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## A New Early Eocene Mammalian Fauna from the Great Divide Basin, Southwestern Wyoming: Vertebrate Paleontology, Paleoclimatology, and Biostratigraphy

Edward M. Johnson

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A NEW EARLY EOCENE MAMMALIAN FAUNA FROM THE GREAT  
DIVIDE BASIN, SOUTHWESTERN WYOMING: VERTEBRATE  
PALEONTOLOGY, PALEOCLIMATOLOGY,  
AND BIOSTRATIGRAPHY

by

Edward M. Johnson

A Thesis  
Submitted to the  
Faculty of The Graduate College  
in partial fulfillment of the  
requirements for the  
Degree of Master of Arts  
Department of Anthropology

Western Michigan University  
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June 2005

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2005

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Edward M. Johnson

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BIOSTRATIGRAPHY

Edward M. Johnson, M.A.

Western Michigan University, 2005

A new early Eocene mammalian fauna from a series of localities in the Great Divide Basin of southwestern Wyoming is described in this Masters Thesis. Seven localities in the vicinity of Tipton Buttes have yielded 1627 fossil specimens that have been identified, catalogued, and analyzed. The goal of this thesis is to develop a biostratigraphic framework for dating this fossil assemblage based on comparisons with well-dated assemblages from other localities in the American West. Field crews from Western Michigan University have collected fossil vertebrates from Tipton Buttes during most summer field seasons between 1995 and 2003. The analyses indicate that the fossils from Tipton Buttes most likely date from the Lysitean (Wa6) subage of the Wasatchian North American Land Mammal Age. This identification is based on the presence of representative mammalian taxa from the Lysitean including the apapid primate *Cantius abditus*, the hyopsodontid condylarth *Hyopsodus minor*, and the absence of younger forms like *Lambdotherium*.

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## CHAPTER I

### INTRODUCTION

Today the Greater Green River basin of southwestern Wyoming (see Figure 1) is a region of high desert, between 6000 and 8000 feet in altitude, with countless sandstone formations that have been eroded through eons of wind and rain. The basin is sparsely covered by sagebrush and other species of vegetation that have evolved the ability to subsist in such arid climatic conditions where temperatures frequently climb to greater than one-hundred degrees, and where annual rainfall is minimal at best. The modern-day inhabitants of the basin include herds of pronghorn antelope, elk, and mule deer. There are large communities of prairie dogs, badgers, and rodents. Coyotes frequent the ridges and buttes and their howling may be heard regularly on summer evenings and nights as they go about their foraging.

This description is in sharp contrast to the regional characteristics during the Eocene Epoch of 55 - 38 million years ago (mya). The basin was covered in the Eocene by a vast lake known to geologists as Lake Gosiute. The climate was markedly more tropical than today and plant life grew much more abundantly in the swampy wetlands surrounding the lake. Near its shores the precursors of modern day ungulates, carnivores, and primates foraged along the courses of rivers and streams that emptied into the lake. At its maximum extent, the shorelines of the lake extended over parts of present-day Wyoming, Utah, and Colorado. This large sedimentary basin is today known as the Greater Green River basin, and it is comprised of the

Fossil, Bridger, Sand Wash, Washakie, Green River, and Great Divide basins (Love, 1961). Changes in the climate and tectonics of the region during the Eocene caused several major expansions and contractions of the lake, thus allowing for the deposition of both fluvial and lacustrine sediments.

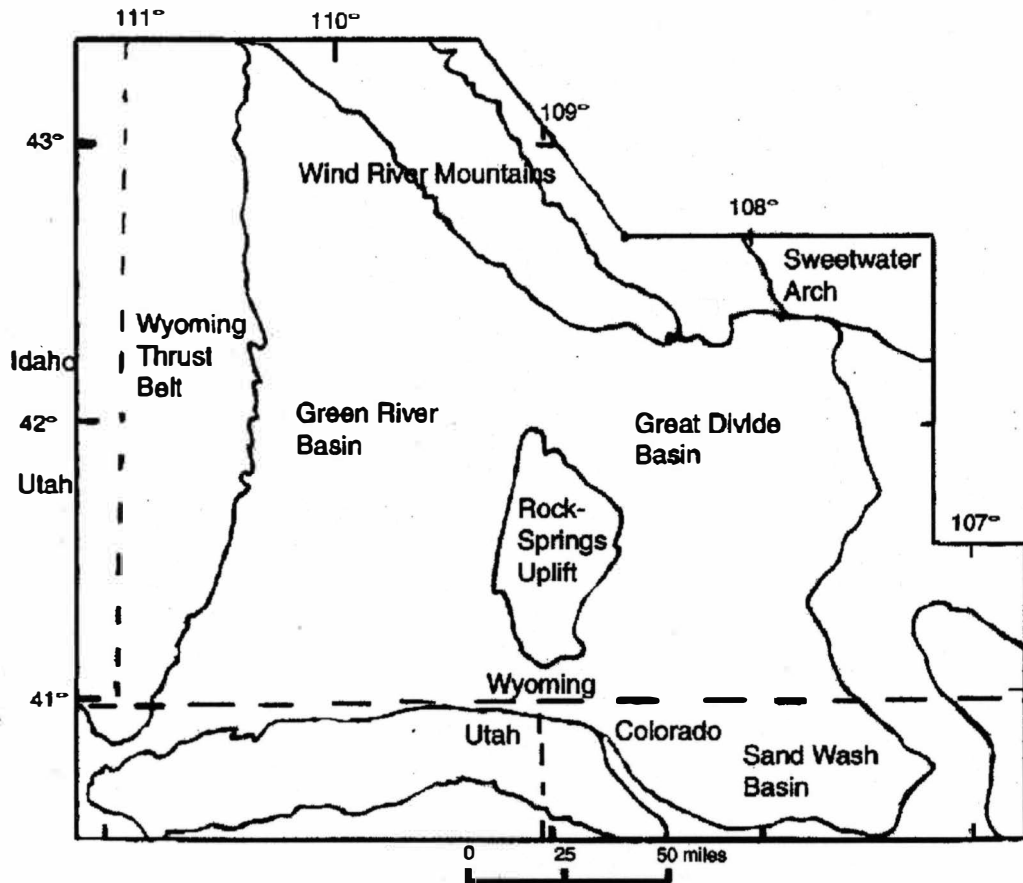


Figure 1. Location of the Great Divide Basin and other geomorphological features in Sweetwater County, Southwestern Wyoming.

Today geologists recognize the fluvial deposits that were laid down by streams emptying into Lake Gosiute as the Wasatch Formation, while the lacustrine deposits laid down by the lake itself are known as the Green River Formation. As the lake

grew in size during more humid climatic conditions, lacustrine beds were extensively deposited and covered a much wider area. During drier periods, the lake's size was greatly reduced, resulting in much less extensive deposition of lacustrine Green River beds, but broader deposition of the fluvial Wasatch Formation. As a result of the changing dimensions of the sedimentary basin during the Eocene, units of the Green River and Wasatch formations interdigitate throughout the entire Greater Green River basin (Roehler, 1992). Figure 2 documents the intertonguing relationships of the individual units of the Wasatch and Green River formations as seen in western Wyoming today.

The Great Divide basin forms the easternmost part of the Greater Green River basin in southwestern Wyoming and can be seen to the north of Interstate 80 between Rawlins and Rock Springs. It is bounded on the east by the Rawlins Uplift and on the west by the Rock Springs Uplift, two arms of the continental divide. To the north, the Great Divide basin is bounded by the Sweetwater Arch and the eastern end of the Wind River Mountains. The Wamsutter Arch forms the southern boundary of the basin, running east to west along the course of Interstate 80 and the Union Pacific Railroad track. Since the continental divide actually splits to encircle it, the Great Divide basin is unique among the major sedimentary basins of Wyoming in that it is an internal drainage basin, draining neither to the Pacific nor the Atlantic Oceans (Baars et al., 1988). The extensive beach sand dune deposits found throughout the basin indicate that during especially wet periods of Earth history (e.g., much of the Pleistocene), the Great Divide basin typically contains a lake.

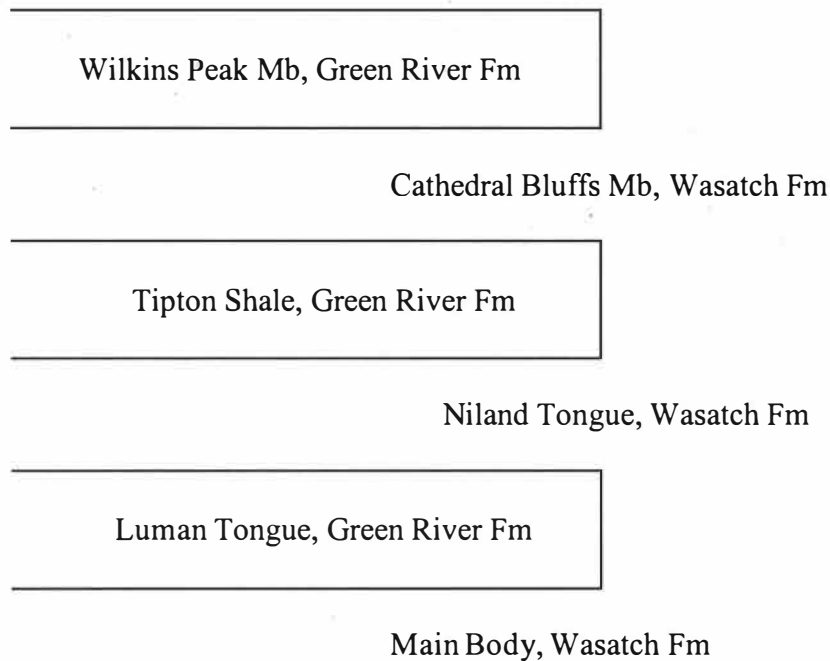


Figure 2. Lithostratigraphic units of the Green River and Wasatch Formations.

The focus of this thesis is an analysis of vertebrate fossil remains recently recovered from a set of seven fossil localities of Eocene age in the southeastern part of the Great Divide basin known as Tipton Buttes. These fossils have been recovered by field crews directed by Dr. Robert L. Anemone of Western Michigan University's Department of Anthropology since 1994 (Anemone, 2002; Anemone et al., 1999, 2000). The fossils have been recovered from a fluvial series of mudstone and sandstone deposits known as the Main Body of the Wasatch Formation. The Tipton Buttes fauna is argued to be of middle early Eocene age, dating to the Lysitean North American Land Mammal Age (NALMA), approximately 53 mya based on a

biostratigraphic analysis of the fossils in comparison to the well-dated sequence of mammalian fossils from other sedimentary basins of the American West. As a result of over one hundred years of vertebrate paleontology in the early Tertiary deposits of the American West, the biostratigraphic sequence of mammalian fossil faunas is now fairly well understood (Granger, 1914; Wood et al., 1941; Schankler, 1980; Gingerich, 1983, 1989), allowing correlation of faunas like that from Tipton Buttes with a well-dated relative sequence of mammalian faunas from places like the Bighorn, Washakie, Wind River, and Powder River basins of Wyoming.

Biostratigraphically, the early Eocene is known as the Wasatchian North American Land Mammal Age and is marked by the first appearance in North America of the Orders Primates, Perissodactyla, Artiodactyla, and hyaenodontid creodonts (Woodburne, 1987). The geological time scale presented in Figure 3 illustrates the sequence of land mammal ages recognized during the Paleocene and Eocene Epochs in North America (Palmer and Geissman, 1999). In the early nineteenth century, the Wasatchian was divided into four major biostratigraphic zones named Sandcoulean, Graybullian, Lysitean, and Lostcabinian and based on the presence of index fossils among the Perissodactyla (Granger, 1914). The earliest Wasatchian fauna is the Sandcoulean, which Granger (1914) defined by the presence of the perissodactyl *Hyracotherium* but not *Homogalax*, and the first primates and artiodactyls. It was originally defined in the Clark Fork basin in northern Wyoming. The Graybullian was based on the presence of *Systemodon* (today known as *Homogalax*) along with *Hyracotherium* and the other typical mammals of the

Wasatchian. Granger (1914) defined the Graybullian on the basis of fossils from near the Graybull River in the Bighorn basin of Wyoming. The Lysitean and Lostcabinian zones were defined by Sinclair and Granger (1911) based on middle and late Wasatchian fossil assemblages from near the towns of Lysite and Lost Cabin, respectively, in the Wind River basin of Wyoming. The Lysitean (middle Wasatchian) was based on the presence of *Heptodon*, while the Lostcabinian (late Wasatchian) was based on the presence of *Lambdotherium*. Extensive modifications to this very basic biostratigraphic zonation have occurred over the years, and will be discussed at some length later in this thesis.

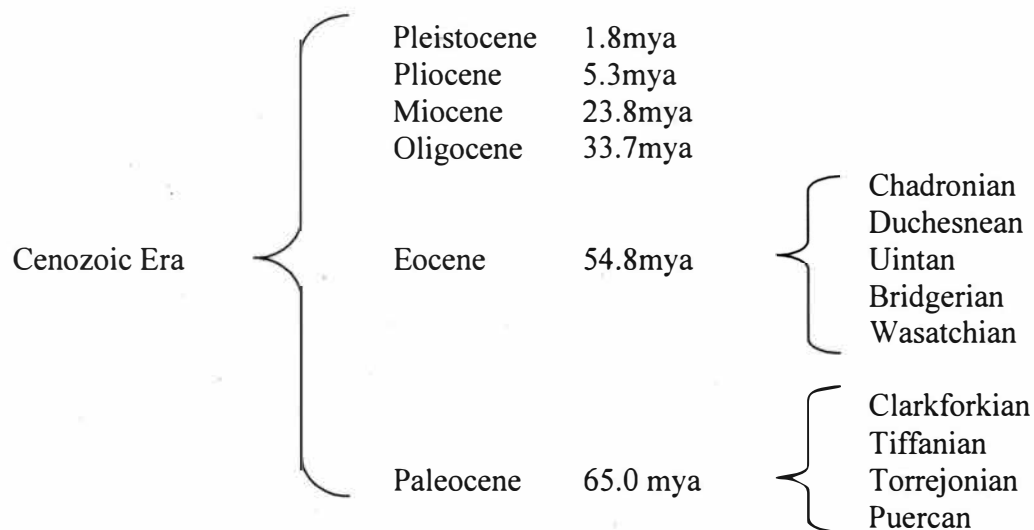


Figure 3. Epochs of the Cenozoic Era and the North American Land Mammal Ages of the Paleocene and Eocene Epochs.

The recorded history of geological and paleontological fieldwork in the Great Divide basin is very brief. Following preliminary geologic work by Veatch (1907) and Nace (1939), Pippingos (1952) did the first detailed geological survey of this basin in the 1950's. In a series of publications on the geology of the Greater Green River Basin, HW Roehler (1977, 1991, 1992a, 1992b, 1993) has also recently described and mapped sections of the Great Divide Basin. As a result of the geological work of Pippingos in the 1950s, small mammalian fossil assemblages were found at three different places in the basin. Each of these assemblages was eventually described in publications authored by CL Gazin, a noted vertebrate paleontologist from the Smithsonian Institution. The first collection was from a locality 12 miles northeast of Creston, WY and 18 miles west of Rawlins, in the North Rawlins Coal Field. Collected by USGS geologists EE Smith and AC Veatch, the small fauna included *Esthonyx acutidens*, *Notharctus venticolus*, *Coryphodon*, and *Heptodon* Gazin (1952). The presence of *Heptodon* and *Notharctus venticolus* suggested to Gazin (1952) a Lostcabinian age and the locality was called Great Divide basin.

The second of these localities was found by Pippingos in 1952 and collected by Gazin in 1953. It was named Red Desert by Gazin (1962) and described as a small area of buff, coarse-grained sandstone located approximately 14 miles east of Steamboat Mountain to the north of the Rock Springs uplift. The wind-eroded, fragmentary specimens obtained there consisted mostly of teeth, and included several characteristic Wasatchian species. Gazin's faunal list includes *Pelycodus* cf. *trigonodus*, *Omomys* cf. *vespertinus*, *Absarokius noctivagus*, *Esthonyx* cf. *bisulcatus*, *Phenacodus* cf. *brachypternus*, *Haplomylus speirianus*, *Meniscotherium* cf. *priscum*, *Hyracotherium* cf.



