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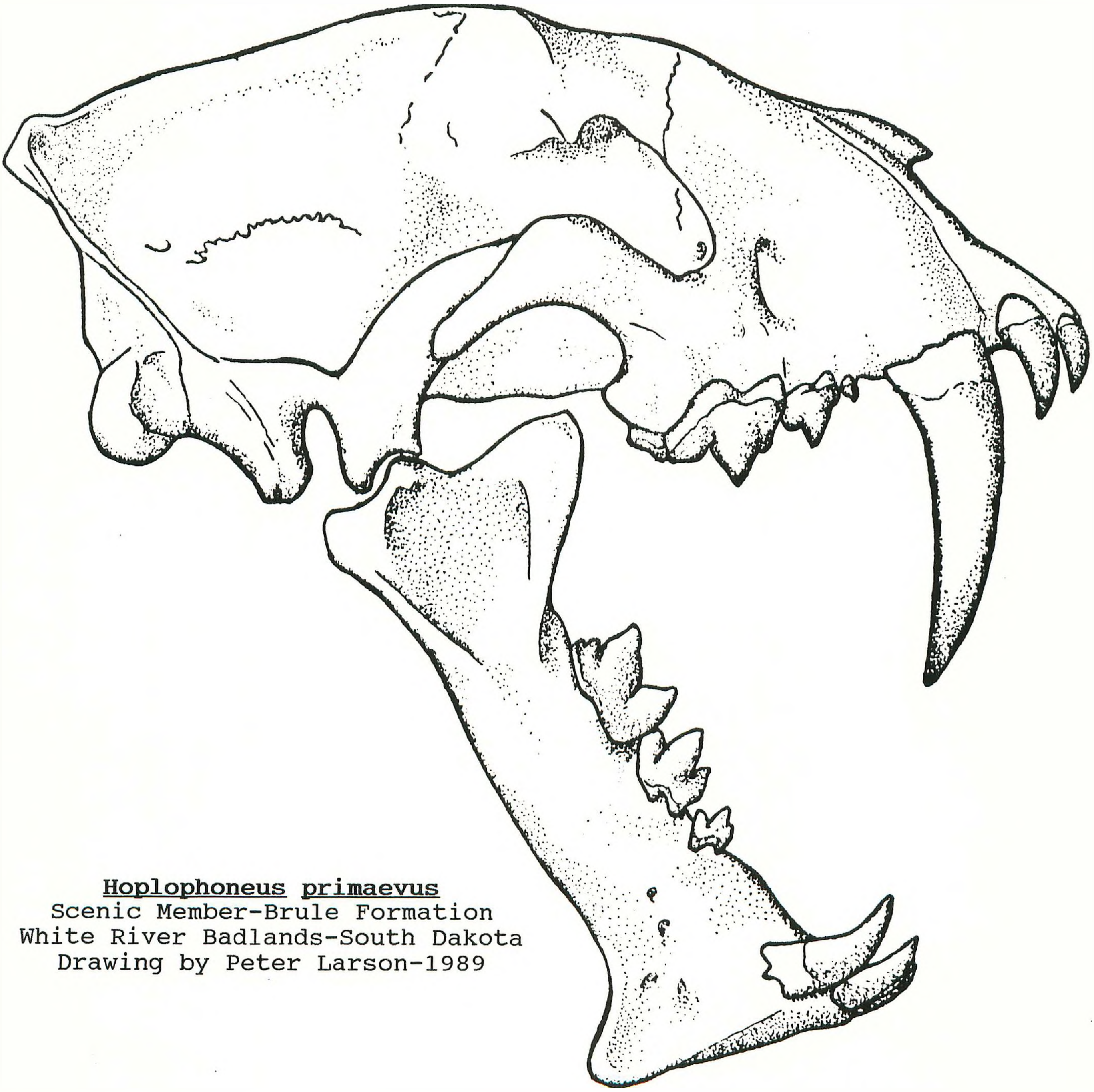

Hoplophoneus primaevus
Scenic Member-Brule Formation
White River Badlands-South Dakota
Drawing by Peter Larson-1989

A LOVE OF FOSSILS BRINGS US TOGETHER

Time Millions Years	Era	Period	Epoch
- .01	Cenozoic	Quaternary	Holocene
2 - .01			Pleistocene
5 - 2		Tertiary	Pliocene
24 - 5			Miocene
40 - 24			Oligocene
55 - 40			Eocene
62 - 55			Paleocene
144 - 62	Mesozoic	Cretaceous	
		Jurassic	
		Triassic	
	Paleozoic	Permian	

MAMMALS

MAPS DIGEST

EXPO XI EDITION

Mid - America Paleontology Society

A Love Of Fossils Brings Us Together

Western Illinois University
Union Ballroom
Macomb, Illinois 61465
April - 1989

FORWARD

The guidance of this issue of MAPS EXPO XI DIGEST, MAMMALS, came largely from Assistant Editor, Dennis Kingery, Rock Springs, Wyoming.

Once the seed is planted, in order for it to sprout and grow, several people, many conversations, many phone calls, many letters, and the DIGEST begins to flow. The Mid-West is not renowned for its mammals so one must go to Vertebrate Country for information--enter Dennis and other loyal MAPS members. Their contacts were from West Coast to East Coast, from North to South.

In the process of gathering data, once the names have surfaced, is the delightful exposure to new fossil enthusiasts as well as long-time MAPS members. This year's publication includes an article from Tom Kelly, a California dentist, whose profession spills over into his hobby and because of that teeth--in this case fossil teeth are no longer chunks of strange shaped stones often causing some of us to wonder how anyone could get excited about a tooth--come alive with pieces of the puzzle revealing information and pictures about vertebrates and the ecology of the ancient past. Another writer, new for MAPS, Gregg Gunnell, Museum of Paleontology, The University of Michigan, quickly answered affirmatively and his article on museum specimens is revealing. This contact is thanks to MAPS member Tom Witherspoon, Dearborn, Michigan. Mr. Gunnell graciously offered a presentation at THE EXPO XI as well, but then commitments to professional meetings superceded.

John and Julie Barrie, Coonaltyn, S. Australia, are new faces but they have also become new members. Gil and Gerry Norris, Rock Island, Illinois, went all the way to Australia for this contact. When they returned one letter, no phone calls, and then came a package and another informative article giving insights into another hemisphere. Although not a MAPS member (yet) Pete Larson has been friend to MAPS and a contributor to MAPS EXPO DIGEST as recently as last year. Pete lives so close to the Badlands his article is almost like writing about his second home. His descriptions of the land give it a charismatic appeal as well as inform us of life among ancient mammals. How lucky we all are.

What you have in your hand, then, is the product of at least two years of work. The cooperation of MAPS members never ceases to be amazing. Occasionally something happens and promised work does not materialize--tears for all of us. But every year we make new friends. Each article has its own distinct appeal as do the authors themselves. How great it would be if everyone could hear the phone conversations to meet the authors as they emerge.

Because of these very unselfish authors who so generously share their expertise, this special EXPO XI EDITION, MAMMALS, will fill some gaps in our constant search for pictures and information into the amazing, often illusive ancient past.

MAPS Board of Directors takes great pleasure in recognizing each of these contributors.

The Mid - America Paleontology Society (MAPS) was formed to promote popular interest in the subject of paleontology, to encourage the proper collecting, study, preparation, and display of fossil material; and to assist other individuals, groups and institutions interested in the various aspects of paleontology. It is a non-profit society incorporated under the laws of the State of Iowa.

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ABOUT THE COVER -- Hoplophoneus primaevus

This is a composite line drawing made from several specimens found over a period of many years, in order to illustrate a complete skull of one of the four genera of "saber-toothed" cats.

The chances of finding a complete specimen are very remote. Although Pete has collected the Badlands for 30 years, he says he has yet to find a complete skull--almost, but not complete.

The collecting sites are a few hours from Rapid City. The cat skulls are mostly found towards the bottom of the Brule Formation, a flooded plain deposit as opposed to a more restricted area. This particular environment supported a large number of species of mammals.

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*Denotes MAPS Member

The article which follows is the Keynote Address to be presented by Peter L. Larson, Black Hills Institute of Geological Research, Inc., Hill City, South Dakota, to the MAPS audience at THE EXPO XI -- MAMMALS, Macomb, Illinois.

MAPS Board of Directors extends a sincere thank you to Lapidary Journal for gracious permission to use this article at this National Fossil Exposition XI.

A FOSSIL WHALE FROM PERU

The following article, entitled "A Fossil Whale from Peru", appeared in the April 1987 issue of the **Lapidary Journal**. It is reprinted here with their permission. This article was written by Peter L. Larson, President of Black Hills Institute of Geological Research, Inc.

A Fossil Whale from Peru

Peru has been renowned for its cultural heritage by scientists and laymen for literally hundreds of years. Nazca and Incan artifacts have given us a greater understanding of the complexity and advancement of these ancient societies. Relatively little is known, however, of the paleontology of Peru. I have been interested for many years in the fossils which occur in South America. Last October I was invited to take part in an expedition with the purpose of excavating a fossil whale from the Miocene deposits occuring along the coast of Peru. I jumped at the opportunity to share in this adventure and learning experience.

The expedition was led by Hans Jakob (Kirby) Siber from Switzerland. In addition to myself and Kirby, the party included Susan Hendrickson, Dr. Hernando de Macedo, Carlos Martin and several Peruvian fishermen who were hired to help excavate this ancient mammal. The actual digging of the specimen was the culmination of nearly a year of preparation by Mr. Siber, which entailed visiting the site, attempting to locate a suitable specimen, and (most time consuming) following governmental channels to obtain the proper permit for the legal excavation, collection and exportation of the fossil whale. Finally in November we were ready to begin the trek.

Our camp was established in a small fishing village in central Peru. The deserts of Peru are fascinating. They extend along the entire coastline of this South American Country. This is an area where it never (well, almost never) rains and is part of the Atacama Desert, which is literally the driest desert in the world. Yet, surprisingly, the ground is wet! This is due, primarily, to the percolation of ground water from the Andes Mountains to the East. Even with ample soil moisture in some places and with some successful irrigation, the vast majority of this desert is completely without vegetation.

Although there are vast expanses of desert exposures, the localities which produce fossils are limited in both number and extent. The Pisco Formation, which contains marine fossils of Miocene and Pliocene age extends for at least 350 km along the Peruvian coast, however, very little of it contains fossils. In addition, the desert environment soon destroys exposed fossils by literally "sand blasting" them out of existence. After much research and exploration, Kirby was finally able to locate a suitable specimen.

When I first saw the fossil whale (which later was given the name Josefina) only the lateral spines of some of the vertebrae and a small portion of the back of the skull was exposed. Even with this limited exposure to the blowing sand, the wind had already taken its toll. It was very obvious that if left to the wind, Josefina (the whale) would soon be destroyed.

We went to work with knives and whisk brooms and began the long and difficult task of uncovering the skeleton. It soon became apparent that nearly the entire vertebral column was present and that the bones seemed to be well preserved. The sandstone which covered Josefina rapidly became hard as we progressed down only a few centimeters. We then had to estimate where the bones would lie and proceed carefully with picks. By the end of the first day it became obvious that we indeed had a difficult task ahead of us. Not only was this a large whale, which increases the technical problem of digging and removal, but Josefina was also enclosed within a very large limestone concretion which was buried in some reasonably hard sandstone. These problems were, to some extent, ignored as the days progressed and the beauty of the specimen disclosed itself.

Josefina's body lay on its right side. The tail followed a graceful arc through the main body section where the arc reversed as it approached the neck. The skull was upright and arched away from the body. In addition to these beautiful curves in the horizontal plane, the vertebral column followed a slight sinusoidal curve in the vertical plane. Taken altogether this translates into a wonderfully elegant and pleasing pose. It was at this point in digging that we all agreed that a specimen of such beauty and grace could only be female and thus the whale was christened Josefina.

Each day of digging brought new discoveries. The ribs from the left side seemed to have floated slightly away and the left hand seemed to be missing. With further excavation we discovered the left hand beautifully articulated but off to the side and slightly under this pile of ribs. Upon closer examination of the ribs and hand as well as the dorsal spines of the vertebrae, we discovered that the bones showed deep scratches or cuts! Speculation upon the origin of these cuts came to an end after the discovery of a shark tooth near the pelvic region. In the digging and preparation of the skeleton nearly 20 teeth from the Miocene shark Isurus were discovered and there positions recorded. Two teeth are actually imbedded in the bones of the skull. These discoveries brought Josefina back to life in our minds.

About eight and one half million years ago this gentle creature was swimming in the ocean near the ancestral coastline of South America. Perhaps she was injured or ill. Sharks swimming in the area sensed that this animal would soon die. Driven by the instinct of self preservation and hunger one shark carefully approached the troubled swimmer. Cautiously circling the whale the shark could see and smell that something was wrong. He was soon joined by another shark and then another. Suddenly one shark darted in and bumped Josefina with its nose. Another approached and bit Josefina's left hand. Blood was drawn. By this time, due to her weakened condition, Josefina was doomed. Sharks are no match for a healthy whale, but Josefina was too weak to successfully resist what was to happen next. The blood drawn by the first attack excited the sharks. A second shark moved in to test the prey. His jaws closed in Josefinas flank and with great shakes of his head he ripped a wound on Josefina's side. Blood poured into the water from this gaping wound. More sharks advanced and attacked. The feeding frenzy which ensued led to a quick and merciful death for Josefina. The death of Josefina gave life to other creatures continuing the cycle of life in the ocean in which nothing is wasted.

This vivid scene became very clear to us as we continued our quarrying. Josefina was not just a fossil, her life and death became a reality. By the time the story unfolded to us we were able to determine many other things. Her skeleton was, basically, articulated. Only part of the left side of the rib cage and left hand had been moved by the sharks who continued to feed after she came to rest on the bottom of the ocean. Her skeleton was also remarkably complete, missing only about 5 vertebrae from the tail and minor fragments of dorsal and lateral spines removed by the sharks and weathering. Her magnificent skull, which is more than two meters long, told us that she belonged to or was ancestral to the genus Balaenoptera whose relatives include the gigantic Blue Whale (the largest animal ever to exist on this planet). This is perhaps the oldest evidence of this genus of Cetacean which feeds on tiny krill or brine shrimp by means of a "baleen structure" used to filter the krill from sea water.

All the joys of discovery during the excavation process soon came to an end as a new task confronted us. In order to share our find with other lovers of fossils we still had to remove and ship Josefina halfway around the world to Kirby's private museum. As many fossil collectors have found, its one thing to uncover a fossil and a completely different thing to pick up and transport that fossil.

In my more than 12 years with Black Hills Institute of Geological Research, Inc. (A private company which supplies fossil specimens to museums for display, teaching and research) I had gained experience collecting many different types of fossils including dinosaurs. The whale, Josefina, however presented her own set of problems. First, the majority of the skeleton is enclosed within a large limestone concretion. This is both good and bad. It is good because the matrix mass is solid - and bad because a rock containing a fossil more than eight meters long is excessively heavy. Fortunately this concretion contained several fractures which should allow us to take Josefina up in sections. Second, those portions of the skeleton which were not enclosed within the concretion were extremely soft and porous. Third, even if we could take Josefina up in sections each section would still have to be lifted about one and one half meters up into a truck for transportation.

We first determined to put plaster of paris jackets around each section, similar to the way a doctor would put a cast on a broken leg. Plaster and burlap were ordered and soon arrived from Lima. We made a jacket around the last tail section and retired for the evening. When we returned in the morning we were dumbfounded to discover that the plaster was soaking wet and so soft that I could push my finger through it to the enclosed fossil. Apparently the humid climate coupled with the quality of the plaster was not going to allow us to protect the fossil in the approved paleontological method! Undaunted, we changed plans.

We now carefully removed and labeled all bones and parts of bones which protruded from the concretion. We then proeeded to construct pallets for sections of the concretions which we could man-handle. These pieces were than padded with burlap and strapped in place. The nose of the whale was bandaged with plaster which hardened. This we rapidly moved it onto a pallet with the knowledge that the plaster would be soft in the morning.

All that remained were the two very large and heavy sections. One containing the bulk of the skull and neck and one containing the main portion of the body. Fortunately there was a fracture at the base of the neck which separated these two pieces. We then proceeded to dig a trench around these pieces deeper and finally to tunnel underneath these large rocks leaving them suspended on pillars.

We then constructed a pallet under each piece. I calculated that the piece containing the skull weighed well over 1000 kilograms (1 ton) and the piece containing the body close to 2000 kilograms (2 tons). Although the fracture at the base of the neck was a small one, I was sure that we could use the sheer weight of the pieces to break them apart.

After construction of the pallet was completed we carefully cut away the pillars under the skull. To our surprise, as the front of the skull slowly lowered onto one of the pallets, the rear of the body section was elevated into the air! The two pieces were still one! After some discussion we came up with a plan to separate the two pieces on this hairline fracture. The solution was fairly simple. We placed a large hydraulic jack and sharp wedge under the neck, at the fracture. We then raised the jack several inches, suspending most of the weight of the whale on the wedge. On this day we had about 10 people at the quarry. This party we divided in two and a party of five climbed on each piece. On the count of three we all jumped and landed on each side of the concretion mass. On the third attempt we succeeded in breaking the concretion on the fracture. The pillars under the body section were then cut away and we had the whale contained on pallets.

The following day, the truck to haul Josefina to the port was scheduled to arrive with a mechanism to lift the pieces on to the truck bed. Early in the morning Kirby Siber carried our large crew of fishermen out to the site to construct a road which would allow the truck to back up to the pallets containing Josefina's parts. Susan and I, after having the lifting mechanisum described to us, had little faith in the apparatus which was to arrive shortly. In desperation, we devised an alternative method using planks, sand and man power and set about trying to find suitable wooden planks in the fishing village. After much searching we finally were able to borrow two large planks of unequal length and questionable strength. Finally the truck arrived and we loaded the planks and drove out to the quarry.

On the way out to the quarry it soon became obvious that we were enveloped in a sand storm. Although the wind and sand had blown every day, this day was exceptionally bad. In fact it was the worst sandstorm since our arrival. Fortunately visiability was still good enough to allow us to find the site. When we arrived we perceived that our Peruvian helpers were used to these frequent sandstorms and protected their faces and windpipes by wrapping articles of clothing about their heads.

We set to work setting up the lifting apparatus, which consisted of two chain hoists and a rather stressed and weak looking steel frame. I was absolutely certain that even if this strange contraption could succeed in raising these heavy pallets off the ground that the sheer weight of these huge pieces of concretion would buckle this fragile appearing framework, and crush one of us beneath the wooden pallet. Kirby, ever the optimist, assured me that the Peruvian owner had perfect confidence in the ability of this apparatus. Finally I agreed that we should at least give it a try. It worked!

Amid the strangest combination of shouting voices - some in Spanish some in German, and my English which Susan then translated into Spanish (all trying to over-come the howling of the wind) we were able to efficiently load all the pallets in a surprisingly short period of time. I surely wish that we had made a recording of the monumental task. The effect of this international shouting contest must have been incredible. Finally Josefina was loaded and on her way to Lima and to the waiting container to be loaded on to a ship. Josefina was going back to sea.

The quarry was empty now. Somehow this hole in the ground looked very sad. But we were also elated because we knew that one of the major portions of our task had been completed. Now all that remained was a long sea voyage and many weeks of preparation and Josefina would be able to be a source or wonderment and education for thousands of children and adults.

This spring I traveled to Switzerland where Kirby Siber, Susan Hendrickson, Karen Lenslinger and myself prepared the whale for display. It was decided to mount the specimen in its enclosing concretion, removing only that portion of the concretion which was only a thin covering over the bone or which covered important anatomical features. The result of the preparation gives the viewer the rare opportunity to see a fossil in its natural state without the inconvenience of blowing sand, and a covering of overburden.

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RADIATION AND DIVERSIFICATION OF MODERN MAMMALIAN ORDERS: EARLY CENOZOIC FOSSIL EVIDENCE FROM NORTH AMERICA

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The fossil evidence for mammals can be traced back to the late Triassic (Clemens, et al., 1979), some 200 million years ago. The Mesozoic radiation of mammals was relatively extensive, represented by 14 families in the Jurassic and 28 families in the Cretaceous (Clemens, et al., 1979). Of these families, only six (in the late Cretaceous) are representative of modern mammalian orders (Insectivora and Marsupialia). The others are members of archaic mammalian orders that are now extinct.

The early Cenozoic (beginning about 62 million years ago) is the time of origin and diversification of most modern mammalian orders. In the pages that follow, I will examine the characteristics of this early Cenozoic radiation in North America as documented by the fossil mammal collections of the University of Michigan Museum of Paleontology (UMMP). Late Cretaceous mammals are represented by 973 cataloged specimens in the UMMP; Paleocene mammals are represented by 4,066 cataloged specimens; 18,279 cataloged specimens are from the Eocene; and 1,207 cataloged specimens are from the Oligocene. All of these specimens come from localities scattered along the Rocky Mountain Corridor from the states of Montana, Wyoming, Colorado, New Mexico, Nebraska, and South Dakota. Table 1 shows the stratigraphic distribution of these specimens by order and family.

Figure 1 shows the distribution of these specimens from the late Cretaceous through the Oligocene. In the late Cretaceous, the mammalian record is dominated by multituberculates (85% of UMMP specimens represent this order). The other mammalian groups are represented by low frequencies (4-6%) of three other orders, Marsupialia, Insectivora/Proteutheria (combined in this study), and Condylarthra. Of 973 specimens, 9.9% are representative of modern mammalian orders.

In the Paleocene (the beginning of the Cenozoic), the frequency of mammalian groups has changed. Multituberculates have reduced in frequency to 22%, while insectivores and condylarths have increased (19 and 25%, respectively). A new group, Plesiadapiformes (often recognized as primates, but more likely to represent a distinct order), has appeared and represents 27% of the Paleocene fauna. Pantodonta and Dinocerata also appear at this time at low frequencies. All of these groups (except Insectivora) are representative of archaic mammalian orders. Two modern orders make their first appearance in the Paleocene, Carnivora and Dermoptera (flying lemurs). Rodents and edentates also appear in the late Paleocene, but at very low frequencies. Modern mammalian orders are represented by 24% of the Paleocene fauna.

A number of modern orders first appear in the Eocene. Among these are the first North American Primates, Artiodactyla, Perissodactyla, and Rodentia (at significant frequencies). Most of the archaic orders remain, at least through the early Eocene, but at low frequencies. The one exception is condylarths which increase to 42% of the Eocene fauna. However, the condylarth fauna has changed from one dominated by phenacodontid condylarths in the Paleocene to one dominated by hyopsodontid condylarths in the Eocene. Creodonta (an archaic carnivorous group) is also present at low frequencies in the Eocene (they first appear in the Paleocene).

Primates represent 10% of the Eocene fauna, rodents 2%, artiodactyls 6%, and perissodactyls 18%. Modern orders are represented by 44% of the Eocene mammalian fauna in UMMP collections. Edentates are also present in the Eocene fauna at low frequency (.3% of total).

By the Oligocene, nearly the entire mammalian community consists of modern orders (99%). The only archaic order left is creodonts. The fauna is dominated by artiodactyls (26%), perissodactyls (15%), rodents (34%), and a new appearance, Lagomorpha (15%).

Representatives of modern mammalian orders began to appear in significant numbers during the Eocene and by the Oligocene had essentially replaced all archaic mammalian groups (except creodonts which persist into the Pliocene in Asia). Where did these new orders originate? In the Paleocene, two modern orders appear, Carnivora and Dermoptera. Paleocene carnivores are similar in many aspects to the late Cretaceous insectivore/proteutherian group and their origin probably lies within this radiation (Van Valen, 1966). Dermopterans are probably derived from this broad radiation as well, perhaps from a leptictid ancestor (Van Valen, 1967).

Near the beginning of the Eocene (at the beginning of the Wasatchian Land Mammal Age of North America; see Gingerich, 1989, Rose, 1981) the orders Primates, Artiodactyla, and Perissodactyla appear in the fossil record. The origins of these groups remains in question. Perissodactyls and artiodactyls may have been derived from condylarths, although these connections are not yet clear. Primates were believed to have been derived from plesiadapiforms (Gingerich, 1976), but recent work indicates that this connection may not be as close as once suggested (Gingerich, 1986; Gunnell, 1989, Wible and Covert, 1987). All three of these orders appear suddenly in the fossil record in North America, which suggests that they are part of a migrational event. These orders may have arisen elsewhere (Asia, Africa, Europe, and India, have all been suggested in the past), and immigrated into North America at the beginning of the Eocene.

Rodents appear in North America in the late Paleocene, becoming a significant faunal element in the Eocene. Lagomorphs (rabbits) appear in North America in the late Eocene, becoming a significant faunal element in the Oligocene. Both of these groups probably arose from eurymyloid anagalids, known from the Paleocene of Asia (Dawson, et al., 1984; McKenna, 1982).

The appearance of primates, perissodactyls, and artiodactyls in the North American fossil record coincides with a warming climate during the Eocene (see Figure 2). Through the Paleocene, climatic conditions were deteriorating from subtropical conditions in the late Cretaceous to a warm temperate climate by the late Paleocene. During the late Paleocene temperatures began to climb again, reaching subtropical conditions through the Eocene (based on paleobotanical information; see Wolfe, 1978; Wolfe and Hopkins, 1967). This suggests that these modern orders may have originated in subtropical areas (more southerly) during the Paleocene and then spread into northern areas along with warming temperatures and the onset of subtropical conditions in the Eocene. Further fossil evidence from appropriate areas and of the right age is needed to solve questions concerning the origins of these groups.

