical purposes a complete skeleton will have eight indistinguishable proximal phalanges. Thus, the expected frequency of rami to proximal (or medial or distal) phalanges is 1:4. The frequency of palates or skulls to phalanges should be 1:8.

Table 4 shows the radical departure of the observed frequencies from the expected frequencies for three taxa found at UALP locality 7498. Table 5 gives some of the data used to calculate these ratios. On *Protolabis*, for example, the rami occur 16 times more frequently than most of the long bones. Palates of *Protolabis* are 1.5 times more frequent than astragali, whereas theoretically the astragali should be twice as abundant as the palates. On the horse, a single metapodial is present; theoretically, metapodials should be twice as abundant as rami, but here they are equal. Most of the UALP locality 7498 skeletal elements belong to Group III, the lag group, or to the intermediate Group II/III. Only a single rib and patella have been recovered from Group I.

The relative abundance of the bones in the different Voorhies Groups is further evidence that the UALP bones were subject to water current action. Group I is probably slightly underrepresented, as the field notes show that a fragmentary rib shaft was found and discarded. Otherwise, collecting bias has been minimal, and the lower number of bones in Groups I, I/II, and

II reflects a real scarcity in the deposit. These bones, which are lighter than those of Groups II/III and III, would tend to be winnowed out in a water current, and the members of Groups II/III and III would remain behind as a lag deposit, as shown by the experiments of Voorhies (1969). Although carnivores might selectively drag off and eat the remains of other animals, the evidence for preferred orientations of the cranial and ramal remains argues against removal of the lighter postcranial elements by agents other than water. The nonrandom orientations of the bones and the preponderance of lag elements at UALP locality 7498 indicates the presence of a water current strong enough to both orient the bones and winnow out some of the lighter elements, as at the Verdigre deposit (Voorhies, 1969). This situation differs somewhat from that reported by Hunt (1978) at the Harper Quarry (Miocene) in Nebraska, in which a water current was strong enough to orient bones preferentially in two perpendicular directions, but not strong enough to winnow out the lighter bones. Thus, the orientations and observed ratios of the bones at UALP locality 7498 are distinctly different from those at locality D856, and indicate the difference between a lag deposit and a sedentary accumulation.

PROCESSES AFFECTING DESTRUCTION AND DISPERSAL OF BONES AT LOCALITY D856

The preservation of the bones at locality D856 gives further evidence on post-mortem events. Damage to bones shortly after an animal's death may usually be attributed to processes of weathering (climatic weathering, chemical effects of soils and roots, and bacterial activity) or to mechanisms of physical damage (carnivore activity, trampling, fluvial transport, and diagenesis) (Behrensmeyer, 1978, p. 153; Hill, 1980, p. 143). Sediment compaction and tectonism can also damage bones. Of these, carnivore activity and weathering best account for the condition of the bones at locality D856.

The bones from locality D856 vary in their preservation. The bones are white, gray, or brown. Tooth enamel

TABLE 4.—*Observed and expected frequencies of bones for Michenia, Protolabis, and Equidae from UALP locality 7498, Yavapai County, Arizona*

[OF, observed frequency; EF, expected frequency; dist, distal; (prox), proximal]

<u>Michenia</u>	OF	EF	<u>Protolabis</u>	OF	EF	<u>Equidae</u>	OF	EF
ramus-----	1.00	1.00	ramus-----	1.00	1.00	ramus-----	1.00	1.00
dist tibia	0.66	1.00	dist tibia--	0.06	1.00	metapodial---	1.00	2.00
radius-			dist radius-			phalanges		
ulna-----	0.33	1.00	ulna-----	0.06	1.00	(prox)-----	0.00	4.00
metatarsal--	0.33	1.00	metapodial--	0.19	2.00			
palate-----	1.66	0.5	astragalus--	0.125	1.00			
			palate-----	0.375	0.5			
phalanges			phalanges					
(prox)-----	0.00	4.00	(prox)-----	0.00	4.00			

is bluish brown. Greenish-gray bones are best preserved; white and brown bones are more split and fragmented. The white color of some bones is due to a thin layer of calcium carbonate deposited on the outside surface; underneath this layer the bone is usually a shade of gray.

The greenish-gray bone is little damaged on its surface, although a few specimens (D856-32, 41) have faint, parallel cracks, and one (D856-56) is heavily damaged on the medial condyle and navicular facet. Some bones are bicolored (gray and brown, gray and white, brown and white); in nearly all cases the brown and white bone is more deeply split and fragmented than the gray bone. Several of the white bones from D856 (D856-77, 78, 28) are deeply pitted, and most show thin, parallel cracks—some rather prominently (D856-25, 35). When recovered, the brown bone was commonly partially matted by living roots. In several bones, brown organic matter was concentrated along splits or in cavities. Roots growing parallel to the bedding planes sometimes led to and surrounded bone. Bone highly disintegrated by roots left a brown stain in the enclosing sediments.

Many of the bones at locality D856 have surface textures similar to those produced by weathering. For example, some bones are nearly unweathered, and have only minute cracks (D856-30, 32, 65, 82). Other bones have thin, parallel cracks and some have a fibrous texture: they resemble bones that have dried and weathered on the surface of the ground (Behrensmeyer, 1975, pl. 1, fig. A). Other quarry bones (fig. 6, *E* and *F*) are deeply weathered with cancellous bone exposed.

There is, however, a strong overprint on many D856 bones caused by the destructive action of living roots. Root acids can create a pattern of etch marks on the surface of bone, or roots can grow into and split bones (Behrensmeyer, 1978, p. 154; Haynes, 1980, p. 349).

Some of the bones at locality D856 were etched and split by Holocene roots, which may have created some of the apparent Miocene weathering textures such as the shrinkage cracks. The bones with the spongiosa exposed (fig. 6, *E* and *F*) however, show no traces of Holocene roots, and their texture is thus more likely to have been caused in the Miocene.

The bones vary in completeness. None of the long bones or metapodials are completely represented; most are proximal or distal ends. The ribs are represented only by their heads; fragmentary shafts probably were destroyed during collection. Complete bones include some phalanges, podials, and vertebrae. The horn core and jaws are partially broken, the scapula is extremely broken, and the pelvis is represented only by the acetabulum.

In general, the breaks and morphological details of the bones are sharp and clear. Several bones have spiral fractures (D856-62, 55, 64; figs. 6*B*, 6*C*, 6*D*), and a few bones (D856-25, 19; fig. 6*A*) have splintered fractures (compare Behrensmeyer, 1975, pl. 2, figs. A, B, C). Some bones (D856-28, 77, 78; figs. 6*E*, 6*F*) have a roughened and pitted surface similar to bones illustrated by Behrensmeyer (1975, pl. 1, figs. A, B, and C). Other bones are crushed or have broken, depressed areas. For example, a distal radius-ulna (D856-25; fig. 6*H*) has the posterior part of the shaft crushed inward, yet the distal end is undisturbed. A phalanx (D856-68; fig. 6*G*) has a crushed shaft although the proximal and distal ends are undisturbed. Nearly all bones are broken or cracked, or have rough, pitted surfaces. No bones larger than camel phalanges are preserved intact.

Some of the damage on the bones at locality D856 is attributable to breakage rather than weathering, and includes the previously mentioned crushing of several of the bones, the destruction of the more fragile shafts

TABLE 5.—Data used to calculate observed frequencies given in table 4

Michenia
rami: 3 separate rami; 1-1/2 individuals maximum.
distal tibiae: 2 separates; 2 individuals minimum.
radius-ulna: 1 separate; 1 individual.
metatarsal: 1 separate; 1 individual.
palates: at least five "1/2 palates" ¹ ; 2-1/2 individuals minimum.
Protolabis
rami: 16 separates; 9 individuals minimum.
distal tibia: 1 separate; 1 individual.
radius-ulna: 1 separate; 1 individual.
metapodials: 3 separates at most; 2(?) individuals.
astragali: 2 separates; 2 individuals.
palates: six "1/2 palates"; 3 individuals.
Equidae
rami: 1 separate; 1 individual.
metapodial: 1 separate; 1 individual.

¹Refers to one-half of a complete palate, broken in the sagittal plane.

of the long bones, and spiral and splintered fracturing. According to Behrensmeyer (1975, p. 480), spiral and splintered fractures occur only on fresh bone, and their presence on several locality D856 bones may indicate that fracturing occurred before burial. Fluvial transport is one possible mechanism of physical damage. The edges of the bones at locality D856 are not rounded or polished, which indicates no prolonged current transport. Current transport of bones can result in extensive breakage without polishing, provided the transport has not been of long duration or over a great distance (compare Behrensmeyer, 1975, pl. 1, fig. B, bones a and b). However, the lack of fluvial deposits at locality D856, and the lack of indications of water transport in either the orientations or abundance of the bones, suggests no fluvial transport.

Sediment compaction or tectonic processes probably do not account for the fragmentation of the bones. The presence of dune foresets greater than 30° in some of the Browns Park roadcuts suggests little or no post-Miocene compaction of the sediments. Although sediment compaction or tectonism could crush the relatively fragile shafts of the long bones, these processes would probably not destroy all traces of these shafts while

preserving the ends, nor would they preserve, undistorted, several delicate cervical vertebrae while crushing the larger and stronger phalanx (D856-68) and radius-ulna (D856-55). There is no direct evidence for tectonic activity in and around locality D856. Dips taken on quarry strata range from 3° SE to 4° NW; slight irregularities on the dip surface and the original surface of deposition can account for these slight variations from horizontal. In the area around Maybell, the rocks are flat lying.

According to Behrensmeyer (1975, p. 482), CaCO₃ deposition can destroy a bone through the outward growth of a calcite nodule. At locality D856, however, there is no evidence for CaCO₃ nodule formation and the subsequent "explosion" of bone; instead, the calcite is a deposit on the surface of the bone. In some instances

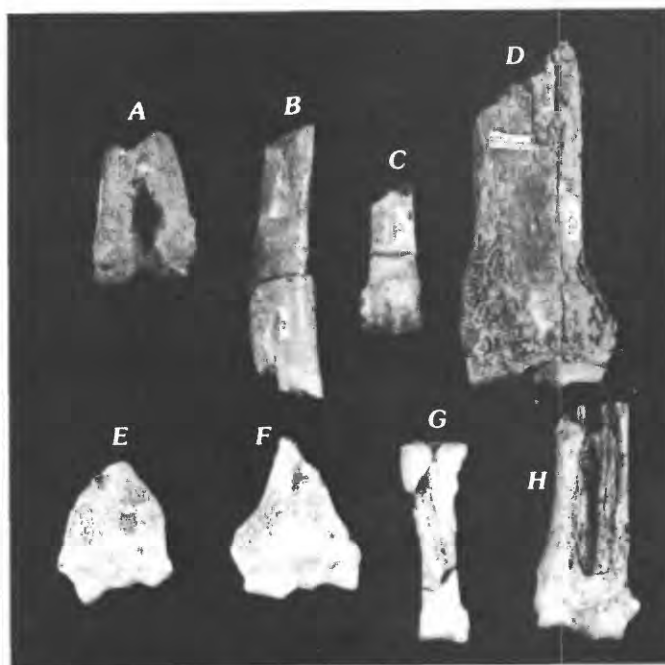


FIGURE 6.—Weathering characteristics of bones from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, posterior view of distal right humerus showing splintered fractures; cf. *Protolabis*, specimen D856-19. B, anterior view of metapodial shaft showing spiral fracture along top; *Procamelus* sp. or *Aepyamelus* sp., D856-62. C, posterior view of distal metapodial showing spiral fracture along top; *Procamelus* sp. or *Aepyamelus* sp., D856-62. D, anterior view of right distal radius-ulna, showing spiral fracture along top; *Procamelus* sp. or *Aepyamelus* sp., D856-55. E, anterior view of right distal radius-ulna showing pitted surface; *Camelinae* sp., D856-77. F, anterior view of left distal radius-ulna showing pitted surface; *Camelinae* sp., D856-78. G, posterior view of proximal phalanx showing crushed central part of shaft; *Procamelus* sp. or *Aepyamelus* sp., D856-68. H, posterior view of left distal radius-ulna showing crushed shaft; cf. *Protolabis*, D856-25. Scale is in centimeters.

(D856-37, 53) gray bone is evident underneath this surface veneer, whereas in other instances (D856-68, 77) the bone is soft and powdery. The fossil layer itself becomes more firmly cemented with calcite near its contact with the overlying highly calcareous layer, and it was from the bottom of this overlying layer that the *Tomarctus* skull and jaws were found. This specimen consists of gray-green bone that is remarkably well preserved, suggesting that CaCO_3 deposition has not destroyed the bone.

Animal trampling and associated kicking could explain some of the features of bones from quarry D856. Trampling would tend to fragment the more fragile shafts of long bones, leaving the ends and the denser bones intact. Incidental kicking is a random dispersive process (Hill, 1979, p. 270) which, like carnivore activity, could scatter and randomly orient the bones at locality D856. Trampling, however, often orients bones at high angles (Andrews and others, 1981, p. 45; Behrensmeyer and Boaz, 1980, p. 87); because most bones at locality D856 are horizontal and none dip at high angles, trampling probably was not the major cause of the observed bone destruction.

Carnivore activity is probably the main cause of bone destruction and dispersal at locality D856. Although there are tooth marks on only one bone (a camel ulna (D856-23) has a probable gnawed area immediately below the semilunar notch), Haynes (1980, p. 343) noted that carnivore gnawing does not always leave identifiable tooth marks on bones. He also noted that removal of the outermost lamellar tissue of bone can eliminate the shallower tooth marks (1980, p. 349). Carnivore activity is indirectly suggested by the absence of proximal humeri, tibiae, proximal and distal femora, and the presence of distal humeri, radii-ulnae, tibiae, and proximal and distal metapodials. The proximal ends of the humerus and tibia, and both ends of the femur, have a high fat content, and are therefore readily eaten by carnivores (Voorhies, 1969, p. 20). Haynes (1980, p. 345-347) reported extensive carnivore gnawing of these same areas on Pleistocene and Holocene bones, but notes little damage to distal ends of long bones except for the femur. According to Voorhies (1969) scavenging by carnivores possibly accounted for the low number of femora, and proximal humeri and tibiae in the Verdigre sample; Hunt (1978, p. 35) also suggested that carnivore activity accounted for the presence of broken limb bones, isolated teeth, vertebrae and ribs at Harper Quarry. The abundance of metapodials, podials, and phalanges at locality D856 could be explained by their having been covered by less meat, thus making them less attractive dietary items to carnivores. The greater density of the podials and the proximal and distal ends of the metapodials and phalanges would also help explain their preservation.

CONCLUSIONS

Fluvial transport, sediment compaction, tectonism, and calcium carbonate deposition do not account for the observed fragmentation and destruction of the bones at locality D856. The physical damage to these bones was most likely caused by carnivore activity, with a possible minor component due to trampling. The surface textures of some of the bones may be due to Miocene weathering phenomena, but the strong overprint caused by etching and splitting due to growth of modern plant roots makes tenuous any interpretation of ancient weathering textures.

The pattern of highly fragmented bones, missing their shafts and nutrient-rich ends, and which are disarticulated and highly dispersed, indicates intense utilization of the original carcasses by carnivores. This suggests a relatively low number of carcasses available to predators when the locality D856 bone deposit accumulated. Where there is an abundance of carcasses, as can occur in catastrophic mortality, there is less utilization of each carcass by carnivores, resulting in less bone destruction and increased chance for burial of intact bones (Western, 1980, p. 48; Coe, 1980, p. 59; Behrensmeyer and Boaz, 1980, p. 85). It is unlikely that the bone assemblage at locality D856 is the result of the catastrophic death of many mammals, but is more likely the result of slow, attritional mortality. With relatively few carcasses available for the number of predators, the bones were more thoroughly consumed, resulting in a fossil deposit of fragmentary, dispersed bones.

VERTEBRATE FAUNA OF THE BROWNS PARK FORMATION

LOCATIONS OF FOSSIL SITES

The fossils described are from four localities (fig. 7; table 6): D854, south side of roadcut in the NE1/4NE1/4 sec. 23, T. 6 N., R. 97 W., Citadel Plateau 15-minute quadrangle; D855, on a hill in the NE1/4NE1/4 sec. 36, T. 6 N., R. 97 W., Citadel Plateau quadrangle; D856, on the same hill in NW1/4NW1/4 sec. 31, T. 6 N., R. 96 W., Citadel Plateau quadrangle; D857, in a roadcut in SW1/4NW1/4 sec. 34, T. 6 N., R. 97 W., Elk Springs 15-minute quadrangle. Locality D855 is 15.2 m stratigraphically below locality D856. Extensive plant cover prevents direct stratigraphic correlation between the rocks at localities D854 and D855. D854 lies topographically 32.6 m below D855 at an elevation of 1,930 m. Similarly, fossil locality D857 cannot be correlated stratigraphically with the other fossil localities.

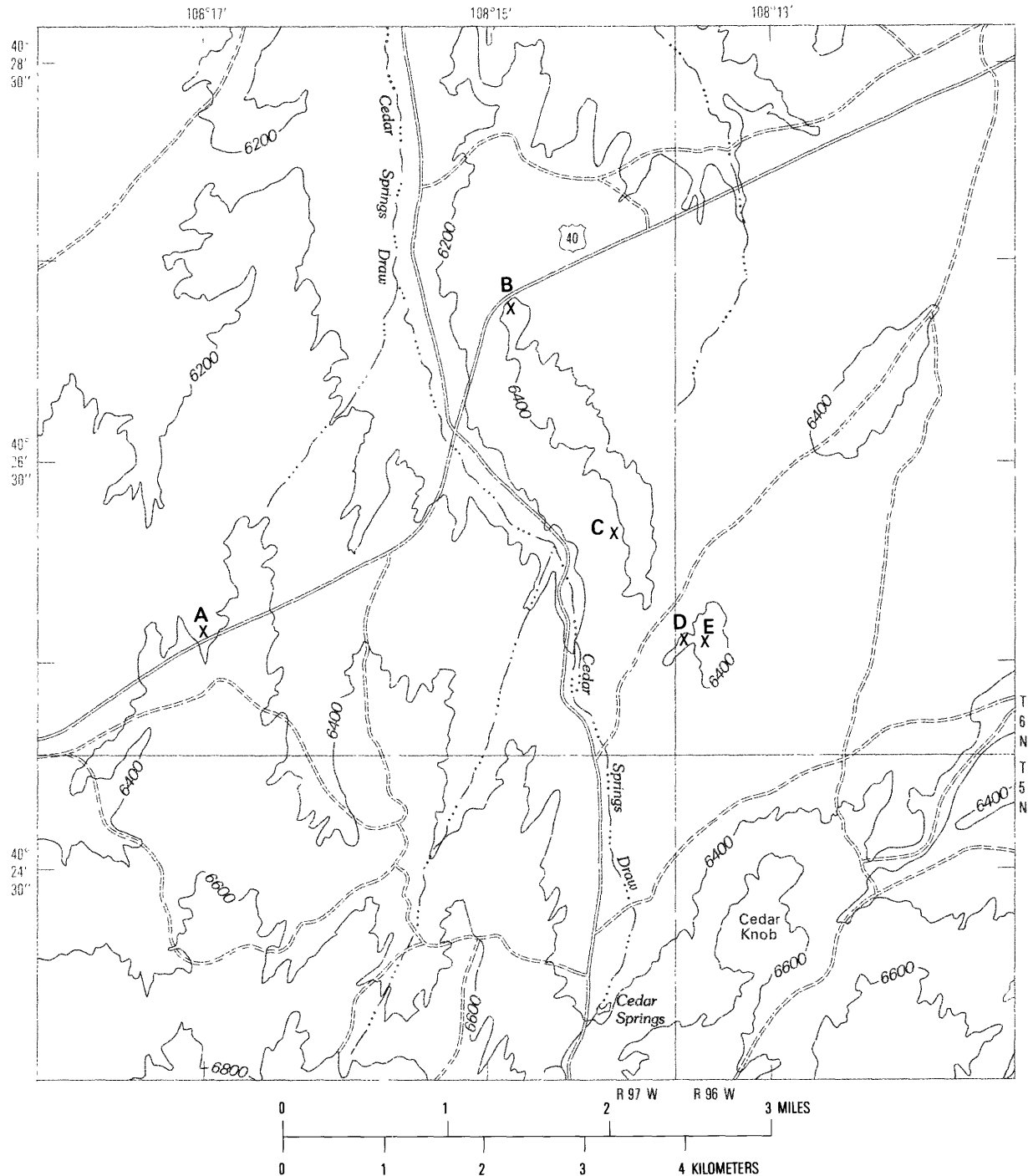


FIGURE 7.—Fossil mammal localities and dated volcanic ash southwest of Maybell, Colo. A, locality D857; B, D854; C, dated ash; D, D855; E, D856. Topographic base from Citadel Plateau and Elk Springs 15-minute quadrangles, Moffat County, Colo. Elevations are in feet; to convert to meters, multiply by 0.3048. Double dashed lines indicate unimproved dirt road.