*angustidens*, and *Diacodexis* cf. *metsiacus*. This faunal list suggests the early Wasatchian or Graybullian.

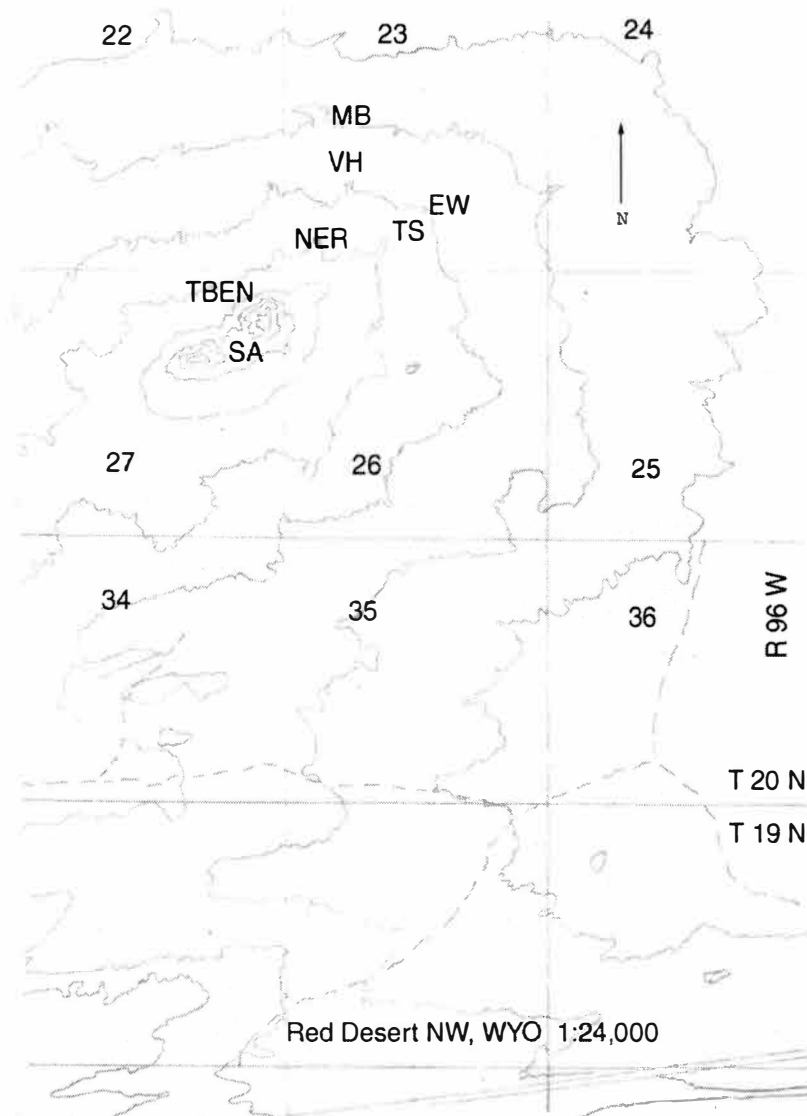
The third and final locality described by Gazin (1962) is Tipton Buttes (Figure 4). Discovered by Brown and Pipiringos in 1952, the Tipton Buttes locality is near the top of the Red Desert member (later named by Roehler (1993) the Main Body) of the Wasatch Formation. It was later described by Pipiringos (1955) as a coal bearing gray-white shale, siltstone, and sandstone that is exposed in several outcrops southwest of the Red Desert Flat at Tipton Buttes. Additional specimens collected there by Gazin in 1953 included *Cynodontomys* (possibly *C. angustidens* = *Microsyops angustidens*), *Pelycodus*, *Esthonyx bisulcatus*, *Paramys* cf. *excavatus*, *Vulpavus* (possibly *V. asiaticus*), *Hyopsodus*, *Meniscotherium* cf. *robustum*, and *Hyracotherium*. The age of the fauna from Tipton Buttes was originally given as Lysitean or Lostcabinian by Pipiringos at Gazin's suggestion in 1955. Gazin (1962) later suggested that the Tipton Buttes fauna was probably Lysitean or late Graybullian in age.

Field crews from the Department of Anthropology at Western Michigan University (WMU) have collected extensively throughout the Great Divide basin during eight summers between 1994 and 2004. (Anemone 2002; Anemone et al 1999, 2000). As a result of this fieldwork, 6,261 mammalian specimens from 88 localities have been catalogued into the WMU Department of Anthropology vertebrate paleontology collections. In addition, Gazin's Red Desert and Tipton Buttes localities have been relocated and intensively collected, greatly increasing the faunal samples from these



Figure 4. View of Tipton Buttes, facing southwest, from Virgin Hills locality.

localities. The focus of this thesis is an analysis of the fossil mammalian assemblage from our seven localities near Tipton Buttes, referred to hereafter as the Tipton Buttes fauna. Figure 5 illustrates the location of these localities on a detail taken from the Red Desert NW 1:24,000 topographic map.



VH= Virgin Hills, TBEN= TBE North, NER= Northeast Ridge, SA= Tipton Saddle,  
MB= Mertle Beach, EW= End of the World, TS= Talus Slope.

Figure 5. Detail from USGS topographic map Red Desert NW, scale = 1:24,000.

## CHAPTER II

### TIPTON BUTTES

Easily visible for several miles when traveling across Interstate 80 in southwestern Wyoming, Tipton's two prominent buttes are located a few miles northwest of the "town" of Red Desert (Figures 4 and 5). The large flat top buttes are the first major relief one encounters on the Interstate west of Rawlins. Geological investigations at Tipton Buttes by Pipiringos in the 1950s produced a small number of isolated teeth from outcrops in Sec. 23, T. 20 N., R. 96 W. These were reported to Gazin and described by him in a series of publications (Gazin, 1952, 1962). Anemone and his field crews have prospected for fossils and new localities on and around Tipton Buttes during the summer field seasons of 1994-1999, 2001, and 2003. Seven localities have been discovered there to date, yielding a total of 1564 catalogued mammalian specimens as well as numerous remains of crocodile, turtle, gar and lizard (Figure 6).

The localities at Tipton Buttes are as follows: TBE North (WMU Loc. 114), Talus Slope (WMU Loc. 116), NE Ridge (WMU Loc. 117), End of the World (WMU Loc. 118), Tipton Saddle (WMU Loc. 134), Mertle Beach (WMU Loc. 135), and Virgin Hills (WMU Loc. 122). All of these localities were discovered by Anemone and his field crews while prospecting the buttes and surrounding terrain during the 1994 through 1996 field seasons. While some of these localities continued to be productive for a few field seasons, only Virgin Hills has yielded any substantial fossil mammalian remains since 1998. The faunal assemblages from all of the Tipton Buttes localities are

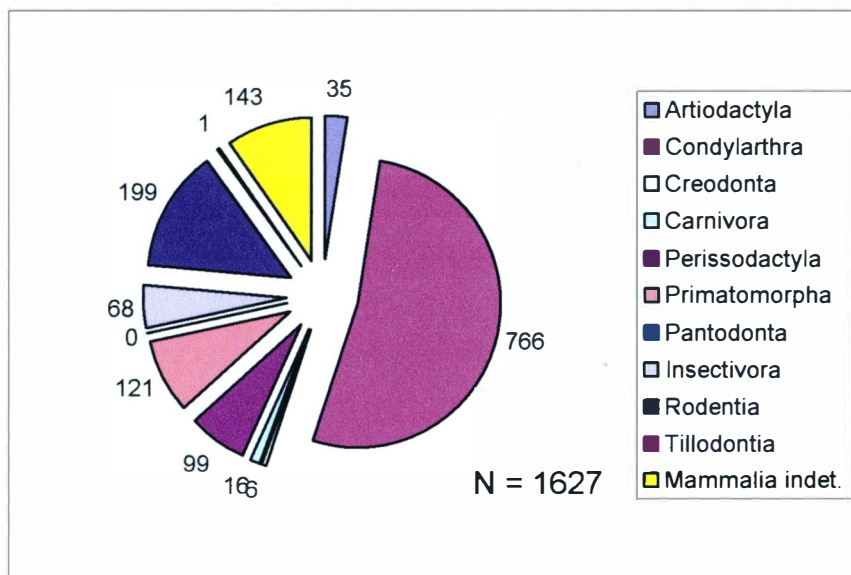


Figure 6. Ordinal diversity among the mammals from Tipton Buttes.

of similar age and stratigraphic position and have the same taxonomic representation with very few exceptions. Only the Virgin Hills locality contains any significant anthills, and none of the other localities have ever been as productive as has Virgin Hills (Figure 7). For these reasons I will treat the fauna from all of the Tipton Buttes localities together in this thesis.

The TBE North locality is located in Sec. 27, T20N, R96W, and is a north-running ridge on the northern side of the eastern butte. It was first discovered by Anemone during the 1994 field season while prospecting in attempts to relocate Gazin's (1962) Tipton Buttes locality during the summer of 1994. Taxa recovered from TBE North include typical Wasatchian forms such as *Meniscotherium*, *Hyopsodus*, *Cantius*, *Paramys*, and *Coryphodon*. With 87 catalogued specimens recovered from this locality, TBE North has been the most productive locality found at Tipton Buttes with the obvious exception of Virgin Hills. The Talus Slope locality is in Sec. 23, T20N, R96W. Fossils

collected there included *Hyracotherium*, *Hyopsodus*, *Meniscotherium*, *Cantius*, and *Coryphodon*. The NE Ridge locality is in Sec. 23, T20N, R96W where crews collected *Homogalax*, *Hyracotherium*, *Hyopsodus*, and *Viverravus*. Nearby, in Sec. 23, T20N, R96W, more specimens of *Coryphodon* were recovered in 1994 at another small locality called End of the World. Talus Slope, NE Ridge, and End of the World are located on small knolls to the northeast of Tipton Buttes and were discovered while prospecting there in 1994.

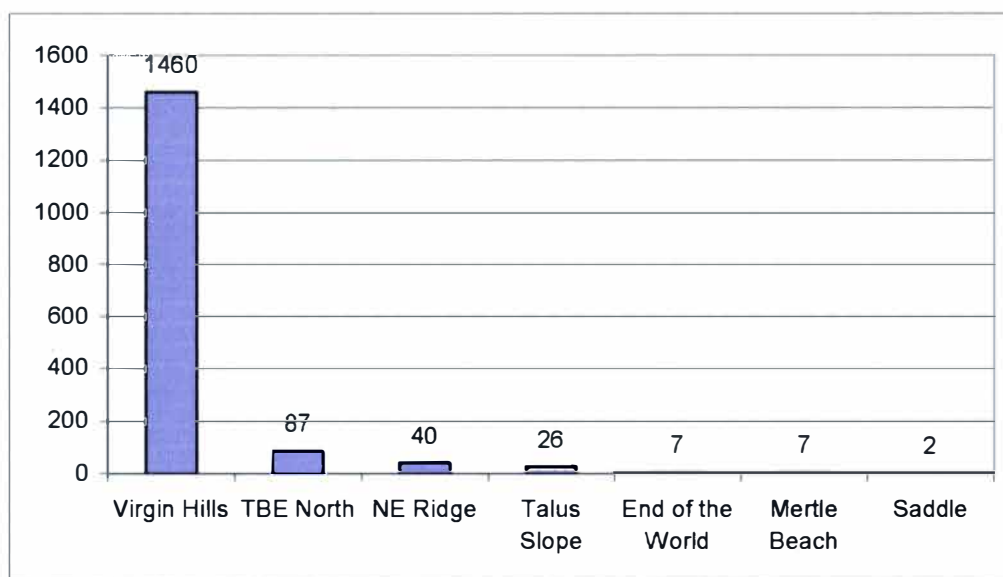


Figure 7. Total number of catalogued specimens from the Tipton Buttes localities.

During the 1996 field season the Tipton Saddle locality was found in the saddle between the two main buttes comprising Tipton. It is easily visible from far south of the buttes because of the approximately 14meter sandstone pillar which is directly adjacent to the locality. The only mammalian taxon recovered at this locality was *Meniscotherium*, represented by a single specimen.

The last locality found in the vicinity of the buttes in 1996 was Mertle Beach, named for the geology student who found the locality. This locality was productive when it was first discovered, with a fauna that included *Meniscotherium*, *Hyracotherium*, *Hyopsodus*, and several rodents. Unfortunately, it was never revisited for collection during the season of its initial discovery, and all attempts to relocate fossils there during subsequent field seasons have been unsuccessful.

The most productive and most important of the localities at Tipton Buttes has been Virgin Hills, which was found while prospecting in 1995. This locality has been collected during seven subsequent field seasons, and has produced nearly fifteen hundred catalogued mammalian specimens (mostly isolated teeth), as well as several thousand broken teeth and small postcranial elements.

The Virgin Hills fossil assemblage (N=1460) accounts for fully 93% of the catalogued specimens from the entire Tipton Buttes area (N=1564). It may be described as a gentle slope located approximately a quarter of a mile northeast of the base of Tipton Buttes with more than a dozen anthills scattered across its expanse (Figure 8).

The lithology includes a gray-green silty mudstone overlying a darker greenish mudstone. The locality extends approximately 150 meters from east to west and slopes upward from north to south for approximately 140 meters. At the southernmost border of the locality is a line of broken reddish-brown sandstone, some of which is scattered downward towards the north across the exposure. It is bordered on its western perimeter by a dry wash approximately 1 meter deep with heavy sagebrush cover. The wash



Figure 8. Collecting on and between anthills at the southern end of Virgin Hills.

continues northward to gradually curve around the northern edge of the locality where its depth is approximately  $\frac{1}{2}$  meter. The eastern border is a much less noticeable wash, but the locality is easily defined on this edge by a sharp decrease in the number of anthills present, as well as a slight upward grade from west to east.

A long-standing practice among paleontologists has been prospecting the low-lying, conical anthills that are commonly found in most badlands environments in the American west (Figure 9). This is because the ants incorporate small fossils into the matrix comprising their nests. The fossils in the hills very closely approximate the grain size of the sand and small stone nodules making up the surface of the region, and therefore they are inadvertently collected by the insects. This is a boon for the paleontologist, greatly reducing the time spent searching non-productive sites, while





Figure 9. Students collecting one of the several productive anthills at Virgin Hills.

greatly improving daily productivity. Collection from anthills drastically increases the microfaunal representation for the localities where they are found, but obviously few large specimens or large taxa are found at anthills. The major drawback of collecting anthills is that it usually only produces isolated teeth of small to tiny mammals. Rarely very small mandibles may be recovered using this method. It has been a practice at some sites in Wyoming where the ant population is critical to the success of collections to actually supplement the anthill with grains of rice on a regular basis to ensure that they continue to thrive and accumulate fossils. Older anthills found to be devoid of active colonies are often dug up; their matrix bagged by the paleontologists and transported back to their labs for scrutiny by their eager graduate students in efforts to collect every available fossil from the matrix.

The fossils from Virgin Hills can be found both around and incorporated into the many active anthills scattered across the locality (Figure 9). When the locality was first discovered in 1995, the majority of anthills there were at least one meter across and a quarter to a half-meter high, with abundant tiny teeth and postcranial elements mixed into the sand lining their slopes. In later years the hills have become less productive, but they continue to yield enough fossils to warrant repeated interest in the locality (Figure 10).