Modern mammalian orders had appeared by the Eocene and were the dominant fauna by the Oligocene. Two other important aspects of mammalian ecology, body size and dietary regime, can be examined through the early Cenozoic. These aspects can help to characterize mammalian evolutionary history during this time period.

I have defined three broad body size categories based on body weight (see Figure 3). Small body size is defined as equal to or below 500 grams, medium body size is defined as between 500 and 10,000 grams, and large body size is defined as over 10,000 grams (about 22 pounds). Figure 3a shows the distribution of 384 modern mammalian species (calculated as family means) over these three categories (2 monotremes, 22 marsupials, 28 insectivores, 5 edentates, 22 bats, 6 rabbits, 5 macroscelidids, 114 rodents, 35 primates, 76 carnivores, 8 cetaceans, 1 tubulidentate, 1 hyracoid, 2 proboscideans, 8 perissodactyls, and 49 artiodactyls; see Eisenberg, 1981). These modern species are rather evenly distributed with 32% representing small species, 36% representing medium species, and 32% representing large species.

Figures 3b-e show the distribution of mammalian body sizes in the late Cretaceous and early Cenozoic. These body sizes are calculated as family means using tooth size to estimate body weight (Gingerich and Smith, 1984). In the late Cretaceous (3e) 75% of mammalian families have mean sizes under 500 grams, while 25% are medium sized. There are no large sized mammals in the late Cretaceous. In the Paleocene (3d) small sized mammals represent 45%, medium 40%, and large 15%. Eocene distributions (3c) are 36% small, 48% medium, and 16% large. Oligocene distributions (3b) are 36% small, 31% medium, and 33% large. Small and medium sized mammals dominate the late Cretaceous and Paleocene, while medium sized mammals dominate the Eocene. By the Oligocene, the modern distribution of body sizes among families has been attained, with larger body sizes becoming more prevalent (this may represent collecting bias in some cases as smaller forms are harder to find than larger forms, but the overall trend towards larger body size is a real one).

Tooth morphology can provide clues to dietary preference among mammals. Teeth that emphasize cusps (points) are used for puncturing hard food objects such as insect exoskeletons. Sharp cusped tooth morphology is indicative of an insectivorous diet, particularly when combined with small body size (at larger body sizes this type of morphology suggests insectivory and omnivory). Teeth that emphasize crests (lines) are used to slice or shear food and are usually indicative of herbivory/folivory. Teeth that emphasize basins (planar areas) are used for grinding food objects and may indicate frugivory or granivory (eating seeds, nuts, and roots). Specialized shearing teeth, such as those developed by carnivores (carnassial dentition), are indicative of a carnivorous diet.

Figure 4a-c shows the distribution of dietary categories through the early Cenozoic. In the Paleocene insectivores/omnivores make up 56% of the fauna, 41% are herbivores, and 3% are carnivores. In the Eocene, insectivore/omnivores drop to 21%, herbivores increase to 72%, and carnivores increase slightly to 7%. In the Oligocene insectivore/omnivores have dropped to 5%, herbivores have increased to 90%, and carnivores remain fairly constant at 5%.

The first fact to note is the relatively constant percentage of carnivorous mammals. Carnivores remain constant through the rest of the Cenozoic as well (6% of 615 UMMP Miocene specimens, 7% of 5,537 Pliocene specimens, and 4% of 3,486 Pleistocene specimens). Insectivorous/omnivorous mammals reduce in percentage through the early Cenozoic, while herbivores increase dramatically through this period.

Two factors contribute to the changing frequencies of insectivore/omnivores and herbivores, increasing body size and changing climate. In the Paleocene most mammals remain quite small. Insects are a good source of energy for small, active mammals with high metabolic rates. As body size increased through the Eocene and Oligocene insects became less important for these larger sized animals and plant foods became more important. Plant foods requires less output of time and energy to find and consume than do insects. Large mammals could conceivably live on insects, but the energy expended gathering the volume of insects needed to feed a 100 kilogram pantodont, for example, would be prohibitive.

At the end of the Eocene a major climatic change occurred (see Figure 2) called the Terminal Eocene Event (or Grande Coupure). The climate rapidly deteriorated from subtropical at the end of the Eocene to cold temperate in the Oligocene. The subtropical forests were replaced with more open woodlands and savannah grasslands. These changes favored mammals that could take advantage of these new ecological situations, specifically grassland grazing forms and woodland browsing forms. A combination of increasing body size and climatic change led to the significant increase in herbivorous mammals through the Oligocene.

Modern mammalian orders began to appear in the early Cenozoic and began to replace archaic mammalian groups. By the Oligocene, nearly all mammals were members of modern orders. The mammals that make up these orders can be typified as small insectivore/omnivores in the Paleocene, evolving into larger, more herbivorous forms through the Eocene into the Oligocene. Carnivorous mammals remain relatively constant in frequency through the early Cenozoic, but do develop larger body sizes (in some lineages) from the Paleocene into the Oligocene.

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TABLE 1. -- Number of specimens of early Cenozoic mammals in the collections of University of Michigan Museum of Paleontology (Specimens identified to family).

Order/Family	Late Cretaceous	Paleocene	Eocene	Oligocene
Multituberculata				
Cimolodontidae	2	38		
Cimolomyidae	10			
Ectypodidae	5			
Eucosmodontidae	92	20	91	
Neoplagiaulacidae	680	377	217	
Taeniolabididae	12	4		
Ptilodontidae		323	6	
Marsupialia				
Didelphidae	37	28	54	21
Insectivora/ Proteutheria				
Adapisoricidae	5	187	12	3
Leptictidae	44	28	70	8
Palaeoryctidae	5	132	87	
Zalambdalestidae	3			
Deltatheridiidae	2			
Apatemyidae		27	90	
Erinaceidae		1	7	1
Mixodectidae		6		
Nyctitheriidae		20	25	
Pantolestidae		195	97	
Pentacodontidae		88	1	
Apternodontidae			8	
Ceutholestidae			2	
Soricidae				8
Talpidae				3
Dermoptera				
Plagiomenidae		47	146	
Dinocerata				
Prodinoceratidae		12	48	
Uintatheriidae		1	3	
Creodonta				
Oxyaenidae		9	204	
Hyaenodontidae			405	10

Order/Family	Late Cretaceous	Paleocene	Eocene	Oligocene
Condylarthra				
Arctocyonidae	52	292	205	
Hyopsodontidae		165	5491	
Mesonychidae		16	105	
Periptychidae		16		
Phenacodontidae		526	1778	
Didymoconidae			25	
Meniscotheriidae			4	
Oxyclaenidae			1	
Carnivora				
Viverravidae		87	496	
Miacidae			251	
Canidae				26
Felidae				17
Mustelidae				10
Edentata				
Epoicotheriidae		1	1	
Metacheiromyidae		1	59	
Pantodonta				
Coryphodontidae		3	429	
Cyriacotheriidae		11	12	
Pantolambdidae		26	4	
Titanoideidae		3		
Plesiadapiformes				
Carpolestidae		165	41	
Microsyopidae		11	294	
Paromomyidae		192	300	
Picrodontidae		5		
Plesiadapidae		725	196	
Taeniodonta				
Stylinodontidae		11	26	
Tillodontia				
Esthonychidae		4	355	
Rodentia				
Paramyidae		5	352	17
Aplodontidae				2
Castoridae				4
Cricetidae				265
Eomyidae				51
Heteromyidae				13
Ischyromyidae				60
Sciuridae				1

Order/Family	Late Cretaceous	Paleocene	Eocene	Oligocene
Artiodactyla				
Agriochoeridae			10	3
Dichobunidae			1067	
Homacodontidae			4	
Hypertragulidae			3	116
Oromerycidae			1	1
Camelidae				32
Entelodontidae				20
Leptochoeridae				15
Merycoidodontidae				117
Tayassuidae				2
Perissodactyla				
Amynodontidae			2	
Brontotheriidae			30	50
Equidae			2600	60
Helaletidae			27	3
Hyracodontidae			3	24
Isectolophidae			552	
Rhinocerotidae				39
Primates				
Adapidae			1404	
Omomyidae			383	
Lagomorpha				
Leporidae				186

FIGURE CAPTIONS

Figure 1.-- Distribution of mammalian orders calculated as a percentage of total mammal fauna from Late Cretaceous through Oligocene, based on collections of the University of Michigan Museum of Paleontology. Bars with vertical lines represent first appearance of new orders (4 in Paleocene, 6 in Eocene, 1 in Oligocene). Bars with cross-hatching represent phenacodontid condylarths. Note decrease in percentage of phenacodontids from Paleocene to Eocene and increase in hyopsodontid condylarths (plotted with phenacodontids) through same period. Abbreviations of orders as follows: Marsup (Marsupialia); Multi (Multituberculata); In/Pro (Insectivora/Proteutheria); Condyl (Condylarthra); Carniv (Carnivora); Dermop (Dermoptera); Pantod (Pantodonta); Plesia (Plesiadapiformes); Primat (Primates); Creodo (Creodonta); Artio (Artiodactyla); Periss (Perissodactyla); Tillod (Tillodontia); Rodent (Rodentia); Lagom (Lagomorpha).

Figure 2.-- Paleotemperature curve for North American western interior, based on paleobotanical evidence. Note cooling through Paleocene, then warming into the Eocene. Grand Coupure is dramatic climatic cooling event that occurred at end of Eocene (also known as Terminal Eocene Event).

Figure 3.-- Distribution of mammalian body weight (estimated from tooth size and calculated as family means) from Late Cretaceous through Oligocene and a sample of recent mammals. Small size is defined as less than 500 grams, medium size between 500 and 10,000 grams, and large size greater than 10,000 grams.

Figure 4.-- Dietary preference (estimated from tooth morphology) for mammalian faunas from Paleocene through Oligocene. Note increase in herbivorous mammals and relatively constant percentage of carnivorous mammals.

FIGURE 1

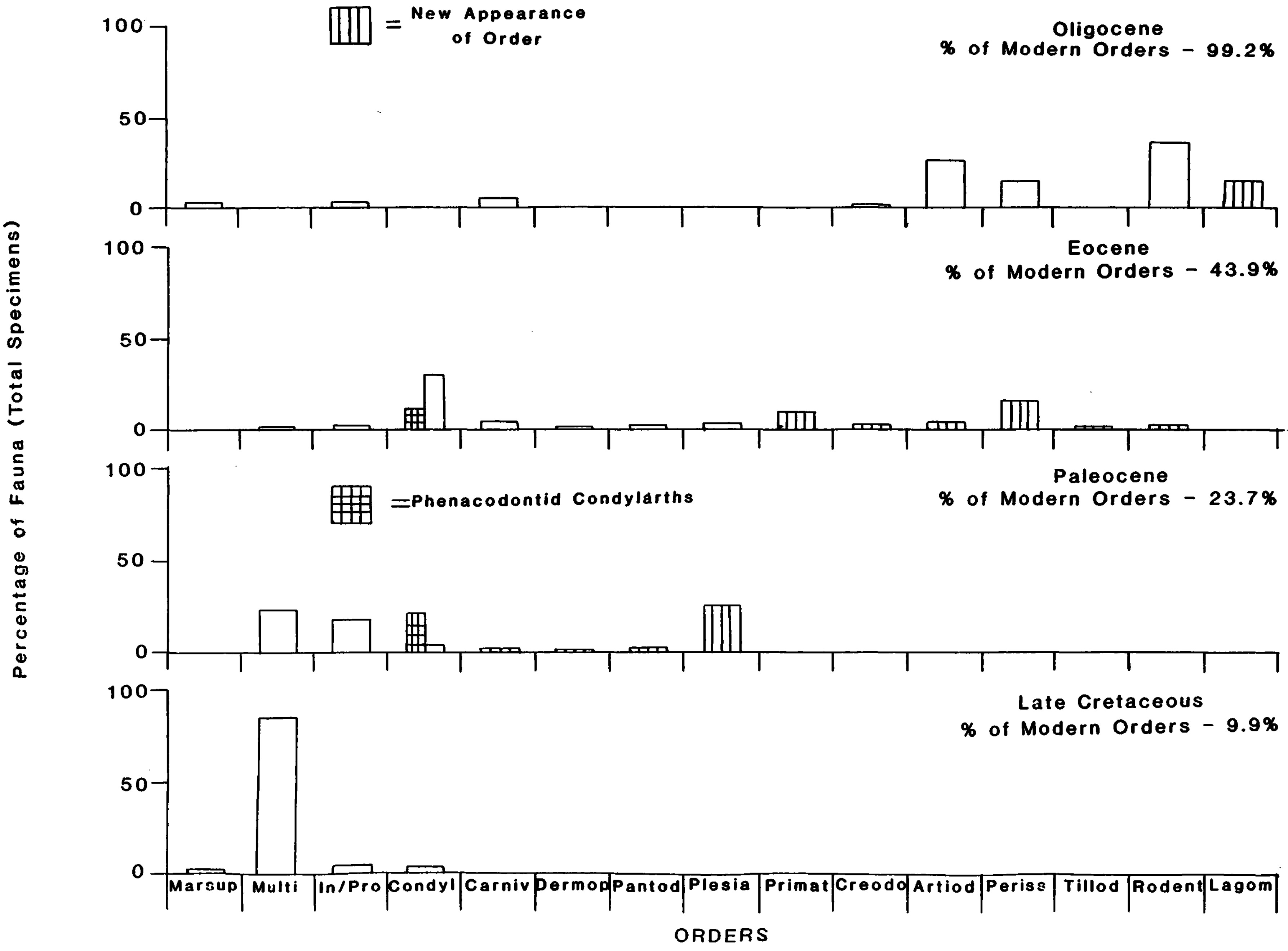
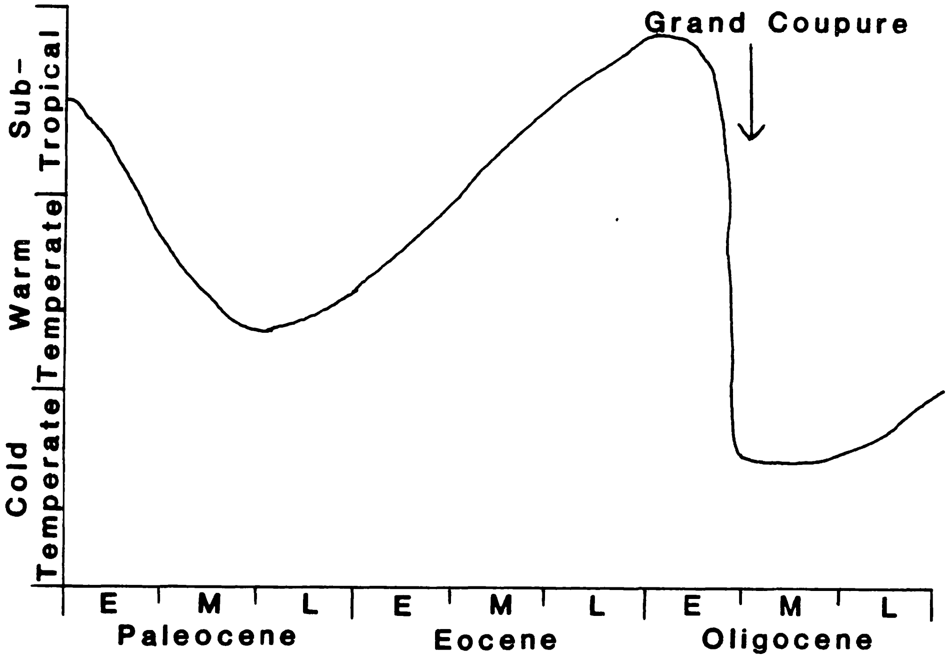

▥ = New Appearance of Order
▦ =Phenacodontid Condylarths
Oligocene
% of Modern Orders - 99.2%
Eocene
% of Modern Orders - 43.9%
Paleocene
% of Modern Orders - 23.7%
Late Cretaceous
% of Modern Orders - 9.9%
Percentage of Fauna (Total Specimens)
100
50
0
Marsup
Multi
In/Pro
Condyl
Carniv
Dermop
Pantod
Plesia
Primat
Creodo
Artiod
Periss
Tillod
Rodent
Lagom
ORDERS

FIGURE 2



Paleotemperature Curve
(Rocky Mountain Corridor)

FIGURE 3

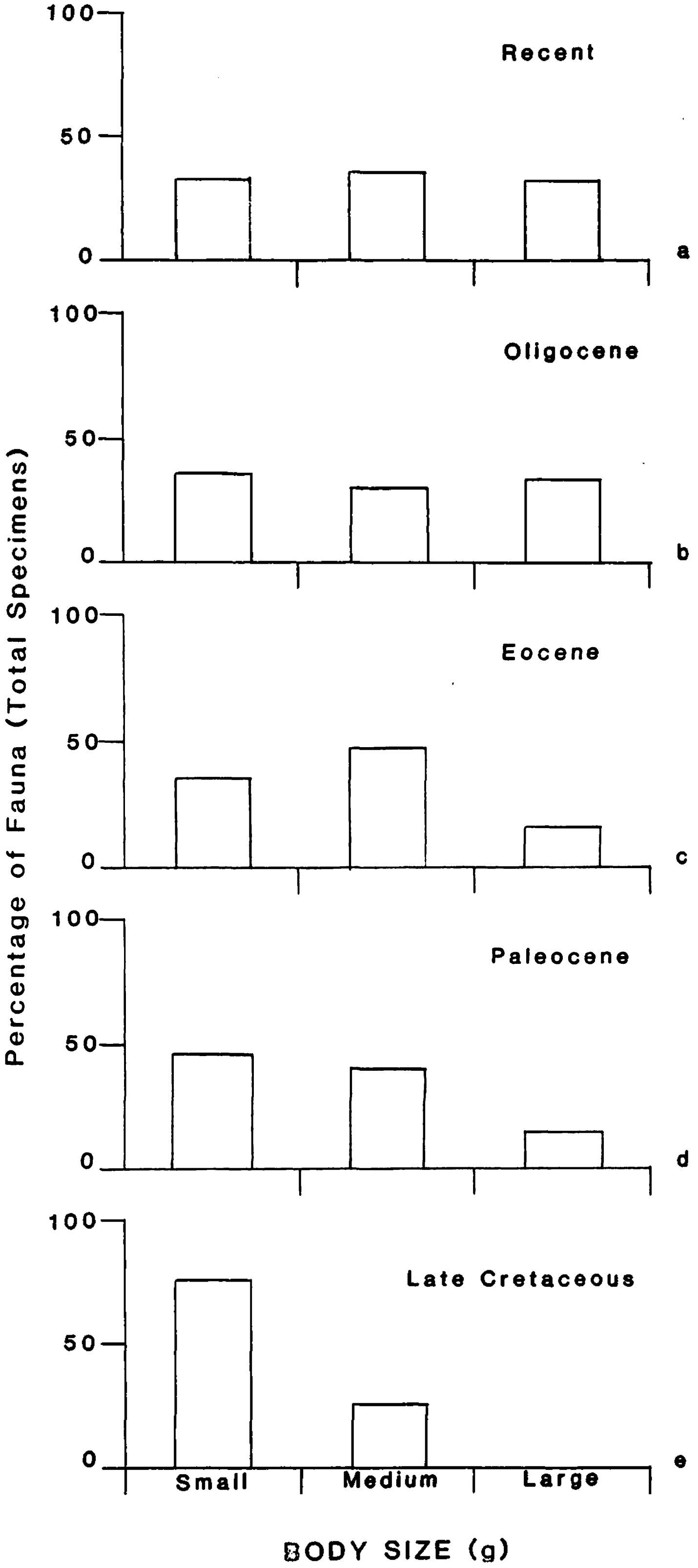
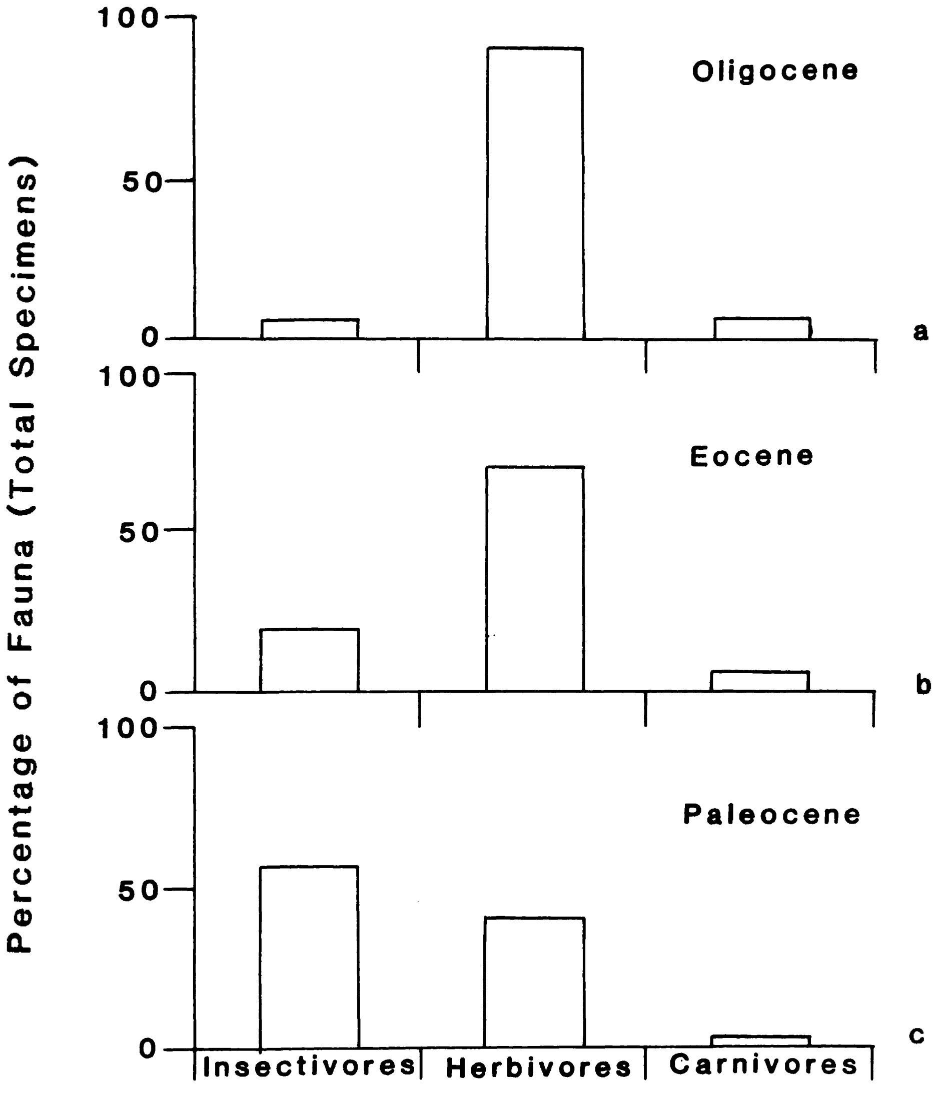

100
50
0
Recent
a
Oligocene
b
Eocene
c
Paleocene
d
Late Cretaceous
e
Percentage of Fauna (Total Specimens)
Small
Medium
Large
BODY SIZE (g)

FIGURE 4



DIETARY CATEGORY

Some Comings and Goings in the History of Mammals

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Study of the evolution of mammal life involves the question of why some mammals did not appear on some parts of the earth until long after they had developed elsewhere, and why some disappeared in one region while thriving in numbers and variety in some other places.

For example, this curious contrast: What large, herbivorous game mammals do we Americans associate with our national history and folklore? The bison or "buffalo," the white-tail deer, and the Rocky Mountain bighorn sheep. These animals originated in the Old World and came to North America at the time the last Pleistocene glacier was melting. This makes them very recent immigrants in the history of animal life in the New World. For comparison, what animals do we Americans consider exotic, not likely to be seen outside of a zoo or a circus? Two good examples are the rhinoceros and the camel. Yet the family history of both of them has been traced back over 40 million years, to the early Tertiary, and mostly in the states of Wyoming, Nebraska, and South Dakota. They were "native Americans" for many millions of years before they showed up in their current habitats of Asia and Africa.

Dr. Robert Sloan of the geology department at the University of Minnesota, and Dr. Leigh Van Valen of the biology department at the University of Chicago, have traced the development of primates back to the end of the Cretaceous, or earliest Tertiary, in the Bug Creek-Hell Creek area of Montana. Primates became very numerous, and migrated to all other parts of the world except Australia, New Zealand, and Antarctica, during the Paleocene and Eocene. Most of the primate evolution that originated us modern humans took place in Africa. Meanwhile, primates disappeared from North America by mid-Oligocene time, about 30 million years ago, and stayed away until the arrival of ancestors of the Indians near the end of Pleistocene glacial times.

The horse and the rhinoceros had a common ancestor, whose remains are found in Eocene sediments (age about 50 million years) of west-central Wyoming. This animal is called Hyracotherium, or the more popular name Eohippus. The ancestors of some other modern mammals start showing up in those beds too. It is believed that land altitude was about 4,500 feet lower, with mountain ranges smaller, fewer, and less rugged than exist today, so the climate was generally milder and rainfall more reliable than we see in Wyoming today. If that was the case, then Eohippus and its mammal neighbors probably browsed their way around a warm-temperate forest.

Hyracotherium or Eohippus was about the size of a fox terrier, and it had some dog-like features about its body conformation. One could scarcely imagine from the sight of this small mammal the world-ranging variety of its descendants. Along with the horse and the rhinoceros, there is the tapir, which resembles a hog with three toes on each foot, and the late titanotheres, which evolved to the form of a giant-size rhinoceros. The horse, the rhino, and the tapir migrated to many other parts of the world via "land bridges." The titanotheres, after reaching a peak of size and numbers in the early Oligocene about 35 million years ago, disappeared suddenly and for no apparent reason.