Its elevation is about 1,963 m, which is the same as at D855 (1,962 m).

The fossils found at these four sites are assigned to two local faunas distinguished by taxonomic and temporal differences. The term local fauna, as used in this

paper, follows that given by Tedford (1970, p. 682-683). He stated that "the local fauna may be represented by samples from a single site or a series of closely associated sites having a limited geographic and stratigraphic distribution." Although the four sites in

TABLE 6.—*Miocene fossil mammals from the Browns Park Formation*
[Locality numbers not arranged in stratigraphic order]

Locality No.	Lithology	Fossils
Cedar Springs Draw local fauna		
D854	Sandstone, white, quartzitic, medium-grained, subrounded, friable.	<u>Meryceros</u> sp.
D855	Sandstone, white, very fine to fine-grained, silty; in part calcareous.	<u>Procamelus</u> sp. or <u>Aepycamelus</u> sp.
D856	Sandstone, light greenish-gray, fine-grained, subrounded; in part calcareous.	<u>Tomarctus</u> cf. <u>T. paula</u> <u>Megahippus</u> sp. cf. <u>Protolabis</u> <u>Michenia</u> sp. <u>Procamelus</u> sp. or <u>Aepycamelus</u> sp. <u>Camelinae</u> sp. <u>Meryceros warreni</u> <u>Merycodontinae</u> sp.
Cross Mountain local fauna		
D857	Sandstone, greenish-gray, quartzitic, fine-grained, subangular to subrounded, well-sorted.	<u>Parahippus</u> cf. <u>P. Teonensis</u> <u>Blickomylus galushai</u>

the Maybell area are close geographically and topographically, the fauna at one site is older than the other three. The older fossil assemblage is here named the Cross Mountain local fauna, based on its nearness to the old settlement of Cross Mountain in the Elk Springs 15-minute quadrangle; the younger fossil assemblage is here named the Cedar Springs Draw local fauna, based on its proximity to a dry wash of that name on the eastern edge of the Elk Springs 15-minute quadrangle and the western edge of the Citadel Plateau 15-minute quadrangle.

MAMMALIAN PALEONTOLOGY

Class MAMMALIA Linnaeus
Order CARNIVORA Bowdich
Family CANIDAE Gray
Subfamily CANINAE Gray
Genus TOMARCTUS Cope
Tomarctus cf. T. paula Henshaw

Table 7, Figure 8

Tomarctus paulus Henshaw (1942, p. 105-108, pl. 2, figs. 3, 4, 4a).

Holotype.—CIT 1229, palate with I¹-M², and left ramus with I₂-M₃, from CIT locality 172, Esmeralda Formation, 9 miles north of Tonopah, Nye County, Nev.

Referred material.—D856-1: broken skull with fragmentary LM¹ and complete LM², a right dentary with canine root, P₁ alveolus, P₂ roots, fragmentary P₃, M₁₋₃ (M₁₋₂ damaged); D856-2, right premaxillary and maxillary with I³, C, P¹; D856-3, condyle of left dentary; D856-4, temporal fossa of left dentary; D856-88, isolated, broken teeth.

Distribution and age.—Holotype from Tonopah fauna, Nevada; Barstovian land mammal age.

Description.—The skull of *Tomarctus* cf. *T. paula* is smaller than that of *Canis latrans*, with a relatively shorter preorbital portion, and the braincase is less expanded. The zygomatic arches are widely flaring which, coupled with the small braincase, results in temporal fossae relatively larger than in *C. latrans*.

The width across the piriform aperture is the same as in *C. latrans*. A small tuberosity on the dorsal border of the premaxillary is more prominent on specimen D856-1 than on *C. latrans*. The incisor alveoli are transversely narrow, and the alveolus for the I³ is much larger than that for either the I¹ or I².

The muzzle is short and deep, with the maxillary nearly as deep but only about half as long antero-posteriorly as in some specimens of *C. latrans*. The muzzle is less broad than that of *C. latrans*. The lateral edge of the palatine between P⁴ and M¹ is strongly depressed.

A large maxillary foramen is located anteriorly on the orbital border of the maxillary. Alveolar foramina are present on the dorsal surface of the maxillary tuberosity. The sphenopalatine and posterior palatine foramina are located 14 mm posteromesial to the maxillary foramen, on the dorsal part of the palatine bone. The rest of the medial wall of the orbit has been destroyed.

The jugal-maxillary contact is V-shaped, with a prominent ventral maxillary process on the jugal. The scar for the origin of the masseteric muscle is pronounced, with the upper margin marked by a distinct ridge. The frontal process of the jugal is mesially inclined.

On the partial right frontal, the external frontal crest trends posteromesially from the zygomatic process to meet its counterpart at the midline and form a strong sagittal crest. The parietals are less inflated than in *C. latrans*. The lambdoidal crest has a more strongly developed posterior flare than in *C. latrans*, and forms a broad, inverted U. Owing to this marked flaring, the posterior surface of the supraoccipital is highly concave on *T. cf. T. paula*. The external occipital crest is poorly developed, whereas on *C. latrans* it is a marked swelling above the foramen magnum. Several dorso-ventrally trending ridges and depressions, for the insertion of the splenius muscle, are present on the supraoccipital.

The foramen magnum and basioccipital are destroyed. Laterally, the lambdoidal crest extends anteroventrally as a strong shelf to join the posterior root of the zygomatic arch. A prominent tubercle is located on the crest and posterodorsal to the auditory meatus. The partially broken bulla is mesiolaterally elongated and less expanded than in *C. latrans*. In *C. latrans*, the bulla is inflated so that its lower border lies below the lowermost portion of the retroglenoid process, whereas on specimen D856-1 the bottom of the bulla is level with the bottom of the process. Owing to this expansion, in *C. latrans* the bullar fusion of the squamosal occurs further down on the retroglenoid process than on specimen D856-1. The lower lip of the external auditory meatus, which on specimen D856-1 lies above the opening of the retroglenoid foramen, is level with or below the opening for this foramen in *C. latrans*. Owing to the less expanded bulla in specimen D856-1, the stylomastoid process is much more prominent and extends below the level of the bulla.

Parts of the basisphenoid and orbitosphenoid are preserved. The posterior opening of the alar canal and the foramen rotundum are smaller, but situated much as in *C. latrans*. On specimen D856-1, a tiny foramen

TABLE 7.—Skull and dental measurements of *Tomarctus cf. T. paula* (specimen D856-1) from locality D856 in the Citadel Plateau 15-minute quadrangle, Moffat County, Colorado

[Measurements in millimeters]

Distance from anterior edge of orbit to anterior edge of premaxillary	55.5
Distance from anterior edge of orbit to posterior edge of interparietal process.....	107.0
Distance from anterior edge of premaxillary to posterior edge of palate behind third molar...	67.5
Width between frontal processes of zygomatic bone.....	72.0
Width between infraorbital foramina.....	30.7
Maximum width across parietals.....	50.0
Width of piriform aperture.....	21.2
Distance from infraorbital foramen to anterior border of maxillary.....	23.5
Height of premaxillary bone at infraorbital foramen.....	32.0
Outside width at narrowest point of muzzle.....	25.9
Palatal width between anterior roots of p ³	19.0
Palatal width between M ³	23.6
I ³ APxTR.....	4.0x4.0
C (upper) APxTR.....	6.8x4.0
M ² APxTR.....	5.9x9.1
C (lower) APxTR.....	6.9x5.7
M ₁ APxTR.....	15.7x6.8
M ₁ heel TR.....	6.5
M ₂ APxTR.....	8.9x5.6
M ₃ APxTR.....	4.0x3.5
C-M ₃	63.9
P ₁ -M ₃	54.7
Jaw depth below M ₁ posterior root.....	15.0
Jaw width below M ₁	9.2
Length from condyle to I ₁ alveolus.....	105.0

is present in the position of the hypophyseal fossa; the dorsum sellae is broad and flat.

An isolated I¹ (specimen D856-88) possesses a broad central cusp bounded laterally by a smaller accessory cusp. The small mesial accessory cusp may have been eliminated by wear. The lingual surface of the tooth is concave and bounded by a broad cingulum. The I³ (specimen D856-2) is larger and more caniniform than the I¹ and has a minute posterior swelling. There is a mesial cingulum at the base of the tooth. The canine is robust and laterally compressed.

The premolars of specimen D856-1 are highly fragmented. A partial P⁴ consists of a paracone and meta-style separated by a notch. A strong cingulum runs along the base of the lingual wall. A fragmentary M¹ shows no differences from that of *C. latrans*. The M²

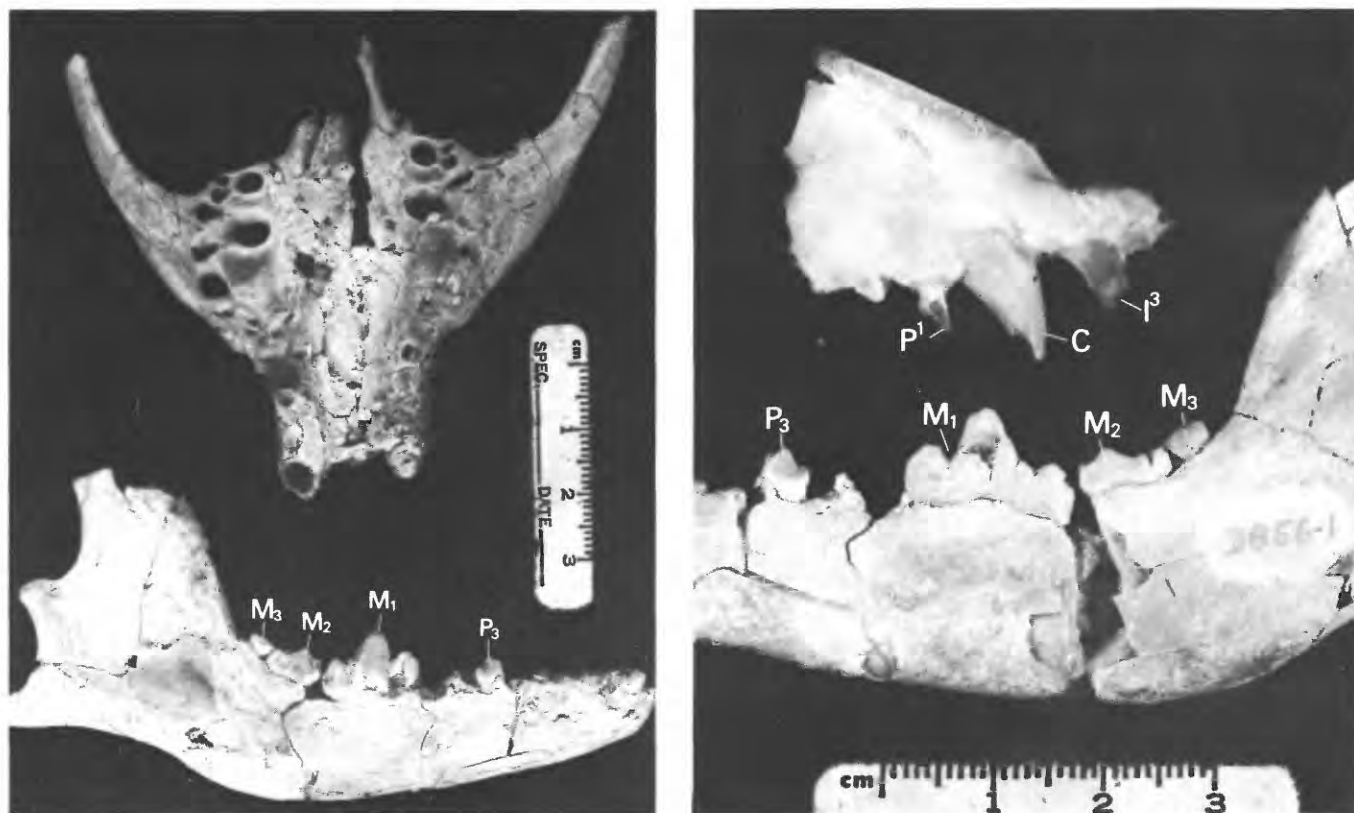


FIGURE 8.—*Tomarctus* cf. *T. paula*, from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. Upper left, ventral view of palate; specimen D856-1. Lower left, buccal view of right dentary showing premolar (P_3) and molars (M_{1-3}) of specimen D856-1. Upper right, lateral view of rostrum showing right incisor (I^3), canine (C), and premolar (P^1) (broken) of specimen D856-2. Lower right, lingual view of right dentary showing P_3 and M_{1-3} of specimen D856-1.

metacone is smaller in relation to the paracone, and the M^2 buccal cingulum is weaker and the posterior edge of the tooth is less concave than that of *C. latrans*.

The lower canine root on specimen D856-1 indicates a large, vertically oriented tooth. The C- P_1 diastema is slightly shorter than that of *C. latrans*. The premolars are too fragmented to be described. The M_1 is broken anterobuccally. The protoconid, paraconid, and metaconid are all strongly developed; the metaconid more so than that of *C. latrans*. Small lingual and buccal accessory cusps are present on the posterior walls of the metaconid and protoconid, respectively. On specimen D856-1, the lingual accessory cusp is more closely appressed to the metaconid than on *C. latrans*. The posterior wall of the M_1 talonid is broken, but it appears that the posterior cingulum is less well developed than in *C. latrans*. The M_2 has some slight anterobuccal breakage. The protoconid and metaconid are well developed on specimen D856-1, and in addition there is a small anterior paraconid—a cusp absent on the M_2 of *C. latrans*. The M_3 is round and simple with two shallow anterior and posterior basins.

The dentary of specimen D856-1 is short and slender. The ventral border is convex beneath the molars, and concave beneath the masseteric fossa. Owing to the shortness of the jaw, the ventral border anterior to the molars is less rounded than in *C. latrans*. A large mental foramen is located beneath the anterior root of the P_2 . The masseteric fossa is deeply excavated. The articular condyle is slightly less elongate laterally than in *C. latrans*. The posterior border of the symphysis lies between the P_1 and P_2 .

Comparisons and discussion.—Specimen D856-1 resembles *Tomarctus* rather than *Canis* in having a short facial region, small braincase, strong lambdoidal crest (McGrew, 1935, p. 305) and a distinct paraconid on the M_2 (Merriam, 1913, p. 360). The presence of M_1 accessory cusps distinguishes specimen D856-1 from *Cynodesmus* (Olsen, 1956, p. 2).

Specimen D856-1 is about 25 percent smaller than *Tomarctus rurestris* (Condon, 1896), figured by Downs (1956, figs. 10 and 11). The dentary is more robust and more strongly convex anterior to the masseteric fossa in *T. rurestris*.

The type of *Tomarctus brevirostris* (Cope, 1873) is a fragmentary jaw with the M_1 present; the M_1 is about 40 percent larger than that of specimen D856-1. The jaws from the Lower Snake Creek fauna (early Barstovian) referred by Matthew (1924, p. 91) to *T. brevirostris*, average about 20 percent larger than specimen D856-1. The teeth are wider and more massive and the dentary is more robust in *T. brevirostris*. The skull is larger, the palatal width at the M_1 is about 29 percent greater, and the auditory bulla is more inflated in *T. brevirostris*.

The type lower dentition of *Tomarctus optatus* Matthew, 1924 (Matthew, 1924, fig. 18) is only slightly larger than that of specimen D856-1. The molar widths are the same, and the referred jaws in the AMNH do not differ from specimen D856-1. However, the upper dentition of undescribed *T. optatus* in the AMNH collection is larger than that of specimen D856-1. In particular, the M^2 of *T. optatus* is less reduced than that of specimen D856-1, and consequently, *T. optatus* more closely resembles other small species of *Tomarctus* which have nonreduced dentitions.

Tomarctus confertus (Matthew, 1918) has a smaller, shorter skull, with narrower palate and less expanded braincase, than specimen D856-1. The mandible of *T. confertus* (AMNH 17203; Matthew (1918), fig. 1) is shorter and narrower dorsoventrally, the premolars are shorter, the canine smaller, and the M_1 narrower than that of specimen D856-1.

Tomarctus euthos (McGrew, 1935), has a bigger skull with wider rostrum and palate than that of specimen D856-1, and the rostrum is not sharply constricted anterior to the P^4 as it is in specimen D856-1. The teeth of *T. euthos* are more robust than those of specimen D856-1.

Tomarctus propter Cook and Macdonald, 1962, based only on an M_1 , is distinguished from specimen D856-1 by being much larger and having a reduced metaconid.

The tooth row of *Tomarctus canavus* (Simpson, 1932), is 8-13 percent longer than specimen D856-1. Although the morphology of the lower molars is similar in specimen D856-1 and *T. canavus*, the molars of *T. canavus* are slightly larger than those of specimen D856-1. The upper teeth of *T. canavus* (including the types of *T. thomasi* White, 1941 and *Nothocyon insularis* White, 1942) are distinctly larger than those of specimen D856-1. In particular, the M^2 of specimen D856-1 is much reduced compared to the M^2 of *T. canavus* (Olsen, 1956, tables 1 and 2). Although the M^1 of specimen D856-1 is broken, the transverse width is less than that of *T. canavus*.

Tomarctus casei (Wilson, 1939), is smaller than *T. canavus*, and has a shorter dentition than that of

specimen D856-1 (measured from the back of the canine to the back of the M^3). Although the transverse width of the M^1 of *T. casei* is less than that of specimen D856-1, the M^2 of *T. casei* is wider—about the size of the M^2 of *T. canavus*. On *T. casei* the M^2 ectocingulum is stronger than on specimen D856-1, and there is a marked concavity on the posterior edge of the tooth not present on specimen D856-1.

Tomarctus thomsoni (Matthew, 1907) is distinguished from specimen D856-1 by having a less reduced M^2 , with a more expanded posterointernal corner. In specimen D856-1 the premolar row is longer, the M_1 is slightly longer, the M_2 is longer and wider with a narrower talonid, and the M_3 is slightly more reduced than that of *T. thomsoni*.

Tomarctus kelloggi (Merriam, 1911) is distinguished from specimen D856-1 in having a more robust jaw and an enlarged M_2 with a well developed paraconid. On a referred M_2 (UCMP 10651), the paraconid is nearly as large as the metaconid, whereas on specimen D856-1 the paraconid is relatively small. The trigonid basin on *T. kelloggi* is wider than that of specimen D856-1.