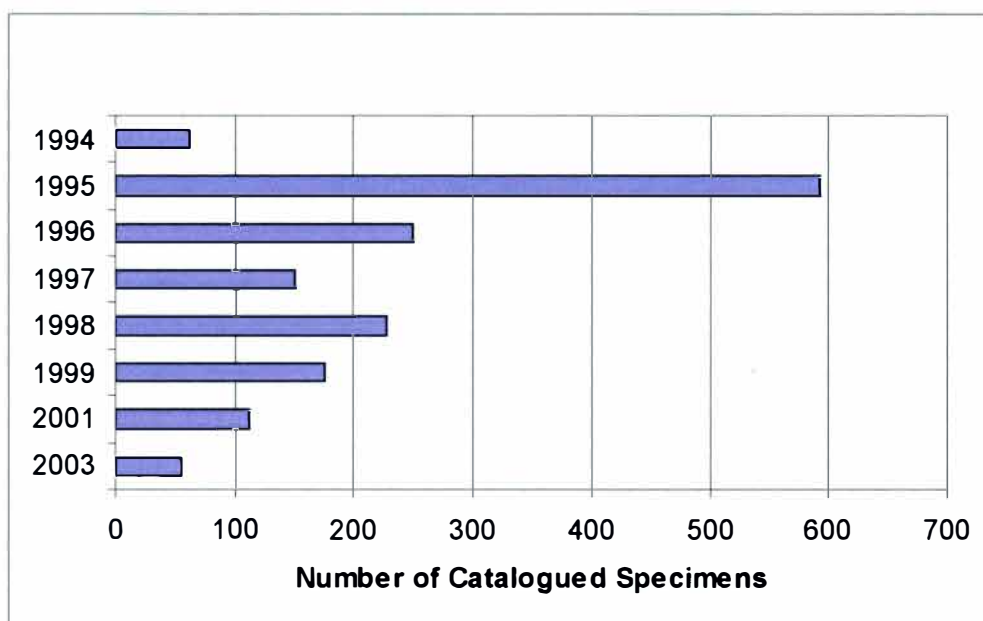


Figure 10. Yearly totals of catalogued specimens from the Tipton Buttes localities.

### CHAPTER III

#### FIELD METHODS

The field methods employed in accumulating the fossil specimens for this project include intensive study, prospecting, and surface collection of the study area in efforts to locate fossiliferous exposures. In actuality the work begins prior to entering the field, when crew-members are instructed in the methods to be employed while collecting. They learn to distinguish between rock and bone fragments in the lab, where they are exposed to actual specimens in order to develop a search image that will enhance their ability to identify scatters of crocodile scutes, turtle shell, or mammalian bones or teeth in the field.

Organization and cooperation among members of the crew is imperative for the successful operation of any field camp. Work in the Great Divide basin is no different and in some ways requires even more optimism and self-discipline than studies in other research areas in the American West. Other sedimentary basins such as the Bighorn, Washakie, and Wind River Basins are renowned for having much more productive localities and for the recovery of more complete specimens than those in the Great Divide. Great Divide basin fossils tend to be more rare and more fragmentary than those found in some of the other, more productive areas where Eocene sedimentary deposits are found in the West. A knowledge of the fauna in the Great Divide basin is, however, no less important for a complete understanding of the regional Eocene biostratigraphy.

Daily field routines include a review of topographical maps of the work area and of the field notes from previous seasons to familiarize the crew with the possible productive areas before working there. This facilitates more efficient time management

once in the field by enabling the crew to concentrate their search to within the productive areas, rather than spending time searching for fossils while moving between them.

Once a promising exposure is located, crews are organized to slowly and attentively move across it in a direction that allows adequate lighting and minimizes attempts at collecting in shadows. If bone scatters are found, the field crew is instructed to slowly crawl the area in the immediate vicinity of the fossils in order to locate any small mammal bones or teeth that may be exposed there. Significantly productive areas are recorded into a global positioning system (GPS) database and their immediate location is marked on the topographic map of the section and in the field notebook. These newly discovered localities are only collected for a short while in order to get an idea of their potential future productivity and of the fauna that may be recovered there. After the fossils are consolidated the crew reorganizes and moves on to the next exposures in an effort to locate other productive sites. By repeating this process in an efficient manner it is possible to find several new localities in a single day. At the end of each day the fossils are inspected more closely and tentatively identified, grouped according to locality and taxon, and stored for transport to the lab after the completion of the field season.

The days spent prospecting for new localities are some of the most arduous and grueling times in the field, but they can also be the most rewarding. Long hours are spent each day searching for fossils over rugged terrain at relatively high altitude (6000-8000 feet above sea level) and in daytime temperatures that routinely surpass 90 degrees Fahrenheit (Figure 11). For the more seasoned workers, though, these days





Figure 11. Collecting at a new locality near the base of a sandstone outcrop.

are the most exciting, for they understand that our best chance to discover new, complete, and interesting fossils is always when we first locate a new locality.

When a new locality has been found, or when an old one is revisited after lying fallow since the previous field season, it must be carefully inspected by an organized crew. This type of collecting involves crawling and meticulously checking the surface of the locality to recover any newly exposed fossils from wind erosion or rains since the previous field season. At localities where a large sandstone outcrop is present, the sands at the base of the stone tend to be the most productive, but the surface of the surrounding mudstone may be productive as well.

The surface of the sandstone outcrop is also meticulously inspected to recover any fossils weathering from the stone. Fossils recovered in this manner are usually in a better

state of preservation because they have been protected inside the stone, rather than incorporated into the coarse substrate where they are subjected to trampling by local wildlife and impetuous students (Figure 12).



Figure 12. Removing fossils from the face of the sandstone.

Specimens are recovered directly from the stone with the use of dental picks to carefully remove the fossil intact within a section of matrix for safe transport to the lab, where they may be properly removed from the stone. Specimens recovered in this manner from several localities in the area have included partial mandibles retaining the majority of the molar dentition.

As mentioned in the earlier discussion of Virgin Hills, localities with active anthills can be very productive. They are best collected by kneeling beside the base of the anthill facing the sunlight so as not to collect in the shade. The grain-size of the sand making up the sides of the anthill closely approximates that of the fossils found there, so



they are best collected using tweezers and dental picks. This makes collection easier and reduces the destruction of the surface of the anthill. Preservation of the anthill both increases the possibility that it will continue to be productive in following field seasons and greatly reduces the potential for stings from the ants defending their nests.

Several older localities that are collected annually, including the Tipton Buttes localities, continue to produce respectable quantities of fossils due to the persistent winds crossing the localities, as well as occasional rains that aid in the erosion of the sandstone outcrops and mudstone exposures. In cases where a historically productive locality fails to produce over the course of several field seasons, the use of screens may be employed to separate any remaining fossils from the matrix. The separated matrix is screen-washed in a river using small gauge wire mesh screen to break up mudstone nodules and recover more minute specimens (Figure 13).



Figure 13. Screenwashing matrix in Bitter Creek.

After wet screen washing, several bags of concentrated matrix are brought back for inspection and removal of fossils from sediment under the light microscope in the lab.

At the end of each field season the fossils are transported back to WMU for cataloguing and storage in the Anthropology Department's Biological Anthropology lab. They are individually identified under a Leica stereomicroscope and logged into a computerized database (using Filemaker Pro software on Windows 2000 PC). The recorded data for all fossils include taxonomic, anatomical, and geographic information, as well as the time and date each fossil was collected. A specimen file and a locality file make up the relational database in which the record for each fossil specimen is linked to a record for the locality at which it was found. The locality database includes fields for GPS-derived coordinates of the locality, the name of the 7.5 minute, 1:24,000 series topographic map on which the locality can be found, and other aspects of the geographic location of the locality.

Identification of each tooth or postcranial element involves knowledge of the most current literature concerning each of the taxa recovered. We maintain in our lab a vertebrate paleontology research bibliography of several thousand titles (using Endnote software) as well as a well-stocked vertebrate paleontology library, enabling students and faculty to access the vast majority of available titles in Cenozoic vertebrate paleontology. Also necessary for proper identification are casts of the most common Eocene fossil mammals. In most instances casts of the type specimens, or those upon which the initial description of the taxon was based, are available. The majority of these casts were obtained from researchers at the Carnegie Museum, American Museum of Natural



History, National Museum of Natural History, University of Colorado, and the University of Michigan Museum of Paleontology, and are maintained in a reference collection in the Biological Anthropology lab. In cases where no cast or literature is available for comparison some specimens are transported to the University of Michigan Museum of Paleontology or other museums for comparison with identified specimens housed in their collections. Input from researchers at other institutions who are considered the authorities in their particular areas is also a valuable resource for the precise identification of particularly difficult specimens.

Once identification of the collection is complete, individual specimen numbers are assigned to each fossil and they are added to the main body of the WMU vertebrate paleontology collection. The specimens collected under the direction of Anemone by WMU crews in the Great Divide basin will ultimately be housed in the collections at the Carnegie Museum in Pittsburgh, PA.

## CHAPTER IV

### BIOSTRATIGRAPHY AND THE WASATCHIAN LAND MAMMAL AGE

Biostratigraphy is a relative dating method that relies on the presence of fossils to determine the age of sedimentary rocks in which fossils are discovered. By comparing faunal lists and the stratigraphic range of fossils from different localities, a sequence of biostratigraphic units (e.g., range zones, assemblage zones, etc.) can be created. The establishment of a chronology based upon sequential mammalian faunas depends on the successful correlation of these biostratigraphic units in widely separated areas, as well as on detailed and accurate stratigraphic work. A series of North American Land Mammal Ages (NALMAs) have been established for the entire Cenozoic Era (Figure 3) as a result of more than a century of paleontological fieldwork (Wood et al., 1941; Woodburne, 1987). Therefore, land mammal ages may be described as geochronologic units based upon mammalian fossil assemblages from sedimentary rock units that represent a particular geologic time in geographically distinct areas with different depositional histories. The Tipton Buttes fauna is a fossil assemblage from the earliest part of the Eocene Epoch, the Wasatchian NALMA.

The establishment of the Wasatchian land mammal age came about through the pioneering work of Hayden, Leidy, Cope, Marsh, Wortman, and Scott. From the beginnings of systematic field exploration, it was realized that the sedimentary rocks and faunas in the various basins of New Mexico, Colorado, Utah, and Wyoming were of different ages, and by the early twentieth century their general sequence was understood.

While working for the US Geological Survey, Hayden (1869) named the Wasatch Formation based on fossiliferous rocks of early Eocene age in Weber Canyon, Utah. Subsequent collections of Wasatchian fossils were made from this area in the 1870s by both OC Marsh and ED Cope. The fauna they recovered included typical Wasatchian forms such as *Hyracotherium*, *Phenacodus*, and *Coryphodon*. These taxa were also recovered from the San Juan basin of New Mexico and the Bighorn basin of Wyoming, and this was evidence enough for Cope (1875, 1882) to extend the range of the Wasatch formation into these areas. He called this the “*Coryphodon* zone” and characterized it by the presence of *Coryphodon* and other typical Wasatchian taxa and by the reddish coloration of its rock strata. Common practice during this time was to define rock units by both their lithological characteristics and their fossil assemblages. Hayden (1869) similarly referred the rocks of the Wind River basin in central Wyoming to the Wasatch formation on the basis of their fossils of Wasatchian age.

The Wasatchian land mammal age was divided into finer units based on faunal turnover and evolutionary changes within mammal lineages in the first several decades of the twentieth century. Granger (1910) formally suggested that the Wasatchian could be divided into four subunits based on fossil assemblages from Wyoming. From oldest to youngest, Granger defined the Sand Coulee beds (from near Big Sand Coulee in the Clark Fork basin), the Gray Bull beds (from near the Gray Bull River in the Bighorn basin), the Lysite and the Lost Cabin beds (from near the towns of the same names in the Wind River basin). Although there is some difference of opinion about the validity of the Sand Coulee (Jepsen, 1930; Krishtalka et al., 1987; Gingerich, 1983), the other three

faunal levels recognized by Granger are now formal subages within the Wasatchian land mammal age (Graybullian, Lysitean, and Lostcabinian).

The beginning of the Wasatchian land mammal age is defined by the first appearance of members of four mammalian orders: Perissodactyla, Artiodactyla, Euprimates and hyaenodontid Creodonts. From the beginning, the perissodactyls have played a leading role in the biostratigraphic zonation of the Wasatchian. According to Granger, the Sand Coulee beds included the “dawn horse” *Hyracotherium* (formerly *Eohippus*) as well as many other typical Wasatchian taxa, but did not include the “index fossil” of the Gray Bull, the tapiroid *Homogalax* (formerly *Systemodon*). The first appearance of *Homogalax*, therefore signals the beginning of the Gray Bull, but note that *Hyracotherium* does not disappear with the end of the Sand Coulee, but is found throughout the entire Wasatchian NALMA. The first appearance of the tapiroid *Heptodon* marked the beginning of the Lysite, while the first appearance of the paleothere *Lambdotherium* defines the beginning of the Lost Cabin. The end of the Wasatchian (and the beginning of the Bridgerian NALMA, representing the middle Eocene) is defined by the penecontemporaneous appearance of typical Bridgerian taxa such as *Hyrachyus*, *Palaeosyops*, *Trogosus*, *Omomys*, *Washakius*, *Anaptomorphus*, *Smilodectes*, *Pantolestes*, *Homacodon*, *Microsus*, and *Helohyus*.

Defining characteristics of the subages of the Wasatchian have been considerably amended and refined in recent decades as a result of detailed stratigraphic collecting and analysis in many basins throughout the American west (including the Bighorn and Wind River basins). Work by Stucky (1984a, 1984b) has shown that the Lostcabinian subage may be further divided into two distinct faunas and biostratigraphic zones. The lower

zone is the type fauna for the Lostcabinian NALMA, and is known as the *Lambdotherium* Range Zone. The upper zone is the *Palaeosyops borealis* Assemblage Zone, and is the equivalent of the Gardnerbuttean fauna as defined by Robinson (1966). The Gardnerbuttean is now recognized as the earliest of the Bridgerian subages, so if Stucky is correct, the Lostcabinian transgresses the Wasatchian-Bridgerian boundary. They suggest that the distinction between these two faunas is a major faunal turnover event that is recognizable in several intermontane basins of the west.

Schankler (1980) developed an alternative biostratigraphic zonation of the Wasatchian based on detailed collecting and measured stratigraphic sections in the Willwood formation in the Bighorn basin. Schankler's contribution includes three different biostratigraphic zones and three major turnover events, which he refers to as "biohorizons". As Table 1 demonstrates, the *Haplomylus-Ectocion* Range-Zone correlates with the lower and middle parts of the Graybullian. The *Bunophorus* Interval-Zone correlates with the upper Graybullian, while the *Heptodon* Range-Zone is equivalent to both Lysitean and Lostcabinian. Biohorizon A marks the faunal turnover and boundary between lower and upper parts of the *Haplomylus-Ectocion* Range-Zone and between the traditionally construed lower and middle Graybullian. It is characterized by the "extinction" of eight species: *Oxyaena gulo*, *Viverravus* sp., *Esthonyx spatularis*, *Coryphodon* sp., *Phenacodus vortmani*, *Phenacodus brachypterus*, *Hyopsodus loomisi/minor*, and *Hyracotherium* sp. Biohorizon A also includes the immigration of seven new species into the Bighorn basin. These include *Anacodon ursidens*, *Didymictis curtidens/lysitensis*, *Tritemnodon strenuous*, *Vulpavus australis*, *Hyopsodus latidens/miticulus*, *Esthonyx bisulcatus*, and *Diacodexis robustus*. Biohorizon B marks the boundary

Table 1

## Biostratigraphic Correlations Within the Wasatchian

	Granger 1914	Gingerich 1976	Gingerich 1980	Shankler 1980	Gingerich 1989	
Wasatchian	Lost Cabin	Lost Cabin	Pelycodus jarrovii Biochron	Heptodon Range Zone	Wa7	Lost Cabin
	Lysite				Wa6	Lysite
		Lysite	Pelycodus abditus Biochron	Bunophorus Interval Zone	Wa5	L. Graybull
					Wa4	M. Graybull
	Graybull		Pelycodus trigonodus Biochron	Haplomylus Ectocion	Upper Wa3	E. Graybull
		Graybull			Wa2	L. Sand Coulee
			Pelycodus mckennai Biochron	Range Zone	Wa1	M. Sand Coulee
	Sand Coulee			Lower	Wa0	E. Sand Coulee

between Schankler's *Haplomylus-Ectocion* Range-Zone and his *Bunophorus* Interval-Zone, as well as the boundary between middle and upper Graybullian. Faunal turnover at Biohorizon B involves the local extinction or emigration of thirteen species, three of which reappear in the Bighorn basin in the *Heptodon* Range-Zone. Biohorizon C separates Schankler's *Bunophorus* Interval-Zone from his *Heptodon* Range-Zone, thus correlating with the Graybullian-Lysitean boundary. It is characterized by a large and sustained immigration into the Bighorn basin of more than twenty new taxa. Schankler (op. cit.) suggests that Biohorizons A and B are related to changes in climate and ecology, while Biohorizon C, with little or no apparent extinction, may show the effects of a breakdown of some barrier to immigration.