What are "land bridges?" In many cases they have been caused by movement of the tectonic "plates" bearing the continents, or pieces of continents, so that regions now separated by a thousand miles or more of ocean were, in past geologic periods, in close contact (and vice versa). South Africa and Argentina, for example, were tucked tightly together until the Triassic period, then slowly split apart as the basin, which would later be the floor of the Atlantic Ocean, began to form. The split worked its way generally northward during the Age of Dinosaurs. By the end of the Jurassic period, the Sahara coast of North Africa, from Dakar to Gibraltar, separated from what would later be the east coast of the United States.

For over 100 years, paleontologists wondered why the remains of Hyracotherium (Eohippus) and its neighbors of the early Eocene could be found in west-central Wyoming, and also in sediments of the same age across the Atlantic in the neighborhood of London and Paris. The mystery was solved by two American fossil-hunters, Robert M. West of the Milwaukee Public Museum, and Mary Dawson of the Carnegie Museum in Pittsburgh. These people walked over Ellesmere Land and other bleak parts of the Canadian Arctic during the short summers of several years until they found Eocene fossil mammal fauna which closely matched those of both west-central Wyoming and the London-Paris basin. This discovery fitted together three more pieces of the giant jigsaw puzzle of plate movements. The final parting of the Old World from the New happened about 48 million years ago, when Greenland pulled away from Labrador to the southwest, and at the same time from Norway and the land mass of the British Isles on the southeast. It is noted that in those days climate was much milder, even in the Arctic, than it is today. Land mammals and reptiles wandered back and forth, through regions of temperate-to-subtropical forests, between North America and Europe.

There is another way that land bridges can be created and destroyed. Somewhat over a million years ago, in the mid-Pleistocene, the most recent "age of glaciers" began. A succession of glacial advances and retreats involved all of the northeastern third of North America, and much of northern Europe and parts of Asia. These regions were sometimes covered by ice sheets several thousands of feet thick. The last retreat of the ice to its present limits in Greenland didn't take place until about 10,000 years ago. At times of maximum mass and extent of the ice, so much of the water in the world was frozen in these glaciers that the level of the oceans dropped about 300 feet. This lower sea-water level allowed a great area of former sea-bottom to be exposed in many places in the world. During this time, several thousand square miles of ocean bed between Siberia and Alaska were open to travel by animals and humans.

Humans--the ancestors of modern "indians"--wandered back and forth across this expanse of former sea-bottom in pursuit of the mastodon, the mammoth, the Pleistocene long-horn bison, and any other game they craved. It is now known that "Beringia" was dry land, not ocean as at present. Humans (Eskimos) can cross that stretch of open water, paddling walrus-skin boats in warm weather, or walking across the ice from one seal-breathing hole to another when it is cold. Herbivorous mammals, on the other hand, have no reason to walk out on bare ice where there is no grass or brush for them to eat. Mammal herbivores go where their appetites direct them to go.

THE EXTINCT HORSES OF NORTH AMERICA

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Introduction

Extinct horses are some of the most common fossils to be found in continental sedimentary rocks of North America. The horses belong to the class Mammalia, order Perissodactyla (central-toed ungulates), family Equidae and range in age from the early Eocene to the present. Their fossils document the evolutionary history of this interesting group.

The first horse, Hyracotherium, which has, at times, been called "Eohippus" or the Dawn Horse, is first recorded from the early Eocene Willewood and Wind River formations of Wyoming. This little horse was about the size of a Fox Terrier and is the most primitive member of the family. It had four toes on the front feet and three toes on the back feet. Advanced species of Hyracotherium gave rise to species of the genus Orohippus during the middle Eocene. Then, during the late Eocene, members of the genus Orohippus evolved into species of the genus Epihippus. Orohippus and Epihippus are much rarer in the fossil record than their ancestor, Hyracotherium, and are primarily known from fragmentary remains from the middle and late Eocene deposits of Utah, Texas and Wyoming.

Advanced species of the genus Epihippus gave rise to species of the genus Mesohippus of the Oligocene. Mesohippus is the common horse of the Chadron and Brule formations of Nebraska, South Dakota and Wyoming. Mesohippus was larger than it's ancestors and had lost one front toe, so that, it had three toes in the front and rear feet. Members of the genus Mesohippus evolved into Miohippus during the early Miocene. Miohippus and Mesohippus are very similar, except for differences in the total length of the premolar series relative to the total length of the molars. The Anchitheriinae, the subfamily which includes the genera Archaeohippus, Hypohippus and Megahippus, were also derived from Mesohippus. This group occurred in the middle and late Miocene, and are primitive offshoots of Mesohippus, from which they differ primarily by larger size and morphological differences in the cheek teeth.

The main evolutionary changes from Hyracotherium to Miohippus are; 1- the premolars of each successive genus became more molar-like (molarization) and 2- a progressive reduction of the digits, so that, early genera had four toes in front while later genera were three toed.

In the early and middle Miocene, advanced species of the genus Miohippus evolved into species of the genus Parahippus. Parahippus is mainly distinguished from it's ancestor Miohippus by further reduction of the size of the side toes resulting in a larger central weight bearing toe and more complex cheek teeth.

During the Miocene, the grasslands began to evolve in North America. This new ecosystem required the horses to change to survive. Early in their history the horses were mainly grazers of soft vegetation. The grasses contain large amounts of minerals and commonly have dirt on their leaves, so that, horses and many other types of herbivores had to change their eating strategy to utilize this new food source. To do this they evolved larger cheek teeth providing a larger grinding surface for the food and their teeth became hypsodont (taller) which allowed them to compensate for the heavy wear caused by eating grasses.

It was during the Miocene that the horses reached their greatest numbers and varieties. The changing environment allowed for many new ecological niches to be opened up which the horses rapidly evolved to fill. The most common of the new genera of pony-sized horses from the Miocene were Merychippus, Protohippus, Pliohippus, Dinohippus, Hippparion, Neohipparion and Cormohipparion. These horses were fully adapted to grazing on grass with well developed grinding cheek teeth and longer legs for running across the open savannahs. Members of the genus Hipparion migrated across the Bering Land Bridge between Siberia and Alaska during the late Miocene and populated the old world. Advanced species of the genus Dinohippus continued to evolve during the latest Miocene and probably gave rise to Equus, the genus which includes the modern horse and zebras. Members of the latest Miocene genus Astrohippus evolved into species of the genus Asinus, which includes the living donkey and ass.

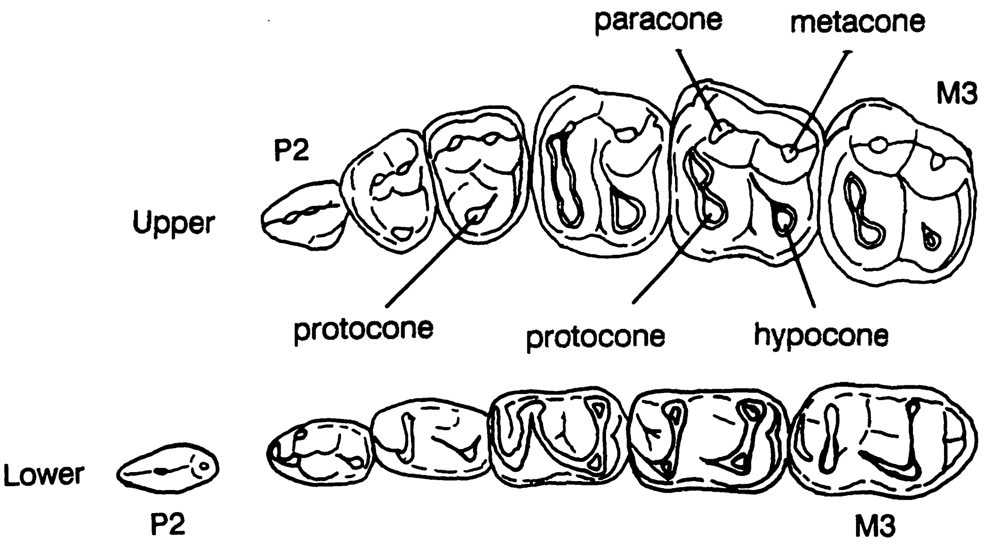
In the following section on equid systematics I have included an updated list of most all the know extinct horses of North America and the living horses of the world. Descriptions of the characters which distinguish each genus are included with an account of the species assigned to that genus, the author and date when first described, and the locality were the holotype specimen was found.

In the early horses of the Eocene through the early Miocene, the main dental character which distinquishes different kinds of horses is the degree of molarization of the premolars, that is, how much the premolars look like the molars. In the earliest horses the upper premolars have only three cusps. Then as they evolved, each premolar, starting with the third, successively began to change its structure and became more molariform. So that, by the time Mesohippus first appeared in the early Oligocene, the second through forth premolars were fully molariform. In horses, the first premolar is commonly represented by a very small peg-like tooth which is found just in front of the larger, grinding cheek teeth. This tooth is called the wolf tooth.

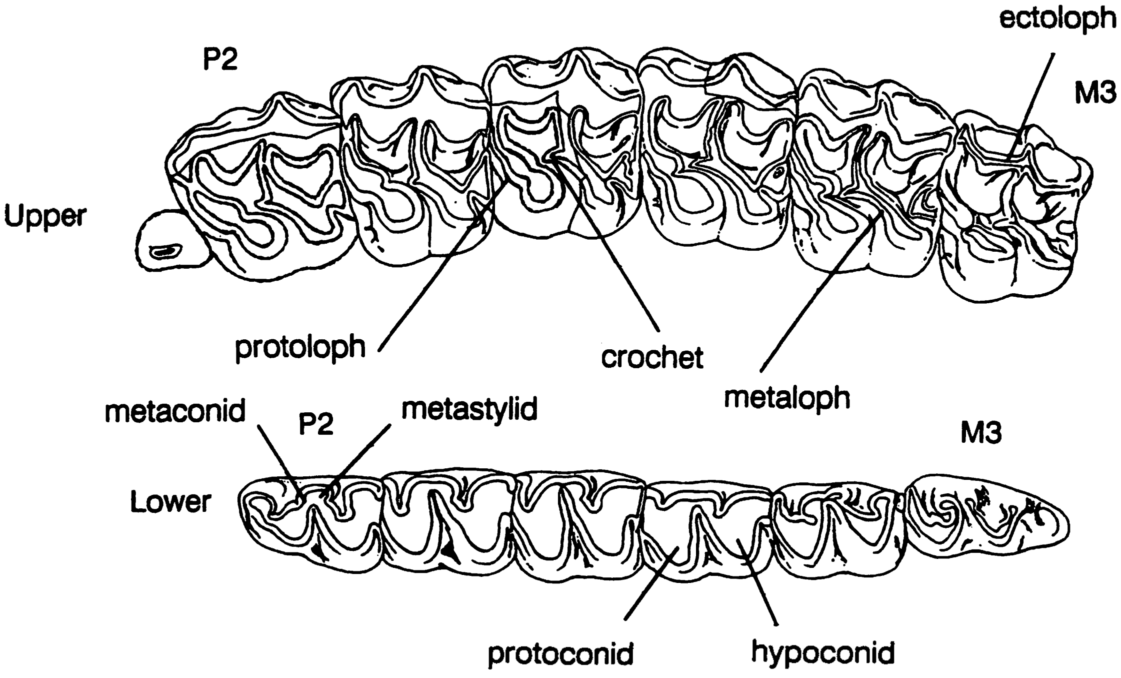
The dental nomenclature used in the descriptions may appear confusing at first, however, I have included illustrations which explain what each term refers to (Figures 1 and 2). Most of the dental nomenclature just refers to the various cusps, crests, lophs, bumps, or pockets which are present on the grinding surface or the sides of the cheek teeth. Horses which are more closely related have similar patterns in their cheek teeth. The upper and lower dental formulas of all mammals refers to the types of teeth and numbers of each type which are present on one side of the mouth. In the horses the upper and lower dental formulas are the same because they have the same number of teeth in the skull and the mandible. The upper and lower dental formula of horses consists of three incisors, one canine, four premolars, and three molars. The formula can also be expressed as I1-3 (the three incisors), C (the one canine), P1-4 (the four premolars) and M1-3 (the three molars) and any individual tooth is then labeled by the first letter of its type and its number, such as, P2 equals the second premolar or M3 equals the third molar.

In the later horses of the middle Miocene through the Recent, the main distinquishing characters are the presence or absence of fossae in the skull and the pattern of the grinding surfaces of the cheek teeth. The term fossa (pleural = fossae) refers to a pocket-like depression which is present on the skull in front of the orbits (Figure 3). Some types of horses have no fossae, others may have only one and some have two. If the term is preceded by another name, such as lacrimal fossa, that just means that the pocket-like depression occurs over the lacrimal bone of the skull. Likewise, the term malar fossa would refer to a pocket-like depression over the malar bone of the skull, whereas, maxillary fossa means it occurs over the maxilla bone of the skull.

I hope that the list and descriptions will introduce the reader to the variety of extinct horses which occurred in North America and how different kinds of horses are distinguished from one another. If you are interested in pursuing the subject of fossil horses, then the publications which I have marked with an asterisk in the literature cited section, would be a welcome addition to your library.



Hyracotherium



Parahippus

Figure 1. Dental nomenclature of the cheek teeth of the early horses of the Eocene through the early Miocene. All views are of the occulsal (grinding) surfaces. (After Granger, 1908 and Osborn, 1918)

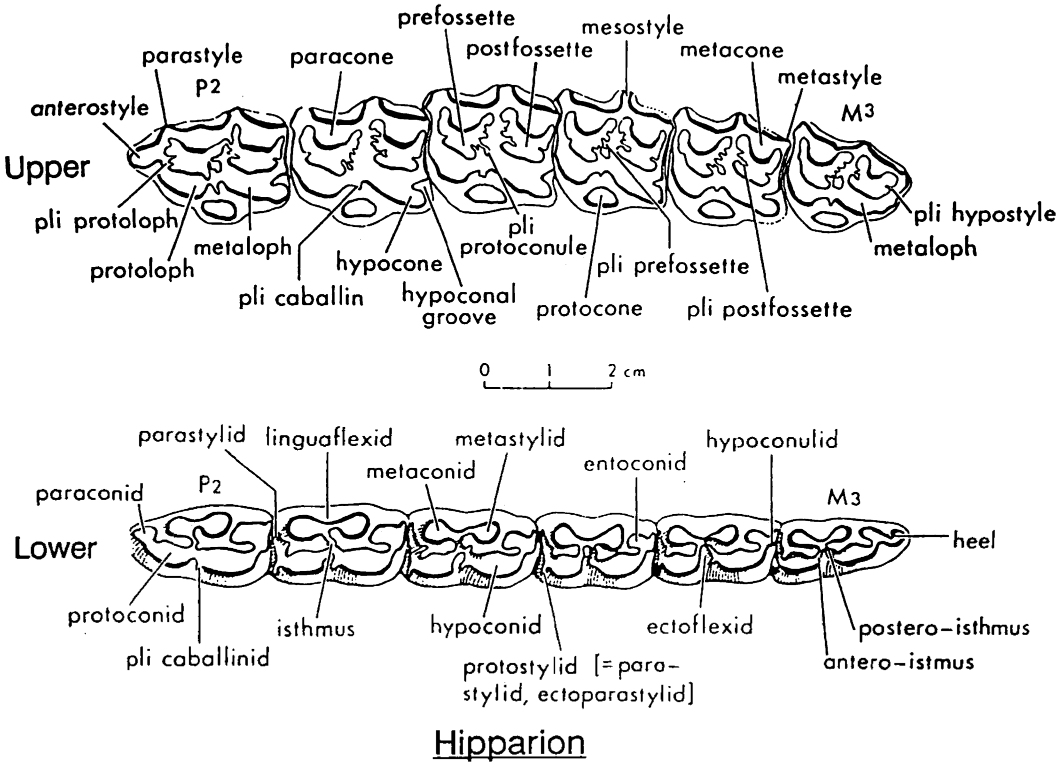


Figure 2. Dental nomenclature of the cheek teeth of the later horses of the middle Miocene through the Recent. All views are of the occulsal (grinding) surfaces. (Modified from Macfadden, 1985)

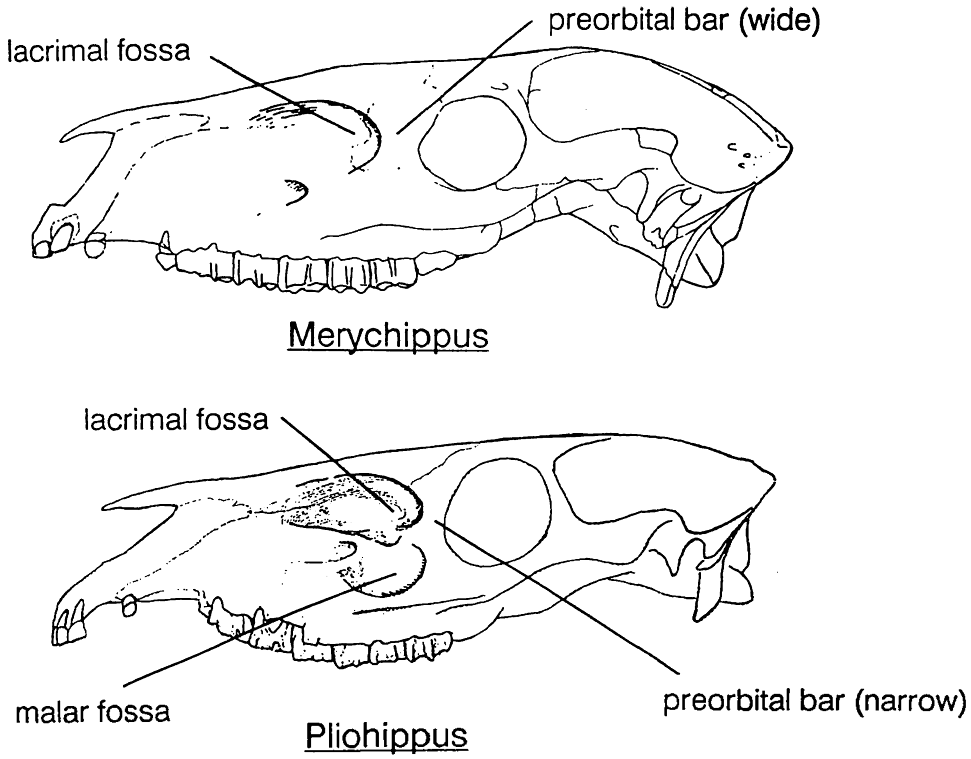


Figure 3. Nomenclature of the facial fossae of the skulls of the later horses. (Modified from Osborn, 1918)

Equid Systematics

Family Equidae Gray 1821

Subfamily Hyracotheriinae Cope 1881

Genus Hyracotherium Owen 1840- Also known as the Dawn Horse. A diastema (space) is present between the upper first and second premolar. The upper third premolar is never molariform but a well-developed fourth major cusp is present in advanced species. The upper forth premolar with three major cusps. The upper molars with well-developed lophs but with intermediate cusps usually prominent. A mesostyle is absent. A diastema is present between the lower first and second premolars. The lower forth premolar is never fully molariform but can have a well-developed entoconid in some individuals. The mesolophid of the lower molars is sharply oblique.(description modified from Kitts, 1956) Included species are:

H. angustidens Cope 1875 - Largo or Almagre, New Mexico
H. vasacciense Cope 1872 - Knight, Wyoming
H. craspedotus Cope 1880 - Lost Cabin, Wyoming
H. index Cope 1883 - Knight, Wyoming

Genus Orohippus Marsh 1872- Th upper third and forth premolar with four major cusps in all species and fully molariform in advanced species. A mesostyle is present on the upper molars in all species and on the upper third and forth premolars in advanced species. The upper molars have well-developed lophs, however, the intermediate cusps are detectable. The ectoloph on molars is V-shaped in crown view in all species and on the upper third and fourth premolars of advanced species. The lower forth premolar is molariform. The mesolophid is sharply oblique. The digits (toes) I an V are absent in pes (foot). (description from Kitts, 1957) Included species are:

O. major Marsh 1874 - Millersville, Bridger, Wyoming
O. pumilus Marsh 1871 - Marsh's Fork, Bridger, Wyoming
O. progressus Granger 1908 - Twin Buttes, Wyoming
O. sylvaticus Leidy 1870 - Henry's Fork, Wyoming
  synonym: Epihippus uintensis Marsh 1875 - Bridger C, Wyoming
O. agilis Marsh 1873 - Henry's Fork, Wyoming

Genus Epihippus Marsh 1877- This horse is very similar to Orohippus except, its teeth are more molariform. The third and fourth upper premolars are molariform and the mesostyle is fully developed. Epihippus differs from other Eocene horses in having external cresentic cusps. The second upper premolar possesses a prominent posterointernal cusp and a small anterointernal cusp. No diastema occurs between the first and second premolars. The third and fourth lower premolars are molariform. In the second lower premolar there is one anterior cusp, whereas, posteriorly there are two cusps. The feet are like those of Orohippus, but the central digit is relatively larger. (description modified from Stirton, 1940). Included species are:

E. gracilis Marsh 1871 - Uinta Basin, Utah
E. parvus Granger 1908 - Uinta County, Utah
E. intermedius Peterson 1931 - Duchesne River, Utah.

Subfamily Anchitheriinae Osborn 1910

Genus Mesohippus Marsh 1875- The premolars are equal to or smaller in length (anterior to posterior) than the molars, and upper and lower, second through the forth premolars are molariform. The metaloph is not connected to the ectoloph. The teeth are bunolophodont to lophodont. There is no cuboidal facet on the third metatarsal and the manus (front foot) has three digits (toes). (description from Stirton, 1940) Included species are:

M. celer Marsh 1874 - "Chadron", Nebraska
M. latidens Douglass 1903 - Thompson's Creek, Nebraska
M. montanensis Osborn 1904 - Pipestone Creek, Montana
M. hypostylus Osborn 1904 - Cheyenne River, South Dakota
M. proteulophus Osborn 1904 - Cheyenne River, South Dakota
M. bairdii Leidy 1850 - Bear Creek, South Dakota
M. obliquidens Osborn - Badlands, South Dakota
M. barbouri Schlaikjer 1935 - Goshen County, Wyoming
M. eulophus Osborn 1904 - Cedar Creek, Colorado
M. texanus McGrew 1971 - Gulf Coast, Texas
M. grandis Clark and Beerbower 1967 - Gulf Coast, Texas
M. latidens Douglass 1903 - Thompson's Creek, Montana
M. montanensis Osborn 1904 - Pipestone Creek, Montana
M. portentus Douglass 1903 - Pipestone Creek, Montana
M. viejensis Clark and Beerbower 1967 - Gulf Coast, Texas

Genus Haplohippus McGrew 1953- Rare genus, not well known. Included species:

H. texanus McGrew 1953 - Texas.

Genus Miohippus Marsh 1874- Miohippus is very similar in morphology to Mesohippus, except the length of the premolars are equal to or larger than the length of the molars. The upper and lower premolars are molariform but the metaloph is not connected to the ectoloph. A cuboidal facet is present on the third metatarsal, and the foot has three toes. The third digit (central main toe) is larger than in Mesohippus. Included species are:

M. brachystylus Osborn 1904 - Cheyenne River, South Dakota
M. crassicuspis Osborn 1904 - Cheyenne River, South Dakota
M. gidleyi Osborn 1904 - Cheyenne River, South Dakota
M. intermedius Osborn and Wortman 1895 - Cheyenne River, South Dakota
M. meteulophus Osborn 1904 - Badlands, South Dakota
M. validus Osborn 1904 - Badlands, South Dakota
M. equiceps Cope 1879 - Middle John Day, Oregon
M. equinanus Osborn 1918 - Porcupine Creek, South Dakota
M. annectens Marsh 1874 - John Day, Oregon
M. anceps Marsh 1874 - John Day, Oregon
M. brachylophus Cope 1878 - John Day, Oregon
M. longicristis Cope 1878 - John Day, Oregon
M. acutidens Sinclair 1905 - John Day, Oregon
M. primus Osborn 1918 - John Day, Oregon
M. quartus Osborn 1918 - John Day, Oregon
M. gemmarosae Osborn 1918 - Bear-in-Lodge Creek, South Dakota

Genus Parahippus Leidy 1858 - A lacrimal fossa is present, whereas, a malar fossa is absent. Osborn (1918) divided this genus into three groups.

Group I - This group is characterized by; relatively short crowned teeth, shallow lacrimal fossa, heavily proportioned limbs, feet which are moderately elongate, and ungual phalanges which are short and small.

P. cognatus Leidy 1858 - Fort Niobrara, Nebraska
P. texanus Leidy 1868 - Independence, Texas
P. avus Marsh 1874 - Mascall, Oregon
P. nebrascensis Peterson 1907 - Sioux County, Colorado
P. texanus Leidy 1868 - Independence, Texas
P. tyleri Loomis 1908 - Agate, Nebraska

Group II - This group is characterized by; cheek teeth are short-crowned with simple patterns, a crochet which is simple in construction, incipient accessory foldings of metaloph, size small, lacrimal fossa rather deep, limbs slender and moderately long, phalanges short, and ungual phalanges long and narrow.

P. pawniensis Gidley 1907 - Logan County, Colorado
P. crenidens Scott 1893 - Deep River, Montana
P. pristinus Osborn 1918 - Porcupine Creek, South Dakota
P. pawniensis atavus Osborn 1918 - Agate, Nebraska

Group III - This group is characterized by; teeth which are long-crowned, a well developed crochet with accessory minor crests, prominent external ribs on the molars, the feet long and slender, the lateral digits greatly reduced, and phalanges of moderate length.