Specimen D856-1 is quite similar to *Tomarctus paula* Henshaw, 1942¹. *T. paula* resembles specimen D856-1 in the reduction of the M^2 , which is greater than in the other small species of *Tomarctus*. The morphology of the M^2 is also similar; although *T. paula* appears to have a stronger lingual cingulum, that of specimen D856-1 is broken and thus reduced in size. As indicated by the length of the lower dentition, *T. paula* is slightly shorter faced than specimen D856-1, and the P_1 - M_3 length of *T. paula* is about 7 percent shorter than that of specimen D856-1. The P_1 - M_3 length is probably a truer measure of the relative size of these two animals than is the length given for the condyle to the I_1 ; in both fossils this latter measurement is approximate and Henshaw's (1942, pl. 2, fig. 4) drawing shows that the position of the condyle is hypothetical. As in specimen D856-1, the posterior part of the palate on *T. paula* is relatively wide. The lower teeth of *T. paula* are slightly smaller than those of specimen D856-1.

Henshaw's (1942, pl. 2, fig. 4) illustration shows that the M_1 metaconid on *T. paula* is the size of that on specimen D856-1. The M_2 of *T. paula* is not elongated in relation to the M_1 as it is in *T. kelloggi*. Henshaw (1942, p. 106) noted the presence of a "distinguishing paraconid" on the M_2 , but his illustration (1942, pl. 2,

¹*Tomarctus paula* was originally named *Tomarctus paulus*. According to G. G. Simpson (written commun., 1977), *Tomarctus* is feminine in gender in Latin and *paulus* is masculine. According to Article 30 of the 1971 International Code of Zoological Nomenclature, adjectival specific names must agree with the generic name in gender, and (Article 34) must be changed, if necessary, to conform to the gender of the generic name. Thus, the change from *paulus* to *paula* is a "justified emendation" (Article 33).

fig. 4a) shows only a strong crest anterior to the protoconid and metaconid. Wear sometimes causes the paraconid to lose its cusped form and become incorporated into an anterior ridge. Other small differences with specimen D856-1 include a slightly greater depth anteriorly on the dentary, a greater inclination from the horizontal of the ascending part of the ramus, and a slightly narrower masseteric fossa.

Canid indet. BEG 31081-1255 (Wilson, 1960, p. 994, Fig. 5e) is similar to both specimen D856-1 and *T. paula*. The partial palate of Wilson's specimen has a reduced M^2 similar in size to that of D856-1.

Specimen D856-1 and the type lower jaw of *Tomarctus temerarius* (Leidy, 1858) are almost identical; there are no significant size differences in either the M_1 or the dentary. Although a labial accessory cusp does not appear in Leidy's (1869, pl. 1, fig. 12) illustration of the M_1 , it may have been eliminated by wear.

Similarly, the type of *Tomarctus marylandica*² Berry, 1938 cannot be distinguished from the M_{1-2} of specimen D856-1. Berry (1938, p. 159) noted that in *T. marylandica*, "the protoconid, the most outstanding feature of the tooth, is about twice as high as the metaconid." The M_1 metaconid on specimen D856-1 stands only slightly over half the height of the protoconid, and is thus similar to that of *T. marylandica*. On the M_2 of *T. marylandica* a tiny basin is present posterior to the ridge between the entoconid and hypoconid. This depression was probably caused by overlap by the succeeding M_3 , and is therefore due to crowding of the last two molars. On specimen D856-1 the M_3 is closely appressed against the M_2 . The upper teeth of *T. marylandica* are unknown.

Although the M_1 of specimen D856-1 cannot be distinguished from that of *T. temerarius*, or the M_1 heel and the M_2 of specimen D856-1 cannot be distinguished meaningfully from *T. marylandica*, specimen D856-1 skull and jaws are not referred to either of these species: specimen D856-1 in fact closely resembles the more completely known *T. paula*. *T. paula* and specimen D856-1 are both short-faced forms with reduced M^2 , and the measurements on the upper molars of the two are nearly identical. Nothing is published of the skull proportions of *T. temerarius* or *T. marylandica*, so it is premature to assign the brachycephalic specimen D856-1 skull to either of these species. For this reason, specimen D856-1 is assigned to *Tomarctus* cf. *T. paula*.

²Tedford and Hunter (1984) suggested that *T. marylandica* is a primitive member of the genus *Cynarctus*.

Order PERISSODACTYLA Owen
Suborder HIPPOMORPHA Wood
Family EQUIDAE Gray
Genus MEGAHIPPUS McGrew
Megahippus sp.

Table 8, Figure 9

Referred material.—D856-5, right premaxillary; D856-6, 10 incisors; D856-7, $dP^x(?)$; D856-8, right and left dP_1 ; D856-9, right dentary with dP_{1-4} , M_1 ; D856-10, $LdP_x(?)$.

Description.—The right premaxilla preserves the symphysis and the three incisor alveoli. The anterodorsal border of the premaxilla is elevated posterior to the symphysis. The alveoli for the I^1 and I^2 are subequal in size and larger than the alveolus for the I^3 .

None of the incisors were found socketed, but their number suggests that some came from the lower jaw. The incisors, all probably deciduous, are low crowned and strongly cupped, and have long, strong roots. Five slightly worn incisors possess narrow, discontinuous lingual cingula. The labial surface is smooth or may have a cingulum running continuously along three sides. The broken $dP^x(?)$ is low crowned with a cingulum anterior to the slightly worn protocone, and between the hypocone and hypostyle.

The dP_1 is large and single rooted, consisting of a prominent central cusp, swollen basally, from which sharp anterior and posterior crests descend. A strong basal cingulum is present buccally. The cingulum is more shelflike anteriorly and posteriorly than centrally.

The dP_2 is elongate and relatively narrow anteriorly. A labial basal cingulum runs from the cusp-like parastylid to the hypostylid, and is more strongly developed on the hypolophid than on the protolophid. A short, shallow groove about 2 mm long separates the metaconid and metastylid. The dP_3 and dP_4 each have a strong, shelflike buccal cingulum running from the paralophid to the hypostylid. The hypostylid has a short, posteriorly directed shelf that does not reach the base of the tooth. The metaconid and metastylid are separated by a groove 2 mm long. The dP_2 paralophid and protolophid are more widely separated than those of the dP_3 and dP_4 . The anterior and posterior walls of the dP_2 protoconid join to form a sharp buccal ridge; on the dP_3 and dP_4 this junction is wide and rounded. None of the deciduous premolars have a lingual cingulum. The M_1 is unerupted and incomplete. The metaconid and metastylid are only faintly separated lingually. A remnant of a cingular structure is present lingually at the bottom of the postflexid.

The mandible is deep dorsoventrally and flat ventrally. It is eroded anteriorly, but there is evidence of strong

TABLE 8.—Dental measurements of *Megahippus* sp. from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colorado

[Measurements in millimeters]

Incisor length.....	n=6; O.R.=11.8-13.2; \bar{X} =12.3
?dP ^x AP length at protocone and hypocone.....	26
dP ₁ AP.....	n=2; O.R.=11.0-11.2; \bar{X} =11.3
dP ₁ TR.....	n=2; O.R.=7.8-8.3; \bar{X} =8.1
dP ₂ APxTR.....	28.7 x 18.7
dP ₃ APxTR.....	26.6 x 19.5
dP ₄ APxTR.....	27.2 x 19.5
?dP _x APxTR.....	29.5 x 21.3
M ₁ Height of unworn metaconid...	19.4
Narrowest depth of ramus between dC and dP ₁	29.2
Narrowest depth of ramus below dP ₄ protocone.....	41.0

upturning at the symphysis. The post-canine diastema is short. The mental foramen is 14.5 mm below the dP₁.

Comparisons and discussion.—McGrew (1938, p. 315) defined *Megahippus* on the basis of *M. matthewi* found at the Burge quarry in the Burge Member of the Valentine Formation, Neb. Although about one-fourth smaller than *M. matthewi*, and thus similar in size to *Hypohippus affinis*, specimen D856-9 differs from *H. affinis* in having a strongly upturned symphysis, short post-canine diastema, and more hypsodont M₁. A strongly upturned symphysis, short post-canine diastema, and more hypsodont dentition were among the characteristics considered diagnostic of *Megahippus* by McGrew. M. F. Skinner of the AMNH (oral commun., 1975), notes that the lower cheek teeth of later *Megahippus* possess lingual cingula, whereas those of *Hypohippus* do not. Examination of anchitheriines in the Frick collection corroborates Skinner's statement. In New Mexico, *Megahippus* from the Pojoaque Member of Galusha and Blick (1971) of the Tesuque Formation possess the lower lingual cingula on the permanent dentition. In contrast, specimens from the stratigraphically lower Skull Ridge Member of Galusha and Blick (1971) of the Tesuque Formation lack the cingula. The small cingular structure below the M₁ postflexid of specimen D856-9 is suggestive of, but not so well developed as, the cingular structures seen on the Clarendonian *Megahippus* cf. *M. matthewi* from the Esmeralda Formation at Cedar Mountain, Nev. (Mawby, 1968, fig. 1).

The lower lingual cingula of *Megahippus* progressively increased in size during the Barstovian. This increase in size probably correlates with the progressive development of the lingual cingula on the upper premolars of *Megahippus*. Tedford and Alf (1962, p. 119) pointed out that the upper premolar cingula of the late Barstovian form *M. mckennai* are less well developed than those of the latest Barstovian and Clarendonian form *M. matthewi*.

McGrew (1938, p. 315-317) considered the absence of P₁ diagnostic of *Megahippus*. However, specimens in the Frick collection show that some early Barstovian (Pawnee Creek Formation of Galbreath (1953) in

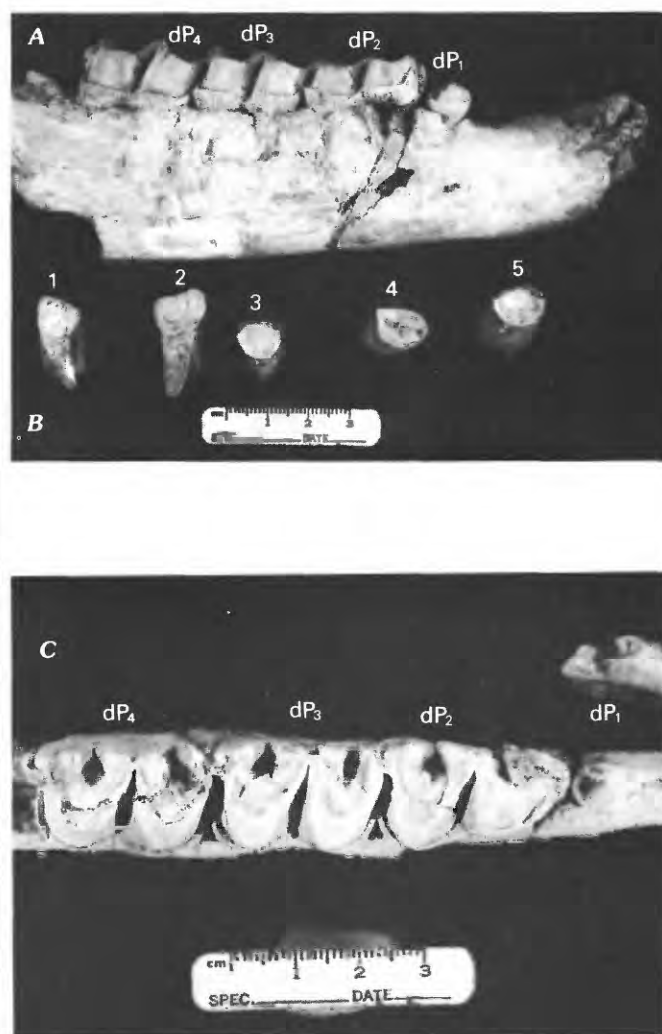


FIGURE 9.—*Megahippus* sp., from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, buccal view of right dentary with deciduous premolars (dP₁₋₄) of specimen D856-9. B, labial (1,2) and occlusal (3-5) views of incisors; D856-6. C, occlusal view of right deciduous premolars (dP₁₋₄) of specimen D856-9.

northeast Colorado) forms have a well-developed P_1 . Some late Barstovian to possibly early Clarendonian (Pojoaque Member of the Tesuque Formation) forms have a reduced P_1 , and some latest Barstovian (Burge quarry)³ forms lack the P_1 . Similarly, the dP_1 is well developed in the early Barstovian forms and is small or absent in latest Barstovian and Clarendonian forms.

Cupped incisors are characteristic of adult *Megahippus*, but are also occasionally found in adult *Hypohippus*. Deciduous incisors of both genera are cupped.

The features listed above and comparison of fossil horse D856-9 with specimens in the Frick collection suggest that specimen D856-9 should be referred to *Megahippus*. Specimen D856-9 matches a deciduous dentition in the AMNH (field number ESP 399-1842) of *Megahippus* from the Pojoaque Member of the Tesuque Formation. The eroded symphysis of specimen D856-9 was probably strongly upturned, which suggests *Megahippus* affinities: the more complete jaw from New Mexico (ESP 399-1842) has a strongly upturned symphysis. The New Mexico specimen of *Megahippus* has a short diastema, strong dP_1 , and lacks lingual cingula on the dP_{2-4} , as does specimen D856-9. The height of the M_1 metaconid of specimen D856-9 is greater than that of *H. affinis*. Webb (1969, p. 77) notes that the metaconid on the unworn M_1 of *H. affinis* is 15 mm high; on specimen D856-9 it is 19.4 mm high. Thus, the teeth of specimen D856-9 are the same length but higher crowned than those of *H. affinis*.

The deciduous dentition found in the Browns Park cannot at present be allocated to any previously named species of *Megahippus*.

Genus PARAHIPPUS Leidy
***Parahippus* cf. *P. leonensis* Sellards**

Table 9, Figure 10

Parahippus leonensis Sellards (1916, p. 83-87, pl. 11, figs. 3, 6-9, 12).

Holotype.—FGS 5084, right upper cheek tooth, probably M^1 .

Referred material.—D857-1: crushed skull with RI^{2-3} , LI^3 , R and L canine, RP^{2-3} , R and LM^{1-3} .

Distribution and age.—Thomas Farm, Griscom Plantation, Tallahassee, Alum Bluff, and Chattahoochee faunas, all in Florida; Hemingfordian land mammal age.

Description.—The skull is highly eroded with many of the cranial features destroyed. It is long and narrow.

TABLE 9.—Skull and dental measurements of *Parahippus* cf. *P. leonensis* (specimen D857-1) from locality D857 in the Elk Springs 15-minute quadrangle, Moffat County, Colorado
[Measurements in millimeters]

Distance from anterior edge of orbit to nasal tubercle.....	155.0
Height of infraorbital foramen above alveolar border.....	28.5
Width of palate between canines...	26.4
Width of palate between M^3	35.5
I^3 -C diastema.....	14.0
C- p^1 diastema.....	37.5
Length p^{2-4}	53.5
Length M^{1-3}	47.3
Length p^2 - M^3	99.4
I^2 APxTR.....	8.1x6.6
I^3 APxTR.....	7.8x5.9
C APxTR.....	4.2x3.8
p^2 APxTR.....	18.6x18.0
p^3 APxTR.....	17.1x18.7
M^1 APxTR.....	14.1x21.1
M^2 APxTR.....	16.8x20.8
M^3 APxTR.....	17.3x20.4

Anteriorly, the premaxillaries are preserved. The incisive foramen, present between and dorsal to the alveoli for the first two incisors, is anterior to a small tubercle situated in the anterior opening of the narial cavity. Ventrally are remnants of the palatine processes of the premaxillaries. The nasal processes of the premaxillaries are broken approximately at their sutures with the nasals. The infraorbital foramen lies above the anterior moiety of the P^4 . Mesial to the molars, palatine grooves are preserved on the palatine processes of the maxillaries. The anterior edge of the U-shaped posterior nares is opposite the anterior edge of the M^2 . Posteriorly, and forming two small tubercles on either side of the narial opening, are remnants of the pterygoid hamuli.

The skull is broken posterior to the basisphenoid. The temporal condyle and part of the glenoid cavity of the temporal are preserved. Owing to crushing, the malar part of the zygomatic arch is slightly flared out in the region of the facial crest.

³The Burge fauna was considered Clarendonian by Wood and others (1941) and Webb (1969). Recently, the Burge fauna has been placed in the latest Barstovian (Tedford, R. H., and others, unpub. data, cited in Skinner and Johnson, 1984).

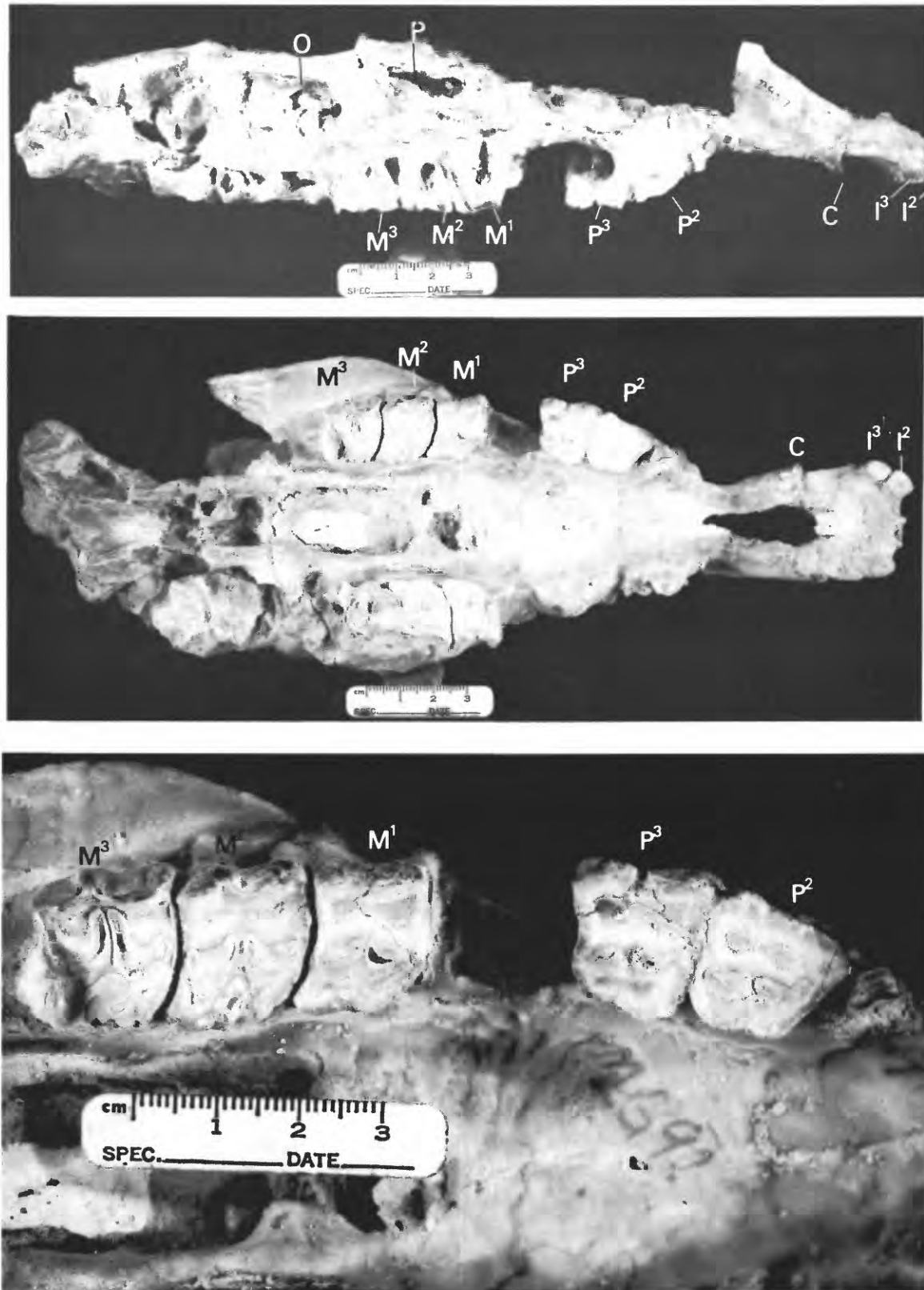


FIGURE 10.—*Parahippus* cf. *P. leonensis*, specimen D857-1, from locality D857, Elk Springs 15-minute quadrangle, Moffat County, Colo. Top, lateral view of right side of skull showing incisors (I²⁻³), canine (C), premolars (P²⁻³), and molars (M¹⁻³); O, orbit; P, preorbital fossa. Middle, palatal view of skull. Bottom, closeup view of right P²⁻³, M¹⁻³.