In 1983, Gingerich presented a revised biostratigraphic zonation of the entire Paleocene and the early Eocene (i.e., Wasatchian) based on ten years of intensive fossil collecting by University of Michigan field crews in the Clark's Fork and Bighorn basins of northern Wyoming. While he recognizes the validity of Schankler's (1980) biohorizons, Gingerich's (1983) biostratigraphic scheme closely resembles Granger's (1914) original zonation but provides a new set of names for the subages of the Wasatchian and for the entire Paleocene. His seven biostratigraphic zones for the Wasatchian are based on first appearances of "principal" and "auxiliary taxa" and are numbered from Wa1 at the base (equivalent to the early Sandcoulean) to Wa7 (equivalent to the Lostcabinian). As Figure 14 clearly illustrates, the principal taxa whose first appearances define these zones are essentially the same as those used by Granger (1914) to define the Sand Coulee, Graybull, Lysite and Lost Cabin "beds". In 1989, Gingerich added an eighth subage at the base of the Wasatchian (Wa0) as a result of intensive

collecting at a series of localities in the Clark's Fork and Bighorn basins that yielded a set of more primitive taxa found in stratigraphically lower beds than typical Wa1. Gingerich (1989) suggests that dwarfing is present among nearly a third of the taxa represented at Wa0 localities. Taxa making their first appearance in the Wa0 are small species of typical Wasatchian forms such as *Cantius*, *Arfia*, *Prolimnocyon*, *Diacodexis*, and *Hyracotherium*. In later Wasatchian assemblages, these genera are represented by larger species. To date, the only other well-documented Wa0 fauna comes from Suzanne Strait's "Castle Gardens" locality in the central Bighorn basin (Strait, 2003).



CHAPTER V  
SYSTEMATIC PALEONTOLOGY

Class MAMMALIA Linnaeus, 1758

Subclass THERIA Parker and Haswell, 1880

Infraclass EUTHERIA Gill, 1872

Order PRIMATES Linnaeus, 1758

Suborder PLESIADAPIFORMES Simons and Tattersall, 1972

Superfamily PLESIADAPOIDEA Trouessart, 1879

Family PAROMOMYIDAE Simpson, 1940

Genus *PHENACOLEMUR* Matthew, 1915

*Phenacolemur* cf. *jepseni* Simpson, 1955

*Type.-* AMNH 48005, a skull with the associated mandible from the early Eocene Almagre facies of the San José formation, San Juan Basin, northwestern New Mexico.

*Age and Distribution.-* Late Paleocene through middle Eocene .

*Diagnosis.-* *Phenacolemur* possesses a lower dental formula of 1-0-1-3, a conspicuously large P<sub>4</sub>, and procumbent upper and lower incisors that are narrow in comparison to those of other mammals. Also present are robust cheek teeth, particularly notable in the protocones, and there is a tendency for the major cusps to become incorporated into the crests leading to them. There is extreme enlargement of the hypocone of M<sup>3</sup> in relation to those of M<sup>1</sup> and M<sup>2</sup> (Szalay and Delson, 1979)

*Referred Specimens.*- Virgin Hills: WMU-VP 402, 403, 404, 405, 406, 1547, 1548, 1590, 2646, 4520, 4540 (Figure 15).

*Discussion.*- All of the referred specimens were collected between 1995 and 1999.

Superfamily MICROSYOPOIDEA Osborn and Wortman, 1892

Family MICROSYOPIDAE Osborn and Wortman, 1892

Genus *MICROSYOPS* Leidy, 1872

*Microsyops latidens* Cope, 1882.

*Type.*- AMNH 4195, a right mandible with M1 and M2, and a left mandible with P4, from south of Otto, in the Bighorn basin, Wyoming.

*Age and Distribution.*- Lysite and equivalent (Wa6, Lysitean, Heptodon Interval-Zone) of the Bighorn, Wind River, and Great Divide Basins, Wyoming (Gunnell, 1989).

*Diagnosis.*- *M. latidens* is one of the best known and most common species in the Eocene of North America. Its form is variable between robust and gracile, and between large and small representatives of the species. All upper molars have characteristic bunodont morphology with angular, pointed paracone and metacone, and a broad-based, angular protocone. A very distinctive paraconule and metaconule is present near the base of the paracone and metacone, at the end of the buccal slope of the protocone. No parastyle or metastyle is present. A small variably occurring cingulum may be present around the protocone from the base of the paraconule to the base of the metaconule. Lower molars have variably broad talonids ranging from the width of the trigonid to slightly broader, with the cristid obliqua angled anterior-lingually to posterior-buccally.

*Referred Specimen.*- Virgin Hills: WMU-VP 347, 688, 770, 771, 810, 815, 828, 833, 834, 878, 893, 1061, 1062, 1088, 1104, 1143, 1145, 1183, 1300, 1468, 1569, 1575,

1576, 1577, 1578, 2315, 2316, 2556, 2557, 2558, 2559, 2561, 2562, 4559, 4589, 4591, 5695, 5787; TBE North: 657, 661, 664, 1388 (Figure 15).

*Discussion.*- The WMU-VP specimens were found during the 1995 through 1999, and 2001 field seasons. The majority of the specimens are well preserved.

Infraorder TARSIIFORMES Gregory, 1915

Family OMOMYIDAE Trouessart, 1879

Subfamily ANAPTOMORPHINAE Cope, 1883

Tribe ANAPTOMORPHINI Cope, 1883

Genus *ABSAROKIUS* Matthew, 1915

*Absarokius* sp.

*Type.*- ACM 3479, right P<sub>3</sub>-M<sub>3</sub> and right M<sup>2</sup>-M<sup>3</sup>; from Cottonwood Creek, Lysite Member of the Wind River Formation, Wind River basin, Wyoming.

*Age and Distribution.*- Known from middle and late Wasatchian (Wa5-Wa6) of the Wind River, Bighorn, Green River, and Great Divide Basins of southwestern Wyoming and from the Huerfano basin of Colorado.

*Diagnosis.*- These are isolated teeth and are therefore difficult to assign to a particular species. The dimensions of the Virgin Hills specimens fall within the range noted for *A. gazini*, *A. noctivagus*, *A. australis*, and *A. nocerae*, but are smaller than the published range for *A. abbottii* and *A. moetecus* (Bown and Rose, 1987). Crenulations are known from the talonids of *A. australis*, *A. witteri*, and *A. gazini*, and from both the upper and lower molars of *A. moetecus* and *A. nocerae*. Specimens of *A. australis*, *A. nocerae*, *A. witteri*, and *A. gazini* are known only from the late Wasatchian (Bown and Rose, 1987). Both teeth are well preserved with obvious crenulations in both the trigonid and

talonid of WMU-VP 2591, and on the protocone and the center of the trigon of WMU-VP 4561. WMU-VP 4561 exhibits no attachment between the postprotocrista and postcingulum, making it morphologically consistent with the genus *Absarokius*. The lower molar WMU-VP 2591 is morphologically consistent with *Absarokius*, when compared to casts of other specimens and to illustrations in the published literature on the genus. The Virgin Hills specimens do not easily fit the criteria for assignment to any of the above species.

*Referred Specimens.*- Virgin Hills: WMU-VP 4561, 2591 (Figure 14).

*Discussion.*- WMU-VP 2591 was collected in 1998 and is a left  $M_2$  measuring 2.04mm mesiodistally and 1.9mm buccolingually. WMU-VP 4561 was collected in 1999 and is a right  $M^2$  measuring 1.44mm mesiodistally and 3.44mm buccolingually. The  $M^2$ , though well preserved, has been broken transversely along the base of the paracone and metacone. The two halves are complete and do approximate perfectly so study of the overall morphology of this tooth is not compromised.

Tribe TROGOLEMURINI Szalay, 1976

Genus *ANEMORHYSIS* Gazin, 1958

*Anemorhysis* cf. *sublettensis* Gazin, 1958

*Type.*- USNM 19205, Left mandibular ramus with  $P_4$ - $M_2$  preserved from upper Wasatchian beds, Sublette County, Wyoming.

*Age and Distribution.*- Late-early through late Wasatchian- middle *Bunophorus* Interval Zone through the base of the lower *Heptodon* Range Zone of Schankler (1980), Bighorn and Great Divide Basins, Wyoming.

*Diagnosis.*- *A. sublettensis* is identifiable by its mesiodistally compressed, buccolingually broad  $P_4$  with a short but distinct cristid oblique, and its nearly straight postcristid noted on  $M_1$  and  $M_2$  (Bown and Rose, 1987).

*Referred Specimens.*- Virgin Hills: WMU-VP 694, 695, 2639, 4566 (Figure 14).

*Discussion.*- *Anemorhysis sublettensis* is the species upon which Gazin based his description of the genus. WMU-VP 4566 is a left mandible fragment preserving  $P_4$  through  $M_2$ . The teeth are well preserved with minimal to no wear.  $P_4$  measures 1.14mm mesiodistally and 1.14mm buccolingually,  $M_1$  measures 1.79mm mesiodistally and 1.30mm buccolingually,  $M_2$  measures 1.63mm mesiodistally and 1.47mm buccolingually. The other WMU specimens are isolated teeth.

Genus *ARAPAJOVIVUS* Savage, 1978

*Arapajovius* cf. *gazini* Savage, 1978

*Type.*- UCMP 100000, a right maxilla with  $P^3$  through  $M^3$  included alveoli for  $P^2$  and C. collected from the lowest portion of the upper third of the Main Body of the Wasatch Formation, mid-Wasatchian Age (early Eocene), Sweetwater County, Wyoming.

*Age and Distribution.*- Lysitean to early Lostcabinian of the Wind River Formation of Wyoming (Savage and Waters, 1978); Lysitean of the Wasatch Formation of the Great Divide basin, Wyoming.

*Diagnosis.*- The posterior premolars of *Arapajovius* are not enlarged relative to molars and all molars, premolars, and incisors exhibit strongly crenulated enamel on their occlusive surfaces. Hypocones are absent on all molariform upper teeth, while posterior

lower premolars are relatively molariform. May be differentiated from *Anemorhysis* by its larger size and more crenulated enamel (Savage and Waters, 1978).

*Referred Specimen.*- Virgin Hills: WMU-VP 1202 (Figure 14).

*Discussion.*- Found in 1996, this specimen is a left P<sup>4</sup> exhibiting very heavy crenulations throughout the occlusive surface. It measures 1.63mm mesiodistally and 2.78mm buccolingually.

Subfamily OMOMYINAE Trouessart, 1879

Tribe OMOMYINI Trouessart, 1879

Genus *STEINIUS* Matthew, 1915

*Steinius vespertinus* Matthew, 1915

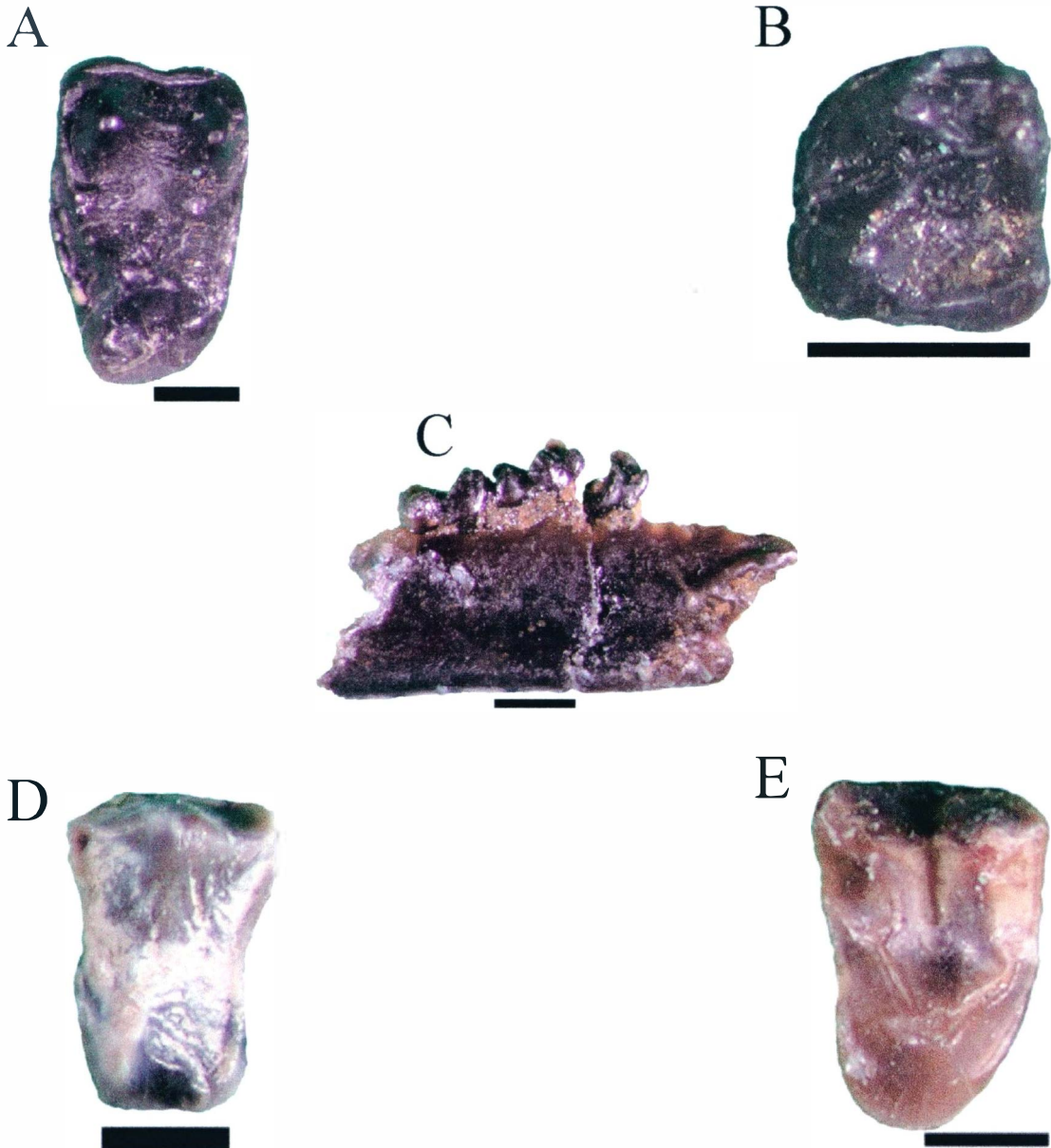
*Type.*- AMNH 16835, fragment of a left ramus with M<sub>1</sub> through M<sub>3</sub> from the Willwood Formation of the Bighorn basin, Wyoming.

*Age and Distribution.*- Willwood Formation, lower Eocene (late-early Wasatchian – lower and middle *Bunophorus* Interval Zone of Schankler (1980) of the Bighorn basin; lower Eocene of the Indian Meadows Formation; early Wasatchian Green River, Wind River, and Great Divide Basins, Wyoming.

*Diagnosis.*- *Steinius vespertinus* is the only known species of this genus.

*Referred Specimen.*- Virgin Hills: WMU-VP 2592 (Figure 14).

*Discussion.*- WMU-VP 2592 is an isolated right upper molar found in 1998. It measures 1.96mm mesiodistally and 2.45mm buccolingually. It was identified through comparison with casts in the WMU-VP collection and with other catalogued specimens at the University of Michigan Museum of Paleontology with the assistance of G. Gunnell.



All scales measure 1mm. A. *Absarokius* sp. LM/ WMU-VP 4561; B. *Absarokius* sp. L/M WMU-VP 2591; C. *Anemorhysis* L Mandible P/4-M/2 WMU-VP 4566; D. *Arapajovius* cf. *gazini* LP4/ WMU-VP 1202; E. *Steinius vespertinus* R M/ WMU-VP 2592.

Figure 14. Omomyid Primates.