P. coloradensis Gidley 1907 - Logan County, Colorado
P. coloradensis praecurrens Osborn 1918 - Porcupine Creek, Colorado

Not assigned to a Group by Osborn, 1918

P. brevidens Marsh 1874 - Cottonwood Creek, Oregon
P. leonensis Sellards 1916 - Tallahasse, Florida
P. agrestis Leidy 1873 - Red Rock Creek, Montana
P. wyomingensis Schlaikjer 1925 - Upper Harrison, Wyoming
P. vellicans Hay 1924
  synonym: P. socius Hay 1924 - Garvin Gully, Texas

Genus Desmatippus Scott 1893 - This horse very similar in morphology to Parahippus and may assignable to Parahippus. Originally described as a rather brachyodont (short crowned) species with a well developed crochet. Included species:

D. integer Matthew 1924 - Lower Snake Creek, Nebraska

Genus Archaeohippus Gidley 1906 - These small Miocene horses are primitive and very similar to the Oligocene genus, Mesohippus. The metaloph is connected to the ectoloph, and the crochet may be present or absent on the upper cheek teeth. The ribs between the styles are as well developed on the cheek teeth in this genus as in Parahippus. All teeth are lophiodont and low crowned. The lacrimal fossa is shallow and the malar fossa forms a deep pit posteriorly. (description from Stirton, 1940) Included species are:

A. equinanus Osborn 1918 - Porcupine Creek, South Dakota
A. nanus Simpson 1932 - Thomas Farm, Florida
A. blackbergi Hay 1924 - Garvin Gully, Texas
A. minutalis Hay 1924 - Garvin Gully, Texas
A. penultimus Matthew 1924 - Sheep Creek, Nebraska
A. ultimus cope 1886 - Mascall, Oregon
A. minimus Douglass 1900 - Madison Valley, Montana
A. mourningi Merriam 1913 - Barstow, California

Genus Anchitherium Meyer 1844 - This genus is represented by large, primitive Miocene horses which occur in North America and Europe. The genus is characterized by: the metaloph connected to the ectoloph, however, there is no crochet present on upper cheek teeth, ribs are usually present or faintly indicated between styles on upper teeth, the upper third molar is slightly larger than upper second molar, the teeth are lophidont and low crowned and the preorbital fossa is usually relatively shallow, but not pocketed anteriorly as in advanced species of Hypohippus. (description from Stirton, 1940). Included species are:

A. praestans Cope 1879 - John Day, Oregon
A. gracilis Marsh 1892 - John Day, Oregon
A. agatensis Osborn 1918 - Agate, Nebraska
A. avus Schlaikjer 1935 - Lower Harrison, Nebraska
A. clarenci Simpson 1932 - Quincy, Florida

A. australis Leidy 1873 - Independence, Texas
A. navasotae Hay 1924 - Garvin Gulley, Texas

Genus Hypohippus Leidy 1858 - This genus is represented by large, primitive late Miocene horses. The metaloph is connected to the ectoloph, but no crochet appears on the upper cheek teeth except sometimes in milk teeth. A wide V-shaped valley is present between the styles. The upper third molar is much smaller than second upper molar. The lacrimal fossa is deeply pocketed anteriorly and posteriorly, however, in some primitive species the fossa is open anteriorly. Hypohippus is larger than Anchitherium. (description modified from Stirton, 1940) Included species are:

H. equinus Scott 1893 - Deep River, Montana
H. osborni Gidley 1907 - Pawnee Creek, Colorado
H. affinis Leidy 1858 - Burge, Nebraska
H. nevadensis Merriam 1913 - Esmeralda, Nevada

Genus Megahippus McGrew 1937 - This genus is represented by very large, primitive, middle to late Miocene horses. Diagnostic characters are; large size, upper premolars have continuous cingula (ridges around the base of the tooth), and very large procumbent lower and upper incisors. Included species are:

M. matthewi McGrew 1937 - Devil's Gulch, Nebraska
M. mckennai Tedford and Alf 1962 - Barstow, California

Subfamily Equinae Steinmann and Doderlein 1890

Tribe Merychippini - This tribe is characterized by; a facial crest which is generally convex to flat (not dorso-ventrally compressed as seen in Stylonini), a lacrimal fossa is present, no malar fossa, a wide preorbital bar, and the feet are monodactyl (one-toed) to tridactyl (three-toed). (description after Kelly and Lander, 1988).

Genus Merychippus Leidy 1856 - The genus is characterized by a protocone which is separated from protoloph until well worn, fossettes with complex patterns, and tridactyl. Included species are:

M. insignis Leidy 1856 - Bijou Hills, South Dakota
    synonym: M. paiensis Cope 1874 - lower Pawnee Creek, Colorado
M. tertius Osborn 1918 - Sheep Creek, Nebraska
    synonym: M. insignis tertius Osborn 1918 - Sheep Creek, Nebraska
M. republicans Osborn 1918 - Driftwood Creek, Nebraska
M. primus Osborn 1918 - Sheep Creek, Nebraska

Genus Merychippus ? - Species of this group probably are referable to Merychippus but the facial fossae are undescribed at this time. Included species are:

M. ? patruus Osborn 1918 - Driftwood Creek, Nebraska
M. ? sumani Merriam 1915 - Barstow, California
M. ? eohipparion Osborn - Pawnee Creek, Colorado
M. ? eoplacidus Osborn 1918 - Pawnee Creek, Colorado
M. ? labrosus Cope 1874 - Pawnee Creek, Colorado

Genus Protohippus Leidy 1858 - This genus is characterized by the protocone united to protoloph early in wear, the fossettes are of simple pattern, and the feet are tridactyl to anisotridactyl. Included species are:

P. perditus Leidy 1858 - Niobrara River, Nebraska.

The holotype specimen (U.S.N.M. no. 619) is a partial maxilla with P4-M3 (forth premolar through third molar). A referred neotype by Gidley (1906) (A.M. 10838) is an immature skull with dP2-dP4 and M1 and M2 erupting. The cheek teeth of the neotype do not exhibit the characters of the holotype (fossettes less complicated, protocone and hypocone differ, etc.) and was found along the Little White River, near the Rosebud Indian Agency, South Dakota, which is considered Clarendonian (late Miocene), whereas, the holotype is from deposits considered Barstovian (middle Miocene). The type of P. simus comes from same deposits and it is likely that the neotype referred to P. perditus is instead referable to P. simus.

P. perditus secundus Osborn 1918 - Driftwood Creek, Republican River, Nebraska. This area is considered Barstovian in age (middle Miocene). If the referred material is actually P. perditus then it would suggest that P. perditus was tridactyl. Osborn (1918) describes the associated foot as anisotridactyl, and notes that this specimen has a slender, elongate, laterally compressed central medipodial (fig. 166a, Osborn, 1918). Also P. parvulus is tridactyl with some reduction of the lateral digits.

P. intermontanus Merriam 1915 - Barstow, California
P. proparvulus Osborn 1918 - Pawnee Creek, Colorado
P. parvulus Marsh 1868 - Antelope Station, Nebraska
P. profectus Cope 1889 - Driftwood Creek, Nebraska
P. simus Gidley 1906 - Little White River, Rosebud Indian Agency, South Dakota

Genus Protohippus ? - Species included here are with unknown foot structure, they could be assigned to Protohippus (tridactyl to anisotridactyl) or Pliohippus (monodactyl), but until the number of toes on their feet are known, they are questionably referred to Protohippus. Included species are:

P. ? niobraensis Gidley 1906 - Fort Niobrara, Nebraska
P. ? simus Gidley 1906 - Little White River, South Dakota
P. ? tehonensis Merriam 1915 - Tejon Hills, California
P. ? castilli Cope 1885 = indeterminate sp.-Tehuichila, Mexico

Tribe Pseudohipparini

Genus Pseudohipparion Ameghino 1904 (synonym: Griphippus Quinn 1955) - This genus is characterized by a long and simple lacrimal fossa, a vestigial (very faint) malar fossa, a large elliptical protocone on the upper molars which is isolated in early wear and connected in later wear, slender limbs, a wide preorbital bar, a facial crest which is straight to dorso-ventrally compressed; and tridactyl feet. Included species are:

P. retrusum Cope 1889 - near Long Island, Kansas
P. gratum Cope 1889 - Little White River, South Dakota

Tribe Dinohippini

Genus Dinohippus Quinn 1955 - Members of this genus are characterized by a maxillary fossa (no true lacrimal fossa) which is deep and narrow, no true malar fossa is present but a scar of levator labialis muscle can be present as pocket-like structure, the fossae are anteriorly placed on rostrum resulting in a wide preorbital bar, and the feet are monodactyl. Included species are:

D. fossulatus Cope 1893 - Clarendon, Texas
    synonym: ? Protohippus ? pachyops Cope - Donley County, Texas
D. interpolatus Cope 1893 - Clarendon, Texas
D. spectans Cope 1880 - Rattlesnake, Oregon
D. sp., cf. D. spectans - Cuyama Badlands, California
D. leidyanus Osborn 1918 - Aphelops draw, Nebraska
D. edensis Frick 1921 - Mount Eden, California
D. osborni Frick 1921 - Mount Eden, California
D. coalingensis Merriam 1914 - Etchegoin, California
D. albidens Mooser 1968

Tribe Callipini

Genus Callipus Matthew and Stirton 1930 (Stirton, 1935) - This genus is characterized by no lacrimal or malar fossae present, the protocone is connected to protoloph in early wear, the upper cheek teeth are slightly curved, the fossettes with little or no plications (simple), small size, and the feet are tridactyl. Included species are:

C. placidus Leidy 1858 - Niobrara River, Nebraska
C. regulus Johnston 1937 - Clarendon, Texas
C. anatinus Quinn 1955 - Lapara Creek, Texas
  synonyms: C. optimus Quinn 1955 - Lapara Creek, Texas
  Astrohippus curtivallis Quinn 1955 - Lapara Creek, Texas
C. proplacidus Osborn 1918-Sand Canyon,Pawnee Creek, Colorado

Tribe Nannippini

Genus Nannippus Matthew 1926 - These little horses are characterized by lacrimal and malar fossae absent, an elongated rostrum, an elongated post-canine diastema, reduced anterostyles and paraconids, hypsodont (tall) cheek teeth, a protocone which is large relative to the tooth, a protocone which is isolated until the tooth is well worn, development of protostylids (in primitive species), usually moderately developed pli caballinids and ectoflexids, small size, and feet are tridactyl. (description after MacFadden, 1984) Included species are:

N. minor Sellards 1916 - Alachua, Florida
N. ingenuus Leidy 1885 - Alachua, Florida
N. beckensis Dalquest and Donovan 1973 - Beck Ranch, Texas
N. peninsulatus Cope 1885 - Tehuichila, Mexico

Tribe Cormohipparini

Genus Cormohipparion Skinner and MacFadden 1977 - Members of this genus are characterized by a dorsal preorbital fossa well developed with continuous anterior and posterior rims, a lacrimal fossa moderately to deeply pocketed, and tridactyl feet. Cormohipparion is probably derived from the Merychippini. (description after MacFadden, 1984) Included species are:

C. goorisi MacFadden and Skinner 1981 - Trinity River, Texas
C. sphenodus Cope 1889 - Sand Canyon, Colorado
C. occidentale Leidy 1856 - Little White River, South Dakota

Tribe Hipparini

Genus Hipparion De Christol 1832 - Members of this genus of horse are found as fossils in North America, Europe and Asia. The are characterized by a lacrimal fossa which is not as well developed anteriorly as Cormohipparion and is also shallower than Cormohipparion. The lacrimal fossa of Hipparion is moderately well defined with a continuous rim posteriorly whereas a malar fossa is absent. This genus was probably derived from Merychippini. (description after MacFadden, 1984) Included species are:

H. shirleyi MacFadden 1984 - Gulf Coast, Texas
H. tehonense Merriam 1916 - South Tejon Hills, California
H. forcei Richey 1948 - Black Hawk Ranch, California

Tribe Neohipparini

Genus Neohipparion Gidley 1903 - This genus is characterized by a dorsal preorbital fossa present which is relatively poorly defined and differs from Merychippus by increased size, increased crown height (hypsodonty) and relatively elongated protocones. It was probably derived from Merychippus. (description after MacFadden, 1984) Included species are:

N. coloradense Osborn 1918 - Sand Canyon, Colorado
N. affine Leidy 1869 - Niobrara River, Nebraska

N. trampasense Edwards 1982 - Bolinger Canyon, California
N. leptode Merriam 1915 - Thousand Creek, Nevada
N. eurystyle Cope 1983 - Palo Duro Canyon, Texas
N. gidleyi Merriam 1915 - Petaluma, California

Tribe Stylonini - The tribe is characterized by a lacrimal and malar fossa present, monodactyl to tridactyl feet, a facial crest which is dorso-ventrally compressed, and a narrow preorbital bar.

Genus "Stylonus" - One species, "S". carrizoensis, is placed in this category because it is similar to Stylonus, however, certain characters indicate it probably represents a new genus closely related to Stylonus. It is characterized by a lacrimal fossa present, a malar fossa present which is small and pocket-like in shape, the lacrimal and malar fossae are separated by a distinct small posterior ridge, a narrow preorbital bar, the protocone is connected to the protoloph early in wear, the pattern of the fossettes is simple, and the feet are tridactyl. (description after Kelly and Lander, 1988) Included species:

"S". carrizoensis Dougherty 1940 - Caliente Mountain, California

Genus Stylonus Cope 1879 - This genus is characterized by a lacrimal and malar fossa present which is separated by an indistinct ridge, the protocone is isolated from the protoloph until the tooth is from 1/3 to 1/2 worn, and tridactyl feet. (description after Kelly and Lander, 1988) Included species are:

S. seversus Cope 1879 - Mascall, Oregon
    synonyms: Merychippus isonesus Cope 1889 - Cottonwood Creek, Oregon
        M. isonesus quintus Osborn 1918 - Sheep Creek, Nebraska
        M. isonesus secundus Osborn 1918 - Sheep Creek, Nebraska
S. missouriensis Douglass 1908 - Confederate Creek, Montana
S. calamarius Cope 1875 - Lower Santa Fe, New Mexico
S. sejunctus Cope 1874 - Lower Pawnee Creek, Colorado
S. stylodontus Merriam 1915 - Barstow, California
S. californicus Merriam 1915 - North Coalinga District, California
S. sp. - Kelly and Lander, 1988 - Cuyama Badlands, California

Genus "Pliohippus" - One species "P". campestris, is assigned to this taxon which is very similar to Pliohippus (in the strict sense), however, it is more primitive than Pliohippus because it is tridactyl (three toed) whereas Pliohippus is monodactyl (one-toed). It probably represents the ancestor of Pliohippus and should be given a new genus name. It is characterized by a lacrimal and malar fossa distinctly separated by a well developed ridge (double fossa), the protocone is connected to protoloph early in wear and tridactyl feet. (description after Kelly and Lander, 1988) Included species are:

"P." campestris Gidley 1907 - Lower Pawnee Creek, Colorado

Genus Pliohippus Marsh 1874 - This genus is characterized by a protocone which unites with the protoloph early in wear, a lacrimal fossa and malar fossa present which are distinctly separated by a well developed ridge (double fossae), monodactyl feet, and broad, flat ungual phalanges. (description after Kelly and Lander, 1988) Included species are:

P. pernix Marsh 1874 - ? Minnechaduza, Nebraska
P. supremus Leidy 1869 - Little White River, South Dakota
P. lullianus Troxell 1916 - Oak Creek, South Dakota

Tribe Equuini - The tribe is characterized by absence of facial fossa, very hypsodont (tall) cheek teeth, a protocone which is attached to the protoloph, a protocone which is large relative to the tooth and eliptical in shape, the ectoflexid of the lower molars penetrates deeply into the metaconid-metastylid isthmus, and monodactyl feet. This group may be derived from Dinohippus. This taxon is represented by the genus Equus Linnaeus, 1758, which is currently subdivided into four subgenera. (descriptions of the subgenera modified from Kurten and Anderson, 1980).

Genus Equus **(subgenus** Equus) - This subgenus is characterized by broad and shallow, usually U-shaped linguaflexids (the internal folds between the metaconid and metastylid). Included species:

E. (E.) caballus - the living, domesticated Horse.
E. (E.) przewalskii - the living, wild horse of Mongolia

Genus Equus **(subgenus** Dolichohippus Heller 1912) - This subgenus includes the living, african Grevys Zebra. It is characterized by the linguaflexids are narrow and usually V-shaped, and no parastylids in the lower cheek teeth. Included species are:

E. (D.) grevyi - the living, african Grevys Zebra
E. (D.) simplicidens Cope 1892 - Blanco, Texas
    synonyms: E. proversus Merriam 1916 - San Joaquin, California
        E. idahoensis Merriam 1918 - Hagerman, Idaho.
        Pliohippus francescana Frick 1921 - San Timoteo, California
        Plesippus shoshonensis Gidley 1921 - Hagerman, Idaho.

Genus Equus **(sugenus** Hippotrigris Smith 1841) - This subgenus includes the living, african, Lowland Zebra. It is characterized by V-shaped linguaflexids and parastylids are usually present on the lower cheek teeth. Included species are:

E. (H.) parastylidens Mooser 1959 - Cedazo, Mexico.
E. (H.) burchelli - the living, african, Lowland Zebra.

Genus Equus **(subgenus** Hemionus Cuvier 1832) - This subgenus includes the stilt-legged horses of North America and their relatives, the old world onagers. It is characterized by cheek teeth which tend to be relatively slender and very hypsodont (tall), and the linguaflexids of the lower cheek teeth are narrow and usually V-shaped. Included species are

E. (H.) calobatus Troxell 1915 - Sand Draw, Nebraska
E. (H.) hemionus Pallas 1775 - the living, Onager, Asia.
E. (H.) tau Owen 1869 - Pleistocene, Mexico
    synonyms: E. littoralis Hay 1913
        E. francisci Hay 1915
        E. achates Hay and Cook 1930
        E. quinni Slaughter et. al. 1962

Tribe Asinii - This tribe consists of the true Donkey, Wild Ass and their relatives. It is characterized by the facial fossa absent or present, hypsodont cheek teeth, a protocone which is attached to the protoloph, a protocone which is large relative to the tooth and eliptical in shape, ectoflexids which do not enter the metaconid-metastylid isthmus, and monodactyl. Advanced members of the genus Astrohippus probably gave rise to the genus Asinus in the latest Miocene.

Genus Astrohippus Stirton 1940 - This genus is characterized by moderate to high crowned cheek teeth, a distinctly separate metastylid and metaconid which are widely separated, pli caballinid absent, a malar fossa is reported to be present, and monodactyl feet. Included species are:

A. ansae Matthew and Stirton 1930 - Coffee Ranch, Texas
A. martini Hesse 1936 - Beaver, Oklahoma
A. stocki Lance 1950

Genus Asinus Frisch 1775 - This genus includes the living donkey, ass and their extinct relatives. This group is characterized by the absence of facial fossae. Included species are:

A. asinus - the living, Wild Ass
A. cumminsii Cope 1893 - Blanco, Texas

Genus Asinus ? - This group of horses is usually assigned to the genus Equus, however, they all have Asinus-like molar patterns and are probably referrable to the genus Asinus. A complete revision of the group is needed and until then, they are provisionally placed in the genus Asinus. Included species are:

A.? giganteus Gidley 1901 - Pleistocene, Texas
A.? pacificus Leidy 1869 - Pleistocene, California
A.? mexicanus Hibbard 1955 - Valley of Mexico, Mexico
A.? pectinatus Cope 1899 - Port Kennedy Cave, Pennsylvania
A.? crinidens Cope 1894 - Valley of Mexico, Mexico
A.? occidentalis Leidy 1865 - Tuolumne Co., California
A.? bautistensis Frick 1921 - Bautista Beds, California
A.? complicatus Leidy 1858 - Niobrara River, Nebraska
A.? fraternus Leidy 1860 - Charleston, South Carolina
A.? scotti Gidley 1900 - Rock Creek, Texas
    synonym: E. midlandensis Quinn 1957 - Midland, Texas
A.? niobrarensis Hay 1913 - Grayson, Nebraska
    synonym: E. hatcheri Hay 1915 - Grayson, Nebraska
A.? conversidens Owen 1869 - Valley of Mexico, Mexico
    synonym: E. simiplicatus Cope 1893 - Blanco, Texas
A.? lambei Hay 1917 - Gold Run Creek, Yukon.
A.? excelsus Leidy 1858 - Pleistocene, Nebraska
    synonyms: Onager hibbardi Mooser 1959
        O. arellanoi Mooser 1959 - Mexico
        O. hibbardi Mooser 1959.-. Mexico
        Asinus aquascalentensis Mooser 1959 - Aquascalentia, Mexico

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Fossil Mammals of Florida

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I really had to sit down and think about what to write when it concerns Florida Fossil Mammals. I've been collecting fossils in Florida for 35 years. I first collected along the Gulf beaches in southwest Florida at the age of five. I knew somewhat of what I was finding, but was far from understanding the meaning of Geology and Paleontology. It was not until the sixties that I realized that finding fossils in lime rock, in certain clays, sand, the bottom of river beds, etc., played an important part in Florida's geologic past. It was once this became a reality to me that I started finding the large number of fossil vertebra I had always dreamed about. Since then, I have discovered numerous important Fossil Vertebra sites in Florida. I have correlated and excavated many of these sites with the help of the Florida State Museum and the Bone Valley Fossil Society. I have donated countless thousands of fossils to the Florida State Museum, many local museums, museums around the United States and the Smithsonian Institute. I have worked closely with the Mulberry Phosphate Museum in identifying and displaying fossil vertebra. Most of my larger fossils are on display at the Mulberry Museum, which includes an articulated Baleen Whale (Balaenoptera floridana)-Kellogg-Miocene, a complete Porpoise Skull (Pomatodelplis inaequalis)-Miocene, a very large Mastodon Maxilla (Mammut Americanum)-Kerr-Pliestocene, a complete large Mandible & Maxilla of the large Mammoth Imperator (Archidiskodon)-Leidy-Pliestocene.

Some of the more important fossils I have found that are in my private collection are:

1. A complete lower mandile of a juvenile Mastodont with three molars and one pre-molar on each side. (Gomphotheriidae simplicidens)-Osborn-Pliocene. This is the finest Mastodont jaw I have ever seen.

2. Upper tuck of a Mastodont with two molars (Amebelodon)-Shovel Tusker-Pliocene.

3. Skull and lower jaws of a Rhino (Teleoceras Longipes)-Pliocene.

4. Large Cave Bear complete lower jaw (Tremaretor species)-Pliestocene. Largest ever found in Florida.

5. Large Porpoise beak upper and lower-5 feet long-163 teeth (Pomatodelphis species)-Miocene. Largest ever found in Florida.

6. Fifteen inch Sloth Claw with lower jaw (Eremotherium)-Pleistocene.

7. Complete lower mandible with maxilla of the last known Mastodont (Gomphotheriidae cuvieronius)-Pliestocene.

8. I have found 14 complete Dugong skulls to date-ancestrial of the Sea Cow (Felsinotherium floridanum)-Hay-Miocene.

I have many species of Mammals in my collection: carnivors, rodents, camels, horses, sloths, tapir's alligator, crocodile, antelope, beavers, peccary, rhino, deer, sharks, bison, and armidillo, all found in Florida. As always, my own personal museum is always open to the public and to professionals who want to study my fossils.

I almost forgot to list some of the rare fossils I have found, which were most important in the understanding of the climatic changes in Florida's past history. These fossils include a Horn Gopher, walrus, sea otter, and seal.

Even though this years 1989 M.A.P.S. Expo is the year of the mammal, I still have the love and enjoyment of all fossils and I do not have any one particular interest. The rest of my writings will include some of Florida's geology and its problems.

Florida's Epochs and some Fossil Fauna Occurrences

(Geologic Setting)

As is true the world over, the nature and occurrence of fossil vertebrate deposits in Florida is controlled, primarily by the nature of its regional geology. The key to understanding the geologic framework in which fossil vertebrate deposits occur in the state of Florida, lies in the fact that virtually the entire Florida Peninsula is underlain by vast limestone formations. These rocks, ranging in age from Eocene to Miocene, are highly soluble in ground water. Through the millions of years since their formation, they have been subjected to the geologic process termed "karstification." This process results from the great solubility of limestone: water dissolves the surface in complex fashion and then diverts surface waters into underground routes. The majority of fossil vertebrate deposits presently known from Florida occur in situations resulting from this process; for example, caves, sinkholes, underground streams, potholes, fissures, etc. Although this has been a fortunate circumstance in most respects, especially in the great numbers of potential fossil sites produced, it also has led to difficulties in others.

(Geological Difficulties)

The great difficulty in the deciphering of these faunas is inherent in the geologic conditions which prevail in Florida. None of the fully exposed sections as seen in the western United States, where the faunal sequence is frequently so clearly displayed, occur in the low-lying peninsular state. The fossils have usually been found in mining, dredging, realigning roadcuts or other operations which disturb the original deposit and usually damage any articulated animal remains that they may contain. Many fossils are collected from stream deposits which were from eroded beds of several different ages and these mingled remains were redeposited into a single bed from which the collections were taken and, in a few cases, several different age determinations were given to the same strate, depending on which fauna was being interpreted.

(Florida Faunas)

The remainder of this section is designed to familiarize you with the fossil vertebrate faunas collected from the various rock units present in Florida.

I. Cretaceous

Florida's oldest vertebrate and only fossil from this fauna was recovered during the summer of 1955 by the Amerada Petroleum Corporation, during the course of drilling operations near Lake Okeechobee. A well core, containing a partial skeleton of an aquatic turtle was brought up from a depth of 9,210 feet from the Glen Rose formation of the early Cretaceous period.