Although partially crushed, the bones of the orbital region reveal significant details. Anteriorly, the facial portion of the lacrymal is depressed, forming the preorbital fossa. The orbital and facial portions of the lacrymal are separated by the preorbital bar, which has a distinct tubercle on its anterodorsal margin. On the orbital surface is a small foramen mesial, and slightly ventral, to a larger lacrymal foramen. The naso-lacrymal duct leads forward from the lacrymal foramen and passes beneath the wall of the preorbital fossa. Examination of some skulls of *Merychippus* in the American Museum of Natural History, collected from the middle part (Skinner and others, 1977) of the Sheep Creek Formation (Matthew and Cook, 1909), reveals that the small foramen below the lacrymal foramen apparently passes anteriorly and mesially into the maxillary sinus. This lower foramen was not seen on modern horse skulls. At the same position in the modern horse is the depression for the origin of the obliquus oculi inferior muscle. On the Sheep Creek horses, the lower foramen is probably too deep to serve as a muscle origin. The foramen is not a second opening into the naso-lacrymal canal as it is in the tapir, in which it merges with the upper naso-lacrymal canal and empties into the nares. On the Sheep Creek horses, this smaller foramen passes medially as well as anteriorly and would not merge with the lower lacrymal duct to exit in the region of the external nares. Possibly, one of the branches of the maxillary part of the trigeminal nerve enters the maxillary sinus through this foramen. According to Getty (1975, p. 655), "small caudal maxillary alveolar branches [of the infraorbital branch of the maxillary branch of the trigeminal nerve] are given off in the pterygopalatine fossa, pass through small foramina in the maxillary tuber and supply the caudal molar teeth and the maxillary sinus. The middle maxillary alveolar branches are given off in the infra-orbital canal and constitute the chief nerve supply to the cheek and the maxillary sinus." Because this foramen on the Sheep Creek horses courses into the maxillary sinus, it possibly carried the posterior or middle alveolar nerve.

A small sphenopalatine foramen is present 34 mm posterior to the preorbital bar and midway up the mesial wall of the orbit. The large vacuity for the optic foramen is 22 mm posterior to the sphenopalatine foramen. Ventrally, the optic foramen is separated by a sharp ridge of bone from the smaller orbital foramen. The foramen rotundum lies ventral and slightly posterior to the latter. A small supraorbital foramen is present on the dorsal margin of the orbit. On the dorsal surface of the parietal, a crest curves mesially and posteriorly from a small supraorbital tuberosity located above the

supraorbital foramen. The frontal-parietal suture is apparent down the midline.

The incisors are worn nearly to their roots, and their occlusal surfaces are flat with centrally located, narrow lakes. The I^3 is more transversely compressed and smaller than the I^2 . A short diastema separates the I^3 from the small, peglike canine. A longer diastema separates the canine from the P^1 , which apparently has two closely appressed roots.

The cheek teeth are worn nearly to the roots, and the diagnostic occlusal pattern is nearly obliterated. The P^2 is subtriangular and anteroposteriorly longer than wide. The prominent mesostyle is much larger than the diminutive metastyle. Owing to wear, the pre- and post-fossettes are flattened ovals near the lingual side of the crown; consequently, the ectoloph is broad. The borders of the lophs are smooth, owing to destruction of the plications. At this stage of wear the protocone and hypocone are indistinctly separated by a small medivallum. The hypocone is larger than the protocone. Labially, two widely separated roots are visible. The P^3 is transversely elongated with the buccal side wider than the lingual. The parastyle and metastyle are subequal in size, and the parastyle slightly overlaps the metastyle of the P^2 . The fossettes are nearly obliterated. The protocone is larger and more mesially projecting than the hypocone, and the posterolingual border of the tooth is reduced in relation to the anterolingual border. In contrast, the anterolingual borders of the molars are reduced in relation to the posterolingual borders. The P^4 is missing.

The M^{1-2} are transversely elongate and posteriorly concave. The transverse elongation is due to the anteroposterior length decreasing toward the root and the transverse width remaining constant. Being less worn, the M^3 is less transverse than the M^1 or M^2 . The molar parastyles are prominent and overlap the preceding metastyles. Ribs are only faintly expressed between the styles. The mesostyles are larger than the parastyles, which are larger than the metastyles. Ectocingula run along the base of the teeth and are confluent with the styles. Wear has simplified the molar occlusal patterns, resulting in the loss of the pli-caballinae. The M^3 retains a small pli-hypostyle on the post-fossette and has a hypoconal groove which extends nearly to the post-fossette. The teeth are worn so that the buccal edges are higher than the lingual edges. The molars have long, widely flaring roots and buccal coatings of cement. The M^3 is less worn than the other teeth and has better preserved buccal cement.

Comparisons and discussion.—Comparisons with other horses are difficult owing to the old age of the individual and the crushing and erosion of the skull. In

size and morphology, however, the worn dentition of specimen D857-1 compares most favorably with those of advanced species of *Parahippus* and primitive species of *Merychippus*. *Merychippus* and advanced species of *Parahippus* have cementum on the teeth. Downs (1956, table 9) suggested that the thickness of this coating is useful in distinguishing between *Merychippus* and *Parahippus*; according to his comparison, the amount of cement on the teeth of advanced *Parahippus* is less than that on the teeth of two of the most primitive species of *Merychippus*, *M. primus* and *M. gunteri*. Simpson (1932, p. 23), however, noted that some of the *P. leonensis* from the Thomas Farm quarries in Florida "have as much cement as the less coated Midway [fossil quarries in Florida] *M. gunteri* specimens" and White (1942, p. 22) noted that *P. leonensis* occasionally has more cement than on *M. primus*.

Specimen D857-1 has less cement on the buccal side of the teeth than some *Merychippus* from the Sheep Creek Formation (Matthew and Cook, 1909) of late Hemingfordian age. The amount of cement on specimen D857-1 is similar to that on *P. avus* (Marsh, 1874) (= *P. brevidens* (Marsh, 1874) according to Downs (1956, p. 240)) and also to that on *P. leonensis* Sellards, 1916. The type of *P. avus* is similar in size to specimen D857-1; on the type of *P. brevidens* the M^3 is equal in size and the M^2 is larger than that of specimen D857-1. The amount of cement on specimen D857-1 is equal to that on the type of *P. avus*. A partial skull of *P. avus* (AMNH 14182) illustrated by Osborn (1918, pl. 6) has no features preserved useful for comparison with specimen D857-1. *P. leonensis* is slightly smaller than *P. avus*. Downs (1956, table 6) listed statistics on the lengths and widths of the cheek teeth of *P. avus* and *P. leonensis*; for length and width, specimen D857-1 falls nearer the means for *P. leonensis*. Downs (1956, p. 243) noted that *P. avus* and *P. leonensis* are similar in the amount of cement present on the teeth.

P. crenidens (Scott, 1893), and *P. coloradensis* Gidley, 1907, also have cement on the teeth. According to Downs (1956, table 9), *P. crenidens* has less cement than *P. avus* and, therefore, the cement is also less than on specimen D857-1. Downs (1956, table 9) characterized *P. coloradensis* as having only a light coat of cement. In the original diagnosis of *P. coloradensis*, no mention of cement was made by Gidley; Gazin (1932, p. 77) referred some teeth from Skull Spring, Oreg., to this species, noting that they lack cement.

The size of the teeth and the amount of cement on them closely matches that of *P. leonensis*, although the difference with *P. avus* is not great. For this reason, specimen D857-1 is assigned to *Parahippus* cf. *P. leonensis*.

Order ARTIODACTYLA Owen
Suborder TYLOPODA Illiger
Family CAMELIDAE Gray
Subfamily STENOMYLINAE Matthew
Genus BLICKOMYLUS Frick and Taylor

Blickomylus galushai Frick and Taylor

Table 10, Figure 11

Blickomylus galushai Frick and Taylor (1968, p. 23-36, figs 8-11).

Holotype.—F:AM 50840, a nearly complete skull with I^1 - M^3 , from Blick Quarry in the Chamisa Mesa Member of the Zia Sand of Galusha (1966), in Sandoval County, N. Mex.

Referred material.—D857-2, LP^4 , LM^{1-2} , LP^4 ; D857-3, distal fragment right radius-ulna; D857-4, proximal fragment right metacarpus; D857-5, fragmentary distal metapodial.

Distribution and age.—Chamisa Mesa Member of Galusha (1966) and Cañada Pílares Member of Gawne (1981b) of the Zia Sand of Galusha (1966); Arikaree Formation, Fremont County, Wyo.; Browns Park Formation, Moffat County, Colo.; Hemingfordian land mammal age.

Description.—The P^4 is small and heavily worn, and the fossette between the buccal and lingual cusps has disappeared. The M^1 is short and transversely narrow and tapers strongly antero-posteriorly toward the roots. The pre- and post-fossettes are present as shallow depressions lacking internal enamel rings. Ribs and styles are absent on the flat buccal wall, and the posterior lobe of the tooth is longer than the anterior lobe. The M^2 is transversely narrow and hypsodont with only the the anterior lobe completely preserved. A fossette is present on this lobe. Except for a faint parastyle, the buccal wall is smooth. On the M^1 and

TABLE 10.—Dental and skeletal measurements of *Blickomylus galushai* from locality D857, Elk Springs 15-minute quadrangle, Moffat County, Colorado

[Measurements in millimeters]

P^4 APxTR.....	8.1 x 5.0
M^1 APxTR.....	15.0 x 9.6
M^2 APxTR of first lobe.....	13.5 x 10.1
P^4 TR.....	3.5
Radius-ulna shaft TR width above distal end.....	16.3
Proximal metacarpus APxTR....	15.8 x 19.8

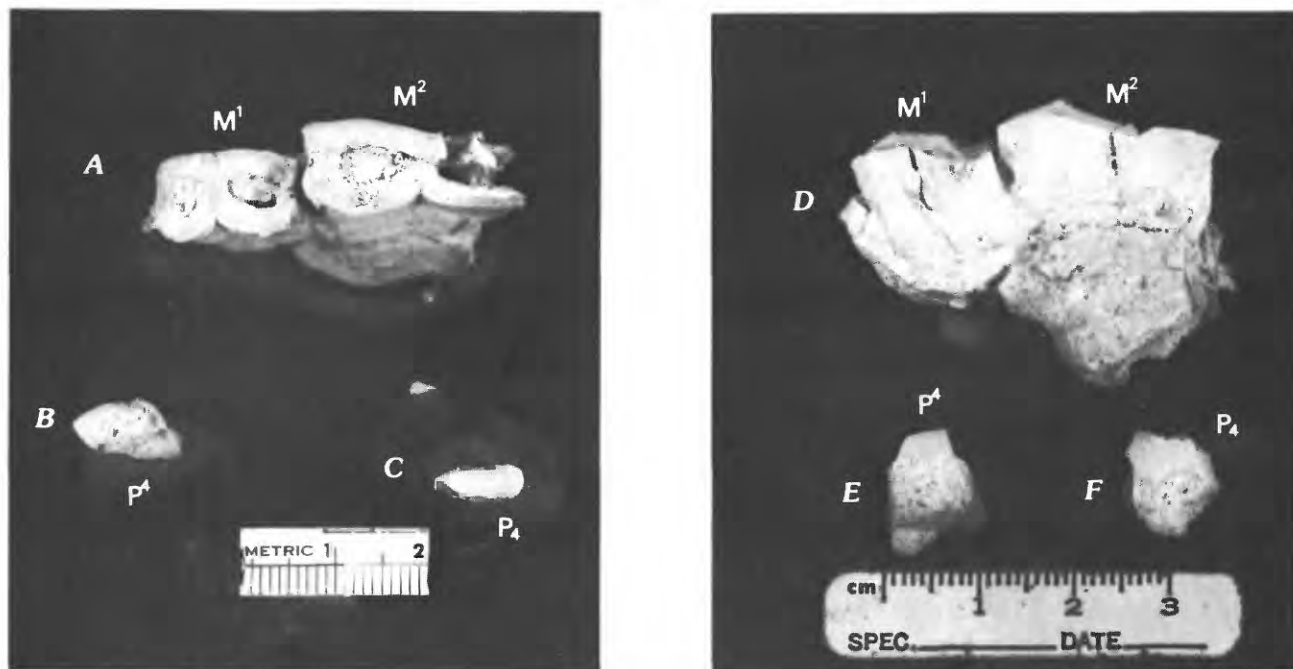


FIGURE 11.—*Blickomylus galushai*, specimen D857-2, from locality D857, Elk Springs 15-minute quadrangle, Moffat County, Colo. Left photo: A, occlusal view of left molars (M^1 - M^2); B, occlusal view of left premolar (P^4); C, occlusal view of left P_4 . Right photo: D, lingual view of left M^1 - M^2 ; E, buccal view of left P^4 ; F, buccal view of left P_4 . Both scales in centimeters.

M^2 the wall of the metaconule is flatter and does not project as far lingually as does the wall of the protocone. The P_4 is compressed laterally and tapers markedly anteriorly. It lacks a paraconid inflection.

The shaft of the distal part of the radius-ulna is relatively slender. Only half of the distal end is preserved. The lunar and cuneiform condyles are subequal in size, and the lunar condyle has a proximolaterally trending trough on its medial side. Anteriorly, the lateral and medial carpal extensor grooves are present, the medial groove being deeper and narrower than the lateral. A prominent tuberosity lies between them. Anterodorsal to the cuneiform condyle is a distal interosseous foramen. A posterior distal interosseous foramen is also present with a vertical groove extending approximately 20 mm proximally. The lateral surface of the shaft immediately above the cuneiform condyle is highly rugose.

The proximal metacarpal preserves the trapezoid, magnum, and unciform facets. Rugose depressions for metacarpals 2 and 5 are present posteriorly beneath the trapezoid and unciform facets respectively. Metacarpals 3 and 4 are completely fused proximally.

Comparisons and discussion.—The narrow, hypsodont teeth with smooth buccal walls clearly identify this

camel as a member of the subfamily Stenomylinae. Direct comparisons of many specimens, including the types of *Blickomylus* and *Rakomylus*, establish that the Browns Park stenomyline is a *Blickomylus*. Both specimen D857 and *Blickomylus* differ from most *Stenomylus* in having more solidly fused metacarpals. The metacarpals are completely uncoossified on *S. hitchcocki* Loomis, 1910, and on an unnamed *Stenomylus* from Wellton, Ariz. In *S. gracilis* Peterson, 1906, the proximal halves of the third and fourth metacarpals are fused, but the line of fusion is usually very prominent, as in the type. On specimen D857-4 and *Blickomylus*, this line of fusion is very faint. A few specimens of *Stenomylus* though, such as F:AM 36815 (Frick and Taylor, 1968, fig. 6), have strongly coossified metacarpals which resemble those of *Blickomylus*. The P^4 of specimen D857-2 and *Blickomylus* is more reduced than that of *Stenomylus*. The length of the P^4 of specimen D857-2 is 8.1 mm; that of *Blickomylus* ranges from 7.8 to 9.0 mm. The length of the P^4 of *S. gracilis* ranges from 10.0 to 10.3 mm. Although the length of the P^4 of the Wellton *Stenomylus* is the same as that of specimen D857-2, the P^4 of the Wellton camel is 2 mm wider. The molars of the Wellton *Stenomylus* are shorter than those of specimen D857-2

and *Blickomylus*. Similarly, though the molars of *S. gracilis* have the same length as those of specimen D857-2 and *Blickomylus*, the P⁴ is longer.

The crown patterns and tooth sizes of specimen D857-2 match those on some *Blickomylus* from the Chamisa Mesa Member of the Zia Sand and differ significantly from those of *Rakomylus*. Both specimen D857-2 and *Blickomylus* differ from *Rakomylus* in having a relatively larger M¹. The M¹ of *Rakomylus* is 9.3 mm long (Frick and Taylor, 1968, table 6), whereas that of *Blickomylus* ranges from an estimated 10 mm to 17.5 mm (Frick and Taylor, 1968, table 4); specimen D857-2 measures 15.0 mm. The P⁴ of specimen D857-2 also lies within the size range of *Blickomylus* given by Frick and Taylor, and is larger than the P⁴ of *Rakomylus*. Also, the concave wear facets on the anterior lobes of the two teeth match those on *Blickomylus*.

The metacarpal of *Rakomylus* is about 30 percent shorter than that of *Blickomylus*, but the metacarpal of specimen D857-2 is too incomplete to offer any information about size. However, the dental evidence is conclusive that this camel is *Blickomylus*. The only known species of *Blickomylus* is *B. galushai*. The Browns Park camel cannot be distinguished morphologically or metrically from *B. galushai* and is therefore assigned to that species.

Subfamily CAMELINAE Gray
Tribe PROTOLABIDINI Cope

Genus cf. PROTOLABIS Cope

Table 11, Figure 12

Referred material.—D856-17, distal fragment left humerus; D856-18, distal fragment left humerus; D856-19, distal fragment right humerus; D856-20, proximal fragment left radius-ulna; D856-21, proximal left radius-ulna; D856-22, proximal fragment left radius-ulna; D856-23, proximal fragment right radius-ulna; D856-24, distal fragment right radius-ulna; D856-25, distal fragment left radius-ulna; D856-26, distal fragment left radius-ulna; D856-27, distal fragment left tibia; D856-28, left astragalus; D856-29, left astragalus; D856-30, left astragalus; D856-31, left astragalus; D856-32, right astragalus; D856-33, right calcaneum; D856-34, right proximal fragment calcaneum; D856-35, left calcaneum; D856-36, left calcaneum; D856-37, left distal fragment calcaneum; D856-38, right proximal fragment metatarsal; D856-39, right proximal fragment metatarsal; D856-40, right proximal fragment metatarsal; D856-41, distal fragment metapodial; D856-42, distal fragment metapodial; D856-43, distal fragment

metapodial; D856-44, proximal phalanx; D856-45, proximal phalanx; D856-46, medial phalanx; D856-47, medial phalanx; D856-48, proximal phalanx; D856-49, proximal phalanx; D856-50, proximal phalanx; D856-51, proximal phalanx.

Comparisons and discussion.—The postcranial elements are practically indistinguishable from those of *Protolabis coartatus*. The humeri, radii-ulnae, and tibiae are completely within the range of morphological and size variation of that species. The calcanea, astragali, and metapodials of the locality D856 camel are somewhat larger than those of most specimens of *P. coartatus*, but the difference is insignificant—for example, the proximal widths of the metatarsals range from no greater to at most 8 percent wider than the largest known metatarsal of *P. coartatus*. The phalanges from locality D856 are similar in length, but slightly more slender, than those of *P. coartatus*. The anterior limb elements from locality D856 are, like those of the *P. coartatus* specimens from the Milk Creek Formation (Clarendonian) of Arizona, slightly smaller than those of the type of *P. coartatus*.