Family ADAPIDAE Trouessart, 1879

Subfamily NOTHARCTINAE Trouessart, 1879

Genus *CANTIUS* Matthew, 1915

*Cantius abditus* Gingerich, 1977

*Type*.- UM 66000, right and left mandibles collected by G. Gunnell and B.H. Smith from Yale-Michigan locality 45, southwest of Red Butte, Big Horn County, Wyoming.

*Age and Distribution*.- Upper Wasatchian faunal interval, "Lysite" beds and equivalent, known from the Bighorn and Wind River basins of northwestern Wyoming, and the Fossil and Great Divide Basins of southwestern Wyoming.

*Diagnosis*.- *Cantius abditus* differs from *C. ralstoni*, *C. mckennai*, and *C. trigonodus* in being somewhat larger, having a stronger mesostyle, and a small hypocone. It differs from *C. frugivorus* in being larger, and having a less well-developed mesostyle and hypocone. It differs from *Pelycodus jarrovi* in being smaller and having a less well developed mesostyle and hypocone. It differs from *Copelemur feretutus* in the absence of an entoconid notch (Gingerich and Haskins 1981).

*Referred Specimens*.- TBE North: WMU-VP 215; Talus Slope: WMU-VP 305; Virgin Hills: WMU-VP 360, 361, 362, 364, 367, 370, 387, 768, 789, 814, 822, 856, 1092, 1100, 1102, 1146, 1190, 1194, 1298, 1581, 1582, 1583, 1585, 1586, 2319, 2320, 2321, 2322, 2353, 2360, 2362, 2363, 2459, 2585, 2586, 2588, 2589, 2590, 2598, 2637, 2638, 4531, 4532, 4567, 4568, 4571, 4574, 4575, 4577, 4578, 4582, 4586, 4590, 5699, 5750, 5751, 6792, 6793 (Figure 15).



*Discussion-* *Pelycodus jarrovi* was initially described by Cope in 1874 based on a mandible fragment preserving  $M_1$  and  $M_2$  found in the Wasatch of New Mexico. Confusion surrounded the identity of this species, because the original specimens were lost before the first comprehensive study of *Pelycodus* was done by Matthew and Granger (1915). They assigned a late Wasatchian neotype, in the absence of the original material. It was accepted for sixty years before it was noted (Gingerich and Simons, 1977) to actually represent different species, *Pelycodus* (now *Cantius*) *abditus*. Gingerich and Haskins (1981) reassigned the remaining *Pelycodus jarrovi* specimens from Wyoming to *Cantius venticolus*. The revision by Gingerich and Haskins (1981) returned five of the other *Pelycodus* species to the genus *Cantius*, and only allowed specimens of *P. jarrovi* to maintain the generic assignment of *Pelycodus*. This is due to the marked dissimilarity of this other material to the *Pelycodus jarrovii* type specimen from the San José Formation of New Mexico.

*Cantius* is believed to represent an older, less derived genus of early Eocene Adapidae. It is named for the Latin translation for Kent, the English county in which the genus was first discovered. Distribution of *Cantius* differs from that of other Eocene adapids in that it is the only taxon with a European and North American distribution (Gingerich and Haskins, 1981).

The specimens were collected from 1994-1999, 2001, and 2003. Upper molars are characterized by a prominent mesostyle and hypocone. The hypocone becomes less prominent from  $M^1$  to  $M^3$  in the upper dentition, and more prominent from  $M_1$  to  $M_3$  in the lower dentition. Lower molars exhibit an open trigonid on  $M_1$  and the paraconids and

metaconids become progressively more mesiodistally compressed on  $M_2$  and  $M_3$ . Genus

*COPELEMUR* Gazin, 1962

*Copelemur feretutus* Gingerich, 1977

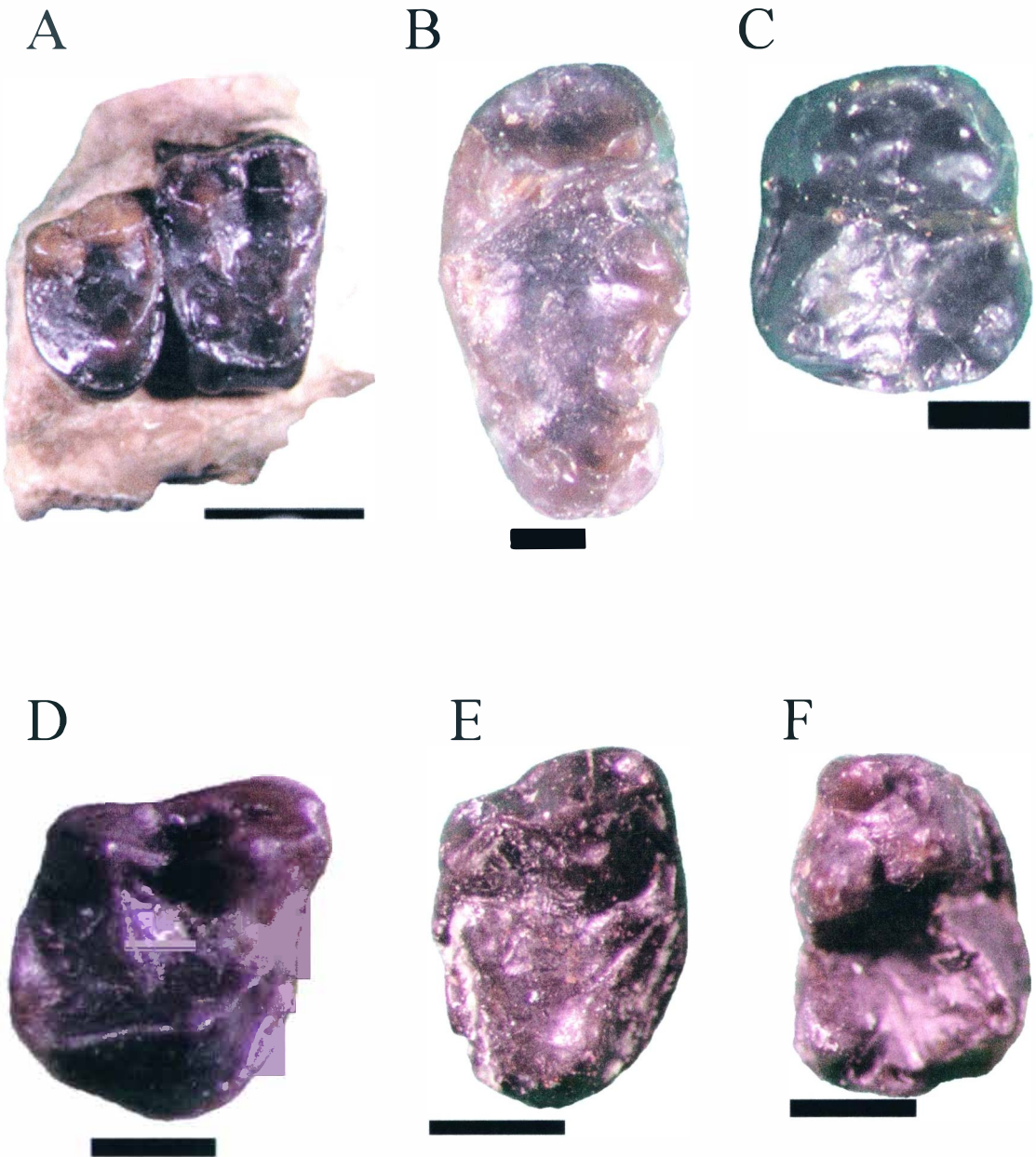
*Type.-* ACM 4326, an isolated right  $M_1$  from the Lysite member, Wind River Formation, Wind River basin, Wyoming.

*Age and Distribution.-* Upper Wasatchian faunal interval, Lysite beds and equivalent, Wind River and Bighorn Basins, northwestern Wyoming; Lysite beds, Great Divide basin, southwestern Wyoming;

*Referred Specimens.-* Virgin Hills: WMU-VP 6791, 1580 (Figure 15).

*Diagnosis.-* *Copelemur* differs from *Cantius* and other adapids in the presence of an entoconid notch in the talonid between the hypoconulid and entoconid in lower molars. In the trigonid of  $M_1$  the paraconid and metaconid are distinctly separated, while in  $M_2$  and  $M_3$  these cusps become mesiodistally compressed. This is the only species of *Copelemur* from the Lysite.

*Discussion.-* The specimens were collected in 1995 and 1998. WMU-VP 1580 is an  $M_2$  that is immeasurable due to the absence of the mesial portion of the trigonid. It does however retain the paraconid and metaconid, thus allowing for its identification. The majority of the talonid is intact, and the entoconid notch is well preserved. WMU-VP 6791 is an  $M_1$  in excellent condition and measures 3.59mm mesiodistally and 2.94mm buccolingually. The entoconid notch is well preserved in this specimen. It has an open trigonid, with the paraconid and metaconid distinctly separated.



All scales measure 1mm. A. *Cantius abditus* Right maxilla M 2-3/ WMU-VP 215; B. *Cantius abditus* Right M /3 WMU-VP 2590. C. *Copelemur feretutus* Left M/1 WMU6791; D. *Phenacolemur cf. jepseni* Right M/ WMU-VP 4540; E. *Microsyops latidens* Right M3/ WMU-VP 4572.

Figure 15. Primates and Plesiadapiformes.

Order CONDYLARTHRA Cope, 1882a

Family MENISCOTHERIDAE Cope, 1874

Genus *MENISCOTHERIUM* Cope, 1874

*Meniscotherium chamense* Cope, 1874

*Type.*- USNM 1093, right maxilla fragment with three molars from the San Juan basin, New Mexico.

*Age and Distribution.*- Common in late Paleocene through early Eocene (Wasatchian) of western North America (Wyoming, Colorado, New Mexico, California, USA; Baja California, Mexico).

*Diagnosis.*- *Meniscotherium chamense* is a small to medium sized condylarth with very derived lophodont-selodont cheek teeth. It is distinguishable from *Ectocion* by its more lophodont dentition (Williamson and Lucas, 1992). There is a prominent metastyle and parastyle, and a prominent paraconule and metaconule on each upper molar. The trigonid is open with a prominent paraconid, and the talonid has a prominent cristid obliqua that extends from the hypoconid to the metaconid on lower molars. The trigonid and talonid are of nearly equal height and width (Williamson and Lucas, 1992).

*Referred Specimens.*- WMU-VP 302, 303, 374, 375, 376, 377, 378, 384, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 595, 851, 1212, 1213, 1214, 1215, 1216, 1217, 1218, 1219, 1469, 1470, 1491, 1551, 1552, 1553, 1554, 1555, 1556, 1557, 2356, 2357, 2358, 2359, 2430, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 4529, 4530, 4533, 4534, 4588, 5753, 5754, 5755, 5756, 5757, 5758, 5759 (Figure 16).

*Discussion.*- The WMU-VP specimens were found at the Virgin Hills, Tipton Saddle, NE Ridge, TBE North, Talus Slope, and Mertle Beach localities during all field seasons since 1994.

*Meniscotherium* was initially described by Cope in 1874, and has had several species assigned to it since that time (*M. chamense* Cope, 1874; *M. terraerubrae* Cope, 1881b; *M. tapiacitus* Cope, 1884; *M. priscum* Granger, 1915; *M. semicingulatum* Russell, 1929; *M. robustum* Thorpe, 1934. Gazin (1965) revised the genus and reduced it to three valid species, *M. chamense*, *M. tapiacitus* and *M. robustum*, based upon dissimilarities in the dental robusticity of *M. chamense* and *M. tapiacitus*, and on the cranial and postcranial size differences of *M. chamense* and *M. robustum*. Gazin (op. cit.) questioned the validity of *M. semicingulatum* because it was based solely on one deciduous P<sup>4</sup>. Williamson and Lucas (1992) again revised the genus, basing their changes on a cladistic analysis of 52 characters. It revealed the presence of only two actual species differentiated predominantly by size. It placed *M. terraerubrae* and *M. robustum* within *M. chamense*, and *M. priscum* within *M. tapiacitus*. Williamson and Lucas also noted that "*M. tapiacitus*" was misspelled and the correct species name applied by Cope (1882) was *M. tapiacitum*. *M. chamense* and *M. tapiacitum* are the currently accepted species of this genus.

Family PHENACODONTIDAE Cope, 1881

Genus *PHENACODUS* Cope, 1873a

*Phenacodus vortmani* Cope, 1880

*Type.*- AMNH 4824, a left mandible with P4 and partial M1, the roots for P3, and the alveoli for P1-2, from Lost Cabin Beds, Alkali Creek, Wind River basin

*Age and Distribution.*- Late-middle Paleocene Tiffanian *Pleasiadapis churchili*/  
*P. simonsi* Lineage zone through Bridgerian *Palaeosyops* Zone of the Powder River,  
Bighorn, Green River, Wind River, Green River, Fossil, Great Divide, Washakie, Sand  
Wash, Laramie, Shirley, Piceance, Huerfano, and San Juan Basins (Thewissen, 1990).

*Diagnosis.*- *P. vortmani* is smaller than other Wasatchian *Phenacodus*. It has a  
narrower  $M_2$  and  $M_3$ , and  $M_2$  is shorter in relation to those of other species (Thewissen,  
1990).

*Referred Specimens.*- Virgin Hills: WMU-VP 2184, 5749 (Figure 16).

*Discussion.*- The WMU specimens were found in 1995 and 2001. WMU-VP 2184  
is a left lower molar measuring 6.54mm mesiodistally and 8.02mm buccolingually.  
WMU –VP 5749 is a right P4 measuring 2.94mm mesiodistally and 6.21mm  
buccolingually.

#### Family HYOPSODONTIDAE Lydekker, 1889

##### Genus *HYOPSODUS* Leidy, 1870

##### *Hyopsodus paulus* Leidy, 1870

*Type.*- USNM 1176, right mandible preserving P<sub>4</sub> through M<sub>3</sub> from Smith's Fork,  
near Fort Bridger, Bridger Formation, Bridger basin, Wyoming.

*Age and Distribution.*- Earliest Wasatchian through middle Bridgerian of western  
North America; very well represented in the Wasatchian of the Bighorn, Green River,  
and Great Divide basins.

*Diagnosis.*- Length of second lower molar between 3.7mm and 4.8mm; always  
smaller than *H. powellianus* and *H. mentalis*, and always larger than *H. minisculus*, *H.*  
*minor*, and *H. loomisi*. Other than size, this species can be differentiated from *H.*

*powellianus* by its greater P3 bucco-lingual width than anterior-posterior length. It differs from *H. minor* and *H. powellianus* in having a developed entoconid on P4. Molars are more lophodont and have more gracile cusps than other species. The parastyle is most distinct in *H. paulus* (Redline, 1997).

*Referred Specimens.*- A total of 715 *Hyopsodus* specimens have been recovered from the Tipton Buttes localities, 693 of which were recovered at Virgin Hills.

*Discussion.*- *Hyopsodus* is by far the most common taxon from Tipton Buttes, with 716 specimens found there since the area was first collected in 1994. In his revision of the genus, Redline (1997) explains that *Hyopsodus paulus* encompasses most specimens previously assigned to *H. miticulus* (as described by Gazin, 1968), *H. mentalis* Cope, 1875, *H. simplex* Loomis, 1905, *H. wortmani* Osborn, 1902, and *H. latidens* Denison, 1937.

#### *Hyopsodus powellianus* Cope, 1884

*Type.*- AMNH 4147, right mandible fragment with M<sub>1</sub> through M<sub>3</sub> collected from the Willwood Formation, Bighorn basin, Wyoming.

*Age and Distribution.*- Lysitean of the Buffalo basin, Wyoming; Lysitean through Lostcabinian of the Bighorn basin, Wyoming; Lysitean through earliest Bridgerian of the Wind River basin, Wyoming; Lysitean of the Great Divide basin, Wyoming; Late Graybullian through earliest Lysitean of the Piceance basin, Colorado (Redline, 1997).

*Diagnosis.*- Larger than other species of *Hyopsodus*. The length of P<sup>3</sup> either approaches or exceeds the width and the crown is more triangular than in other species. Differs from *H. paulus* in that its M<sup>3</sup> hypocingulum is more strongly developed and flares posteriorly. The M<sub>1</sub> and M<sub>2</sub> hypoconulids are larger than those found in other species of

*Hyopsodus*. This species of *Hyopsodus* differs from all others in having large conical cusps on all molars (Redline, 1997).