II. Eocene

The oldest rocks exposed on the surface belong to part of the Eocene series. The common vertebrates known from the Ocala Formation are the sharks, fish, skates, rays, and marine turtles. The most impressive vertebrates in the Eocene of Florida are the extinct zeuglodont whales, Basilosaurus and Pontogeneus, and the Sirenians (manatee relatives).

III. Oligocene

The Oligocene deposits of Florida are almost entirely marine. Formal stratigraphic divisions include the Marianna Limestone and the Suwannee Limestone. The former two units are restricted mostly to the Panhandle, whereas the latter extends farther down into the Florida Peninsula. These marine formations have yielded numerous shark teeth and several kinds of Teleost fishes.

A land vertebrate fauna of Late Oligocene age from a tiny solution cavity in the Ocala Limestone near Gainesville. Known as the I-75 fauna, this represents the oldest extensive Cenozoic terrestrial vertebrate fauna in eastern North America and has revealed the former presence in Florida of a large and surprisingly diversified assemblage of land vertebrates. There are two toads, two salamanders, a turtle, a tortoise, three kinds of lizards, and five kinds of snakes. The mammals number more than a dozen species including mouselike (cricetid) rodents, small canids, horses of the genus Mesohippus, and several oreodonts.

IV. Miocene

Until 1963 practically all that was known of Miocene land vertebrates in Florida had come from the Thomas Farm Quarry in Gilchrist County. A few bones and teeth had been recovered from Midway, Quincy, Ashville, and Polk counties in north Florida, but were shown to be only slightly younger than those from the Thomas Farm. Northeast of Brooksville, in Hernando County, is the only evidence we now have of Early Miocene land vertebrate life in Florida. To date, the Brooksville site has yielded alligators, canids, tapirs, rhinoceratids, and oreodonts. The Thomas Farm deposit in Gilchrist County, has produced a continuous harvest of valuable skeletal material, now comprising an extensive fauna of quite varied aspect. The fossil-bearing sediments accumulated in a sinkhole formed in the underlying Ocala Formation.

The mammals represented at Thomas Farm are 32 species and shrews, bats, and several kinds of rodents. At least five kinds of dogs are present, including such widespread genera as Cynodesmus and Tomarctos. The huge dog-like bear, Amphicyon, plus three species of small mustelid carnivores, much like weasels and badgers.

The hoofed mammals include a large conservative horse Anchitherium, and two advanced species, the small Parahippus blackbergi and the large Parahippus leonesis. Two rhinoceroses, the small Diceratherium and the large Floridaceras are conspicuous. The pigs are represented by a single species, Desmathyas olseni. The Thomas Farm contains two tiny deer, both not much larger than a jackrabbit, the widely known genus Blastomeryx and the fragil Machaeromeryx. Nothokemas and the unique Floridatragulus, a small camel with a strikingly long and narrow snout and the bizarre horned protoceratid, Prosynthetoceras were also found. Another site found in the Suwannee River is closely related to the Thomas Farm site. Near the same time period it is represented with peccaries, a three-toed horse and a giant pig and many other rare fossils.

Another new Miocene find was made near Buda, Florida, in which was found the remains of a large carnivore, a large oreodont, and a dwarf version of the large chalichothere.

All other middle and late Miocene deposits are mostly of marine. Represented by many mammal species of whales, porpoises, sirenias and sharks. However, there have been a few Late Miocene-Early Pliocene terrestrial fossils found in the Bone Valley Formation of Polk County. Such as: Heameryx, Kyptoceras, Peccary and Three-Toed Horse.

V. Pliocene

The Pliocene vertebrate sites of Florida start around the Georgia border and run for 240 miles into south Florida.

The phosphate deposits are one of the major sources of the fossil bones and teeth during this epoch. Other important Pliocene sites include the Withlacoochee River, Mixon's Bone Bed, McGeehee Farm, Love site, and the incredible Moss Acres site where many articulated skeletons have been found.

Fossil mammals found at the Moss Acres site include the largest known shovel-tusked Gomphothere ever found, a complete alligator skeleton (ten feet long), seven species of three-toed horses (along with one new species of three-toed horse found there), a three-horned Girafloid-pediomeryx, a bear size ground sloth, and rhinoceros.

The fossil mammals of importance at the other Pliocene sites include several kinds of gomphotheres, mastodonts, rhinocerotids-Teleoceras and Aphelops, six genera of horses, camelids, antilocaprids, deer, peccaries, tapir, horned gopher, carnivors of biting and stabbing cats, bears, large giant bear dogs, deer like animal Kyptoceras (last survivor of the protoceratids), many species of rodents, rabbits, moles, snakes, seals, sea otters, walruses, sharks, and dugongs.

VI. Pleistocene

The most numerous fossil mammals found in Florida are from the Pleistocene Epoch. It has been stated many times over that no fossil vertebrate field in the world exceeds the richness of Florida's Pleistocene deposits. There are two special factors that help produce the wealth of skeletal material. First, the recency of the Pleistocene has allowed little time for erosion to strip away or for deposition to cover up the fossil deposits. Presumably, this is the reason for the increasing number of sites from deposits of younger age. Secondly, the unique climatic history of the Ice Ages (equals Pleistocene) has favored greater deposition of fossil material, principally by causing changes in the level of the sea. The vast volumes of water that were locked up in continental glaciers caused the oceans to drop hundreds of feet during each glacial maximum. Then, during interglacial episodes, the seas rose to levels higher than the present. As a result, vast areas of land were repeatedly exposed and then covered with water, thus favoring deposition of great hordes of animals. Even on the land, the rise and fall of the sea caused the water table and associated lakes and streams to wax and wane. Consequently, large areas above even the highest seas were repeatedly exposed and covered by water.

The most productive sites are found in one of the following situations: 1) Sinkholes or fissures filling in early Tertiary limestones; 2) Bottom sediments of present rivers or springs; or 3) Deposits in former coastal marshes and intracoastal waterways.

Rich fossil deposits are found along both the east and west coasts of the Florida Peninsula. They include such renowned sites as Vero, Melbourne, Apollo Beach, West Palm Beach, Hog Haven, Reddick, Haile Quarry, and Leisey Shell Pit. Their fame has spread partly because of their proximity to the major population centers of the state, but, of course, also because of the wealth of beautifully preserved fossil vertebrates.

The Pleistocene faunas include every species of animal that now lives in Florida, and several others besides. The most impressive members of the Pleistocene fauna are the large, extinct herbivores: mammoths, mastodonts, and ground sloths. Llamas, horses, tapirs, and peccaries also abounded. With so many herds of grazing and browsing animals, it is not surprising that the kinds of large carnivores were more varied than today. The cats included two genera of sabre-toothed tigers, jaguars, biting cats larger than lions, and a considerable variety of smaller cats including margays, bobcats, and jaguarundis. The bear and dog families were also more diversified than now. The most remarkable rodents were the giant amphibious capybaras and beavers.

Conclusion

Even though Florida's Eocene Epoch does not contain any *land* mammals, it is evident that during the Pliocene and Pleistocene, faunas' of Florida were the Garden of Eden of Land Mammals. Florida has all species of horses, rhinos, camels, mastodonts, and mammoths that have ever been found in the world, with even more new species popping up all the time and only known to Florida.

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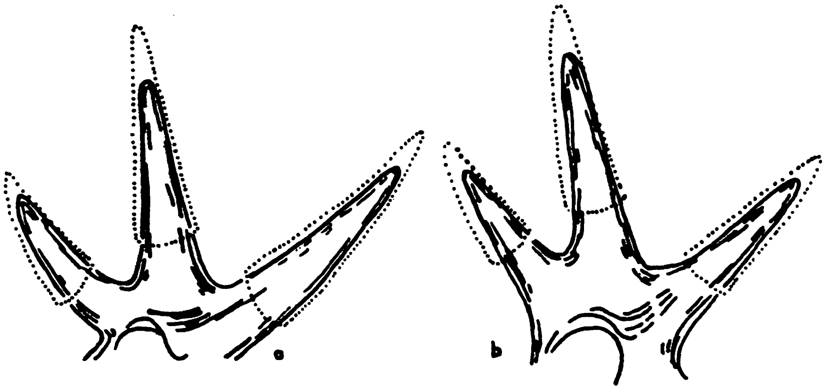
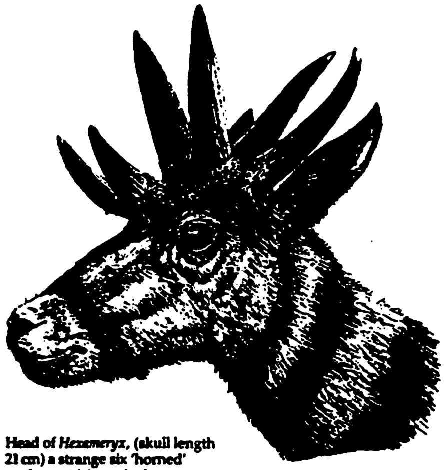
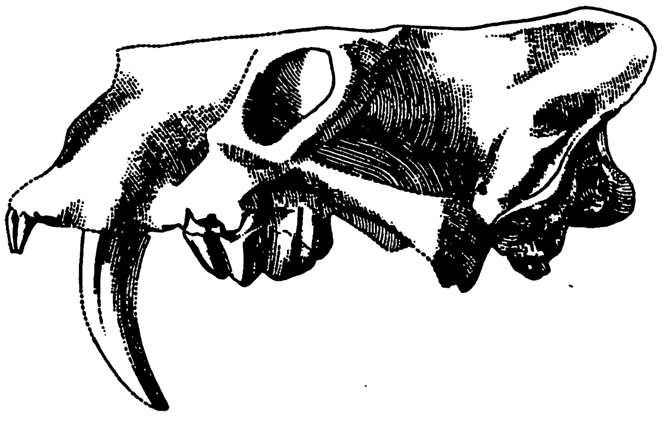
(By Dr. S. David Webb)



Left side view of Hexameryx horn rack. On the left (a) represents a presumed male which is larger, has a relatively longer posterior horn, and a more central anterior horn than the presumed female on the right (b). The dotted lines indicate the approximate outlines of the horn sheaths; only the bony cores are actually preserved.



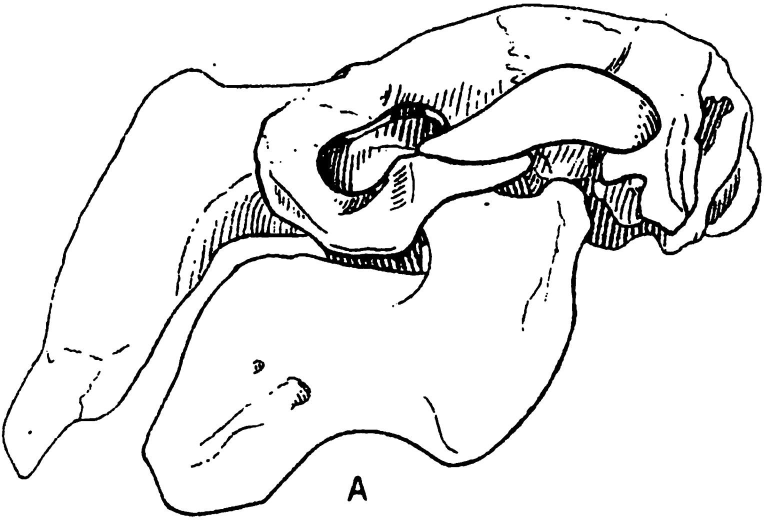
Head of *Hexameryx*, (skull length 21 cm) a strange six 'horned' antilocaprid from the late Miocene of Florida. (After Webb).



Skull of *Barbourofelis* (drawn by Lauren Keswick).

Skull of the scimitar-toothed *Homotherium serum* (from Meade).

Skulls of characteristic Sirenians. A, Recent Dugong. B, Metaxytherium, common Miocene and Pliocene dugongid from Florida and elsewhere in North Atlantic.



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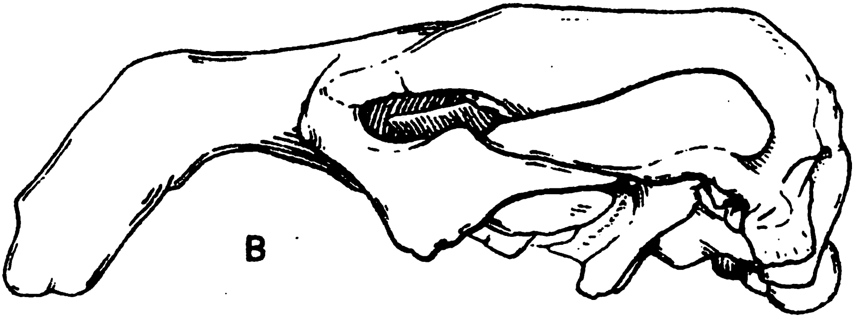

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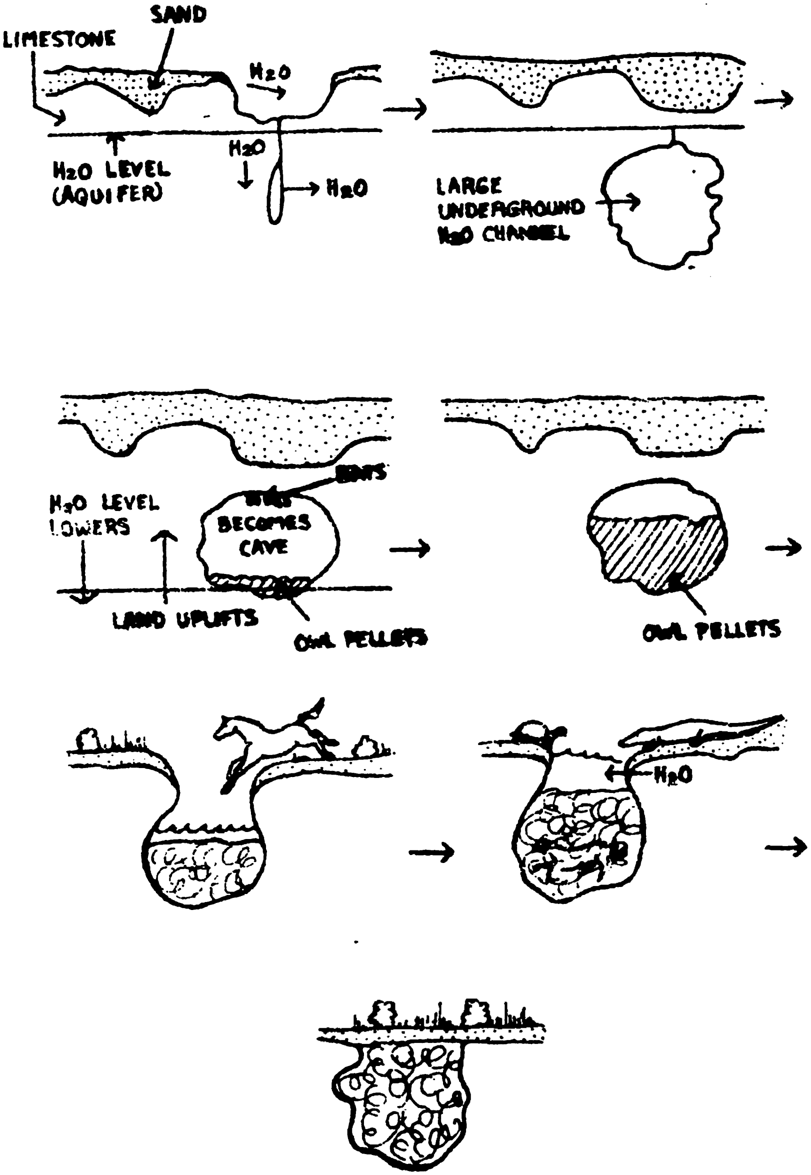
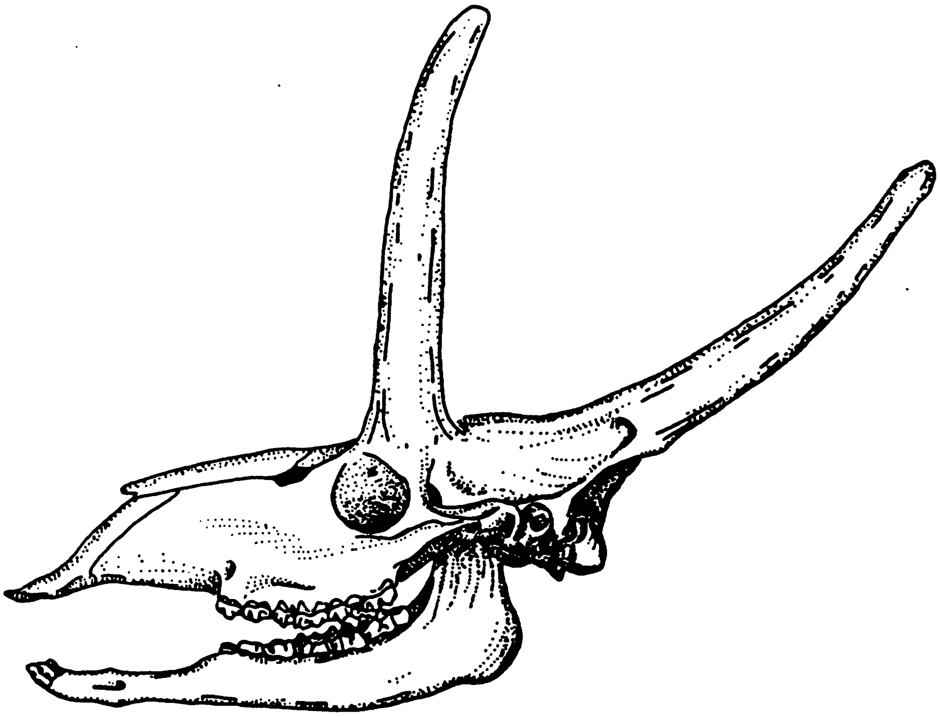
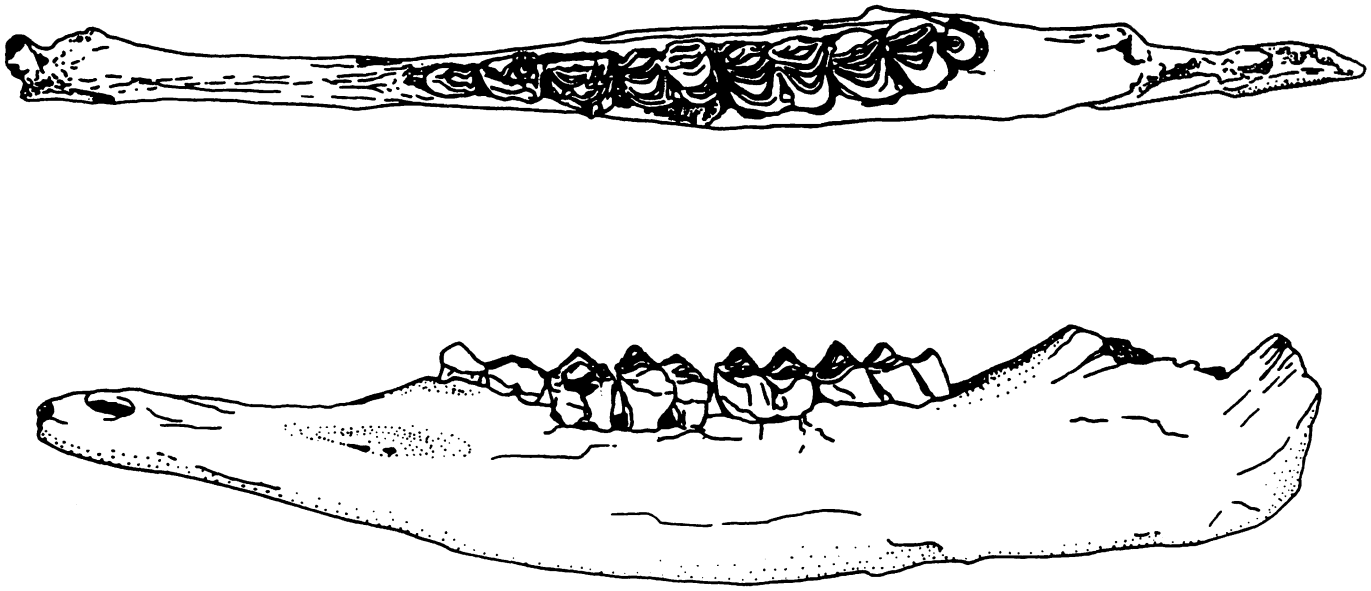


Florida cave-sinkhole fossil traps.

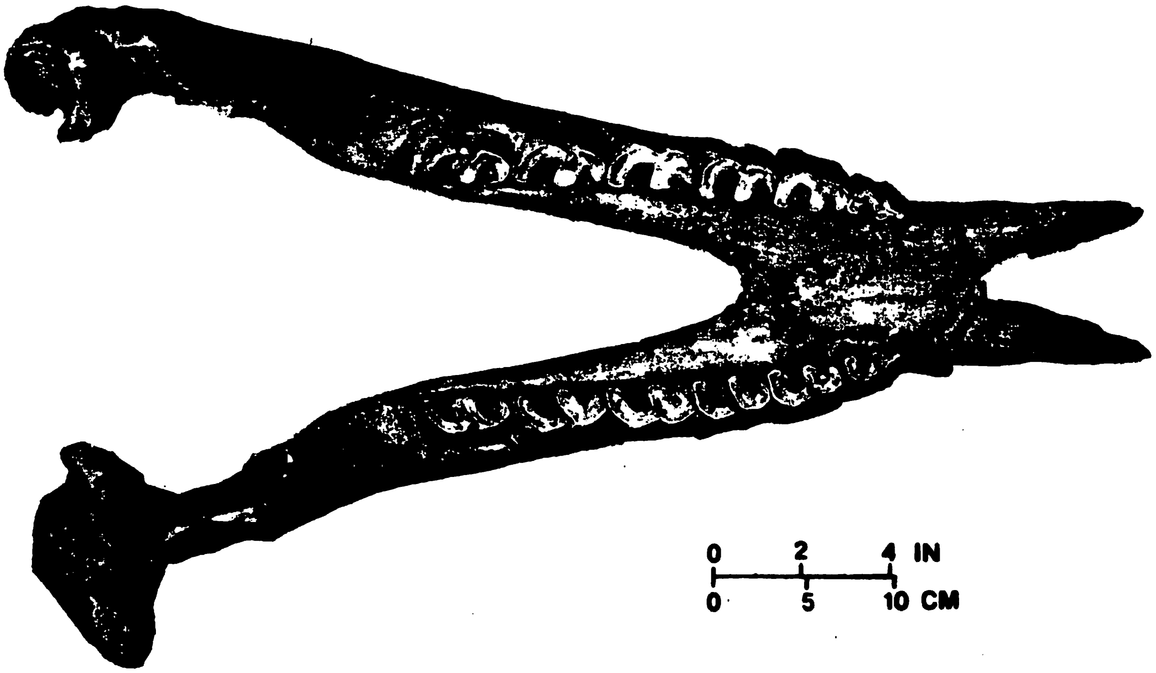


Skull of Pediomeryx hamiltoni from Love Bone Bed, with paired frontal horns and median occipital horn. This genus includes the largest Tertiary ruminants known in North America.

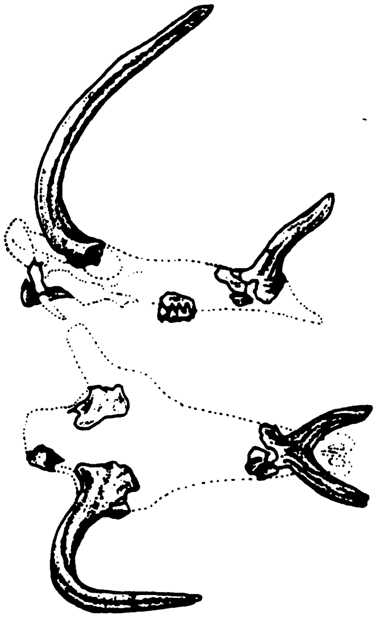


Left mandible of Pediomeryx hamiltoni. In lateral view note long low profile and long diastema between sockets for incisiform teeth and shortened premolars.

Right side view of skull of *Teleoceras* from the Miocene of northern Florida. Darker areas are reconstructed.



Lower jaw of *Aphelops* from the Miocene of northern Florida.



Skull of *Kyptoceras* (length 45 cm), probably the last survivor of the protoceratids in the latest Miocene of Florida. (After Webb).

Head of *Kyptoceras*, the last protoceratid which died out about 5 million years ago. The orbital horns reached a length of 50 cm.

A Day at the Creek

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It was early in the morning when I started out on my hunt, as I've done dozens of times. It's a time of solitude where you get a chance to be alone and think and to look, listen, and learn about the great mysteries of nature and all the treasures to be shown and shared.

So, with mask and snorkel in hand, looking kind of comical to all around, this tall man, in full wet suit and weight belt, walks through the woods along one of my favorite creeks. I go at a slow pace, looking and listening as life abounds around me. I walk upstream to one of my productive spots. Well, here we go, thought I, into the water that is only three to four feet deep but, oh, so cold at first. After working up a sweat getting here, the water seems even colder but, as usual, after a few minutes I'm as comfortable as if I were home in my easy chair. With mask on and water visibility very good, we start.