None of the various limb elements were associated. However, they can be assumed to belong to the same species because of their close match in size and morphology to similar limb elements of *P. coartatus*. Because of this close correspondence, the limbs from locality D856 probably belong to a species of *Protolabis*, although not necessarily *P. coartatus*. At present, there are few characteristics other than size and proportions, that can be used to separate the postcrania of various genera of Miocene camels. For the sake of completeness, the following comparisons are offered.

The locality D856 camel limb elements are smaller than those of *Aepycamelus*, *Hesperocamelus*, *Megatylopus*, *Titanotylopus*, *Pliauchenia magnifontis*, *Hemiauchenia*, *Alforjas*, and *Procamelus grandis*. The limbs of *Procamelus occidentalis* cannot be adequately compared with those from locality D856. *Oxydactylus*, *Priscocamelus*, *Miolabis*, *Nothotylopus*, and probably *Aguascalientia* have unfused metapodials. *Tanymycter* has unfused metacarpals and only weakly fused metatarsals, in contrast to the strongly fused metapodials of D856. The limb bones of *Stenomylus* are smaller and the metapodials generally more slender and less coossified than those from locality D856. Frick and Taylor (1968) illustrated the metapodials of *Blickomylus* and *Rakomylus*, and they belong to smaller animals than the locality D856 camel (the *Blickomylus* distal radius from the Browns Park Formation also supports smaller size for these camels). The limbs of *Australocamelus*, *Nothokemas*, and *Floridatragulus* have not been adequately described. *Michenia* has smaller, slenderer limbs than the locality D856 camel. Thus,

TABLE 11.—*Skeletal measurements of cf. Protolabis sp. from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colorado*

[Measurements in millimeters; leaders (---) indicate no data]

Specimen	n	O.R.	\bar{X}
Humerus trochlear TR width.....	3	42.3-43.6	42.9
Humerus trochlear height.....	3	29.5-32.0	31.13
Radius-ulna TR width distal articular surface..	2	41.9-43.5	42.7
Radius-ulna AP width distal articular surface..	3	37.9-39.3	38.4
Tibia TR width distal end.....	1	41.5	---
Tibia AP length distal end.....	1	25.8	---
Astragalus lateral length.....	5	38.9-44.1	41.1
Astragalus medial length.....	5	34.3-40.0	36.3
Astragalus minimum length.....	5	29.7-33.8	30.9
Astragalus greatest TR width.....	5	25.8-28.8	27.4
Astragalus distal trochlear TR width.....	5	23.9-27.1	25.4
Calcaneum maximum length.....	3	91.2-91.6	91.4
Calcaneum maximum AP length.....	4	35.9-38.1	37.1
Calcaneum tuberosity TR width.....	3	21.5-23.6	22.6
Calcaneum tuberosity AP length.....	3	22.0-23.0	22.6
Proximal metatarsal TR width.....	3	29.5-34.0	32.2
Distal metapodial (forefoot?) trochlear surface APxTR.....	1	23.1x23.0	---
Distal metapodial (hindfoot?) trochlear surface AP.....	2	19.2-20.2	19.7
Distal metapodial (hindfoot?) trochlear surface TR.....	2	18.4-19.8	19.1
Proximal phalanx; TR distal width.....	6	14.1-15.4	14.7
Proximal phalanx; AP distal length.....	5	11.0-12.6	11.8
Medial phalanx length.....	2	37.8-39.0	38.4
Medial phalanx proximal TR width.....	2	13.0-13.3	13.15
Medial phalanx proximal AP length.....	2	12.8-13.2	13.0
Medial phalanx distal TR width.....	2	12.7-12.9	12.8
Medial phalanx distal AP length.....	2	8.3-8.4	8.35

these limb elements probably belong to *Protolabis*. A thorough study of that genus, however, is necessary before specific assignment of these limbs can be made.

Genus MICHENIA Frick and Taylor

Michenia sp.

Table 12, Figure 13

Referred material.—D856-11, RI₂₋₃ roots, RC; D856-12, fragmentary symphysis with RP₁; D856-13, right dentary with P₁₋₄, M₁₋₂, M₃ (broken); D856-14,

distal fragment right humerus; D856-15, proximal fragment left radius; D856-16, proximal right metacarpal.

Description.—The I₃ is the only incisor with the crown preserved. In early wear it is highly spatulate and transversely flattened with a crown 20.2 mm high. The incisor roots are small. The canine is separated from the I₃ by a 4.0 mm diastema. The canine is small, slightly recurved, and transversely flattened with the buccal side convex and the lingual side concave dorsoventrally. Anterodorsally, a slight pinching of the enamel forms a small flange.

The C-P₁ diastema is not preserved. The P₁ is suppressed; that is, although fully formed, the tooth has

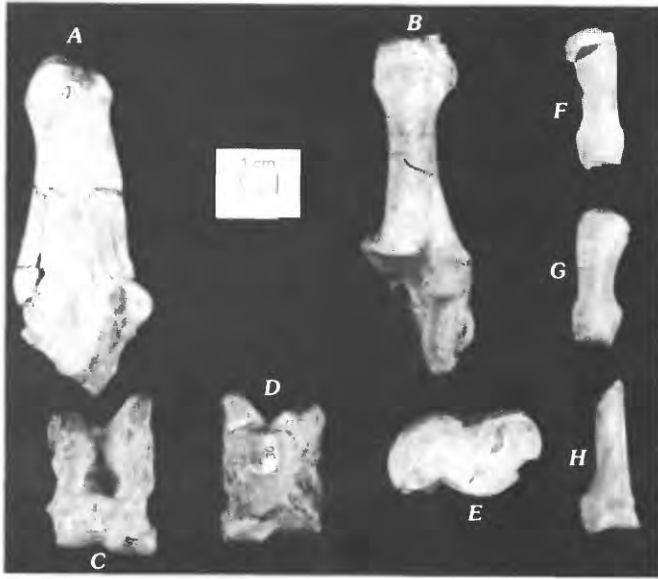


FIGURE 12.—Cf. *Protolabis*, from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, right calcaneum, lateral view; specimen D856-33. B, left calcaneum, anterior view; D856-36. C, left astragalus, anterior view; D856-29. D, left astragalus, posterior view; D856-30. E, right astragalus, lateral view; D856-32. F, medial phalanx, anterior view; D856-46. G, medial phalanx, anterior view; D856-47. H, proximal phalanx, anterior view; D856-49.

not erupted in the mature animal. The P_1 has only one root; it cannot be determined whether this root formed from a single root or from two fused roots. Excavation of the bone shows that the P_1 is vertical.

The P_2 lies 23.5 mm behind the P_1 . The P_2 is short and transversely narrow, with the simple crown consisting only of a low protoconid. A shallow median sulcus on the single root indicates that it formed from the fusion of two separate roots. The P_3 is transversely narrow and double-rooted. The protoconid, swollen at the base, is the most distinctive cusp. A ridge runs anteriorly from the protoconid and terminates in a minute and slightly lingually inflected paraconid. Posteriorly, another ridge terminates in a small but distinct swelling formed from the entoconid and hypoconid. The P_4 is transversely narrow and nearly as long as the combined lengths of the P_2 and P_3 . The protoconid is the highest cusp. A lingual sulcus separates the protoconid from the lingually inflected paraconid. The entoconid and hypoconid have, by wear, united to form a posterior swelling as broad as that of the protoconid. A broad, shallow buccal sulcus lies between the protoconid and hypoconid. Wear has eliminated the fossettid between the hypoconid and entoconid.

The M_1 is worn nearly to the roots. It is relatively long, and the posterior lobe is wider than the anterior

lobe. On the M_2 , wear has eliminated the anterior fossettid, and the posterior fossettid is relatively small. The lingual wall is flat, with only a small parastylid present. The M_3 is broken behind the anterior moiety. The worn crown height measures 17.2 mm on the protoconid. The parastylid is prominent lingually, but the mesostylid is only a low ridge. Lingual ribs are absent. None of the molars have intercolumnar stylids or protostylids.

Erosion has eliminated most of the details of the dentary. The right dentary is narrow transversely—6.3 mm wide between the P_1 and P_2 . The minimal depth of the dentary between the P_1 and P_2 is not preserved; however, it is less than the depth at the suppressed P_1 , where it is 22.5 mm.

On the basis of size, three fragmentary limb elements are referred to this camel. The distal fragment of the humerus has the trochlea preserved. Anteriorly, above the medial condyle, is a transverse trough for the origin of the common digital extensor. The proximal fragment of the radius has only the humeral articular surface preserved. The lateral tuberosity is smaller than on cf. *Protolabis*. The proximal metacarpal preserves the small, triangular trapezoidal facet posteriorly. Anterior to the trapezoidal facet is the large, concave magnum facet, quadrilateral in shape. Below its anterior edge is

TABLE 12.—Dental and skeletal measurements of *Michenia* sp. from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colorado

[Measurements in millimeters]

Lower canine AP.....	6.4
P_2 APxTR.....	5.0x2.5
P_3 APxTR.....	8.4x3.4
P_4 APxTR.....	12.7x6.2
M_1 APxTR.....	20.0x11.0
M_2 APxTR.....	23.9x12.9
M_3 APxTR of first lobe.....	13.8x13.6
Depth jaw between P_1 and P_2	<22.5
Depth jaw below P_1	22.5
Humerus trochlear TR width.....	33.7
Humerus maximum trochlear height...	25.3
Radius; width proximal articular surface.....	33.2

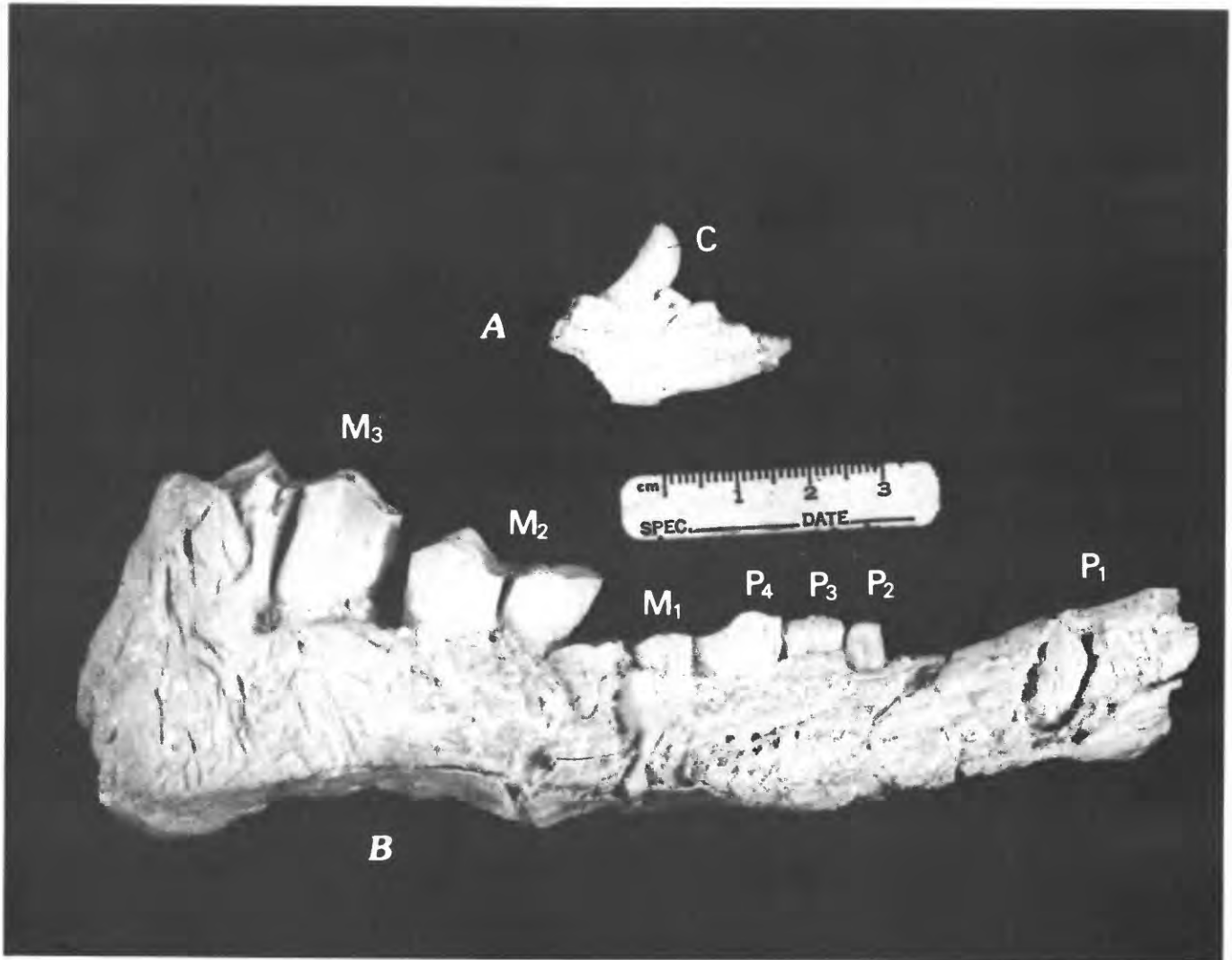


FIGURE 13.—*Michenia* sp., from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, lateral view of right symphysis with incisor roots and canine (C) of specimen D856-11. B, lateral view of right dentary with premolars (P_{1-4}) and molars (M_{1-3}) (M_3 broken) of specimen D856-13.

a small tuberosity. Only the anterior portion of the unciform facet is preserved. Metacarpals 3 and 4 are completely fused, and the line of fusion is not visible.

Comparisons and discussion.—Specimen D856-13 differs from *Oxydactylus*, *Priscocamelus*, *Tanymykter* and *Nothokemas* in having higher crowned molars, reduced premolars, and suppressed P_1 . Reduced premolars and suppressed P_1 separate specimen D856-13 from *Australocamelus*, *Aepycamelus*, and *Hesperocamelus*; in addition, the latter two are much larger. *Procamelus* has relatively nonreduced premolars, fully erupted P_1 , and more hypsodont molars than specimen D856-13. *Miolabis* is distinguished from specimen D856-13 by the absence of P_1 , relatively

shorter and less laterally compressed premolars, and lower crowned molars with stronger metastylids. *Miotylopus* is distinguished from specimen D856-13 by rather brachyodont, short molars, and nonreduced premolars. *Nothotylopus* differs from specimen D856-13 in having more brachyodont molars, larger P_3 with well-defined cusps, absent P_2 , and erupted P_1 . Low-crowned molars, nonreduced premolars, and P_{2-3} diastema distinguish *Floridatragulus* from specimen D856-13. *Aguascalientia* is much smaller than D856-13, with non-reduced P_{2-3} , and with brachyodont, laterally swollen molars with intercolumnar tubercles on M_{1-2} . The stenomylines possess extremely hypsodont and flat-walled molars. *Hemiauchenia*

lacks the P_2 and has so-called llama buttresses on the lower molars; *Paleolama* has low-crowned molars with strong mesostylids.

Pliauchenia magnifontis Gregory, 1942 is larger than specimen D856-13 and has a large and erupted P_1 ; the P_{2-4} are longer and broader than on specimen D856-13. *Pliauchenia singularis* Matthew, 1918 differs from specimen D856-13 in having broader P_{3-4} , shorter molars, and M_{2-3} with prominent parastylids. Specimen D856-13 cannot adequately be compared with *Pliauchenia minima* Wortman, 1898, as it has never been illustrated, and measurements were not given in the original description. Gregory (1942, p. 379) noted that *P. minima* "looks about as much like an antelope as a camelid * * * and cannot be definitely assigned to any family at present." Specimen D856-13 differs from *Pliauchenia humphreysiana* Cope, 1875, *Protolabis heterodontus* (Cope, 1874), and *Protolabis barstowensis* Lewis, 1968, in having a small canine and suppressed P_1 . These same criteria separate D856-13 from most individuals of *Protolabis coartatus* (Stirton, 1929), although a few individuals of *P. coartatus* have a suppressed P_1 .

Specimen D856-13 resembles *Michenia* in possessing a small, semiincisiform lower canine and differs from *Protolabis* which possesses a larger, caniniform canine. The sizes of the lower canines in *Michenia* and *Protolabis* do not overlap (Honey and Taylor, 1978, p. 418). Specimen D856-13 resembles derived forms of *Michenia* in having a suppressed P_1 . Although not restricted to *Michenia*, suppression of the P_1 is much more common in that genus than in *Protolabis*, in which it is only known to occur in a few individuals of the derived *P. coartatus*.

Reduction in size of the premolars occurs in *Michenia* and *Protolabis*, and is greatest in *Protolabis coartatus* and *Michenia yavapaiensis* Honey and Taylor, 1978. The size of the P_2 and P_3 of specimen D856-13 is close to the mean size given for *Michenia yavapaiensis*, and is further removed from the mean size for *Protolabis coartatus* (Honey and Taylor, 1978, tables 4 and 10). The P_4 however, is relatively long and is closer to the mean length for *Protolabis coartatus* than for *Michenia yavapaiensis*, although it falls within the observed range of the latter species. Fracturing has lengthened the M_1 of specimen D856-13 slightly, but nevertheless it is closer to the mean length of *P. coartatus* than to *M. yavapaiensis*. The M_2 length (but not width) is closer to the mean length of *P. coartatus*, but it also falls within the observed range of *M. yavapaiensis*.

The ramal depth of *Michenia* is less than that of *Protolabis*. The ramal depth at P_1 of specimen D856-13 is 22.5 mm, which is intermediate between average ramal depths for currently recognized species of *Michenia* and *Protolabis*.

Although some of the above characteristics are equivocal, the small canine and suppressed P_1 indicate that the material from locality D856 belongs to *Michenia*. The limb elements are referred to this genus because they cannot be separated from those of *Michenia yavapaiensis*. The reduced premolars and suppressed P_1 exclude this specimen from *M. agatensis* Frick and Taylor, 1971; the D856 camel is distinct from *M. exilis* (Matthew and Macdonald, 1960) in having a suppressed P_1 , P_{2-3} reduced relative to P_4 , more elongate molars, and fused metapodials. The depth of the jaw is greater than in *Michenia yavapaiensis*, and the lengths of the P_4 - M_2 lie at the extremes of the observed ranges of these teeth in *Michenia yavapaiensis*. For these reasons, this small camel from locality D856 is not included within *Michenia yavapaiensis*. It may be a representative of a new species, but a larger sample is needed before this can be verified.

Subfamily CAMELINAE or AEPYCAMELINAE

Procamelus sp. or *Aepycamelus* sp.

Table 13, Figure 14

Referred material.—D855-1, right ramus with dI_{2-3} , $I_1(?)$, dC , dP_{3-4} , M_1 ; D855-2, right astragalus; D856-52, right distal fragment humerus; D856-53, left distal fragment humerus; D856-54, right proximal fragment radius-ulna; D856-55, right distal fragment radius-ulna; D856-56, left astragalus; D856-57, right lunar; D856-58, right scaphoid; D856-59, right cuneiform; D856-60, distal fragment metapodial; D856-61, distal fragment metapodial; D856-62, distal fragment metapodial; D856-63, distal fragment metapodial; D856-64 through D856-72, eight proximal phalanges; D856-73, medial phalanx; D856-74, medial phalanx; D856-88, medial phalanx.

Description.—The spatulate I_1 is in the process of eruption. It lies beneath the broken, slightly anteroposteriorly flattened root of dI_2 . The laterally flattened root of dI_3 follows a diastema of 7.5 mm. The broken root of dC is directed anteriorly.