*Referred Specimens*.- A total of 715 *Hyopsodus* specimens have been recovered from the Tipton Buttes localities, 693 of which were recovered at Virgin Hills (Figure 16).

*Discussion*.- This species is much less common than *H. minor* in the Tipton Buttes area of the Great Divide basin.

*Hyopsodus minor* Loomis, 1905

*Type*.- ACM 3492, right mandible fragment with M<sub>1</sub> through M<sub>3</sub> collected from Lysite Beds, Wind River basin, Wyoming.

*Age and Distribution*.- Late Graybullian through Lysitean of the Bighorn basin, Wyoming; ?late Graybullian through ?early Lysitean of the Piceance basin, Colorado, and the San Juan basin, New Mexico; ?early Lysitean through ?early Lost Cabinian of the Wind River basin, Wyoming; Lysitean of the Great Divide basin, Wyoming.

*Diagnosis*.- *H. minor* is very small in size in comparison with all other *Hyopsodus*. The anterior cingulids of its lower molars are weaker than those of other species. The M<sub>1-3</sub> paraconids are variably present, but much less common than in other species of *Hyopsodus* (Redline, 1997).

*Referred Specimens*.- A total of 715 *Hyopsodus* specimens have been recovered from the Tipton Buttes localities, 693 of which were recovered at Virgin Hills.

*Discussion*.- With the exception of the Lysite Member of the Wind River basin, *H. minor* is documented as being a fairly common constituent of Lysitean faunas in the Bighorn basin of Wyoming the San Juan basin of New Mexico, and the Piceance basin



of Colorado (Redline, 1997). This research shows it to be quite common in the Great Divide basin as well.

Genus *HAPLOMYLUS* Matthew, 1915

*Haplomylus speirianus* Cope, 1880

*Type.*- AMNH 4190, lower mandible with M<sub>1</sub> through M<sub>3</sub> from the lower Wasatch of the Bighorn basin.

*Age and Distribution.*- Late Paleocene through Early Eocene (Wasatchian) of the Bighorn and Great Divide basins, Wyoming. "Lysite and Lost Cabin beds of the Wind River Valley" (Matthew and Granger, 1915).

*Diagnosis.*- Matthew and Granger's revision of the taxon was based upon the differences in the upper molars, with those of *Haplomylus* being more obliquely set than those of *Hyopsodus*. Their distinction between *Haplomylus* and *Microsyops* involves the configuration of the molar cusps of *Haplomylus* and its compressed premolars (Matthew and Granger, 1915).

*Referred Specimens.*- Virgin Hills: WMU-VP 410, 692, 693, 1671, 2552, 2560, 4560, 6795 Figure 16).

*Discussion.*- This taxon was initially described by Cope (1880), when he assigned it to the genus *Hyopsodus*, and later referred it to the plesiadapid genus *Microsyops* (Cope, 1885). Osborn (1902) reaffirmed its classification to the genus *Microsyops*. Matthew (1915) reassigned the species to the new genus *Haplomylus*.

Genus *APHELISCUS* Cope, 1875c

*Apheliscus* sp. Cope, 1875c

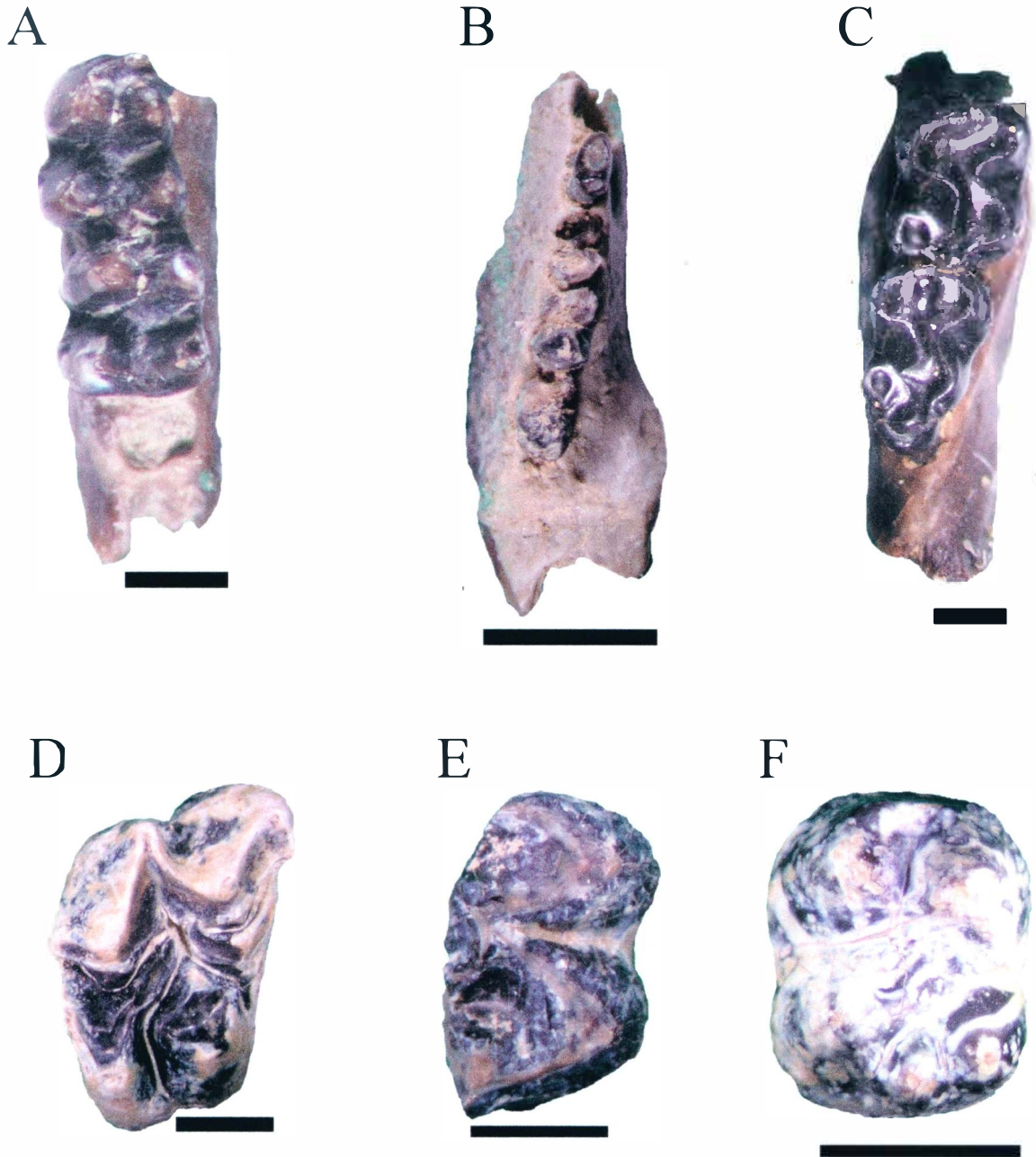
*Type.*- USNM collections – missing. Type is described as a dentary with P<sub>4</sub> through M<sub>3</sub> intact.

*Age and Distribution.*- Late Paleocene through early Wasatchian. Occurring in the “upper Gray Bull” of the Willwood Formation of northwestern Wyoming (McKenna, 1960). Occurs in the Lysitean of the Great Divide basin.

*Diagnosis.*- Trigonids of *Apheliscus* are typically hypsodont in structure, mesiodistally compressed, and without paraconids. There is an anteriorly looping ridge from the protoconid to the metaconid, and there is usually a strong anterior cingulum on the lower molars. Mental foramina are located at the base of P<sub>1</sub> and P<sub>3</sub> on each dentary (McKenna, 1960). Upper molars are identifiable by a strong parastyle, and a strong labial cingulum extending from the protocone to the parastyle, then distally to the metacone. There is no metastyle and the paracone is much more prominent than the metacone (McKenna, 1960).

*Referred Specimens.*- Virgin Hills: WMU-VP1233 (Figure 16).

*Discussion.*- WMU-VP 1233 is a right mandible with P<sub>4</sub> preserved and only the roots of M<sub>1</sub> and M<sub>2</sub>. The occlusal surface of M<sub>3</sub> is broken off. The only defining features on this specimen are the presence of mental foramina beneath and behind P<sub>3</sub>. The portion of the dentary mesial to P<sub>4</sub> is missing, thus the mental foramen is not preserved in this specimen. The identification of this specimen was made through comparison with WMU-VP 205, a right mandible from a Clarkforkian locality in the Great Divide basin. Very little has been published on this genus



All scales measure 5mm with the exception of A and C, which measure 1mm. A. *Haplomylus speirianus* Right Mandible P/4-M/1 WMU-VP 410; B. *Apheliscus* sp. Right Mandible P/4-M/3 WMU-VP 1233; C. *Hyopsodus powellianus*, Right Mandible M /2-3, WMU-VP 2216. D. *Meniscotherium chamense* R M/ WMU-VP 5754; *Meniscotherium chamense* R /M WMU-VP 390; F. *Phenacodus vortmani* L /M WMU-VP 2184.

Figure 16. Condylarthra.

Order PERISSODACTYLA Cope, 1882a

Family EQUIDAE Gray 1821

Genus *HYRACOTHERIUM* Owen, 1821

*Hyracotherium vassaciense* Cope, 1872

*Type.*- AMNH 4680, an M<sub>2</sub> from the Wasatch formation, Wyoming.

*Age and Distribution.*- Wasatch, Wyoming; Largo, New Mexico; Lysite, Wyoming; Lysite equivalent of Willwood Wyoming; Hiawatha, Wyoming; Huerfano, Colorado; DeBeque, Colorado; Big Bend, Texas; Lost Cabin, Wyoming (Kitts, 1956).

*Diagnosis.*- Medium to small in size, *H. vassaciense* has a P<sup>3</sup> with an anteriorly located paraconule, a simple and triangular P<sup>4</sup>. M<sup>1</sup>-M<sup>3</sup> all have conspicuous paraconules and metaconules. There is a prominent cingulum from the protocone buccally to the paracone, then distally to the metacone and lingually to the hypocone. As with other species of *Hyracotherium*, the paraconid is absent on all lower molars and the talonid of M<sub>3</sub> is elongated with a large rounded hypoconulid (Kitts, 1956).

*Referred Specimens.*- Virgin Hills: WMU-VP 379, 380, 381, 382, 385, 386, 407, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 594, 656, 747, 766, 767, 890, 901, 1058, 1059, 1101, 1193, 1204, 1205, 1206, 1207, 1208, 1209, 1210, 1211, 1235, 1294, 1295, 1296, 1516, 1517, 1558, 1559, 1561, 1562, 1563, 1564, 1565, 1566, 1567, 1568, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2645, 4405, 4406, 4407, 4408, 4409, 4410, 4411, 4412, 4413, 4570, 4573, 4585, 4587, 5788, 5789, 6797. NE Ridge: WMU-VP 247, 248, 250, 251, 254, 255, 270, 272, 607, 1490,

1976, 2000. TBE North: WMU-VP 649, 662, 663, 684, 685, 696, 1394, 2432, 2657, 2658, 2659. Mertle Beach: WMU-VP 279, 300, 301, 304 (Figure 17).

*Discussion.*- All specimens collected from all Tipton Buttes localities were identified through comparison with casts of the type and other specimens.

Family ISECTOLOPHIDAE Peterson, 1919

Genus *HOMOGALAX* Hay, 1899

*Homogalax protapirinus* Wortman, 1896

*Type.*- AMNH 4460, a right maxilla with left and right dentaries from Bighorn Valley, Wyoming.

*Age and Distribution.*- Middle to early-late Wasatchian localities in the Bighorn and Clarks Fork basin, northwestern Wyoming; Great Divide basin, southwestern Wyoming.

*Diagnosis.*- *Homogalax* has very lophodont molars. Upper premolar and molar crowns are broader transversely than mesiodistally. *H. protapirinus* differs from other species of *Homogalax* in having 8-12% greater linear dental dimensions and in having relatively broader lower molars. Differs from both species of *Cardiolophus* in having larger premolars.

*Referred Specimens.*- NE Ridge: WMU-VP 246 (Figure 17).

*Discussion.*- WMU-VP 246 is a right upper molar preserving the complete occlusal surface with very little wear. It has a trapezoidal outline as is characteristic of *Homogalax* and heavy lophs projecting mesiobuccally from both the protocone to the parastyle and from the hypocone to the crest connecting the paracone and metacone. This specimen measures 10.47mm mesiodistally and 12.59mm buccolingually.

Specimens of *Homogalax* were initially assigned to the genus *Systemodon* (Cope, 1885) and included three species, *S. semihans*, *S. protapirinus*, and *S. primaevus*.

Order ARTIODACTYLA Linnaeus, 1758

Family DICHOBUNIDAE Sinclair, 1914

Genus *DIACODEXIS* Cope, 1882b

*Diacodexis secans* Cope, 1881

*Type.*- AMNH 4899, left and right P<sub>4</sub>-M<sub>3</sub>, from the Wind River formation, Wind River basin, Wyoming.

*Age and Distribution.*- Earliest Wasatchian through middle Bridgerian of Wyoming and Colorado.

*Diagnosis.*- Dentition of *D. secans* is larger than that of all other penecontemporaneous species, with more inflated molar protocones, metaconids, and hypoconids. Has a less medial, less reduced paraconid on M<sub>1</sub> through M<sub>3</sub>, and more nearly square M<sub>1</sub> and M<sub>2</sub> compared to those of *D. gracilus*. M<sub>1</sub> through M<sub>3</sub> talonids are more bunodont than in *D. minutus*, and the metaconids are less inflated in relation to tooth size than those of *D. woltonensis* (Krishtalka and Stucky, 1985).

*Referred Specimens.*- Virgin Hills: WMU-VP 365, 366, 368, 422, 423, 572, 790, 796, 798, 827, 829, 830, 831, 906, 907, 908, 1093, 1904, 1199, 1523, 1574, 1592, 1593, 1672, 1673, 2304, 2554, 2555, 2652, 4558, 4569, 4623, 5693, 5786, 6790 (Figure 17).

*Discussion.*- *D. secans* is the oldest known species of artiodactyl in North America and its first appearance, along with that of *Hyracotherium*, Euprimates, and hyaenodontid creodonts signals the beginning of the Wasatchian (Krishtalka and Stucky, 1985).

These specimens were identified through comparison with casts in the WMU collection of the type and other specimens.

Order TILLODONTIA Marsh, 1875

Family ESTHONYCHIDAE Cope, 1883

Genus *ESTHONYX* Cope, 1874

*Esthonyx bisulcatus* Cope, 1874

*Type.*- USNM 1103, a left mandible with P<sub>3</sub> and M<sub>1</sub> through M<sub>3</sub> from Arroyo Blanco, San Juan basin, New Mexico.

*Age and Distribution.*- Lysitean and Lostcabinian of the early Eocene, *E. bisulcatus* is known from the Big Horn, Wind River, and Great Divide basins of Wyoming.

*Diagnosis.*- A distinct open trigonid on the molariform P<sub>4</sub> and the open and deeply basined talonids distinguish *E. bisulcatus* from early Wasatchian *E. spatularis*.

*Referred Specimens.*- Virgin Hills: WMU-VP 333 (Figure 17).

*Discussion.*- WMU-VP 333 is a well preserved right M<sub>3</sub> found in 1995. It measures 11.45mm mesiodistally and 6.54mm buccolingually.

Order PANTODONTA Cope, 1873b

Family CORYPHODONTIDAE Marsh, 1876

Genus *CORYPHODON* Owen, 1845

*Coryphodon* sp. Owen, 1845

*Age and Distribution.*- Paleocene through late Eocene of western North America, Paleocene through latest Eocene in Europe.

*Diagnosis.*- *Coryphodon* was the largest land-mammal of the North American Early Eocene and its dentition is, therefore, easily differentiated from that of other taxa.

*Referred Specimen.*- End of the World: WMU-VP 245, Talus Slope: WMU-VP 319.