After a few minutes of looking and fanning away debris on the creek bottom, things start to turn up. At first, only small shark teeth, then a good size shark tooth, about two inches or so, seems like a good start to the day. It makes you want to think back when the owner of this tooth was a free swimming giant in the deep blue sea so long ago in time. Now, on we go with our hunting. After a few feet of working, this particular gravel bed seems to be playing out so we continue upstream. Looking around as we reach a shallow sand bar and stand up, there on the bank is an old bull looking at this funny looking thing that just emerged from water - makes you want to laugh just picturing it.

On we go to a gravel bed up the creek a little ways. As the water starts to get deeper, we return to the watery realm to indulge our curiosities as to what marvels await us. Sifting away the debris that covers the gravel layer on the bottom, bigger gravel than the other spot, there all over the bottom are bone chips. It looks promising. There, among the gravel, lies a horse tooth in good shape. Into the collecting bag it goes. Mixed into the gravel are also small shark teeth. After a little while, a beautiful deer antler base also goes into the bag. There seems to be a good, thick layer of gravel here. I will come back to this spot later. After all, I'm just checking out spots today and I could spend a week here in this spot. So, after putting a few more objects in the bag from the gravel surface, we move onward.

Having worked a half mile of creek, it is time for a break. Out onto the bank to take a breather - under the old majestic oaks we sit. How beautiful they look all covered with ferns and wild orchids. There's nothing around you but peace and quiet. It makes you want to sit here forever and just watch and listen; but that is not why we came out today. Back into the water we go.

After covering the next half mile with not much to show, we come to another spot that looks promising. After we get started there, on the bottom looking up in all of its splendor, is a beautiful bison tooth. As we clear around it, there is more of this beautiful creature revealed to my eyes, not one tooth, but one whole side of its jaw lies on the bottom (now cleared of debris). After pausing for a few minutes to study this treasure of time, the whole item is lifted out and carefully wrapped and put in the bucket that was brought (too fragile to just put in the collecting bag). Now we continue to search for more of this massive beast. This bison, whose bellow thundered over the savanna-like land (that was Florida thousands of years ago) had horns that stretched six feet from tip to tip, a massive bull head, and a shaggy coat of fur towering above all around it. They shared this land with such animals as camels, horses, elephants, saber cats, giant sloths and many more. But, on this day, all that is given up of this massive animal is a few teeth in the jaw.

Looking around, I realize that a good part of the day is gone; so, with my find of the day, I decide to quit. Back to the car we go. At once, the smells and sounds of nature fade. As we approach the highway, it's hard to believe that such a short distance away from these asphalt paths, life goes on as it has for thousands of years. Unfortunately, 99% of the people that go by never even look into the surrounding area to see nature's beauty; but that is their loss, not ours. Back at the car and loaded up, off we go to join the civilized world once more, richer for the beauty we were allowed to share. This memory we will enjoy until the next time the funny looking creature in the black wet suit wanders along the creek looking to find what little treasures the waters will reveal. Until then, I can always sit back and remember.

Try this little test yourself with me. Just close your eyes and let your mind drift to the time long, long ago when there were no cars or roads. The only sounds were what nature allowed at that time - the bellow of a bull elephant, the roar of some large cat causing the neighs of horses as they roamed the grassy lands, the splash of a fish in the waters of a pond or stream, the splash of an alligator or turtle as it enters the water, a shadow of a bird as it takes wing overhead. There, on the plains, you'd hear the sound of thunder as the massive bison move from one area to another or maybe the roar of a bear calling her cubs. It is hard to place this picture in the central part of Florida where all people think of is beach and oranges. This is the land that I think of when I relive this beautiful area just by closing my eyes and sharing a thought as to how it could be or how it was.

Until next time - good hunting!!

P.S. If you're driving down the highway one day and you see this man in a black wet suit walking to his car or through woods - no, it's not a monster or a walking alligator - it's just some crazy fossil hunter hunting along the creeks and streams. Stop by and say "hi."

FOSSIL MAMMALS OF THE WHITE RIVER BADLANDS

by
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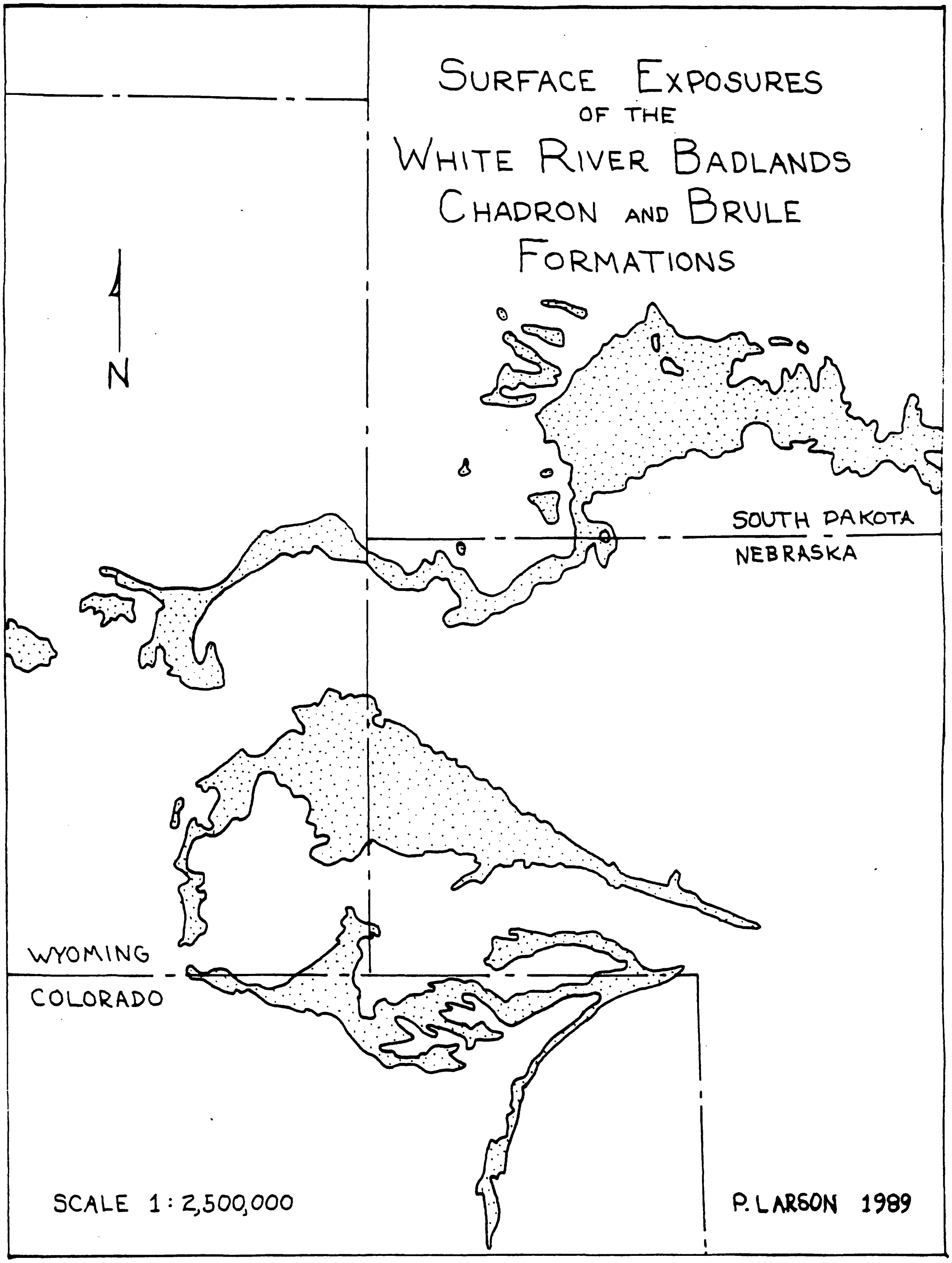
INTRODUCTION

Mauvaises terres. That is what the French trappers called this land. The Sioux Indians also had a name for it, calling it *Mako Sica* in the Lakota language. Both of these terms translate into what we know today as the "Badlands". Yet, this name is somewhat of a misnomer.

The French trappers and the Sioux Indians found plentiful game here. Then, as now, the land held ample places to hide and provided bountiful food for a multitude of animals. The French trapped beaver, muskrat, fox and other animals for their fur. The Indians hunted bison, elk, bear, deer, antelope and others for food, and used their hides for clothing, tools and shelter. Later, white settlers used these same animals as well as domestic stock which also flourished.

The "Badlands" is still home to a multitude of native mammals. These include the carnivorous cougar, bobcat, coyote, red fox, badger, skunk, ferret, weasel, mink and moles. The grazers and browsers include the bison, mule deer, whitetail deer, big horn sheep and pronghorn antelope. Rodents are particularly plentiful. Among others there are the chipmunks, gophers, field mice, voles, kangaroo mice and, of course, prairie dogs. Two species of lagomorph also thrive here, the cotton tail and the jackrabbit. These mammals are supported by an abundant variety of grasses, shrubs, wild flowers, cactus, yucca, wild grapes, choke-cherry and buffalo-berry bushes, and plum, cottonwood, elm, oak, cedar, juniper, spruce and pine trees.

Obviously the French and the Indians did not refer to this land as "Badlands" because it was unproductive. No, this name was given for a different reason. This land was BAD to traverse. It was bad to cross because it was "broken" or "cut" up, by erosion, into a series of tables, ridges, gulleys, canyons and escarpments which made passage through this land nearly impossible. As the old saying goes, *you can't get there from here*.


SURFACE EXPOSURES
OF THE
WHITE RIVER BADLANDS
CHADRON AND BRULE
FORMATIONS
N
SOUTH DAKOTA
NEBRASKA
WYOMING
COLORADO
SCALE 1 : 2,500,000
P. LARSON 1989

The Badlands is a topographical and geological feature which stretches across the western part of South Dakota and passes across the border into western Nebraska. From this stronghold, stringers and outliers go across the Nebraska border into Wyoming and Colorado (see figure). The Badlands is composed of eroded sediments which were deposited from 25 to 40 million years ago during, what paleontologists term, the Oligocene Age. These sediments have been sculpted by wind, rain, frost and the sun into what we call badlands topography.

THE BADLANDS

Badlands topography is a landform which has been recognized in many places on this planet. However, no place is more spectacular than the original Mauvaises terres of southwestern South Dakota. Anyone who has driven through the Badlands National Park will tell you that there is something special about the way the land is eroded into peaks, spires, knife-edged ridges, cliff-sided tables, steep-walled gorges and hummocky-grassless areas. The texture and structure of the weathered rock is both beautiful and awe inspiring.

I first became enchanted with the Badlands before I was even old enough to read. My uncle, a minister from back east, took my older brother and myself out looking for fossils in a small outlier of the Badlands north of the Indian community called Soldier Creek. This is one of the many outliers and is a miniature version of the "Big Badlands". My mind was captured by these wonderful landforms. The shadows and the colors were quite unbelievable! *You really had to be there.*

Our attention (and eyes) eventually shifted to the ground at our feet. There, close to where we had gotten out of my uncle's 1951 Studebaker, was a fragment of a jaw. The jaw was white in color and protruding from the jaw were teeth. The teeth were almost black. These were the remains of a mammal which has been extinct for millions of years, and this discovery was the beginning of my lifelong love affair with the Badlands.

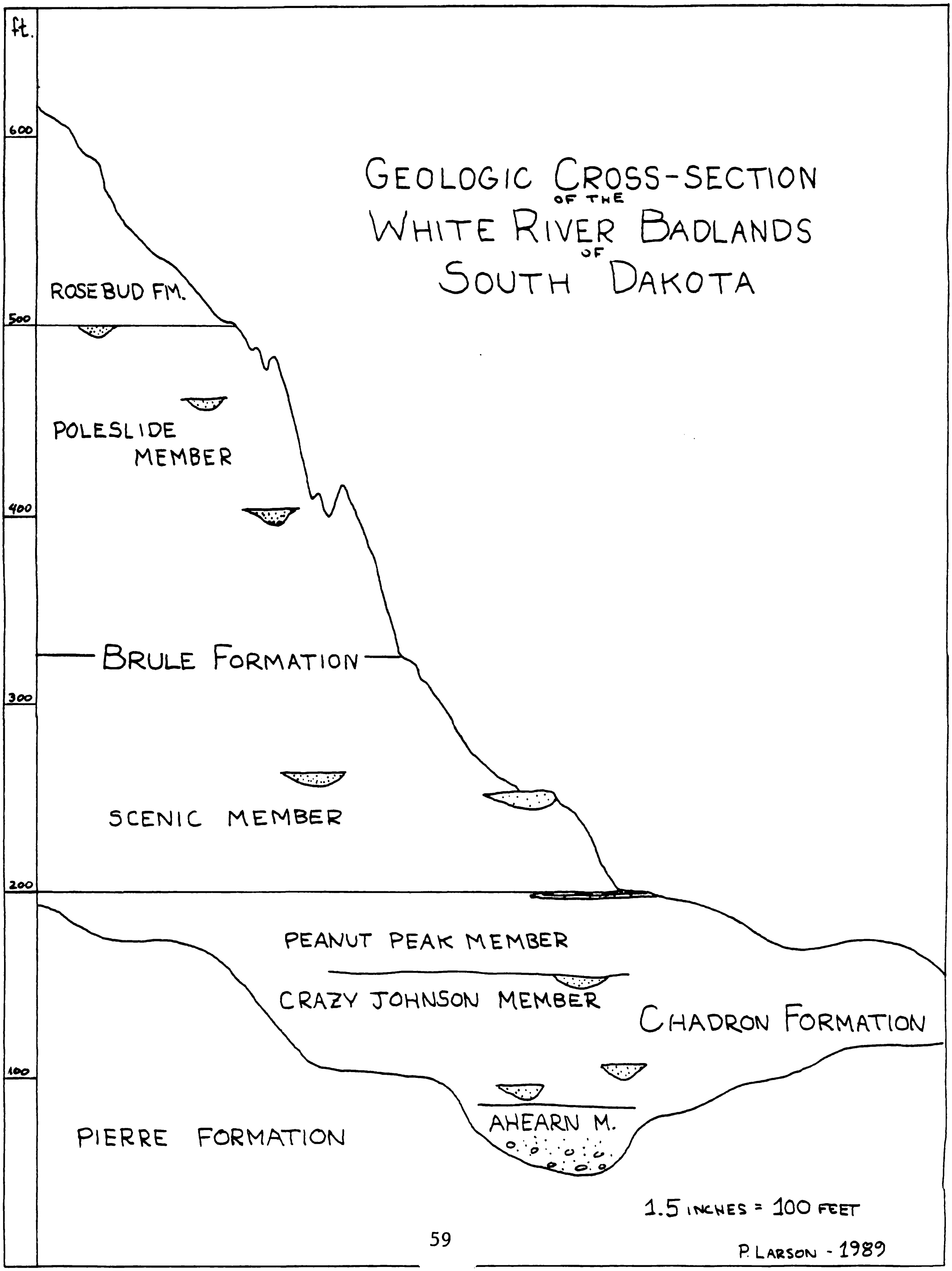
EARLY FOSSIL COLLECTORS

I was, obviously, not the first one to find the remains of fossil mammals in the Badlands. Fossils were probably found by the Native Americans who lived here before the French trappers arrived. They were collected and carried by the Sioux Indians for their "good medicine".

The first specimen which was collected and described for its "scientific value" appeared in the American Journal of Science in the year 1847. Here Dr. Hiram A. Prout described a fragment of a lower jaw of a titanothere. This description was followed shortly by Dr. Joseph Leidy's description of the skull of *Poebrotherium*, an ancient camel. These two papers sparked an interest in these Badlands and the fossil graveyard which was said to exist within its confines. This led to a series of expeditions into the Badlands, expeditions to learn about the geology and paleontology of this spectacular land.

In the years which followed, many of the great early collectors of vertebrate fossils visited the Badlands. Dr. John Evans, collecting for the Geological Survey under David D. Owen, came in 1849. Thaddeus Culbertson visited the region in 1850, collecting on behalf of the Smithsonian Institution. The first comprehensive geological observations and fossil mammal collections, however, were made by Ferdinand V. Hayden in the 1850's and 60's. Hayden's frequent visits were noted by the Sioux, who, believing him to be insane and thus holy, gave him the name "man who picks up stones while running". Dr. Joseph Leidy reported much of what Hayden collected in the 1853 publication "Ancient Fauna of Nebraska". Hayden and Leidy's early contributions to our knowledge of the ancient animals of the Badlands led to the descriptions of scores of newly described species, and also helped to stimulate the interest of later paleontologists.

Other collectors soon went to the Badlands in search of these newfound species of mammals. Othniel C. Marsh and Edward Drinker Cope both collected there. William B. Scott and John Bell Hatcher, one of history's most famous fossil collectors, made many important Badlands discoveries. Subsequent investigations were conducted by E. H. Barbour, C. M. Sternberg, C. C. O'Harra, W. D. Matthew, A. E. Wood, J. D. Bump, C. B. Schultz, John Clark and many others.


GEOLOGIC CROSS-SECTION OF THE WHITE RIVER BADLANDS OF SOUTH DAKOTA
ft.
600
500
400
300
200
100
ROSEBUD FM.
POLESLIDE MEMBER
BRULE FORMATION
SCENIC MEMBER
PEANUT PEAK MEMBER
CRAZY JOHNSON MEMBER
CHADRON FORMATION
AHEARN M.
PIERRE FORMATION
1.5 INCHES = 100 FEET
P. LARSON - 1989

Researchers today are unraveling the story that Badlands fossils have to tell. It is not a simple story. Nor is it one upon which all experts agree. New and undescribed species are still being discovered, and surely they will continue to be found long after I am dead and buried.

THE WHITE RIVER GROUP

The Oligocene sediments of the White River Badlands have been divided and classified by stratigraphers since the first fossil discoveries were made. The oldest rocks in the White River Group are Early Oligocene in age (Chadronian Stage), or from 40 to 35 million years old. These rocks have been named the Chadron Formation, for the town of Chadron, Nebraska. The Chadron Formation generally erodes into a greenish, buff-colored hue and rolling exposures. In South Dakota, the Chadron Formation has been divided into the lower Ahearn Member, middle Crazy Johnson Member, and upper Peanut Peak Member. Lithologically the Chadron Formation consists of siltstones, sandy siltstones, sandstones and sandy conglomerates. The finer sediments were deposited in a flood-plain environment. The sands and conglomerates were deposited in stream channels.

There is a change in sedimentation at the top of the Chadron Formation. The result is a series of rocks called the Brule Formation, named for the Brule Indian tribe. The Brule Formation, a portion of the White River Group, is further broken down into two members. The lower is the Scenic Member of South Dakota (called the Orella Member in Nebraska, Wyoming and Colorado), which is Middle Oligocene in age (Orellan Stage). This member was deposited over the period of 35 to 30 million years ago. The Scenic Member is characterized by buff colored exposures with a "pinkish" hue, and it erodes into steep faces. It is composed of siltstones and sandy siltstones with less frequent stream channel sands and conglomerates.

The upper member of the Brule Formation is called the Poleslide Member in South Dakota, and the Whitney Member elsewhere. These rocks are Late Oligocene in age (Whitneyan Stage) and were deposited from 30 to 25 million years ago. The Poleslide Member is very steep, nearly vertical, where exposed, and is buff to almost white in color. Lithologically it is similar to the Scenic Member, although it contains a higher percentage of sand and occasional ash beds..

Taken as a whole, the White River Group was deposited in a flood-plain environment. Sediments accumulated in and near stream beds. These sediments originated from upland areas in the Black Hills of South Dakota and the Front Range of Colorado and Wyoming.

THE OLIGOCENE AGE

The sediments of the White River Badlands were deposited during what is called the Oligocene Age. This Age began about forty million years ago and lasted until about twenty five million years ago. During the Oligocene Age the area we now call western South Dakota was much different then it is today. For one thing, annual rainfall was greater. Instead of the 12 to 15 inches of precipitation, the annual rainfall must have been closer to 100 inches.

The temperature was different too. Today temperatures may vary from 120 degrees Fahrenheit in the summer to 50 degrees below zero in the winter. Forty million years ago, at the beginning of the Oligocene age, it did not freeze and the climate was subtropical. Vegetation was markedly different. Grasses abound today, but they were a recently evolved group back then and were still unfavored in the competition for soil space. The foliage which existed then was more lush and less abrasive to the low crowned teeth of the developing mammals.

The topography of this area showed both similarities and differences to the topography of today. The Rocky Mountains had just completed a period of mountain building known as the "Laramide Orogeny". Mountain ranges occupied about the same spaces on the map as they do today, but they were younger, steeper and higher. The areas which we know as the Badlands today were broad river valleys forty million years ago. The new Rocky Mountains were rapidly being eroded and the rocks, sand and silt which was being removed from them was being just as rapidly deposited in the flood plains of these meandering river and stream valleys. To add to this accumulation of sediment, wind blown ash came from various volcanoes in the newly raised Rocky Mountains.

The animals living on these ancient flood plains were somewhat different too. There were birds, fishes, lizards, snakes, crocodiles, tortoises, and of course mammals. Except for the presence of crocodiles, this list looks similar to that of today. However, on a species level these groups look quite different.

THE FOSSIL MAMMALS

The Oligocene Age was a very important period in the development of mammals. Dinosaurs, which had ruled the earth for more then 200 million years, had only recently left the scene. Although mammals had been around as long as the dinosaurs, dinosaurs had dominated virtually every niche possible for larger animals, thus limiting the diversity of the mammals. Mammalian evolution had taken a long time deciding upon which direction to take.

The mammals which appeared in the Oligocene were different and somehow more modern than their predecessors. For the first time we are able to discern modern forms. Fossil mammals from the Oligocene age White River Badlands actually resemble their present day counterparts.

Paleontologists and zoologists, both amateur and professional, may easily recognize these fossils as cats, dogs, camels, horses, rhinoceroses, rabbits, squirrels and mice. The trained eye may also note the presence of peccary, ancestral antilocaprids (american antelopes), hippopotamus (anthracotheres), tapirs, mustelids, bears, and raccoons. Poorly represented, but present, were bats and primates. In addition to these forms there were some groups which are now extinct. These included the carnivorous creodonts, marsupial didelphids, rodent-like multituberculates, entelodonts (giant pigs), pantolestids and the most common of all White River mammals: the oreodonts.

ORDER ARTIODACTYLA

This is the group which is called the EVEN TOED UNGULATES (ungulate means "nail walker"). This is because the axis of the foot falls between the second and third digit, yielding a foot which possesses 2 or 4 functioning toes.

SUBORDER SUINA

This group includes the pigs, peccaries and hippopotami. In the White River Oligocene, there are three genera of peccary (Tayassuidae) and three genera of Leptochoeridae, close relatives. There are four recognized genera of ancestral hippopotami (Anthracotheriidae). Suina also includes the Entelodontidae or "giant pigs".

SUBORDER RUMINANTIA

INFRAORDER TYLOPODA

The ruminants, or "cud chewers" are divided into two Infraorders. The first of these are the Tylopods, or camels and their close relatives. Represented in the Badlands are the oreodonts and the true camels.

OREODONTS

The fossil which I picked up on my first trip to the Badlands north of Soldier Creek more then thirty years ago belonged to this most common group. It was the lower jaw of an oreodont. The oreodonts were a diverse group of particularly ugly and unexciting mammals. They possessed a head much to large for their sheep sized body. However, their graceless appearance did not stop them from becoming the most abundant and, in their time, the most successful of the Oligocene mammals.

The oreodonts are divided into two groups: the primitive Agriochoeridae and the more advanced Merycoidodontidae. The rare Agriochoeridae are represented by the genus *Agriochoerus*. In contrast, the Merycoidodontidae are represented by more than twenty accepted genera and many more species in the White River Oligocene. Many of the species are virtually indistinguishable to the amateur and indeed most researchers. Although it is possible that many of these genera are valid, this "splitting" has little practical value.

CAMELS

The second fossil specimen described from the Badlands was the skull and lower jaws of *Poebrotherium* , an early camel. Leidy recognized this as the first record of a group living today only in the eastern Hemisphere. As more fossils and localities were studied it became apparent that the camel was truly an American animal and it had migrated out of North America only a short time ago (geological speaking). In addition to *Poebrotherium* , there are four other genera of camel found in the Badland

INFRAORDER PECORA

This group contains the deer, giraffe, antelope, cattle, and the Traguloidea, mammals which seem to have given rise to the modern, Pecora. White River Traguloidea include the Hypertragulidae (3 genera), *Leptomeryx*, and the Protoceratidae (6 genera). Although often referred to as "deer" by collectors, these are actually related to the Pronghorn or American "antelope", and are thus more closely related to cows than to true antelope.

ORDER PERISSODACTYLA

This group is known as the ODD TOED UNGULATES. This is because the axis of the foot falls on the third digit. In advanced forms such as the living horse, the number of functioning toes has been reduced to one.

In the Oligocene sediments of the White River Badlands, the perisodactyls are represented by three genera of horses, two genera of tapirs, and three families (Hyracodontidae, Amynodontidae and Rhinocerotidae) and ten genera of rhinoceros.

The early Oligocene Chadron Formation also contains the remains of an extinct group of perissodactyls known as the titanotheres (Family Brontotheriidae). These abundant, rhinoceros-like animals reached near elephantine proportions. Their diversity is shown by the presence of six recognized genera. For some unexplained reason they suddenly became extinct at the end of the early Oligocene. No remains of Titanotheres have been found in the Orellan age sediments.

ORDER RODENTIA

Rodents comprise a large portion of the total mammalian fauna of the White River Oligocene. Among these are fifteen genera of squirrels, fourteen genera of mice, one beaver and several other rarer forms. Rodents, as they are today, were one of the more abundant life-forms in the Oligocene.

ORDER LAGOMORPHA

Contrary to popular belief, rabbits are not rodents. They are the order Lagomorpha. The White River Oligocene had four genus of rabbits. One, Paleolagus, seems to have been quite abundant.