The mandible is broken 26 mm behind the deciduous canine and 23 mm in front of the dP_3 , and the jaw length between these two teeth is not measurable. A fragment from the left side of the jaw contains the roots of the dP_2 , and (18 mm anteriorly) the alveolus for the P_1 (camels lack a deciduous predecessor to the P_1 , according to Frick and Taylor, 1968, p. 14). The dP_3 is long, narrow, and double-rooted, consisting of three cusps consecutively wider posteriorly; the third cusp is much wider than the preceding two. Buccally, two sulci separate the three cusps, and the posterior sulcus is wider than the anterior sulcus. On the lingual side of

TABLE 13.—*Dental and skeletal measurements of Procamelus sp. or Aepycamelus sp. from localities D855 and D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colorado, and comparative measurements on Aepycamelus from the Pojoaque Member of Galusha and Blick (1971) (late Barstovian and possibly early Clarendonian) of the Tesuque Formation*
[Measurements in millimeters; leaders (---) indicate no data. F:AM—Frick, American Museum numbers]

Specimen	n	O.R.	\bar{x}	F:AM 38606	F:AM 24101	F:AM 38585	F:AM 68577
dP ₃ APxTR.....	1	16.5x8.5	---	---	---	---	---
dP ₄ APxTR.....	1	30.4x15.6	---	---	---	---	---
Humerus trochlear TR							
width.....	1	55.9	---	---	---	56.1	---
Humerus trochlear height..	1	46.2	---	---	---	40.5	---
Radius midshaft TR.....	1	52.1	---	46.7	---	---	---
Radius distal TR width....	1	61.6	---	63.8	60.6	---	---
Proximal phalanx:							
length.....	5	81.4-95.5	90.1	93.4	---	---	---
proximal TR width.....	7	26.1-31.2	27.9	29.1	---	---	---
proximal AP width.....	7	24.2-27.8	26.7	25.8	---	---	---
distal TR width.....	6	22.9-25.5	24.2	23.7	---	---	---
distal AP width.....	6	20.6-23.0	21.7	22.9	---	---	---
Medial phalanx:							
length.....	3	46.8-54.2	51.6	55.6	---	---	---
proximal TR width.....	3	20.9-24.6	22.8	27.6	---	---	---
proximal AP width.....	3	16.6-18.7	17.5	23.6	---	---	---
distal TR width.....	3	20.2-20.9	20.5	23.1	---	---	---
distal AP width.....	3	13.6-16.7	15.5	17.0	---	---	---
Astragalus:							
lateral length.....	2	61.0-62.2	61.6	---	---	---	58.6
medial length.....	2	53.9-56.6	55.2	---	---	---	52.6
minimum length.....	2	45.5-46.5	46.0	---	---	---	45.1
greatest TR width.....	2	38.1-39.9	38.9	---	---	---	38.2
distal trochlear							
TR width.....	2	37.2-37.4	37.3	---	---	---	37.1
Metapodial midshaft TR....	1	31.7	---	39.6	---	---	---
Distal metapodial							
trochlear surface TR....	4	27.2-28.7	28.1	29.5	---	---	---
Distal metapodial							
trochlear surface AP... 4	4	31.8-33.6	32.9	29.8	---	---	---
Spread of distal							
metapodial.....	1	58.1	---	---	---	---	---

the tooth is a narrow, anterior sulcus. Owing to wear, all traces of fossettids have been eliminated.

The dP₄ is three-lobed with the posterior lobe widest. A small tubercle is present in the anterior buccal sulcus between the first two lobes. Formed as a small fold on the posterior wall of the first lobe, the tubercle disappears before reaching the base of the crown. Traces of ribs are preserved on the lingual walls of the second and third lobes, and a small stylid is present between the

first and second lobes. Wear has eliminated all fossettids.

The second lobe of the M₁ is broken. Although the tooth is in wear, the prefossettid is still present. An intercolumnar tubercle is present between the protoconid and hypoconid near the base of the tooth. Lingually, the parastylid and mesostylid are prominent. The metaconid is 25.4 mm high and has a faint rib. The M₂ is fragmentary, revealing nothing diagnostic. The unerupted M₃ is lost.

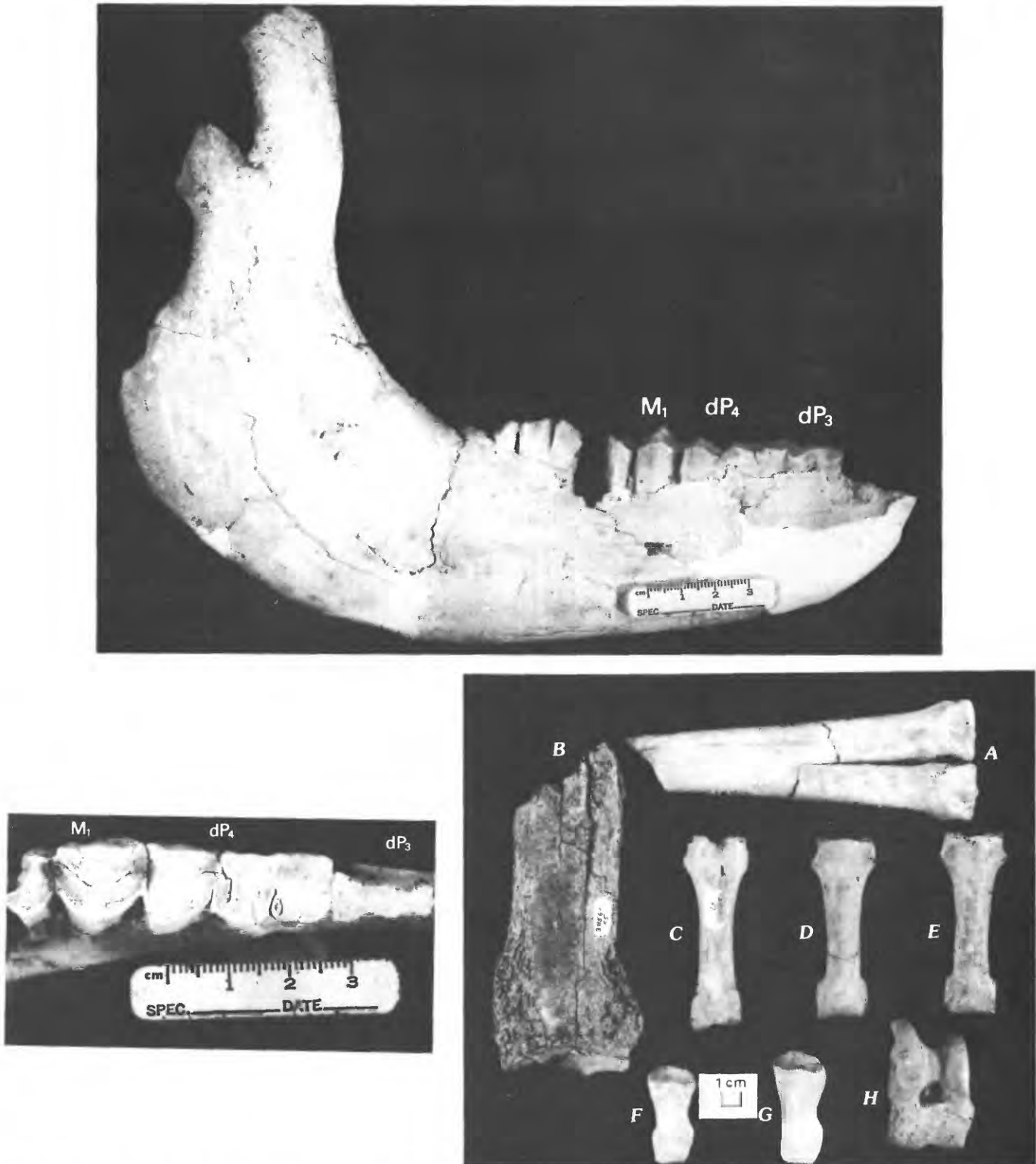


FIGURE 14.—*Procamelus* sp. or *Aepycamelus* sp., from localities D855 and 856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. Top, lateral view of right dentary; specimen D855-1; M, molar; dP, deciduous premolars. Lower left, occlusal view of right dP₃₋₄, M₁ (broken); D855-1. Lower right, A, anterior view of distal metapodial; D856-61. B, anterior view of right distal radius-ulna; D856-55. C, posterior view of proximal phalanx; D856-67. D, anterior view of proximal phalanx; D856-65. E, anterior view of proximal phalanx; D856-70. F, anterior view of medial phalanx; D856-74. G, anterior view of medial phalanx; D856-73. H, anterior view of right astragalus; D855-2. Scale is in centimeters.

The dentary is long and deep, with a convex ventral edge. A mental foramen is present 18.7 mm below the dorsal edge of the dentary and 17 mm posterior to the canine. The dentary is thin near the angle. Above the angle the camelid hook is broken, and the condyle is heavily eroded and possibly laterally flattened. The coronoid process projects approximately 49 mm above its junction with the condyle. It has a slight medial inflection and is 25.5 mm wide anteroposteriorly.

Large size is the most distinctive feature of the postcranial elements of this camel. On the medial condyle of the humerus is a large tuberosity, more prominent than that found on the cf. *Protolabis* from this fauna. The common digital extensor depression (above the medial condyle) is shallower and shorter than that of cf. *Protolabis*.

The humeral articular surface of the radius is broad and has a small pit lateral to the median sagittal ridge. The lateral tuberosity is small. The shaft of the radius is broad—about 50 mm wide above the distal extremity. The ridge between the grooves for the carpal digital extensor is prominent.

The astragali are much larger than those of cf. *Protolabis*. Medially, the ridge between the navicular and medial malleolar facets is broad, contrasting with the narrow ridge on cf. *Protolabis*. Similarly, the tibial ligament surface is broader than that of cf. *Protolabis*.

A scaphoid, lunar, and cuneiform are referred to *Procamelus* sp. or *Aepycamelus* sp. on the basis of large size. The distal metapodials are distinguished from those of cf. *Protolabis* only by larger size. The medial phalanges are much larger and more robust than those of cf. *Protolabis*.

Comparisons and discussion.—The large camel from the Browns Park Formation was compared with camels in the Frick collection at the American Museum of Natural History. In size, the limb elements correspond well with those of undescribed specimens of *Aepycamelus* from the Pojoaque Member (late Barstovian and possibly early Clarendonian) of the Tesuque Formation, N. Mex., and with large specimens of *Procamelus* from the Burge Member (latest Barstovian) of the Valentine Formation of Lugin (1938), Nebraska. The dentition also closely resembles those of *Procamelus* and *Aepycamelus*. The crown height of the partially worn M_1 of specimen D855-1 is matched by specimens of the large *Procamelus* from the Burge Member. The M_1 of specimen D855-1 is higher crowned than in most *Aepycamelus* in the Frick collection; a few, however, from the Pojoaque Member of the Tesuque Formation, have teeth as high-crowned as specimen D855-1. The rami of these specimens of *Aepycamelus* are shallower than those of specimen D855-1. The ramal

depth of specimen D855-1 matches that of adult specimens of *Procamelus* from the Burge Member. The size and morphology of the dP_{3-4} on specimen D855-1 was matched by specimens of *Procamelus* from the Clarendon fauna (Clarendonian); on these forms, however, the M_1 is higher crowned.

The postcranial material of the large Browns Park camel is about 12 percent smaller than that of *Aepycamelus procerus* (Matthew and Cook, 1909), which is a smaller species than *A. giraffinus* (Matthew, 1909). Specimen D856 cannot be compared with either *A. priscus* (Matthew, 1924), or *A. leptocolon* (Matthew, 1924), as they lack adequate description. Camel D856 limb materials are slightly smaller than those of *A. (?) stocki* (Henshaw, 1942), and *Procamelus grandis* Gregory, 1942.

Specimen D855-1 compares favorably with the lower jaws UCMP 32312 and UCMP 33420 from the Clarendonian Big Spring Canyon fauna (Gregory, 1942, figs. 32 and 33b). The individual represented by UCMP 32312 is younger than D855-1, and the jaw is thus slightly narrower dorsoventrally. The crown length of the dP_4 is 25 percent longer than on specimen D855-1; the latter, however, is worn nearly to the roots. Data taken on mandibles of *Protolabis coartatus* show that the dP_4 undergoes a 35–40 percent change in length from the crown to the base. Also, on UCMP 32312 there is a small labial intercolumnar tubercle between the second and third lobes, as on specimen D855-1. The length of the dP_4 of UCMP 33420 is similar to that of specimen D855-1. The M_1 is not associated with these jaws. Gregory (1942) was unable to assign these specimens to either *Procamelus* or *Pliauchenia*. However, Loring and Wood (1969, p. 1209) assigned the relatively smaller UCMP 33446 from Big Spring Canyon to *Pliauchenia* because it possessed cement. They did not assign the larger deciduous jaws to any genus.

The camel from localities D855 and D856 cannot be positively excluded from *Hesperocamelus*. Comparison with the measurements given for *H. alexandrae* (Davidson, 1923), showed that the distal humeri and radii-ulnae are 10–20 percent larger on *H. alexandrae*. The proximal phalanges, though, are the same size on both camels. *H. stylodon* Macdonald, 1949 is smaller than *H. alexandrae*. The distal metapodials of D856 appear to be the same size as those of *H. stylodon*; other measurements cannot be made from Macdonald's illustrations. In most measurements, the large camel from D855 and D856 is slightly larger than *Pliauchenia magnifontis* Gregory, 1942. *Megatylopus* and *Titanotylopus* are much too large for the Browns Park camel. *Alforjas taylori* Harrison, 1979, is larger than the Browns Park camel, and evidently lacks a buccal

tubercle on the dP₄. Dentary D855-1 is excluded from *Hemiauchenia* because it lacks a so-called llama buttress on the M₁; although a parastylid is present on specimen D855-1, the protostylid is absent. Dentary D855-1 is higher crowned than *Paleolama*. Other Miocene camels are smaller than the camel from localities D855 and D856.

The camel from localities D855 and D856 cannot, with certainty, be assigned to either *Aepycamelus* or *Procamelus*. Diagnostic differences in the lower deciduous teeth have never been established in the literature for *Aepycamelus* or *Procamelus*. Measurements on selected postcranial elements of *Aepycamelus* from the Pojoaque Member of the Tesuque Formation are given in table 13, along with measurements for the Browns Park camel.

Subfamily CAMELINAE sp.

Table 14, Figure 15

Referred material.—D856-75, left proximal fragment radius-ulna; D856-76, right distal fragment radius-ulna;



FIGURE 15.—Camelinae sp., from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, anterior view of right radius-ulna; specimen D856-77. B, anterior view of left distal radius-ulna; D856-78. C, anterior view of proximal phalanx; D856-80. D, anterior view of proximal phalanx; D856-81. E, anterior view of proximal phalanx; D856-82.

TABLE 14.—Skeletal measurements of *Camelinae* sp. from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colorado

[Measurements in millimeters; leaders (---) indicate no data]

Specimen	n	O.R.	\bar{x}
Radius-ulna TR width distal end.....	3	48.5-52.9	51.4
Proximal phalanges (manus?):			
length.....	4	77.0-83.2	79.6
TR proximal width.....	3	21.4-23.0	22.1
AP proximal length.....	4	21.2-22.9	21.9
TR distal width.....	6	18.5-21.5	19.7
AP distal length.....	6	14.8-19.2	16.5
Proximal phalanx (pes?):			
length.....	1	66.7	---
TR proximal width.....	1	19.8	---
AP proximal length.....	1	17.6	---
TR distal width.....	1	16.7	---
AP distal length.....	1	13.6	---

D856-77, right distal fragment radius-ulna; D856-78, left distal fragment radius-ulna; D856-79 through D856-83, proximal phalanges; D856-84, distal end of proximal phalanx; D856-85, distal end of proximal phalanx.

Description and comparisons.—A possible fourth camel is represented in this fauna. The distal humeri are indistinguishable from those of *Procamelus* or *Aepycamelus* sp. except by size. They are slightly smaller and are about the size of the distal humerus of *Pliauchenia magnifontis*.

Some proximal phalanges are indeterminate. The indeterminate phalanges are shorter and more slender than those belonging to *Procamelus* or *Aepycamelus* sp. These phalanges are larger than those referred to *Michenia* sp. and appear to be too large to belong to any species of *Michenia*. The phalanges are excluded from cf. *Protolabis* on the basis of morphology. The phalanges of *Protolabis coartatus* and the *Protolabis* from New Mexico, referred by Cope to *Procamelus occidentalis* (Cope, 1877, pl. 79, figs. 7 and 7a), are shorter and have wider, rounder shafts than the D856 phalanges. The distal trochlea on these *Protolabis* specimens are also more massive and prominent than on D856. These indeterminate phalanges do not necessarily belong to the same camel as the indeterminate humeri, but are classified with them for the sake of convenience.

Suborder RUMINANTIA Scopoli
 Infraorder PECORA Linnaeus
 Superfamily BOVOIDEA Gray
 Family ANTILOCAPRIDAE Gray
 Subfamily MERYCodontinae Matthew
 Genus MERYCEROS Frick
Meryceros warreni (Leidy)

Table 15, Figure 16A

Cervus warreni Leidy, 1858, p. 23.

Cervus warreni Leidy. Leidy, 1869, pp. 172 and 379, pl. xxvii, fig. 12.

Meryceros warreni (Leidy). Frick, 1937, p. 361, figs. 2 (in part), 2a (in part), 25B (in part), 28 (in part), 28B, 28C, 35A (in part), 39.

Holotype.—U.S.N.M. 149, right horn core.

Referred material.—D856-86, right horn core.

Distribution.—Niobrara River fauna (including Crookston Bridge Quarry) Nebraska; Trail Creek Quarry, Wyoming; Kennesaw fauna, Colorado, probable occurrence; Devil's Gulch Horse Quarry, Nebraska; Horse and Mastodon Quarry, Colorado: all late Barstovian land mammal age; possibly also from Lapara Creek fauna, Texas: Clarendonian.

Description.—The shaft of the horn core is short and transversely flattened and there is no apparent twisting. The two partial tines are parallel to the sagittal plane. Part of the orbit is preserved and has a small foramen on the medial wall. This foramen exits on the frontal bone and anteromesial to the base of the horn core.

Comparisons and discussion.—The short-shafted, transversely flattened horn core is assigned to *Meryceros* Frick, 1937. *Meryceros* is characterized by a single-forked, transversely flattened horn core.

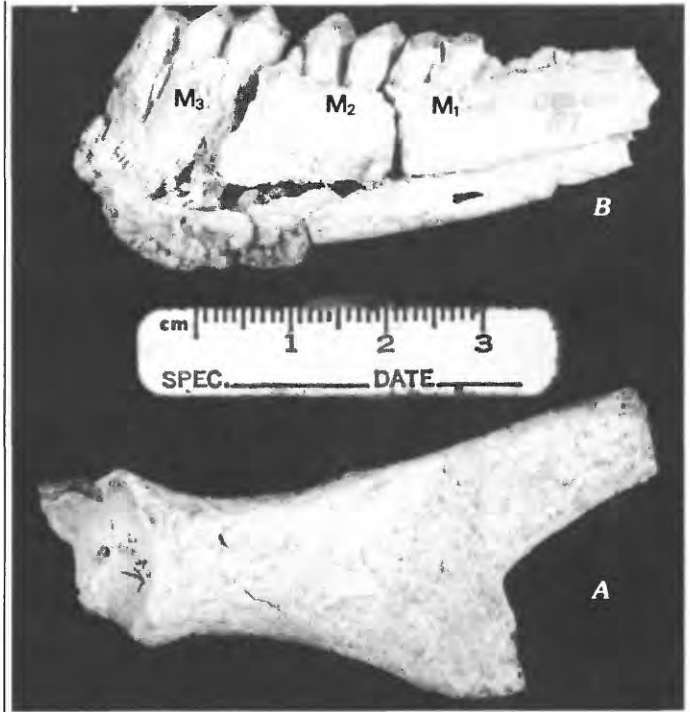


FIGURE 16.—*Meryceros warreni* and Merycodontinae sp., from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, *Meryceros warreni*, lateral view of right horn core; specimen D856-86. B, Merycodontinae sp., buccal view of right dentary with molars (M_{1-3}) of specimen D856-87.