*Discussion.*- WMU-VP 245 is a group of dental enamel specimens that were found in association at the End of the World locality in 1994. Each of the fragments exhibits very thick enamel and dentin. Large cingula are evident on several of the fragments. WMU-VP 319 is a distal tibia that was found in two pieces at the Talus Slope locality in 1994.

Order CARNIVORA Bowdich, 1821

Family MIACIDAE Cope, 1880

Genus *MIACIS* Cope, 1872

*Miacis* sp. Cope, 1872

*Type.*- AMNH 15176, right and left maxillae from Graybullian beds at Lower Forks, Dorsey Creek, Wyoming. The right preserves P<sup>4</sup> through M<sup>2</sup>. The left preserves P<sup>3</sup> through M<sup>1</sup>.

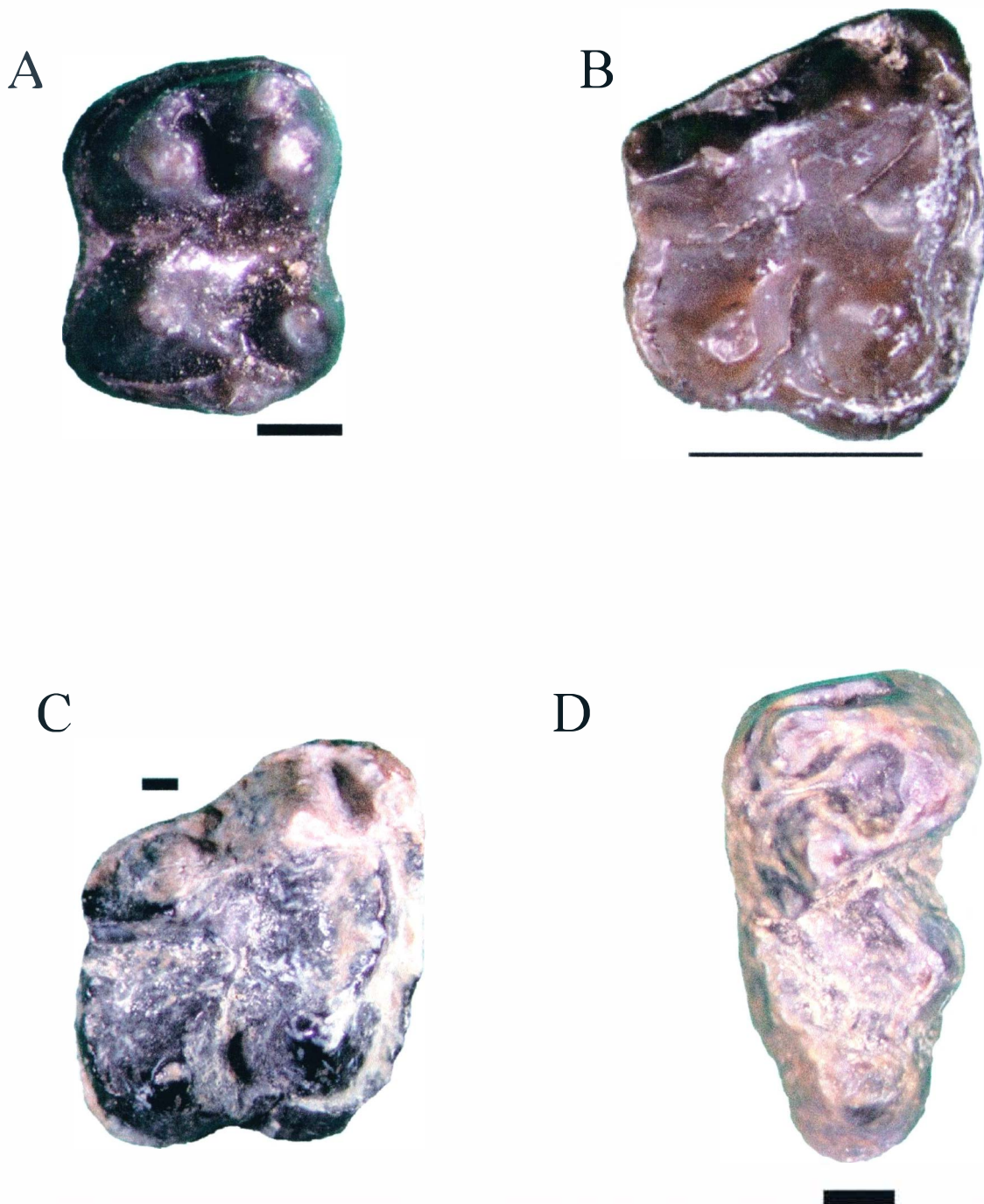
*Age and Distribution.*- Early Wasatchian through Duchesnean land-mammal ages (early through late Eocene) in North America.

*Diagnosis.*- The carnassials and premolars of *Miacis* are moderate to large; M<sup>1</sup> in earlier forms has a small hypocone; M<sup>3</sup> is vestigial or absent in some species.

*Referred Specimen.*- Virgin Hills: WMU-VP 6788

*Discussion.*- The referred specimen is an isolated left M<sup>3</sup>. Its cusps are relatively worn and the mesiobuccal corner of the tooth is broken off. It was found at Virgin Hills





All scales measure 1mm with the exception of C, which measures 5mm. A. *Diacodexis secans* Left lower molar, WMU-VP 752; B. *Hyracotherium vassaciense* Right M /3, WMU-VP 6797; C. *Homogalax protapirinus* Right M/, WMU-VP 246; D. *Esthonyx bisulcatus* Right M /3, WMU-VP 333.

Figure 17. Ungulates.

in 1996. Its measurements are 2.61mm mesiodistally and 4.77mm buccolingually. It was identified to genus through comparison with casts from the WMU collection of the type and other specimens.

Genus *DIDYMICTIS* Cope, 1875

*Didymictis* sp. Cope, 1875

*Type.- D. protenus* Cope, 1874, from the Wasatch of New Mexico (Matthew and Granger, 1915).

*Age and Distribution.-* Clark Fork through Lysite beds in the Bighorn basin; has been reported from the Powder River basin, Bitter Creek - "west of Elk Mountain" (Gazin, 1962), Sand Butte, and Dad (Gazin, 1965), the Wind River Lysite Member, Four Mile, the Laramie basin (Bown, 1979).

*Diagnosis.- Didymictis* is difficult to identify to species with isolated teeth, and is still problematic with specimens preserving several teeth because of the very similar morphology of the  $M_1$  and  $M_2$  and considerable overlap in their dimensions.

*Referred Specimen.-* Virgin Hills: WMU-VP 2351.

*Discussion.-* WMU-VP 2351 is a right lower molariform tooth that is nearly identical to the cast specimen AMNH 4251. The talonid is completely intact, but part of the trigonid is missing (the paraconid and the mesial half of the protoconid). The enamel of the tooth is very worn. It was found at the Virgin Hills locality in 1997.

Family VIVERRAVIDAE Cope, 1880

Genus *VIVERRAVUS* Marsh, 1872

*Viverravus* sp.

*Type species.*- *V. gracilis* Marsh, 1872

*Age and Distribution.*- Lost Cabin and Lysite Beds in the Big Horn basin (Matthew and Granger, 1915), Lysitean of the Great Divide basin.

*Diagnosis.*- Premolars high, short compressed, similar to those of the Miacinae; there is a small posterior accessory cusp on P<sub>4</sub> (Matthew and Granger, 1915).

*Referred Specimen.*- NE Ridge: WMU-VP 683; Virgin Hills: 687, 2317.

*Discussion.*- WMU-VP 683 is a left lower M<sub>2</sub> found at the NE Ridge locality, retaining the protoconid, metaconid, and the complete talonid with very little wear. The paraconid is missing. In all features with this exception the tooth is in good condition.

WMU-VP 687 and 2317 are both lower molar trigonids, with all trigonid cusps well preserved, but the talonids for both specimens are lost. Both were found at the Virgin Hills locality.

Order CREODONTA Cope, 1875

Family HYAENADONTIDAE Leidy, 1869

Genus *PROTOTOMUS* Cope, 1874

*Prototomus* sp. Cope, 1874

*Type.*- Indeterminate; type specimen lost (Gingerich and Deutsch, 1989).

*Age and Distribution.*- Wasatchian, early Eocene, of western North America.

*Diagnosis.*- The M<sub>3</sub> is reduced to some degree in every species of this genus (McKenna, 1960). The species of this genus are so similar that the only defining factor

between them is their overall size and pattern of change (Gingerich and Deutsch, 1989).

*Prototomus* differs from other North American creodonts and carnivores because of its mesiodistally compressed protoconid and paraconid, resulting in a closed, broad trigonid.

Each lower molar has a sectorial talonid (Gingerich and Deutsch, 1989).

*Referred Specimens.*- TBE North: WMU-VP 653, 658; Virgin Hills: 1243, 2313, 2314, 4403, 4592, 6794.

*Discussion.*- *Prototomus* was the first early Eocene hyaenadontid Creodont described from North America. The specimens WMU-VP 653 and 658 were found in 1995 at the TBE North Locality. Each is a well-preserved M<sub>2</sub>. WMU-VP 1243, 2313, 2314, 4403, 4592, and 6794 were found at Virgin Hills in 1995, 1997, and 1999. All are lower molars with well-preserved trigonids and talonids.

Order PANTOLESTA Cope, 1880

Family PANTOLESTIDAE Cope, 1884

Genus PALEOSINOPA Matthew, 1901

*Paleosinopa* sp. Matthew, 1901

*Type.*- UM 69722 , a partial skull and mandible from the lower part of the Willwood formation, Park County, Wyoming.

*Age and Distribution.*- Sandcoulean and Gray Bull beds in the Big Horn basin; Lysitean of the Great Divide basin. Lower Gray Bull through Lysite in Bighorn basin, Washakie, Powder River, and Great Divide Basins, Wyoming; Lost Cabin Member of the Wind River Formation, Wind River basin, Wyoming, and San José Formation, New Mexico.

*Diagnosis.*- Intermediate in tooth size for penecontemporaneous species.  $M^3$  narrows mesiodistally in comparison to  $M^1$  and  $M^2$ . Strong cingulum present around the protocone of all upper molars. Broad based protocone with conical paracone and metacone.

*Referred Specimen.*- Virgin Hills: WMU-VP 4400.

*Discussion.*- WMU-VP 4400 is a right  $M3$  found in 1999. It is fairly worn but the features distinguishing the tooth are still present. Its measurements are 3.43mm mesiodistally and 6.87mm buccolingually. This tooth was identified by comparison to casts in the WMU-VP collection.

Order LIPOTYPHLA Haeckel, 1866

Family AMPHILEMURIDAE Hill, 1953

Genus *MACROCRANION* Weitzel, 1949

*Macrocranium* cf. *nitens* Matthew, 1918

*Type.*- UW 9641, an isolated  $M^1$  from the McNeil quarry of the Willwood formation, Early Eocene, Wyoming. (Bown, 1979)

*Age and Distribution.*- Early Wasatchian – Lower Gray Bull zone through Upper Lysite zone (Bown and Schankler, 1982) Willwood Formation of the central Bighorn basin; Wasatch Formation of the Great Divide basin.

*Diagnosis.*- Strong protocone and prominent hypocone off crista between protocone and metacone. Metacone and paracone are distinctly separated. Small parastyle and metastyle (Krishtalka, 1976).

*Referred Specimens.*- Virgin Hills: WMU-VP 344 (Figure 18).

*Discussion.*- Found in 1995, WMU-VP 344 is a left upper molar with very little wear, but missing the paracone and parastyle. Its measurements are 1.47mm mesiodistally and 2.12mm buccolingually. With the exception of the features mentioned above this tooth is well preserved, and was identified through comparison with a cast of CU 58782, a *Macrocranium* right upper molar.

Order RODENTIA Bowdich, 1821

Family ISCHYROMYIDAE Alston, 1876

Genus *PARAMYS* Leidy, 1871

*Paramys* sp. Loomis, 1907

*Type.*- ACM 327, a right mandible with M<sub>1</sub> through M<sub>3</sub> and partial P<sub>4</sub> from the Lost Cabin Member of the Wind River Formation.

*Age and Distribution.*- Early Eocene (Clarkforkian through Gardnerbuttean) - Lysite Member, Wind River, Willwood, and Wasatch Formation, Wyoming; DeBeque Formation, Colorado; San José Formation, New Mexico.

*Diagnosis.*- Lacks hypocone on P<sub>4</sub>; M<sub>2</sub> is longer than M<sub>1</sub> buccolingually; entoconid is continuous with the posterior lophid on lower cheek teeth (Korth, 1984, 1994).

*Referred Specimens.*- Virgin Hills: WMU-VP 902, 1095, 1155, 1156, 1157, 1161, 1307, 1312, 1457, 1520, 2604, 2609, 2610, 2613, 4527, 4535, 4537, 4543, 4549, 5707, 6773, 7149 (Figure 18).

*Discussion.*- All specimens were collected from Virgin Hills since 1995. They are all isolated teeth or mandibular fragments retaining partial dentition. All were identified

through comparison with casts of the type and other specimens in the WMU-VP collection.

Genus *NOTOPARAMYS* Wood, 1962

*Notoparamys* sp. Wood, 1962

*Type.*- AMNH 55111, a crushed skull with left and right P<sup>4</sup> through M<sup>3</sup> from the lower Huerfano Formation in Colorado.

*Age and Distribution.*- Early Eocene of Colorado, Wyoming, and New Mexico; Lysitean of the Great Divide basin, Wyoming.

*Diagnosis.*- Differs from contemporaneous species by the unique double attachment of the hypoconulid to the entoconid on lower molars; a deep groove between the hypocone and protocone of M<sup>1</sup> and M<sup>2</sup>. The fine crenulations noted in the basin of the cheek teeth of *Thisbemys* are absent in those of *Notoparamys* (Korth, 1984, 1994).

*Referred Specimens.*- Virgin Hills: WMU-VP 228, 733, 832, 1144, 1246, 1247, 1248, 1249, 1250, 1251, 1252, 1253, 1254, 1255, 1256, 1257, 1258, 1259, 1260, 1261, 1262, 1263, 1264, 1265, 1266, 1267, 1268, 1269, 1270, 1271, 1272, 1273, 2607, 2625, 4551, 4552, 4553, 4635, 4651, 5772, 6767, 6768, 6769, 6770, 6771, 6772, 7145, 7146, 7151; TBE North: WMU-VP 228, 1393; NE Ridge: WMU-VP 1481, 1482.

*Discussion.*- All referred specimens are isolated teeth or mandibular fragments, and were identified through comparison with casts of the type and other specimens in the WMU-VP collection and with the assistance of W. Korth.

Genus *MICROPARAMYS* Wood, 1959

*Microparamys* sp. Wood, 1959

*Type species.*- *Microparamys minutus* Wilson, 1937

*Age and Distribution.*- Middle to late-early Eocene (Lysitean to Lostcabinian); Lysite of the Great Divide basin.

*Diagnosis.*- Upper molars symmetrical with prominent protocone; two lophs from protocone to paracone and metacone; cingulum from protocone to paracone and from protocone to metacone on the mesial and distal edges of the tooth. Lower molars with very compressed talonids, with no distinction between paraconid and metaconid (Korth, 1984, 1994).

*Referred Specimens.*- Virgin Hills: WMU-VP 1167, 1170, 1171, 1172, 1173, 1174, 1175, 1176, 1177, 1178, 2624, 4536, 4548, 4554, 4555, 4564, 5769 (Figure 18).

*Discussion.*- All referred specimens identified through comparison with casts of the type and other specimens in the WMU-VP collection and with the assistance of W. Korth.

Genus *FRANIMYS* Wood, 1962

*Franimys* sp. Wood, 1962

*Type.*- ACM 10524, a skull with the right P<sup>4</sup> and M<sup>2</sup>-M<sup>3</sup>, edentulous mandible, and several postcranial elements from the Willwood Formation, Wyoming.

*Age and Distribution.*- Early Eocene of Wyoming and New Mexico

*Diagnosis.*- P<sup>4</sup> small, narrow, and oval in occlusal outline, without a hypocone; hypocone on upper molars small (Korth, 1984, 1994).