ORDER CREODONTA

This is an extinct group of primitive carnivores. Creodonts, or Hyaenodonts, were characterized by a very strong carnassial, or shearing, morphology of the molar dentition. They used their back teeth to cut their food, bone and all. There are three recognized Hyaenodont genera from the White River Group.

ORDER CARNIVORA

SUBORDER FISSIPEDIA

FAMILY FELIDAE

Probably the most exciting fossil mammals found in the Badlands are the "saber-toothed" cats. The Oligocene cats all seem to possess an elongated canine. Of the four genera of cats present in the Badlands, *Hoplophoneus* and *Eusmilus* show the development of true "sabers". However, the "main-stream" cats such as *Dinictis* and *Nimravus* also have proportionately elongated upper canines.

FAMILY CANIDAE (Including AMPHICYONIDAE)

Dogs, like the cats, are easily recognizable fossils in the White River sediments. There are ten described genera of canids from the Badlands. These species show many similarities to modern dogs, including a wide range of sizes.

OTHER CARNIVORES

Other carnivores include early ancestors of the bears (Ursidae), Mustelids and raccoons (Procyonidae).

MAMMALIAN FAUNA OF THE WHITE RIVER GROUP

Age
Chadronian - C
Orellan - O
Whitneyan - W

ORDER - Family - Genus	Age
MULTITUBERCULATA	
Neoplagiaulacidae	
c.f. Parectypodus	C
MARSUPIALIA	
Didelphidae	
Herpetotherium	COW
Nannodelphys	CO
"Peratherium"	C
LEPTICTIDA	
Leptictidae	
Leptictis	COW
Prodiacodon	C
LAGOMORPHA	
Leporidae	
Palaeolagus	COW
Megalagus	COW
Chadrolagus	C
Litolagus	O
Ochotonidae	
Desmatolagus	O
PANTOLESTA	
Pantolestidae	
Chadronia	C
Nov. sp.	W
APATOTHERIA	
Apatemyidae	
Sinclairella	CO
CREODONTA	
Hyaenodontidae	
Hyaenodon	COW
Hemipsaladon	C
Ischognathus	C

ORDER - Family - Genus	Age
CARNIVORA	
Miacidae	
Miacis	C
Amphicyonidae	
Proamphicyon	C
Daphoenus	COW
Daphoenocyon	C
Daphoenictis	C
Protemnocyon	O
Ursidae	
Compylocynodon	C
Parictis	CW?
Brachyrhynchocyon	OW
Allocyon	W
Procyonidae	
Plesictis	C
Mustelidae	
Palaeogale	COW
Canidae	
Hesperocyon	COW
Mesocyon	W
Pericyon	W
Cynarctoides	W
Sunkahetanka	W
Felidae	
Dinictis	COW
Hoplophoneus	COW
Eusmilus	COW
Nimravus	W
INSECTIVORA	
Soricoidae	
Centetodon	CW
Ankylodon	C
Apternodus	C
Clinopternodus	C
Micropternodus	C
Oligoryctes	C

ORDER - Family - Genus	Age
INSECTIVORA, cont.	
Soricidae	
Domnina	COW
Pseudotrimylus	0
Talpidae	
Cryptoryctes	C
Oligoscalops	C
Proscalops	0
Erinaceoidae	
Proterix	OW
Geolabidae	
Centetodon	0
Anklyodon	0
CHIROPTERA	C
PRIMATES	
Omomyidae	
Macrotarsius	C
Rooneyia	C
ARTIODACTYLA	
Leptochoeridae	
Stibarus	COW
Nannochoerus	COW
Leptochoerus	OW
Entelodontidae	
Brachyhyops	C
Archeotherium	COW
Entelodon	0
Megachoerus	W
Tayassuidae	
Thinohyus	CO
Perchoerus	COW
Chaenohyus	W
Anthracotheriidae	
Aepinacodon	CO
Heptacodon	COW
Elomeryx	W
Octacodon	W
Agriochoeridae	
Protoreodon	C
Agriochoerus	COW

ORDER - Family - Genus	Age
ARTIODACTYLA, cont.	
Merycoidodontidae	
Merycoidodon	COW
Eporeodon	C
Prodesmatochoerus	CO
Bathygenys	C
Megabathygenys	C
Parabathygenys	C
Limnenetes	C
Aclistomycter	C
Otionohyus	COW
Subdesmatochoerus	OW
Miniochoerus	OW
Platyochoerus	OW
Parastenopsochoerus	0
Paramerycoidodon	OW
Genetochoerus	OW
Hadroleptauchenia	OW
Pseudoleptauchenia	0
Leptauchenia	OW
Promesoreodon	W
Pithecistes	W
Pseudocyclopidius	W
Camelidae	
Poebrotherium	CO
Hidrosotherium	C
Malaquiferus	C
Paratylopus	COW
Pseudolabis	W
Hypertragulidae	
Hypertragulus	CO
Hypisodus	COW
Paravitragulus	C
Leptomerycidae	
Leptomeryx	COW
Protoceratidae	
Heteromeryx	C
Poambromylus	C
"Leptotragulus"	C
Pseudoprotoceras	C
Protoceras	W
Nannotragulus?	W

ORDER - Family - Genus	Age
PERISSODACTYLA	
Equidae	
Mesohippus	CO
Halpohippus	C
Miohippus	W
Brontotheriidae	
Teleodus	C
Protitanops	C
Brontops	C
Menodus	C
Megacerops	C
Brontotherium	C
Helatidae	
Colodon	COW
Tapiridae	
Protapirus	OW
Hyracodontidae	
Hyracodon	COW
Triplopus?	C
Amynodontidae	
Metamynodon	COW
Toxotherium	C
Rhinocerotidae	
Caenopus	COW
Trigonias	C
Penetrigonias	C
Subhyracodon	COW
Amphicaenopus	COW
Diceratherium	OW
PHOLIDOTA?	
Epoicotheriidae	
Epoicotherium	C
Xenocranium	O
Manidae?	
Patriomanis	C
RODENTIA	
Ischyromyoidae	
Leptotomus	C
Mytonomys	C
Microparamys	C
Ischyrotomus	C
Manitsha	C
Ischyromys	COW
Cylindrodon	C
Pseudocylindrodon	C
RODENTIA, cont.	
Ischyromyoidae, cont.	
Ardynomys	C
Jaywilsonomys	C
Aplodontidae	
Prosciurus	COW
Pelycomys	COW
Pipestoneomys	C
Cedromus	CO
Spurimus	C
Eomyidae	
Adjidaumo	CO
Paradjidaumo	COW
Centomanomys	C
Aulolithomys	C
Cupressimus	C
Yoderimys	C
Viejadjidaumo	C
Namatomys	C
Castoridae	
Agnotocastor	COW
Heteromyidae	
Heliscomys	COW
Meliakrouniomys	C
Apletotomeus	O
Akmiaomys	O
Eutypomyidae	
Eutypomys	CO
Cricetidae	
Eumys	CO
Paracricetodon	COW
Eoeumys	CO
Coloradoeumys	O
Wilsoneumys	OW
Scottimus	W
Geomyidae?	
Diplolophus	O
Griphomys	C
Nonomys	C
Subsumus	C
Simimys	C
Guanojuatomys	C
Floresomys	C

OTHER MAMMALIAN GROUPS

Also a part of the paleontological record found in the White River Badlands are the following Orders: Multituberculata, Marsupialia, Leptictida, Pantolesta, Apatotheria, Chiroptera, Primates, and Pholidota.

CONCLUSION

The fossil mammals of the White River Badlands have been collected, studied and displayed for more then one hundred years. Before the white man came to South Dakota, Native Americans also appreciated these fossils which they sometimes carries in medicine pouches. Specimens like the oreodont jaw which I collected as a youngster are still being collected by scientists, professionals and amateurs.

The landscape of the badlands topography is a natural wonder of this planet. We are fortunate, in the United States, to have recognized and preserved the best examples of the Badlands as part of the Badlands National Park - the original Mauvian Terres - in South Dakota. There, fossil collecting is prohibited except under special permit.

There are, however, other exposures of Badlands - part of the White River Badlands- in which anyone may potentially collect fossils. These areas of private land have exposures which weather very quickly. The fossil mammals which erode out are rapidly uncovered by rain, wind and frost. If they are not collected, they are destroyed. When proper collecting techniques are employed - permission to collect obtained, specimens properly excavated and cast. locality and stratigraphic data recorded - the collection of these fossil mammals by scientists, professionals and amateurs will continue to add to our knowledge of past life of the White River Badlands. It will also help us to understand the history of life on earth.

A FOSSIL COLLECTED IS A FOSSIL SAVED.

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PALEOECOLOGY OF OLIGOCENE MAMMALS IN THE BADLANDS, SOUTH DAKOTA AREA

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Many paleontological studies have been done on the relationships of environment and mammal communities of Oligocene times represented by the rocks and fossils of the Badlands, South Dakota. The following is a brief summary of the local environments and the types of mammals found in each for the Chadron and Brule Formations of the Badlands.

LOCAL PALEOENVIRONMENTS

The Chadron Formation was deposited on a surface of deeply weathered Pierre shale, gently rolling, similar to areas near the western banks of the Missouri River in South Dakota today. The relief of the Black Hills was very similar to that of the present. Local streams originating in the southern Black Hills flowed southeast and became confluent in the area of the Badlands forming the ancient "Red River" which flowed southeastward. The northern Black Hills area was drained by an easterly flowing stream whose bed was north of the present Badlands wall. The distinct environments of streams, ponds, river banks and flood plains are recognized in Chadron deposits. Fossils are common only in the flood plain deposits in and above the Peanut Peak Member of the Chadron Formation. In general, fossils are more fragmentary and less abundant in the Chadron than in the overlying Brule Formation. Many Chadron species are known only from a few fragmentary specimens.

By Brule Formation times, there was only one drainage system for the area. The Scenic Member of the Brule Formation is comprised of flood deposits from a system of flowing streams, natural levees and lowlands with dry hollows, temporary slow moving streams, ponds and small lakes. The sediments carried by these rivers were derived from the Black Hills, outcrops of exposed Pierre Shale and airborne volcanic ash. At least six major streams and a series of minor ones have been recognized in the Scenic Member. The streams flowed in a single system southeasterly across a broad floodplain. This river system probably flowed into the Gulf of Mexico.

THE CHADRON FORMATION

The mammals of the early Oligocene Chadron Formation represent a transition between the Eocene jungle forest faunas and the later plains faunas of western North America. Two groups of mammals can be distinguished in Chadron time, a wet-forest fauna and a savanna fauna. In the moist environments were found small artiodactyls, insectivores and Mesohippus (horse), and in the more arid places away from the streams were found the dry-plains animals such as Poebrotherium (camel).

From studies of the sediments and fossil soils, four ecological habitats can be distinguished: aquatic, semiaquatic, river border forest and savanna. Some species were resticted to one habitat, but others such as the carnivores, could range throughout several habitats. Those vertebrates limited to the aquatic habitat would include fish, turtles, and alligators.

The animals of the semiaquatic habitat would be those which spent a large part of their time in the water, but foraged in the surrounding swamp and river border forest areas ajacent to the water. Menodus (titanothere), Trigonias (rhino), Heptacodon and Bothriodon (anthracotheres) occupied this habitat.

Agriochoerus (oreodont), Peratherium (insectivore), Colodon (tapir), Eotylopus (camelid) were forest adapted mammals. Mesohippus, Hesperocyon (fissipede) and possibly Daphoenocyon (bear-dog) were commonly found in the forest. The larger carnivores from the savanna could well have hunted around the edge of the forest habitat.

The rhinocerid animals, Hyracodon, Caenopus and Subhyracodon, Perchoerus (peccary) as well as the camel Poebrotherium and the giant "pig" Archaeotherium (entelodont) can be shown from their teeth structure to have been savanna browsers and grazers. Hyracodon, Caenopus and Poebrotherium are also common in the Brule, which is definitely a dry savanna habitat. Hyaenodon (creodont), Parictis (mustelid), Daphoenocyon, cats such as Mustelavus, Eusmilus, Hoplophoneus and Dinictis, Leptochoerus and Stibarus (entelodonts) are all definitely savanna animals and are found in the late Chadron.

The percentages of the various genera in these habitats have been determined and show that as Chadron time progressed, the climate became drier. The early Chadron has an abundance of aquatic animals, 23% forest animals and only 40% savanna forms. The middle Chadron has 16% forest and 47% savanna forms. In contrast, the late Chadron has only 13% forest types and 73% savanna animals. These percentages show a great reduction of semiaquatic and river forest forms, such as the titanotheres, in late Chadron time. More drastic temperature changes and lowered stream volumes reduced the stream irrigated areas, which in turn reduced the river forest and river border environment for a large variety of mammals.

Two lines of wet-forest genera can be distinguished in the Chadron. One group has close relatives in the North American Eocene and includes Mesohippus, Menodus, Agriochoerus, camels and Eotylopus. The other group comprising Trigonias, Colodon, Daphoenus (bear-dog), Bothriodon and Heptacodon are known from the Eurasian Eocene. These genera found in the Chadron Formation are survivors of Eocene jungle environments. As the Chadron progressed and the jungle or wet forest habitat disappeared, a few types survived in local remnants of this Eocene environment.

The savanna animals can also be split into a North American group and a

Eurasian group. Some of the genera have affinites with Eocene jungle forms, but in general do represent different families which appear rather suddenly in the late Eocene or early Oligocene. The Chadron savanna fauna were relatively stable with no genera becoming extinct and there was a continuation of nearly all these genera into the Brule. This savanna fauna probably is part of an invading group from other areas of North America with some Eurasian immigrants. Because of the competition of these two different groups of animals during Chadron time, the resulting herbivores comprising the Brule fauna were of North American descent while the carnivores were of Eurasian descent.

THE BRULE FORMATION

During the early Brule or Scenic Member-Lower Nodular Zone time, streams were less than 100' wide and 6' deep, capable of carrying only fine sand and silt. Since modern bones flake and fracture after 1 or 2 years exposure, the mud from a Scenic Member flood produced layers at least 18" thick as evidenced by entirely preserved Subhyracodon and Archaeotherium skulls and an entire mass of Hypertragulus (goat-like tragulid) skeletons. Times of non-deposition in the Lower Nodular Zone are shown by fractured and rodent-gnawed bones, coprolites and hackberry seeds. When flooding occurred, the water quickly loaded with clay and became a viscous mass picking up sand, silt and clay chips from the dry surface. These chips can be seen in the rock mass enclosing the fossils. Almost no horizontal movement of bones is seen; they were virtually plastered down where they had lain. The duration of these floods was only a few days and occurred only once in a decade as estimated by perthotaxic studies of fossil material and lack of well developed soils. Paleomagnetic studies estimate a duration of 600,000 to 800,000 years for the deposition of the Scenic Member in South Dakota.

Professional collecting of thousands of specimens allow three different ecological zones within the Scenic Member (Lower Nodular Zone) to be identified: a near stream forest fauna, an open plains fauna and a swampy plains fauna. Selection of localities upon which to base these population studies was done with the assumptions that an area immediately adjacent to geologic evidence of a stream bed and within a short distance of other temporary streams would be considered forested and thus a near stream forest assemblage. Any area several miles from such a temporary or permanent stream and showing no signs of swamp or temporary pools would be considered an open plains environment with little or no forest cover. Any area which would show prominent pond limestones, snails, algal strands, fish bones and limy mudstones would be considered to be a pond or swamp environment.

The majority of animals preferring the near stream environment were medium sized with Mesohippus and Merycoidodon (oreodont) making up over half of the total numbers of animals. The rodent-rabbit population is only about 20% of the total number of animals with Ischyromys (squirrel-like) the most frequent, followed by Paleolagus (rabbit), Eutypomys (rodent), Megalagus (rabbit) and Eumys (mouse). The small artiodactyls (Hypertragulus and Leptomeryx) only constitute 4% of the near stream animals. Carnivores are present at about 5%, with 8 cats, 5 dogs, and 2 creodonts being collected. The perissodactyls account for about 28% of the total animals.

Open plains environments yielded larger numbers of specimens but in a much more fragmented condition. This perthotaxic factor is known today from studies of savanna animals, where bones are more prone to scattering on savannas than in woodlands. In the open plains faunas there is a great predominance of small mammals over the medium-and large-sized mammals. Here, Leptomeryx (deer-like) and Paleolagus (rabbit) are the two most common genera, representing over half of the total number of specimens. Paleolagus is the most common small mammal, followed by Ischromys and Eumys. The rodent-rabbit group makes up almost double the percentage of the mammal community here as compared to the near stream area. The artiodactyls generally constitute 50% of the total population with 12 genera. The small artiodactyls increase in variety and, reflecting their preference for open habitat, increase their numbers from 10% to 40% of the population. Carnivores still make up about 5% of the collected population: consisting of 2 creodonts, 40 dogs, 3 mustelids and 8 cat specimens. Because of the larger number of small mammals found, the percentage of the larger perissodacyls is much lower in this environment as a percentage of total mammals in the open plains. However, the same four genera of perissodactyls which were found in the near stream areas are also found in the open plains areas where they make up the same proportion of the medium- and large-sized mammal population in both the near-stream and open plains communities.

In the swampy plains environment, the medium-sized animals make up almost half of the animal population, where the rodent-rabbit group is only 10% of the total with Ischyromys the only common rodent. Leptomeryx, common in other environments, has dropped to less than 25% of the total population. The swampy plains is apparently the favorite habitat of Mesohippus, forming 30% of the entire animal population and 60% of the medium to large animals. The oreodonts, are only 12% of the total animals and 25% of the medium to large animal population. Apparently, the oreodonts preferred the forested river bank areas as opposed to the Mesohippus, who preferred the swampy environment. Carnivores make up 8% of the population with 4 creodonts, 10 dogs and 4 cats being collected.

Suggestions can be made as to the relationship of some animals to their environment. For example, populations of Ischyromys and Paleolagus are both large in the dry plains habitat and would imply that the two were not in direct competition for food. Paleolagus, like modern rabbits, would feed mostly on leaves of grasses and shrubs, where Ischyromys, like the squirrels of today, could have eaten chiefly seeds. Occasionally, fist-sized aggregations of Celtis seeds occur in the dry plains areas and could be regarded as hoards collected by Ischyromys. Secondly, Ischyromys is common in areas where one would least expect trees. Unlike the squirrels of today, it is probable that Ischyromys was a ground dweller rather than aboreal in habitat.

The total carnivore population for any of the habitats studied was under 10% of the total fauna. Hesperocyon (small dog) was the most numerous, with Dinictis (small cat) second. Hoplophoneus and Dinictis were relatively large and cat-like in their way of life. Hyaenodon (creodont) was apparently an active predator, more in the style of the modern lion or hyaena, while Hoplophoneus, Dinictis and Daphoenus (bear-dog) probably hunted from ambush like the modern leopards and jaguars.

The perissodactyls had a difficult time adapting to the climatic change and shift from forest to savanna prairie in the Oligocene. Colodon and Protapirus (tapirs), Hyracodon (cursorial rhino) and Metamynodon (wading aquatic rhino) barely survived in favored habitats into the late Oligocene and became extinct by the end of it. Only the horse and true rhino survived the changing environment, but both Mesohippus and Subhyracodon, common in the mid Oligocene became very rare in the late Oligocene with local populations recovering in the early Miocene.

The artiodactyls dominate the perissodactyls in Oligocene and later times. Leptomeryx is most abundant in the open plains and second most abundant in the swamp. Success in the swamp or open plains may be due to the lack of any efficient predator; Hesperocyon being too small, not enough cover for the ambushes of Hoplophoneus or Daphoenus, leaving Hyaenodon as the best but far from efficient open plains predator. Merycoidodon is the most abundant genus in the near stream fauna. The larger M. culbertsoni shows a sharp preference for forests over the smaller M. gracilis, who preferred swamp or open plains. The heavy build and dentition also show no evidence of grazing preferences for M. culbertsoni. The small Hypertragulus has been found in large herd assemblages and had a strong preference for swamp habitats. Their remains show that other forms of death besides predation occasionally overtook Oligocene mammals. Death of groups of 20 young adult animals would indicate that the animals may have been sensitive to virulent epidemics or fell victims to unexpected extremely cold or harsh weather conditions.

CONCLUSION

By the mapping of Oligocene landforms present in the Badlands sediments and the careful quantitation of the fossils they contain, a reasonable picture of the ecology of both the early Oligocene Chadron Formation times and the middle Oligocene Brule Formation times can be presented. Further population studies along with even more detailed analysis of the sediments will continue to clarify the relationships of the animals in the Badlands area during the Oligocene.

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GLOSSARY OF OLIGOCENE BADLANDS MAMMALS

Agriochoerus	Artiodactyl	oreodont
Archaeotherium	Artiodactyl	entelodont
Bothriodon	Artiodactyl	anthracothere
Caenopus	Perissodactyl	rhinoceros
Colodon	Perissodactyl	tapir
Daphoenocyon	Carnivore	bear-dog
Daphoenus	Carnivore	bear-dog
Dinictis	Carnivore	large cat
Eotylopus	Artiodactyl	camelid
Eumys	Rodent	mouse
Eusmilus	Carnivore	cat
Eutypomys	Rodent	distant relative of beaver
Heptacodon	Artiodactyl	anthracothere
Hesperocyon	Carnivore	fissipede, dog-like
Hoplophoneus	Carnivore	large cat
Hyaenodon	Carnivore	creodont
Hypertragulus	Artiodactyl	goat-like tragulid
Hyracodon	Perissodactyl	rhinoceros
Ischyromys	Rodent	squirrel-like
Leptochoerus	Artiodactyl	entelodont
Leptomeryx	Artiodactyl	deer-like
Megalagus	Rabbit	rabbit
Menodus	Perissodactyl	titanothere
Merycoidodon	Artiodactyl	oreodont
M. culbertsoni		oreodont, larger
M. gracilis		oreodont, smaller
Mesohippus	Perissodactyl	horse
Metamynodon	Perissodactyl	wading aquatic rhinoceros
Mustelavus	Carnivore	cat
Paleolagus	Rabbit	rabbit
Parictis	Carnivore	mustelid
Peratherium	Insectivore	opossom
Perchoerus	Artiodactyl	peccary
Poebrotherium	Artiodactyl	camel
Protapirus	Perissodactyl	tapir
Stibarus	Artiodactyl	entelodont
Subhyracodon	Perissodactyl	rhinoceros
Trigonias	Perissodactyl	rhinoceros
Celtis	Plant	hackberry tree seed

Collecting Vertebrates in the Badlands

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Hi to all MAPS members. I've been putting off writing an article for the MAPS for many years. I guess it's my time to come up with something to share with you.

I have collected vertebrate fossils from the White River Badlands of South Dakota for 21 years. There has always been a negative image associated with collecting fossils from this region due to the affects of collecting and amounts of fossils available. I return several times a year to my favorite localities. If a thunderstorm happens to drop a few inches of rain, I go back over the same zones in the same areas I collected a few days before. I have never failed to find good specimens when this has taken place. Most fossils that have been eroding for a few years are usually falling apart and being scattered. If the specimens aren't collected within a short time of being exposed, they are of no use to anyone.

I know there are numerous people in the scientific world whose opinions differ from my own. That is a subject that I don't wish to get into at this time. I can only write about my own experiences and judge them for what they are.

I specifically remember a time I was collecting and came across a camel skull. The upper skull and lower jaw were disarticulated in matex in somewhat level ground. After I collected the skull, I dug around a bit in search of skeletal remains. I couldn't find any. About two years later I returned to the location where I found the camel skull. The articulated skeleton had been exposed at least six inches above ground level, showing that the erosion factor was very great in the area. A friend and I collected the skeleton and now it is back with the original skull.

Erosion is the key factor in collecting Badlands fossils. New specimens are being exposed regularly. HAPPY HUNTING.

The use of Micromammals as Vertebrate Fossils

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Introduction

To most of us the term micromammal may bring thoughts of Chihuahuas or Toy Poodles. Other conjure up visions of annoying rats or mice, frightening bats, or our children's gerbils. They are not typically the subject matter of paleontological discourse, but that is precisely the subject matter of this article (minus the Chihuahuas).

To vertebrate paleontologists, micromammals serve as an important tool in deciphering earth history. While large mammals like mastodons and giant sloths are impressive, they are rare, and difficult and time consuming to excavate. Micromammals, on the other hand, are abundant, very diverse, and have specialized to fill almost every terrestrial environment, even those highly altered by human activity.

Teeth

Rodents constitute the bulk of the micromammals with squirrels, beavers, mice, rats, lemmings, voles, and porcupines as the major groups. Other animals on the micromammal list include shrews, moles, bats, weasels, skunks, and rabbits. Many of these micromammals, when living, are difficult to tell apart, even when you have the body to examine. It requires a trained eye to distinguish a house mouse from a harvest mouse or even a vole from a lemming. The discrimination between species becomes simple, however, if the teeth are examined. The teeth of most species are very distinct and provide the diagnostic elements upon which micromammal taxonomy has been constructed. Teeth, commonly preserved as fossils, provide the opportunity for hours of both pleasure and creative thinking. It is, therefore, fundamental to the study of fossil micromammals to understand the arrangement and morphology of their teeth.