TABLE 15.—Comparative measurements of *Meryceros warreni* from locality D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colorado, and *Meryceros cruceusis* from New Mexico

[Measurements in millimeters; leaders (---) indicate no data. F:AM—Frick, American Museum numbers; ESP—field designation, American Museum of Natural History]

Specimen	<u>M. warreni</u>			<u>M. cruceusis</u>		
	D856-86	Type	F:AM 31319	F:AM 51145	ESP 400	F:AM 51180
Height of fork above orbit..	37.0	40.3	34	38.7	32.3	53.0
Shaft TR above orbit.....	11.2	¹ 14.6	---	12.8	10.0	13.7
Shaft AP above orbit.....	14.5	12.6	14	14.2	12.0	14.7

¹Burr present.

Merycodus, which also has a short-shafted and single-forked horn core, is distinguished from *Meryceros* by a rounded shaft in cross-section.

The D856 horn core is referred to *Meryceros warreni*, as it closely resembles the type of that species (figured in Leidy, 1869, pl. 27, fig. 12). Although the shaft of the type is slightly less compressed transversely above the orbit and is taller than specimen D856-86, referred specimens in the American Museum overlap specimen D856-86 in shaft thickness just above the orbit. F:AM 31319 (Frick, 1937, fig. 39), in fact, is close to specimen D856-86. *M. crucensis* Frick, 1937, is a highly variable form with horn cores 20 percent shorter to 48 percent longer than that of *M. warreni*. Specimen D856-86 horn core cannot be separated from some allocated to *M. crucensis* and illustrated by Frick (1937, fig. 39). The range in size of the horn cores allocated to *M. crucensis* suggests that this species may include individuals of more than one species; the smaller individuals do not appear to be specifically distinct from *M. warreni*. *M. joraki* Frick, 1937, is also morphologically close to specimen D856-86, but has a wider shaft. *M. crucianus* Frick, 1937, has a smaller horn core than specimen D856-86. The horn cores of *M. major* Frick, 1937, *M. nenzelensis* Frick, 1937, and *M. hookwayi* (Furlong, 1935), are longer shafted than specimen D856-86.

Meryceros sp.

Table 16, Figures 17, 18A

Referred material.—D854-1, left M^x; D854-2, right M^x; D854-3, left dentary with LI₂(?), LP₂₋₄, LM₁₋₃; D854-4, right scapula; D854-5, right proximal fragment radius; D854-6, left proximal fragment tibia; D854-7, left distal fragment tibia; D854-8, left proximal fragment metatarsal and shaft; D854-9, left naviculocuboid; D854-10, left astragalus; D854-11, left calcaneum; D854-12 through D854-14, three proximal phalanges; D854-15, medial phalanx; all associated.

Description.—The upper molars are typically antilocaprid, being small and hypsodont. The mesostyle is prominent and narrow. The smaller parastyle and metastyle are subequal in size. The buccal wall of the paracone has a pronounced rib, but the buccal wall of the metacone is ribless.

The LI₂(?) is small and near vertical. The concave lingual side faces posteromesially. The premolars successively increase in size posteriorly. The P₂ has the posterior part of the tooth much wider than the anterior part, whereas the P₃ and P₄ have the buccal and lingual walls more nearly parallel. The P₃₋₄ have a mesially-inflected paraconid, separated by a U-shaped valley from a larger, mesially directed metaconid. This

valley does not extend to the base of the enamel. A narrower valley separates the metaconid from the smaller, posterolingually directed entoconid. A small fossettoid lies posteriorly on the entoconid and separates it from the entostylid on the back margin of the tooth. A small hypoconid forms the posterobuccal corner of the tooth, and is separated from the much larger protoconid by a broad and shallow basin. The protoconid lies opposite the valley between the paraconid and metaconid.

The lower molars closely resemble those of other antilocaprids. The lingual walls completely lack mesostylids. The metastylid is faintly suggested on the M₂, and the parastylid is rudimentary on the M₂ and M₃. A weak protostylid is present labially on the M₂ and M₃, and extends nearly to the base of the enamel. The lingual walls of the metaconid and entoconid are convex. The third lobe of the M₃ lacks a posterior stylid. The dentary is narrow dorsoventrally, especially anterior to the P₂. The ventral border beneath the cheek teeth is convex.

The postcrania from locality D854 were compared with those of some specimens of *Antilocapra* and *Capromeryx*, and with some illustrations of *Paracosoryx* and *Ramoceras*. Some differences are noted below.

The proximal radius (specimen D854-5) resembles that of the much larger *Antilocapra*. The bicipital rugosity, however, is less pronounced than in *Antilocapra*.

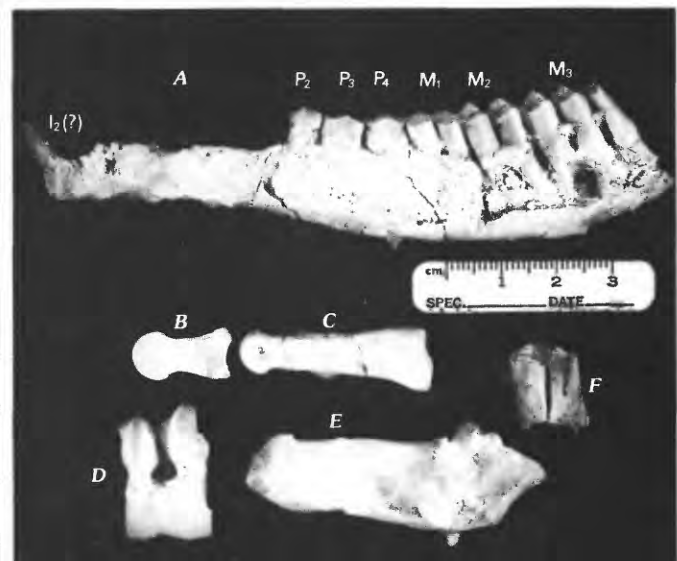


FIGURE 17.—*Meryceros* sp., from locality D854, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, buccal view of left dentary with incisor (I₂?), premolars (P₂₋₄), and molars (M₁₋₃); specimen D854-3. B, side view of medial phalanx; D854-15. C, side view of proximal phalanx; D854-13. D, anterior view of left astragalus; D854-10. E, mesial view of left calcaneum; D854-11. F, lingual view of left M^x, D854-1.

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TABLE 16.—*Dental and skeletal measurements of Meryceros sp. from locality D854, Citadel Plateau 15-minute quadrangle, Moffat County, Colorado, and comparison with M. hookwayi from Nevada*

[Measurements in millimeters; leaders (---) indicate no data. LACM-CIT, Los Angeles County Museum; collection formerly at the California Institute of Technology]

<u>Meryceros sp.</u>		<u>M. hookwayi¹</u>	
D854-1 through D854-15		LACM-CIT 712	LACM-CIT 1257
M ^x APxTR.....	12.3x10.2	---	---
I ₂ APxTR.....	4.1x3.0	---	---
P ₂ APxTR.....	5.4x3.0	---	6.0x
P ₃ APxTR.....	7.0x3.5	---	6.9
P ₄ APxTR.....	8.5x3.9	7.8x	8.9x
M ₁ APxTR.....	8.5x6.3	9.2x	---
M ₂ APxTR.....	9.6x6.9	10.4x	11.0x
M ₃ APxTR.....	16.7x6.4	15.0x	14.0x
P ₂₋₄	20.8	---	---
M ₁₋₃	35.6	---	---
P _{2-M3}	57.8	59.6	56.8
Depth of jaw below P ₂	14.5	---	---
Depth jaw below anterior lobe M ₃	19.3	---	---
Proximal radius TR width.....	21.0	---	---
Proximal tibia AP length.....	34.4	---	---
Distal tibia APxTR widths.....	15.5x20.3	---	---
Proximal metatarsal APxTR widths....	17.7x17.3	---	---
Naviculocuboid APxTR widths.....	19.3x19.2	---	---
Astragalus:			
lateral length.....	24.1	---	---
medial length.....	22.1	---	---
minimum length.....	19.2	---	---
distal trochlear TR.....	15.5	---	---
Calcaneum:			
maximum length.....	54.8	---	---
maximum AP length.....	19.4	---	---
tuberosity APxTR.....	13.7x12.0	---	---
Proximal phalanx (manus?):			
length.....	35.1	---	---
proximal APxTR.....	10.8x10.1	---	---
distal APxTR.....	7.4x8.5	---	---
Proximal phalanx (pes?) proximal			
APxTR.....	n=2; O.R.=9.1-9.4 (AP) 8.6-8.8 (TR); \bar{X} =9.2x8.7		
Medial phalanx:			
length.....	18.0	---	---
proximal APxTR.....	8.6x7.6	---	---
distal APxTR.....	8.7x6.1	---	---

¹Measurements taken from Furlong (1935, table 1).



FIGURE 18.—*Meryceros* sp. and *Merycodontinae* sp., from localities D854 and D856, Citadel Plateau 15-minute quadrangle, Moffat County, Colo. A, *Meryceros* sp., occlusal view of left dentary, showing premolars and molars (P_2 – M_3); specimen D854-3. B, *Merycodontinae* sp., occlusal view of right dentary, showing M_{1-3} ; specimen D856-87.

Proximally, the tibia (specimen D854-6) has the medial condyle and the tubercles of the spine preserved. Medial to the popliteal notch, the attachment tubercle for the posterior cruciate ligament is less pronounced on specimen D854-6 than in *Antilocapra*. Distally, the groove for the flexor digitalis longus is deeper and more sharply defined, and the anteromedial distal process between the astragalar articular grooves is narrower in specimen D854-7 than in *Antilocapra*. Laterally, the fibular articular facets are more strongly developed on *Antilocapra*. The anterior fibular facet on specimen D854-7 is saddle-shaped, being concave from side to side and convex fore-aft. In *Antilocapra* it is strongly convex, forming a rollerlike surface. The posterior fibular facet is shallower and the fibular groove is shallow and less troughlike than in *Antilocapra*.

On the proximal fragment of the metatarsal (specimen D854-9), the ectomesocuneiform facet is less posteromesially expanded than in *Antilocapra*. The entocuneiform facet is more triangular owing to greater posterior extension in *Antilocapra*; it is rounder owing to less posterior extension in *Capromeryx*. The posterior groove bounding the cuboidal facet is less deep in specimen D854-9 than it is in *Antilocapra*.

On the naviculocuboid (specimen D854-10), the metatarsal 4 facet lies more distally from the entocuneiform facet than in *Antilocapra*. The latter facet on specimen D854-10 is relatively longer than on *Paracosoryx* and *Capromeryx* and resembles that of *Antilocapra*. The proximoposterior tuberosity on the medial side of the naviculocuboid is smaller and less rugose than in *Antilocapra*. The medial calcaneal facet

resembles that of *Antilocapra* and *Capromeryx* in that it is more strongly developed than in *Paracosoryx*.

The anterodorsal tuberosity of the calcaneum (specimen D854-11) resembles that of *Paracosoryx* and *Capromeryx* in that it is less strongly developed than in *Antilocapra*. The sustentacular process is slightly less prominent than in *Antilocapra*. The astragalar facet anterior to the cuboidal facet is much smaller on specimen D854-11 than on *Antilocapra*.

The proximal phalanx is more slender on the locality D854 fossil antilocaprid than it is on *Antilocapra* and *Ramoceros*. The proximolateral articular surface is smaller and more distally displaced in relation to the proximomedial articular surface than in *Antilocapra*. The plantar tuberosities are less prominent than in *Antilocapra*. The medial phalanx is more slender and smaller than in *Antilocapra*.

Comparisons and discussion.—Because the horn core is lacking, dental criteria must be used to establish generic identification. Henshaw noted that merycodont evolutionary trends include size increase of the M_3 , lengthening of the post-symphyseal diastema (1942, p. 161) and reduction in the size of the premolars (Henshaw, 1940, p. 26). These characteristics can be determined from most illustrations of antilocaprid dentitions. In their analysis of *Merycodus necatus* and *Cosoryx furcatus*, Skinner and Taylor (1967, p. 44) mentioned reduction of premolars and crown height of molars as diagnostic.

The antilocaprid from locality D854 is distinguished from all genera in the subfamily Antilocaprinae by possessing less hypsodont molars. The absence of a posterior fourth lobe on the M_3 supports placement of the locality D854 antilocaprid within the Merycodontinae, although the presence of the M_3 fourth lobe is somewhat variable in the Antilocaprinae (Skinner, 1942; Webb, 1973).

The dentition of *Ramoceros osborni* (Matthew, 1904) is about 12 percent shorter than that of specimen D854-3, based on F:AM 31636 (Frick, 1937, fig. 43). The premolars are slightly shorter and the molars less anteroposteriorly expanded than in specimen D854-3.

Based on F:AM 31019 and F:AM 31020 (Frick, 1937, fig. 35a), specimen D854-3 differs from *Merriamoceros* in having a dentition 15 percent longer. The premolar row is 10 percent shorter, the P_3 paraconid is less lingually inflected, and the M_3 is less expanded in *Merriamoceros*.

The premolars of both *Cosoryx furcatus* Leidy, 1869, and *Cosoryx cerroensis* Frick, 1937, are highly reduced in relation to those of specimen D854-3, and the M_3 is higher crowned (AMNH 9825, Frick, 1937, fig. 45).

Merycodus sabulonis Matthew and Cook, 1909, is distinguished from specimen D854-3 by having more reduced premolars, and the base of the M_3 is less

anteroposteriorly expanded than in specimen D854-3.

The premolars of *Cosoryx* (*Paracosoryx*) *alticornis* Frick, 1937, (Frick, 1937, fig. 47), are about 20 percent shorter, the molars are slightly shorter, and the M_3 is more anteroposteriorly expanded at the base than in specimen D854-3. The premolars of *C. (P.) furlongi* Frick, 1937, (illustrated in Furlong, 1927, pl. 26, fig. 1) are about 10 percent shorter than on specimen D854-3. The dentition of *C. (P.) loxoceros* (Furlong, 1935) is about 20 percent shorter than that of specimen D854-3. *C. (P.) wilsoni* Frick, 1937, has premolars only slightly more reduced than those of specimen D854-3, and the length of the M_3 is nearly the same. However, the jaw length anterior to the P_3 is much less in *C. (P.) wilsoni*, resulting in an abbreviated look.

The premolars of *Meryceros crucensis* Frick, 1937, are reduced compared with those of specimen D854-3, and the P_4 possesses a posterobuccal sulcus. *M. nenzelensis* Frick, 1937, is similar to specimen D854-3 in having nonreduced premolars. However, the base of the M_3 is longer in *P. nenzelensis* and there is a posterior stylid present on the third lobe of the M_3 (Frick, 1937, fig. 44, F:AM 31902). The premolars are more reduced and the cheek tooth row is shorter in *Meryceros warreni* (Leidy, 1858). The P_2 - M_3 length of specimen D854-3 is greater than in *M. joraki* Frick, 1937. However, in Frick's many illustrations (1937, figs. 46 and 47) of this species, some have unreduced premolars and short M_3 , and others have reduced premolars and long M_3 . These latter specimens also possess posterior stylids on the M_3 . The length of the cheek tooth row of specimen D854-3 is very close to that of *M. hookwayi* (Furlong, 1935). The premolars of *M. hookwayi* are relatively unreduced and the M_3 length is only slightly less than in specimen D854-3; this is due to its being less worn. The posterobuccal sulcus of the premolars is deeper on *M. hookwayi* than on specimen D854-3. The P_4 of *M. hookwayi* differs from that of specimen D854-3 in possessing a small fossettoid posterior to the anterolingual sulcus; this fossettoid is formed by a lingual enamel connection between the metaconid and paraconid, resulting in a P_4 morphologically similar to that of *Antilocapra*. The anterior buccal and lingual stylids of the M_2 and M_3 appear to be slightly stronger on *M. hookwayi*. *M. hookwayi* is similar to specimen D854-3 in that it lacks a stylid on the M_3 posterior lobe. *M. crucianus* Frick, 1937, has a dentition much smaller than that of specimen D854-3. *Meryceros* sp., reported by Cassiliano (1980, p. 48), has shorter premolars relative to the molars than in specimen D854-3.

On the basis of tooth size, nonreduction of premolars relative to molars, and M_3 crown height, specimen D854-3 most closely resembles species of *Meryceros*.

The molariform P_4 with small fossettoid on *M. hookwayi* is a derived characteristic, which nonetheless is merycodontine in development. According to Frick (1937, p. 22-23), "the worn to slightly worn P_4 of ***merycodonts differs from that of *Texoceros* and *Ilingoceros* in the tendency to development of the metaconid rather than the metastylid portion of the median accessory column. In the P_4 of the Recent pronghorn, both metaconid and metastylid are developed, enclosing anterior and posterior fossettes." The P_4 fossettoid on *M. hookwayi* is anteriorly placed, forming from the union of the paraconid and the anterior (metaconid) portion of the median accessory column. If *M. hookwayi* is correctly referred to *Meryceros* (the type of *M. hookwayi* is a ramus; the horn cores from the same locality were referred to that species on the basis of size), then the genus *Meryceros* contains forms both with and without a P_4 fossettoid. Likewise, the presence of the M_3 posterior stylid, a derived characteristic, is variable in *Meryceros*. The individual morphological characteristics of the teeth of antilocaprids are here considered less important taxonomically than are the size and relative proportions of the teeth. Upon this basis, specimen D854-3 falls within the range of variation of *Meryceros*, as this genus was constituted by Frick (1937).

Merycodontinae sp.

Figures 16B, 18B

Referred material.—D856-87, right ramus with M_{1-3} .

Description.—There is little that is distinctive about these teeth. The M_3 possesses a minute posterior stylid. Dental measurements (in mm) for this fossil are as follows: M_1 AP×TR, 7.8×5.6; M_2 AP×TR, 8.8×6.3; M_3 AP×TR, 13.6×6.0; M_{1-3} AP, 36.4.

Comparisons and discussion.—Measurements were taken on *M. warreni* F:AM 31276 from the Devil's Gulch Member of Skinner and others (1968) of the Valentine Formation (late Barstovian) of Lugin (1938), and on *M. warreni johnsoni* N.S.M. 1.23.7.34 and N.S.M. 2.3.8.34 (these last two illustrated in Frick, 1937, fig. 28b). The M_{1-3} is 10-12 percent shorter on these specimens than on specimen D856-87. Frick, unfortunately, did not give measurements or illustrations of the dentitions of *M. crucensis*. In size, specimen D856-87 falls close to the largest specimens of *M. joraki* illustrated by Frick (1937, fig. 47). *M. joraki* includes specimens with the M_{1-3} length from 3 to 26 percent shorter than on specimen D856-87; this large range suggests that more than one species could be included in *M. joraki*. The largest specimen of *M. joraki* differs from D856 in that it has a posterior stylid on the M_3 third lobe. *M. nenzelensis* F:AM 31902, illustrated by Frick

(1937, fig. 44), is slightly larger than specimen D856-87 and has a posterior stylid on the M_3 . The dentition of *M. crucianus* is too small for that of specimen D856-87. The M_{1-3} length is close to that given for *M. hookwayi* (Furlong, 1935, table 1), and specimen D856-87 resembles *M. hookwayi* in that it lacks a posterior stylid on the M_3 . Specimen D856-87 differs from *Meryceros* sp. D854-3 in that the basal part of the M_3 is less anteroposteriorly expanded. This difference, however, is no greater than that seen on specimens of *Cosoryx furcatus* (Frick, 1937, fig. 45, especially F:AM 31274 and AMNH 9825).