*Referred Specimens.*- WMU-VP 1305, 1308, 1519, 1674 (Figure 18).

*Discussion.*- All referred specimens were collected from Virgin Hills, and were identified through comparison with casts of the type and other specimens in the WMU-VP collection and with the assistance of W. Korth.



Genus *THISBEMYS* Wood, 1962*Thisbemys* sp. Wood, 1962

*Type species.* - *Thisbemys corrugatus* Wood, 1959a

*Age and Distribution.* - Middle early Eocene (Lysitean).

*Diagnosis.* -  $P^4$  is roughly square in occlusal outline; anterior and posterior cingula extend the length of the upper molars; metaconule is large-approaching the size of the metacone;  $M^1$  and  $M^2$  are nearly identical, and  $M^3$  is very similar to  $M^2$  in morphology with a reduced hypocone and metacone. Crenulations noted in the molar basins (Korth, 1984, 1994).

*Referred Specimens.* - WMU-VP 1159, 1160, 1168, 1169, 2673, 4538 (Figure 18).

*Discussion.* - All referred specimens were collected from Virgin Hills, and were identified through comparison with casts of the type and other specimens in the WMU-VP collection and with the assistance of W. Korth.

Genus *REITHROPARAMYS* Matthew, 1920*Reithroparamys* sp. Matthew, 1920

*Type species.* - *Reithroparamys delicatissimus* Leidy, 1871

*Age and Distribution.* - Early Eocene Graybullian to later-early Eocene; Lysite in the Great Divide basin.

*Diagnosis.* - Presence of a partial hypolophid and isolation of the entoconid on the lower molars; relatively large hypocone on upper molars; submolariform  $P^4$  with a distinct hypocone. Metaconid positioned lingually on  $M_1$  and  $M_2$ ; hypoconulid present on lower molars (Korth, 1984, 1994).

*Referred Specimens.*- Virgin Hills: WMU-VP 1522.

*Discussion.*- This specimen was identified through comparison with casts of the type and other specimens in the WMU-VP collection and with the assistance of W. Korth.

#### Family SCIURAVIDAE Miller and Gidley, 1918

##### Genus *SCIURAVUS* Marsh, 1871

##### *Sciuravus* sp. Loomis, 1907

*Type species.*- *Sciuravus nitidus* Marsh, 1871

*Age and Distribution.*- Wasatchian (Gazin 1962). Lysite of the Great Divide basin.

*Diagnosis* - Small sciuravid with talonid basins uncomplicated and lacking a meslophid and a metastylid (Gazin, 1962).

*Referred Specimens.*- Virgin Hills: WMU-VP 1162, 1163, 1164, 1165, 1166.

*Discussion.*- All referred specimens were collected from Virgin Hills, and were identified through comparison with casts of the type and other specimens in the WMU-VP collection and with the assistance of W. Korth.

##### Genus KNIGHTOMYS

##### *Knightomys* sp.

*Type species.*- *Knightomys senior* Gazin, 1961

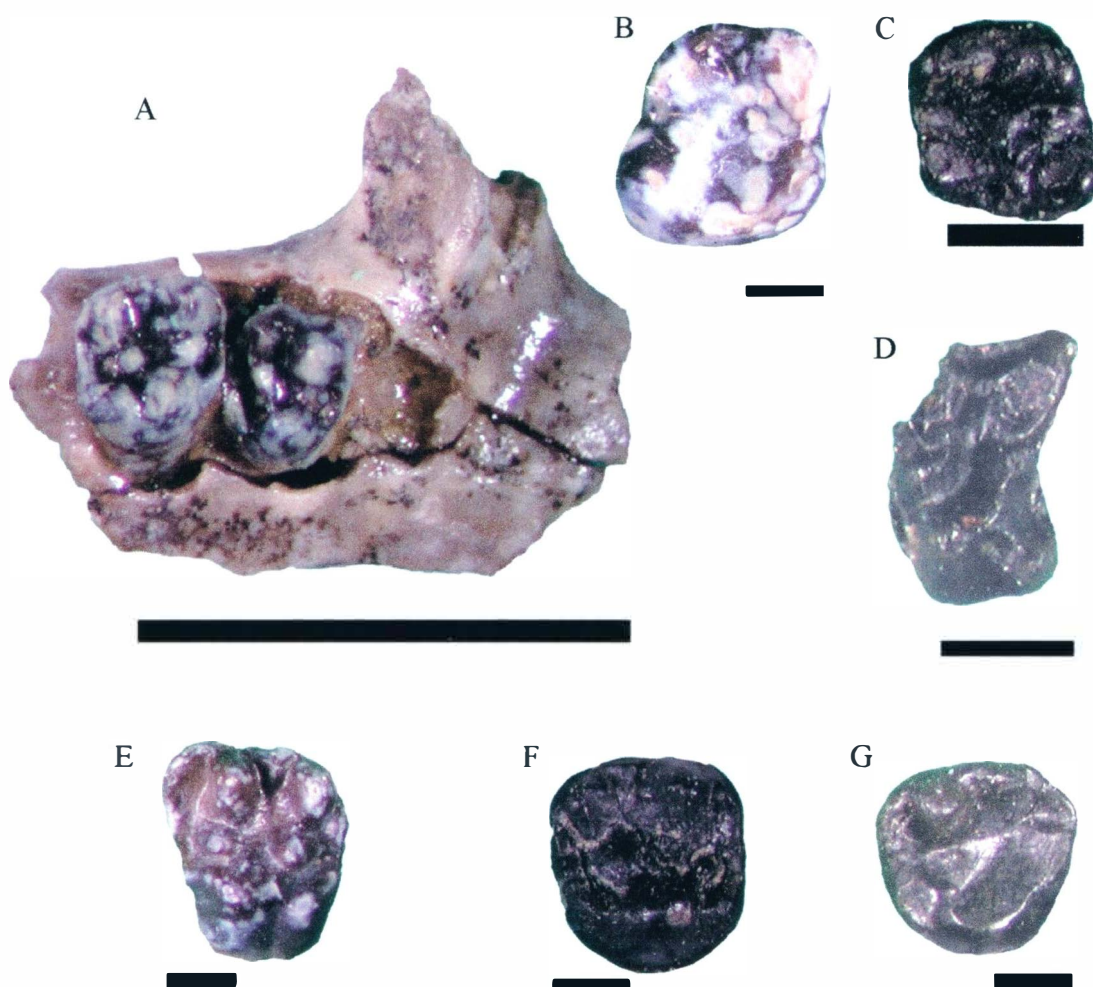
*Age and Distribution.*- Early Eocene of Wyoming, Colorado, and New Mexico.

*Diagnosis.*- Small sciuravid, cheek teeth cusps with rudimentary loph development; protoloph and metaloph complete and separate on upper molars; entoconid

on lower molars isolated with incomplete hypolophid entering into the talonid basin (Korth, 1984, 1994).

*Referred Specimens.*- TBE North: WMU-VP 242; Mertle Beach: WMU-VP 1478 (Figure 18).

*Discussion.*- WMU-VP 242 is an isolated, fairly worn lower molar found at TBE North in 1994. WMU-VP 1478 is a maxilla preserving  $P^4$ - $M^1$  with very little wear found at Mertle Beach in 1996. Both specimens were collected from Virgin Hills, and were identified through comparison with casts of the type and other specimens in the WMU-VP collection and with the assistance of W. Korth.



All scales measure 1mm with the exception of A which measures 5mm.

A. *Knightomys* sp. Left maxilla with P 4/-M 1/, WMU-VP 135; B. *Franimys* sp. Left /M, WMU-VP 1308; C. *Microparamys* sp. Right /M, WMU-VP 1170; D. *Macrocraion* cf. *M. nitens* Left M/, WMU-VP 344; E. *Notoparamys* sp. Left /M, WMU-VP 5772; F. *Thisbemys* sp. Right M/, WMU-VP 1168; G. *Paramys* sp. Left M/, WMU-VP 902.

Figure 18. Rodents and Insectivores.

## CHAPTER VI

### PALEOCLIMATOLOGY AT THE PALEOCENE-EOCENE BOUNDARY

As mentioned above, the Wasatchian NALMA correlates with the beginning of the Eocene Epoch (55 mya) and is marked by the first appearance of the mammalian orders Primates, Artiodactyla, and Perissodactyla, and hyaenodontid Creodonta. While the Paleocene ancestors of these creatures is still debated, much recent research has focused on the suggestion that global climate change at the Paleocene-Eocene boundary may have played a leading role in the faunal turnover that defines the beginning of the Eocene in the terrestrial sediments of North America (Koch et al., 1992; Dickens et al., 1997; Clyde and Gingerich, 1998; Bowen et al., 2002). The notion that climate change may have driven evolutionary change at the Paleocene-Eocene boundary owes much to the “turnover pulse hypothesis” developed by Elizabeth Vrba (1995).

Much evidence indicates that the earliest Eocene was the warmest period of the entire Cenozoic Era, the last 65 million years of Earth history (Bains et al., 1999). The evidence for what is now known as the “Paleocene-Eocene Thermal Maximum” or PETM comes from a series of stable isotope analyses of marine (Kennett and Stott, 1991; Bains et al., 1999) and terrestrial (Koch et al., 1992, 1995; Bowen et al., 2002) sediments that indicate substantial decreases in the relative amounts of carbon 13 ( $\delta^{13}\text{C}$ ) and oxygen 18 ( $\delta^{18}\text{O}$ ). These isotopic excursions from background levels suggest a major global warming trend that may have yielded increased sea surface temperatures of between 4 and 8 degrees Celsius and deep ocean temperatures that may have been warmer by 5 degrees Celsius (Bao et al., 1999; Thomas et al., 2002). These isotopic changes in the

marine and terrestrial record are closely correlated in time with each other (within 150,000 years according to Koch et al., 1992) and with major benthic foraminiferal extinctions (Kennett & Stott, 1991), as well as with mammalian faunal turnover at the beginning of the Wasatchian (Koch et al., 1992, 1995). This linkage of a substantial isotopic event (sometimes referred to as the carbon isotope excursion or CIE), a sudden and large-scale marine extinction, and a major faunal turnover of terrestrial mammals suggests the global and isochronous nature of the Paleocene Eocene Thermal Maximum.

A recent hypothesis has been proposed to explain the cause of the global warming event at the beginning of the Paleocene. The suggestion has been made that an increase in water temperature and resulting changes in oceanic currents may have catalyzed a massive release of methane hydrates from marine sediments in continental shelf deposits (Dickens et al., 1997; Bains et al., 1999; Katz et al., 1999) resulting in the release into the atmosphere of large amounts of carbon dioxide, one of the most effective greenhouse gasses. Röhl et al. (2000) estimate that a release into the atmosphere of 1500 to 2000 gigatons ( $10^9$  tons) of carbon at the Paleocene-Eocene boundary would have resulted in massive greenhouse warming of the entire globe sufficient to account for the observed isotopic changes and their biotic effects. The resulting global warming could explain the biotic changes in both the marine and the terrestrial environments. The foraminiferal extinctions that occur at the end of the Paleocene resulted in a 35-50% reduction of benthic foraminiferal taxa, one of the largest deep-sea extinctions of the last 90 million years (Kennett & Stott, 1991). The faunal turnover among terrestrial mammals in the earliest Wasatchian may be related to global warming through increased levels of

extinction and evolution (Vrba, 1995), or simply by allowing high latitude migrations of mammals from northeastern Asia to North America and Europe (Beard, 1998).

Bowen et al. (2002) have recently synthesized isotopic stratigraphy, magnetostratigraphy, and biochronology from all the Holarctic continents (Asia, North America, and Europe) to make a strong case in support of Beard's (1998) "East of Eden" hypothesis for an Asian origin of North American Wasatchian mammals. In this model, global warming at the beginning of the Eocene opens up high latitude, forested migration routes through which terrestrial mammals (e.g., the earliest adapid and omomyid primates, perissodactyls, artiodactyls, and hyaenodontid creodonts) were able to move from Asia to North America and Europe. Interestingly, Gingerich (1989; Clyde and Gingerich, 1998) described the earliest Wasatchian fauna from the Bighorn basin (Wa0) as distinctive in showing dwarfing in several mammalian lineages. This is perhaps an example of Bergman's rule, which predicts that warm-blooded animals may adapt to life in hot climates through a reduction in body size, with associated increase in surface area to mass ratio.

## CHAPTER VII

### CONCLUSIONS

The presence of euprimates, artiodactyls, perissodactyls, and hyaenodontid creodonts marks the beginning of the Wasatchian NALMA (Woodburne et al., 1987). Each of these groups is well represented at Tipton Buttes and we can be certain that we are dealing with a Wasatchian fauna (Table 2). The Euprimates include members of the families Adapidae (*Cantius* and *Copelemur*) and Omomyidae (*Steinius*, *Arapajovius*, *Anemorhysis*, and *Absarokius*). *Diacodexis* is the earliest of the dichobunid artiodactyls, and it is present at Virgin Hills. The perissodactyls *Hyracotherium* and *Homogalax* are found at several of the Tipton Buttes sites, the latter only from a single specimen. Finally, the hyaenodontid creodonts are represented by *Prototomus* from the Virgin Hills and TBE North localities. The presence of certain species of these taxa allows for more precise identification of the age of the Tipton fauna within the Wasatchian NALMA. The presence of *Cantius abditus* is suggestive of the late Graybullian (Wa5) or Lysitean (Wa6) according to Gunnell (1989), who suggested that *C. abditus* is a lineal descendant of *C. trigonodus*. Also present in the fauna are the condylarths *Haplomylus* and *Apheliscus*, both of which are present in the latest Paleocene (Clarkforkian NALMA) and persist into the Lysitean (Wa6). We have identified three species of *Hyopsodus* at Tipton Buttes based on a combination of morphology and linear measurements. Each of these taxa (*H. minor*, *H. paulus*, and *H. powellianus*) are present in the Lysitean (Wa6). *Hyopsodus powellianus* makes its first appearance in the Lysitean (Wa6) while *H. minor*



Table 2

Faunal List from Tipton Buttes

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*Lepisosteus* sp.  
Testudines indet.  
Lacertilia indet.  
Crocodylia indet.  
*Copelemur feretutus*  
*Cantius abditus*  
*Absarokius* sp.  
*Anemorhysis sublettensis*  
*Steinius vespertinus*  
*Arapajovius* cf. *gazini*  
*Microsyops latidens*  
*Phenacolemur* cf. *jepsoni*  
*Meniscotherium chamense*  
*Phenacodus vortmani*  
*Hyopsodus paulus*  
*Hyopsodus powellianus*  
*Hyopsodus minor*  
*Haplomylus speirianus*  
*Apheliscus* sp.  
*Hyracotherium vassaciense*  
*Homogalax protapirinus*  
*Diacodexis secans*  
*Esthonyx bisulcatus*  
*Coryphodon* sp.  
*Miacis* sp.  
*Didymictis* sp.  
*Viverravus* sp.  
*Prototomus* sp.  
*Paleosinopa* sp.  
*Macrocranion* cf. *M. nitens*  
*Paramys* sp.  
*Notoparamys* sp.  
*Microparamys* sp.  
*Franimys* sp.  
*Thisbemys* sp.  
*Reithroparamys* sp.  
*Sciuravus* sp.  
*Knightomys* sp.

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makes its last appearance in Wa6 times. This evidence strongly supports a Lysitean (Wa6) age for the Tipton Buttes fauna. Absent from the Tipton localities are the large perissodactyls *Heptodon* and *Lambdaotherium*, which serve as index taxa for the Wa6 and Wa7 (Lostcabinian), respectively. Their absence would suggest a late Graybullian (Wa5) fauna, while the presence of other forms such as *C. abditus* and the three species of *Hyopsodus* suggests a Lysitean (Wa6) age. Further research at the Tipton Buttes localities will allow us to better resolve the biostratigraphic placement of the Tipton Buttes fauna within the later Wasatchian.

Appendix  
List of Abbreviations

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### List of Abbreviations

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ACM	Amherst College Museum
AMNH	American Museum of Natural History
UM	University of Michigan Museum of Paleontology
UCMP	University of California Museum of Paleontology
UW	University of Wyoming
WMU-VP	Western Michigan University Vertebrate Paleontology

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