Unfortunately, specimen D856-87 cannot be excluded from *Cosoryx*, especially the two specimens just noted. Although *Meryceros* and *Cosoryx* are distinguished from each other by the relative reduction of the premolars, they cannot be so distinguished by their molars alone. The crown height of specimen D856-87 also overlaps with that of *C. furcatus* (Frick, 1937, fig. 45, F:AM 31724). Specimens of *Cosoryx* (*Paracosoryx*) *alticornis* (Frick, 1937, fig. 47, F:AM 31041 and 31043) also cannot be distinguished from specimen D856-87. The molars of F:AM 30944, a specimen which Frick (1937, fig. 41) could not allocate to *Ramoceros*, *Cosoryx*, or *Meryceros*, are virtually indistinguishable from those of specimen D856-87.

This lower dentition may belong to the same animal as the horn core, that is, to *Meryceros warreni*. The 10 percent difference in the M_{1-3} length with that of *M. warreni* may be within the range of variation of that species, especially if the 23 percent range of variation seen in *M. joraki* is truly due to individuals of just that one species. However, considering the diversity of merycodonts in the Barstovian and Clarendonian, there are no compelling reasons why more than one species cannot be found in the same quarry. For the present, the best procedure is to recognize this specimen as generically indeterminate.

MAMMALIAN AGE AND CORRELATION

Locality D857 has yielded fossils indicative of the Hemingfordian land mammal age. The horse from this locality most closely resembles *Parahippus leonensis* from the Thomas Farm and other Hemingfordian localities of Florida. The presence of cement on the teeth helps establish a maximum age for the rocks of this locality. In Nebraska, the type specimen of *Parahippus nebrascensis*, a form without cement, was collected from the upper Arikareean Marsland Formation of Schultz (1938). Galusha (1975, p. 66) noted that some *Parahippus* teeth from the superjacent Runningwater Formation of Cook (1965) "have a light coating of cement;

most do not." The Runningwater Formation is considered early Hemingfordian (Tedford, 1981, p. 1015). Galusha (1975, p. 58) noted that a skeleton of *Parahippus* cf. *P. vellicans* was found in the Box Butte Formation of Galusha (1975), which overlies the Runningwater Formation, and is late Hemingfordian in age (Skinner and others, 1977, fig. 10). He stated that this specimen has "a fairly strong covering of cement on both the premolars and molars," which is thicker than that on horse teeth from the Thomas Farm fauna of Florida or the Garvin Gulley fauna of Texas. Thus, the presence of cement suggests that the D857 horse is at least post-Marsland in age.

Patton (1969, p. 210) judged that the Thomas Farm fauna is slightly younger than the Garvin Gulley fauna, which he tentatively correlated with the Runningwater fauna. The stage of evolution of the equids suggests that the Thomas Farm is no younger than the Box Butte fauna and may be slightly older; there are no *Merychippus* recognized from the Thomas Farm, while the earliest *Merychippus* in Nebraska occurs in the Box Butte Formation, and the Box Butte *Parahippus* has slightly more cement on the teeth than the Thomas Farm *Parahippus* (Galusha, 1975, p. 59). Tedford and Hunter (1984) noted a near-species identity of horses in the Thomas Farm and correlative Florida faunas with horses from the youngest part of the Runningwater Formation.

Thus, the presence of *P. leonensis* suggests an early to late Hemingfordian age for locality D857. However, as indicated previously, the Browns Park horse is not all that different from *Parahippus avus*. In the Great Plains and Great Basin, *Parahippus* persisted into the early Barstovian. The type specimens of *Parahippus avus* and *P. brevidens* are part of the Mascall fauna of Oregon, and the type specimen of *P. coloradensis* is probably from the Eubanks local fauna of northeastern Colorado. Other early Barstovian occurrences of *Parahippus* include the Virgin Valley, High Rock Canyon, and Camp Creek faunas of Nevada, the Sucker Creek, Skull Spring, and Beatty Buttes faunas of Oregon, and the North Coalinga fauna of California. Thus, the minimum age for the fauna from locality D857 is early Barstovian, based only on the occurrence of *Parahippus*.

The age of the fauna from locality D857 can possibly be further refined by the presence of *Blickomylus galushai*. This species is found in both the Chamisa Mesa Member of Galusha (1966) and the Cañada Pilares Member of Gawne (1981b) of the Zia Sand. The occurrences of *B. galushai* in the Chamisa Mesa and Cañada Pilares Members are considered early Hemingfordian by Gawne (1981a, p. 1007), and early to early late Hemingfordian by Tedford (1981, fig. 3). Frick and Taylor

(1968, fig. 14) show *Blickomylus* as Hemingfordian in age. *B. galushai* also occurs in the Split Rock local fauna (Munthe, 1979). Munthe considered the Split Rock local fauna to be most similar to the fauna from the late Hemingfordian Box Butte Formation of Galusha (1975), though also showing strong similarities to the late Hemingfordian fauna from the Sheep Creek Formation.

The evidence as outlined above indicates that the fauna from locality D857 is early to late Hemingfordian in age. Although the presence of *Parahippus* might also suggest an early Barstovian age, because *Blickomylus* has not yet been found in Barstovian faunas, we restrict the age of locality D857 to the Hemingfordian.

The fossils from the other localities in the Browns Park Formation indicate an age younger than Hemingfordian. The canid, *Tomarctus temerarius*, has been reported only from late Barstovian faunas, and is part of the Niobrara River fauna (Webb, 1969) which was collected from the Crookston Bridge Member of the Valentine Formation (Skinner and others, 1968, p. 404). *Tomarctus paula* is from the late Barstovian Tonopah fauna of Nevada. Early Barstovian assemblages commonly include the large form, *Tomarctus rurestris*. Reported Clarendonian occurrences of *Tomarctus* include large species, such as *T. euthos* or *T. robustus*. An exception to this is the canid, of indeterminate genus and species, reported by Wilson (1960) from the Lapara Creek fauna of Texas. As noted, this canid is similar to specimen D856-1.

The stage of evolution of the Browns Park *Megahippus* can be matched with forms of Barstovian age. Specimen D856-9 is similar in size to *Hypohippus affinis*. As noted, *M. mckennai*, from near the base of the upper member of the Barstow Formation (Tedford and Alf, 1962, p. 114), is also near the size of *H. affinis*. The lingual cingulum on the M_1 of specimen D856-9 is less well developed than on *Megahippus* cf. *M. matthewi* from the Clarendonian Cedar Mountain fauna from Nevada, and less well developed than on the type specimen of *M. matthewi* from the latest Barstovian Burge fauna of Nebraska. The dP_1 on D856-9 is larger than on latest Barstovian and early Clarendonian *Megahippus*. As noted, the Browns Park specimen was matched with one in the Frick collection from the Pojoaque Member of the Tesuque Formation.

The limb bones of cf. *Protolabis* are not useful for correlation because the genus *Protolabis* extends from the Hemingfordian through the Clarendonian. The genus *Michenia* extends from the late Arikareean to the Clarendonian; the relative reduction and simplification of the P_2 and P_3 , and the suppression of the P_1 , suggest a post-Marsland (post-Arikareean) stage of evolution for the *Michenia* from the Browns Park. The early-middle Clarendonian *Michenia yavapaiensis* from

Milk Creek, Ariz., has a P_2 that is variably present, suppressed, or lost; when present it averages about 5 mm in length, which is close to that of the *Michenia*, D856-13.

The large *Procamelus* sp. or *Aepycamelus* sp. of the Browns Park Formation seems to represent a late Barstovian stage of evolution. The size of the limb bones and the crown height of the M_1 match a few American Museum specimens from the Pojoaque Member of the Tesuque Formation, that is, specimens of late Barstovian and possibly early Clarendonian age (Tedford, 1981, fig. 2; Barghoorn, 1981, p. 1040). The large Browns Park camel is also matched in these characteristics by *Procamelus* from the latest Barstovian Burge fauna. Clarendonian *Procamelus* from the Clarendon fauna of Texas have higher crowned M_1 's than those from the Burge fauna; hence, the Browns Park camel probably represents a pre-Clarendonian stage of evolution.

Meryceros warreni is apparently limited to late Barstovian faunas. The type specimen is from the composite fauna from the valley of the Niobrara River (see Webb, 1969, for discussion), and may have been from the lower part of the Valentine Formation, in which the *M. warreni*-type horn is characteristic (Skinner and Taylor, 1967, p. 45). The type of *M. warreni johnsoni* is from the Crookston Bridge Member of the Valentine Formation (Skinner and Johnson, 1984). Galbreath (1953, p. 35) reported its probable occurrence in the late Barstovian Kennesaw fauna of northeastern Colorado, apparently basing this judgment on Frick's (1937, p. 367) reported occurrences in the Horse and Mastodon Quarries in the Pawnee Creek Formation of Galbreath (1953). In an unpublished correlation chart, R. H. Tedford (written commun., 1975) showed the Horse and Mastodon Quarries to be slightly older than the Kennesaw fauna, but younger than the early Barstovian Eubanks fauna. Forsten (1970, p. 50) reported the presence of *Meryceros warreni*-type horns from the Trail Creek fauna of Wyoming (but refers them to *Merycodus* cf. *necatus*, as she considers *M. warreni* a synonym of *M. necatus*). The Trail Creek fauna, considered Barstovian by Voorhies (1965) and Forsten (1970), was assigned a Valentinian⁴ age by Cassiliano (1980, p. 64), who noted it contained genera and species also found in each of the three members of the Valentine

⁴Valentinian is an informal land mammal age used by some paleontologists and stratigraphers, and is based on faunas from the Valentine Formation of Nebraska. Previously it had been used as roughly equivalent to a combined late Barstovian (in part) and early Clarendonian time. However, with the placement of the Burge fauna in the latest Barstovian, the Valentinian falls entirely within the late Barstovian. For discussions of the term Valentinian, see Skinner and others (1968); Webb (1969); Cassiliano (1980); and Skinner and Johnson (1984).

Formation. *Meryceros warreni* is present in American Museum collections from the late Barstovian Devil's Gulch Horse Quarry of Nebraska.

Meryceros crucensis is from the late Barstovian and possibly early Clarendonian Pojoaque Member of the Tesuque Formation. *M. joraki*, the other short-shafted *Meryceros*, is from the upper member of the Barstow Formation (Frick's "First Division" (1937, p. 367)). A longer-shafted form, *Meryceros* cf. *M. major*, has been reported from the Clarendonian Ogallala-Wolf Creek fauna of South Dakota, and Merriam (1916, fig. 42) illustrated a probable long-shafted *Meryceros* from the Clarendonian Cedar Mountain fauna of Nevada. Some of Voorhies' (1969) material from the Verdigre fauna may be *Meryceros*. No *Meryceros* has been reported from early Barstovian faunas. Short-shafted *Meryceros* does not seem to have persisted later than the earliest Clarendonian, and is most common in late Barstovian faunas.

The *Meryceros* from locality D854 is probably the same age as the fossils from localities D855 and D856. As noted in the discussion of specimen D854-3, the reduction of the premolars relative to the molars, and the total length of the cheek tooth row, is similar to that of *M. hookwayi* from the late Barstovian Tonopah fauna. Slight morphological differences in the teeth prevent the Browns Park specimen from being assigned to *M. hookwayi*.

The faunal evidence indicates most strongly a late Barstovian (post-Lower Snake Creek to Burge) age for the fossils from localities D854, D855, and D856 (Cedar Springs Draw local fauna), although an early Clarendonian age is not entirely excluded. The primitive *Megahippus* may indicate a pre-latest Barstovian (pre-Burge) age for the fauna. The Cedar Springs Draw local fauna shares *Meryceros warreni* with the Niobrara River fauna (that is, the fauna from the Crookston Bridge Member of the Valentine Formation (latest Barstovian)). In addition, these two faunas share *Protolabis*, and the two large camels, *Aepycamelus* and *Procamelus*, are both present in the Niobrara River fauna. The D856 locality shares *Meryceros warreni* with the Trail Creek fauna (Valentinian); in addition, Forsten (1970, p. 49) gave measurements for a deciduous *Aepycamelus* sp. (called (?) *Alticamelus* sp. by Forsten, and corrected to *Aepycamelus* by Cassiliano, 1980) which are similar to those for the large Browns Park camel. *Tomarctus* cf. *T. paula* is close to *Tomarctus paula* from Tonopah (late Barstovian). Tonopah also has *Aepycamelus* (?) *stocki*. *Meryceros*, however, is represented at Tonopah by the longer shafted *M. hookwayi*. Except for the occurrences in the Browns Park Formation, *M. warreni* has been reported only east of the Rocky Mountains. The quarries D854, D855 and D856

have a high generic similarity to the Barstow fauna, but none of the species are demonstrably the same. The strongest similarity, however, may be to the fauna from the Pojoaque Member (late Barstovian to possibly early Clarendonian) of the Tesuque Formation, which shares *Megahippus* and possibly *Aepycamelus* sp. *Meryceros crucensis* occurs in the Pojoaque Member of the Tesuque Formation; as defined by Frick (1937), *M. crucensis* includes forms with horn cores nearly identical to those of *M. warreni*. Both *Protolabis* and *Michenia* occur in the Pojoaque Member of the Tesuque Formation.

There is little similarity between the Browns Park fossils described in this study and those described by Peterson (1924, 1928). Peterson's 1928 Browns Park fauna consisted of the following forms:

Bassariscops willistoni
Ticholeptus?
 Camelidae gen. et sp. indet.
 Camelidae near *Stenomylus*
Merycodus? sp.? *Aphelops ceratorhinus*
 Chalicotheroidea
Serridentinus fricki

These fossils were found at several localities throughout the formation, and at least one was collected from another formation. The camelid near *Stenomylus* is considered an indeterminate antilocaprine by Frick and Taylor (1968, p. 7, footnote). Skinner (1968, p. 17) pointed out that the presumed chalicotherid is actually a *Teleodus* from the Duchesne River Formation near Vernal, Utah. McGrew (1951, p. 56) considered the supposed *Ticholeptus* to be an indeterminate oreodont. The other camelid and *Merycodus*? sp. consist of unillustrated postcrania. The *Bassariscops* was found "one mile south and west of Sunbeam, Moffat County, Colorado" (Peterson, 1924, p. 300), whereas the *Aphelops* and *Gomphotherium* (= "*Serridentinus*" = "*Trilophodon*") were found about 22 miles farther west at Douglas Mountain, near Greystone, Colo.

Peterson (1928, p. 88) judged the Browns Park assemblage to be similar in age to faunas from "the Pawnee Creek of Colorado, the Madison Valley, probably the Flint Creek and Deep River of Montana; the Santa Fe of New Mexico; the Mascall of Oregon, and the Virgin Valley of Nevada." McGrew (1951, p. 56) considered the Browns Park Formation to be middle Miocene (Hemingfordian). However, this age was based partly on the presence of the supposed chalicotherid. J. LeRoy Kay (oral commun. related in Untermann and Untermann, 1954, p. 186) considered *Bassariscops* and *Aphelops* to indicate a late Miocene (Barstovian) age.

The only record of *Bassariscops willistoni* is from the Browns Park Formation. Frailey (1979, p. 134-140) has

described a second species of *Bassariscops*, *B. achoros*, from the Arikareean Buda local fauna of Florida. The temporal relationship of the two species relative to each other are unknown, but the Florida occurrence suggests that the Browns Park *Bassariscops* may be as old as Arikareean.

The type and referred material of *Aphelops ceratorhinus* are from the Lower Madison Valley, Montana (Douglass, 1903; 1908). Matthew (1932) considered *Aphelops montanus* Douglass, 1903, from the Flint Creek local fauna, Montana, synonymous with *A. ceratorhinus*. According to Black (1961, p. 75), the Flint Creek local fauna is probably middle to late Barstovian and probably equivalent to part of the Lower Madison Valley fauna.

Osborn (1936, p. 312) considered "*Trilophodon*" *fricki* to be one of the most primitive gomphotheres in North America, and assigned a middle to late Miocene age to Peterson's fauna. Tobien (1973, p. 223) synonymized *Gomphotherium fricki* with *Gomphotherium productum* from the Pojoaque Member of the Tesuque Formation, and (1973, p. 218) considered the Browns Park specimen to be one of the earliest representatives of North American mastodonts. Gomphotheres do not occur in North America until the late Barstovian, when they appear as an immigrant group (Tedford, 1981, p. 1012).

Given that *Gomphotherium productum* is an early, primitive North American gomphothere, and considering the stratigraphic position of the Douglas Mountain fauna, Peterson's Douglas Mountain fauna may be slightly older than the Cedar Springs Draw fauna. Peterson's locality at Douglas Mountain appears to be about midway stratigraphically in the formation. Peterson (1928, p. 93) measured a section of 224.3 m from the base of the formation to the top of his fossil horizon, called by him the "Weller Horizon." The fossils of the Cedar Springs Draw fauna were collected from near the top of the formation in the white crossbedded sandstone unit. As mentioned previously, 510 m of Browns Park was drilled in the Texaco No. 1 State-K well, where the white, cross-bedded unit is exposed on the surface; core holes drilled in the white, crossbedded unit near localities D855 and D856 record a total depth for the Browns Park of 490–535 m.

ISOTOPIC AGE

An ash near the D855 and D856 quarries gave a zircon fission-track age of 11.3 ± 0.8 m.y. This ash (field no. 72G74) is about 1 mile northwest of D856, in the NW1/4SE1/4 sec. 25, T. 6 N., R. 97 W. (fig. 10). The ash is exposed only at a single outcrop and cannot be traced south toward the D855 and D856 fossil localities owing

TABLE 17.—Fission-track age data for zircon microphenocrysts from the upper part of the Browns Park Formation, sample no. 72G74

[t, track; Ps, spontaneous track density; Pi, induced track density; F, neutron fluence; n, neutron; cm, centimeter; yrs, years. \pm is one sigma. Number of tracks counted in parentheses]

Sample no.	Ps $\times 10^6$ t/cm ²	Pi $\times 10^7$ t/cm ²	F $\times 10^{15}$ n/cm ²	Age $\times 10^6$ yrs
72G74	1.88 (189)	1.03 (900)	1.01	11.3 ± 0.8

to plant cover. The topographic position of the ash projected into the level of the D855 quarry; thus, the ash lies about 15 m topographically below the D856 quarry. Table 17 gives fission-track age data for this ash.

This 11.3 ± 0.8 m.y. age falls within the time range of latest Barstovian and early Clarendonian (Tedford, 1981, fig. 2). This age is similar to those determined by Evernden and others (1964, p. 164) for the Fish Lake Valley, Cedar Mountain, and Avawatz faunas. As possible evidence for a close faunal relationship of D856 to Fish Lake Valley is the fact that the postcrania of the D856 cf. *Protolabis* are inseparable from the postcrania of *Protolabis coartatus*, which occurs at the Fish Lake Valley fauna and the slightly older Cedar Mountain fauna. The slightly younger Avawatz Mountain fauna (Henshaw, 1940) has a *Michenia* present and also *P. coartatus*-sized postcrania.

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