Teeth of all mammals are divided into four major types: molars, premolars, canines, and incisors. Incisors are the chisel-shaped front teeth generally used for gripping, nipping, or gnawing. Canines are usually conspicuous, unicuspid teeth used to capture, hold and kill prey. They generally are enlarged in carnivores and may be used for defense or display in both carnivores and herbivores. Frequently, canines and/or other teeth are absent leaving a wide gap termed diastema. Premolars and molars follow behind the canines. The premolars differ from molars by having deciduous (milk) predecessors. Premolars are usually smaller than molars and have fewer cusps, but there is no common morphological

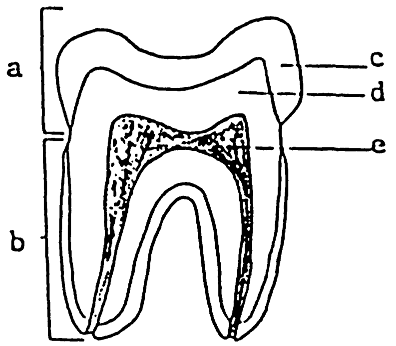

Figure 1. Diagrammatic cross section of a mammalian tooth. a, crown; b, root; c, enamel; d, dentine; e, pulp.

characteristic that invariably separates the two. If they are out of the jaw, it is impossible to tell most molars from premolars in an adult mammal. Therefore, premolars and molars together are referred to as the cheek teeth. The major function of cheek teeth is to masticate food and, therefore, these teeth exhibit a diversity that can be correlated to diet. The shape of the cheek teeth is one of the most important criteria for mammalian classification.

The number of each of the teeth in a mammals mouth is expressed by the use of a dental formula. For example, a mole has the formula 3/3, 1/1, 4/4, 3/3 x 2 =44. This means that this particular species of mole has three incisors, one canine, four premolars, and three molars. The line separates the number of teeth present in the upper and lower jaw. The formula is then doubled to give the number of teeth present. Most mammals, as a result of evolutionary specialization, have fewer teeth than this. Herbivores characteristically have lost teeth toward the front of the mouth, carnivores tend to have lost teeth at the back of the mouth. For example, the dental formula for mice and rats, all herbivores, is 1/1, 0/0, 0/0, 3/3 x 2 = 16. The number and arrangement of teeth is not always the same in the upper and lower jaws, for example, some shrews, carnivores, have three upper incisors and only one lower incisor, three upper premolars and one lower premolar. The dental formula is, however, constant for each individual of a given species.

The various teeth within the mouth (incisors, molars, etc.) are more or less diagnostic depending on the species. In most species, the first lower molar is unique to that species and this tooth, therefore, is used for basic taxonomic purposes. The tooth, as are incisors, etc., is partitioned into two distinct parts: the part above the gum line, or crown, and the part below the gum line, or roots (fig. 1). The interior of the tooth is made of dentine, commonly called ivory, and is chemically similar to bone. The dentine of the crown is covered by the hardest of all animal tissue: enamel. The enamel may be applied in such a way as to create a species specific pattern. Cement is a material which may encase the entire enamel crown of the tooth or fill only depressions or irregularities. As with the enamel, the amount and location of cement is the same for all members of a species. The central living portion of the growing tooth, the pulp, is supplied with blood vessels and nerves through an opening at the base. In most species, this opening constricts and is sealed with dentine when the tooth has reached maturity. The blood supply is reduced and growth stops. These teeth have conspicuous roots. In some species, the opening does not constrict and growth continues throughout the life of the animal. These evergrowing teeth are called rootless. The length of these teeth is kept constant by continual wear.

The morphology of the tooth can yield much information as to its function. As stated earlier, there is a micromammal that inhabits almost every terrestrial niche and collectively micromammals eat almost everything. Shrews feed predominantly on insects. The first lower molar of a shrew (fig. 2a) consists of tall, sharp, cusps. Weasels are true carnivores and have only one upper and two lower molars, but each of these teeth is blade-like with several large cusps used for slicing flesh (fig. 2b). Grazing herbivores have high crowned teeth with flat surfaces (fig. 2c), browsing herbivores (seed and leaf feeders) have low crowned cuspate teeth (fig. 2d). The height of the flat crown of rootless teeth is maintained by the continuous grinding action of the teeth on food. Laboratory animals deprived of course vegetative matter in their diet have ben left unable to close their mouths. The grinding of course vegetation is necessary to keep their growth in check.

Collection, Preparation, and Analysis

There are many situations in which micromammals are in great enough concentrations for amateurs or professionals to consider collecting. Mollusks are easier to spot than are small bones and are frequently associated with micromammal fossil remains (wind derived loess deposits excepted). Once the mollusk-bearing site has been determined and its location carefully recorded, the "outcrop" is usually collected in large sturdy plastic bags and transported back to a laboratory or other convenient site where there is a continual supply of water. The collected matrix is spread out on a plastic tarp or elevated, small mesh, wire screens to dry. This initial drying is necessary because saturated clays and silts do not defloculate in water. Water under medium-low power is then sprayed back and forth over the dried soil to wash away the fine sediment particles without damaging the fragile bones. Screen with a mesh the size of that found in household windows will pass most sediment, but catch most of the teeth and bones. Care and constant vigilance during the washing process are important to help insure that desirable material is not lost or damaged. If the matrix does not completely dissolve the first time, the remaining residue can be dried and washed again.

Dried, washed residue (hopefully with bones, but certainly snails) can be put through a series of sieves to sort it into several different size fractions. With the aid of a binocular microscope, any bones, teeth, and certain snails, seeds, insects, and plant matter are picked from the sediment and identified. The variety of snails that can be seen almost defy the imagination. See how many different kinds that you can find.

Interpretation

Practically all species of micromammals of Pleistocene age and all those that survived the extinction at the end of the ice ages, are either still with us today or have close extant relatives. This permits the reconstitution of paleoenvironments to a high degree of accuracy. This is accomplished by determining an "area of sympatry" for all recovered species. The modern range of each species can be found in most mammalian field guides. The area of overlap of the present day range of several of the species found at the site indicates the kind of environment present at the site during the time that the animals were alive. This will be clarified by way of example.

A major study was undertaken to discern the ecological conditions present in an area of northwestern Arkansas between 16,000 and 2,290 years ago by examining the change in the micromammals present through a stratigraphic section in a cave in Arkansas (Semken, 1984). The remains of nearly 2,000 individual rodent and insectivore jaws and teeth were collected. Most of these species no longer live in Arkansas and it is postulated that climates during the last glacial and interglacial periods were not static; plants and animals shifted north and south in the wake of glacial advance and retreat. If such fluctuations truly existed, it should be reflected in the assemblage of fossil micromammals present in the different levels of cave sediments. The paleoecological conditions during the time of deposition of a single level of cave sediment was partially determined using the concept of sympatry. In one level, the remains of Geomys bursarius (plains pocket gopher), Microtus pinetorum (woodland vole), and Cleitheronomys gapperi (boreal redback vole) were found. Current ranges of these three animals are shown in figures 3a-c. These individual ranges were then superimposed. The area of overlap or sympatry is in central Wisconsin as this is the only area where all three species currently live (fig. 3d). Thus, the climate in northwest Arkansas must have resembled that in central Wisconsin during the last ice age.

Geomys bursarius is restricted to areas with enough open land to allow for the lush surface vegetation that they feed upon. Prairie and park land are the most common habitats. Microtus pinetorum lives in dry, mature deciduous forests. They construct burrows in the litter on the forest floor and feed on leaves and tubers. Cleitheronomys gapperi inhabits damp areas of mixed conifer/deciduous forests or the brushy understory of the forest margins. The habitats of these three species do not appear compatible, because they inhabit prairie, dry deciduous and damp mixed forests respectively. However, the area of sympatry in northwestern Wisconsin is one of the few areas where the eastern prairie, northern mixed-forest, and southeast deciduous-forest presently converge. An area where two ecozones meet is called an ecotone. The presence of three convergent major environmental regions provides a wide variety of habitat types in a relatively small geographical area. Thus, it supports a wide variety of animal and plant species. An expanded ice sheet during the ice age may have been responsible for the southern migration of what is now a uniquely northern ecological region.

Conclusions

The fossil remains of micromammals are most often identified on the basis of their teeth. These teeth reveal much about the animals living and eating habits. Many of the micromammals alive during the Pleistocene and Holocene are with us today. This enables paleontologists to use the animals geographic range to construct sympatry maps. The area of sympatry is assumed to be ecologically analogous to the area under study. The collection, identification, and study of these specimens can provide hours of enjoyment and occupy only a little space. Also, professionals will be interested in what you have recovered.

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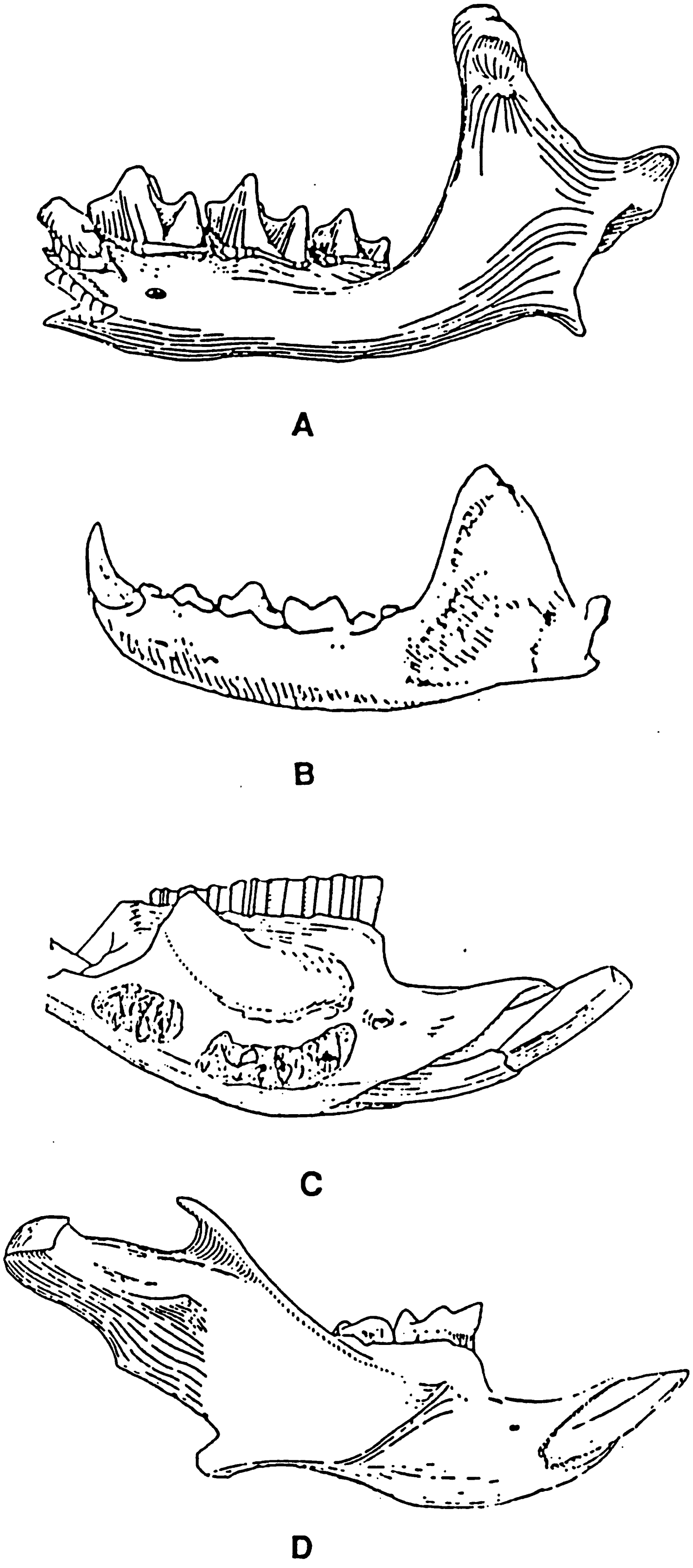

Figure 2. Lower jaw of a (A) shrew; (B) weasel; (C) vole; and (D) harvest mouse.

Figure 3. The current ranges of (A) *Cleitheronomys gapperi* ; (B) *Microtus pinetorum* ; (C) *Geomys bursarius* ; and (D) the area of sympatry located in northwestern Wisconsin.

The following article "New And Revised Records of Pleistocene Mammals of New Jersey," David C. Parris, Bureau of Science, New Jersey State Museum, Trenton, New Jersey 08625, and the Adendum, "Radiocarbon Dates For The Sparta Mastodon" are taken from THE MOSASAUR, pages 1 through 21, Volume 1, January, 1983, The Journal of the Delaware Valley Paleontology Society.

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The Delaware Valley Paleontology Society (D.V.P.S.) was founded in 1978 as an association of amateur and professional paleontologists. The purpose of the Society, as stated in its constitution, is ". . . to promote the gathering and dissemination of information relating to fossil forms." THE MOSASAUR is the scientific journal of the Society, and its goals are to further the purpose of the Society and to serve both the members of the Society and the general paleontological community.

The Society meets monthly September to June, usually on the fourth Thursday at the Academy of Natural Sciences of Philadelphia. It stages an annual "Fossil Fair" in the Spring and publishes a monthly newsletter. Membership is open to anyone interested in paleontology.

Special thanks to MAPS member Frank Bukowski, 1441 E. Oxford St., Philadelphia, Pennsylvania 19125, for his efforts to make this publication possible.

NEW AND REVISED RECORDS OF PLEISTOCENE MAMMALS OF NEW JERSEY

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> "In the consideration of the problems of Pleistocene geology and paleontology, New Jersey is one of the most important states."
>
> O. P. Hay (1923)

While it has long been recognized that New Jersey is an interesting place for studies of the Pleistocene, its record of fossil mammals of that epoch is unfortunately poor. The spectacular and famous specimens of large mammals are an unsatisfactory representation of the Pleistocene mammalian fauna, and serve primarily to impart an even greater feeling of mystery about that time, when glacial and interglacial ages dominated the earth's climates, and humans finally came into prominence. Although Hay recognized the critical geographic position of New Jersey, his expectations have not been realized at least in terms of faunal data.

While a review of present knowledge does not necessarily contribute new data, at least it may clarify the existing record. Furthermore, the reviews of Hay (1923), Richards (1951), and Jepsen (1959 and later revisions) are now rather out-of-date, although they remain valuable references. It is hoped that the present work will serve the scientific community, both amateur and professional, as an additional reference.

Acknowledgements

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The following museums are represented by the letters indicated:

AMNH	American Museum of Natural History
ANSP	Academy of Natural Sciences of Philadelphia
BCM	Bergen Community Museum
NJSM	New Jersey State Museum
NMNH	National Museum of Natural History (Smithsonian)
NSM	Natural History and Science Museum, Blairstown, New Jersey
PU	Princeton University

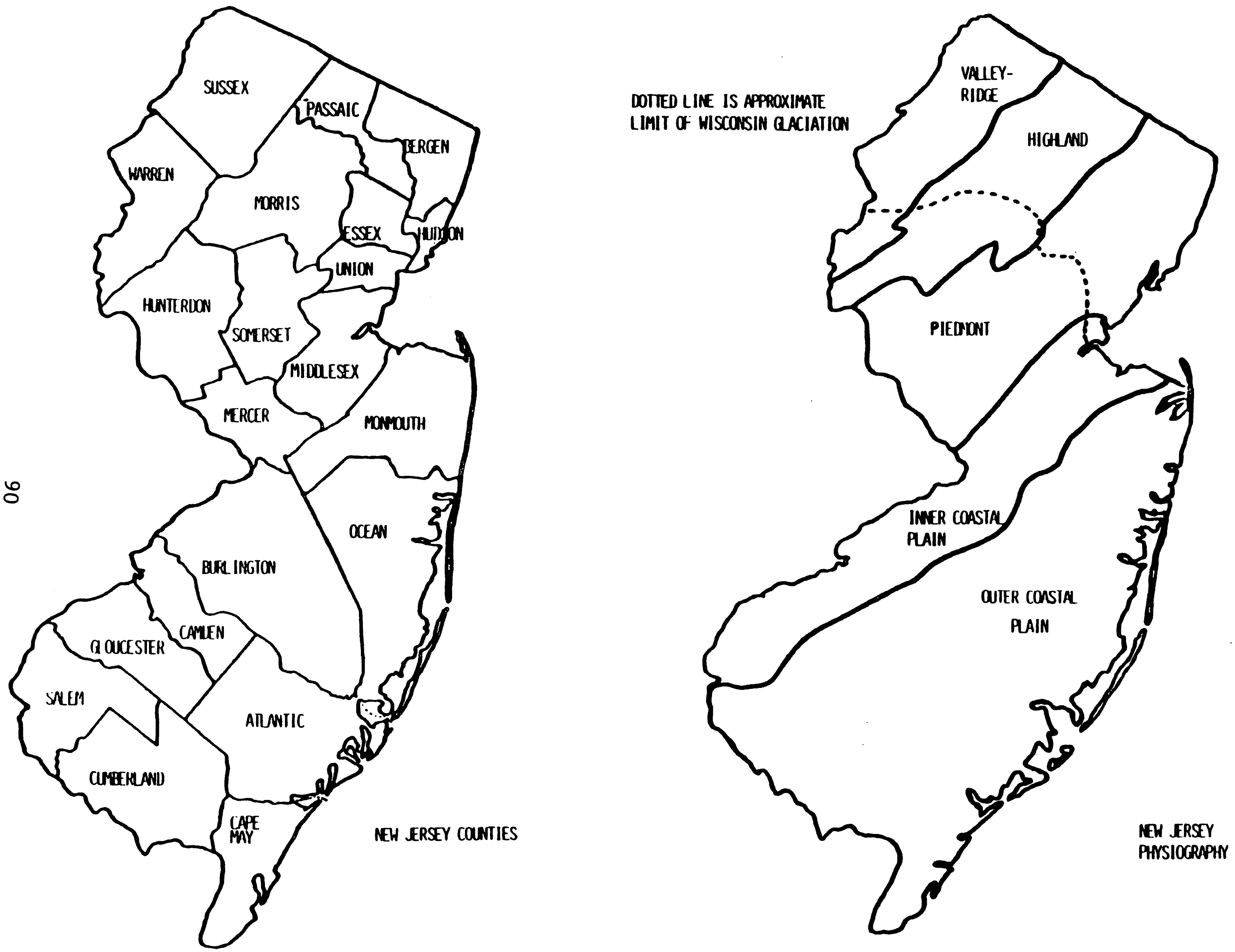

Figure 1. New Jersey Counties and Physiographic Provinces

New Jersey Pleistocene Sediments and Their Fossils

The extent of glacial and interglacial deposits in New Jersey is great, with virtually every area of the state yielding some types of Pleistocene sediments. The distribution of fossils is, however, quite uneven.

In the northwestern counties, where numerous Pleistocene bog deposits are found, the records of extinct mammals are also relatively common. These bogs existed just south of retreating continental ice sheets and yield very well preserved specimens, including some virtually complete skeletons. Typical strata in a bog include basal blue clays, overlain by pond muds (often called marl or shell-marl, from the clam and snail shells frequently found in them), topped by peat, representing the overgrowth of the pond, filled by plant material.

These bog deposits are especially noted for their yield of mastodon (Mammut) specimens, as well as several excellent elk-moose (Cervalces) skeletons. The wide range of individual ages and lack of evidence of injuries support the traditional interpretation that most of these specimens are the remains of animals which were mired and trapped in the bogs. Few show evidence of old age or injury.

Other Pleistocene deposits of northern New Jersey have not as yet yielded many specimens, although cave deposits and bedded drift sediments still offer potential collecting. The Castoroides specimen from the Fairy Hole Rock Shelter indicates that Pleistocene mammals indeed occur in New Jersey caves, and such occurrences are well-known in Pennsylvania where they are a major source of specimens.

While the "Yellow Gravels" of the Pleistocene of southern New Jersey seldom yield fossils, notable exceptions are the brook sites of Monmouth County, in which bedded Pleistocene deposits (apparently fluvial) overlie the Cretaceous and Tertiary formations of the coastal plain. Isolated bones are regularly found in the brook point bars, although mixed with Cretaceous, Colonial, and Recent materials in a confusing composite assemblage. Despite the difficulty of interpreting their precise ages, these isolated records afford welcome glimpses of Pleistocene life, as they include taxa unrepresented in the northern bog deposits.

The third major group of Pleistocene records consists of specimens dredged from the continental shelf. Scallop fishermen, and other people who regularly inspect samples of bottom muds, have obtained numerous specimens of both terrestrial and marine mammals, most of which are presumably Pleistocene. Although many specimens undoubtedly remain in private hands (or are discarded) and precise locality data are seldom obtained, these occurrences provide yet another source of evidence. The almost total lack of stratigraphy and dating of such specimens essentially reduces them to evidence of presence during a vaguely-defined period.

The overall picture of Pleistocene fossil sources of New Jersey, therefore, is abundance and variety of sediments, yielding isolated specimens with few contextual data. Systematic collecting and thorough analysis are still in the future.

The Recent Fauna in Pleistocene Perspective

Despite its great human population and small area, New Jersey retains a substantial number of native land mammal species. Included are one marsupial species, eight insectivores, one primate, some ten bats, three lagomorphs, seventeen rodents, ten carnivores, and one artiodactyl (McManus, 1974). In part, the number of species is attributable to New Jersey's diversity of environments distributed among six physiographic provinces (marine, outer coastal plain, inner coastal plain, piedmont, highland, and valley-ridge), largely based on differing geologic formations and structures.

Presumably, most of the species in the present-day fauna also lived in what is now New Jersey during the Pleistocene, and undoubtedly many others occurred within the area whenever the climate was favorable. However, because no proven Pleistocene record exists for most of these species, most supposed ranges during the Pleistocene are speculative.

The reason for this sad paucity of records is that most mammal fossils of New Jersey are isolated specimens, and it is difficult to state definitely that an isolated specimen is a Pleistocene fossil if it comes from an animal known from the present fauna. Preservation of the specimen is at best an unreliable clue to its age; many specimens from colonial time in New Jersey are preserved in the same way as specimens known to be Pleistocene in age, or are even more strongly stained or permineralized.

Also, most of the mammals that became extinct around the end of the Pleistocene epoch were large. Their large sturdy bones were much more likely to be fossilized and discovered than the more fragile skeletons of small mammals (such as most of the species now inhabiting New Jersey).

Finally, it must be admitted that little attention has been given to the possibility of Pleistocene small mammals in New Jersey. Cave deposits, where specimens could occur, were often dug up quite unscientifically by artifact hunters of past decades. Professional paleontologists have seldom applied their best collecting techniques to New Jersey Pleistocene deposits. Specimens of possible Pleistocene age have been ignored or even discarded if they were identified as belonging to a species of the present-day fauna. All of these factors have left us with little fossil evidence of the animals whose territory we now share. We know a few details about some species, however, and know considerably more about those whose ranges have been affected by human activity. These will be discussed briefly here.

The opossum, Didelphis virginiana, has only recently become a common animal throughout New Jersey. There is little, if any, evidence of the opossum in prehistoric archaeological sites of northern New Jersey, and no fossil evidence for earlier times (Guilday, 1953). It seems likely that this interesting North American marsupial, which thrives near civilization, is expanding its range due to environmental conditions we have created, possibly assisted by introduction by humans as in some western states.

There is no reliable record of the New England Cottontail, Sylvilagus transitionalis, from New Jersey, although biogeographers have long suspected it may occur here. Archaeological evidence from Pennsylvania suggests that it was once more widespread than at present (Doutt et al., 1967). Until recently, this species was probably declining, displaced by the Eastern Cottontail (S. floridanus) which normally occupies more open areas, such as those created by clearing of land for farms. The New England Cottontail was probably present in this area during Pleistocene times.

There is no reliable evidence for the red fox, Vulpes vulpes, in New Jersey except during recent years. It is generally believed to have entered New Jersey during colonial times after land clearing had created more suitable habitats for it. (Prior to that time it had a more northerly range.) It was a potential resident of what is now New Jersey during the various Pleistocene climatic fluctuations, but its presence today is due to a relatively recent immigration.

The coyote, Canis latrans, is presently increasing its range. Enough specimens are now known from New Jersey to warrant its listing as part of the fauna. This species, perhaps interbred with the gray wolf (Canis lupus) and domestic dog (C. familiaris), appears to have entered our area within this century and has no archaeological or paleontological record here (Bekoff et al., 1975).

Of course, there also have been well-documented historical extirpations, such as those of the gray wolf (Canis lupus), mountain lion (Felis concolor), elk (Cervus canadensis), and beaver (Castor canadensis), all of which could be expected as fossils in Pleistocene sediments. Richards (1951) cited a supposed Pleistocene beaver specimen (ANSP 11583) from Medford but its age is uncertain. A radius of Canis (wolf?), ANSP 11623, possibly Pleistocene, was cited by Richards (1951) but incorrectly identified as Ursus. Hay (1923) noted remains of a wolf from Fish House, Camden County.

The cervid genera Odocoileus and Cervus were also recorded from other supposed Pleistocene occurrences by Hay (1923).

Richards (1951) also cited a record of a muskrat, Ondatra zibethica (Linnaeus). This specimen (ANSP 11586), cited as a lower jaw, is actually a skull. Its Pleistocene age is questionable.

A definite record of a Pleistocene muskrat was obtained at the Big Brook locality in Marlboro Township, Monmouth County. The specimen (NJSM 12115), a subadult femur, was collected from the same bed as a Castoroides specimen (NJSM 11883).

Other material of possible Pleistocene age was associated with the type specimen of Grus proavus Marsh from Monmouth County. Although questionably Pleistocene, there is nothing in the collection to suggest otherwise. The specimens include white-tailed deer, Odocoileus virginianus, a subadult mandible with the deciduous third and four premolars, and all three molars, the third unerupted (PU 25426); raccoon, Procyon lotor, a rostral fragment with the left second molar and a fragmentary right innominate (PU 23427); and a vulpine, cf. Urocyon, represented by a left innominate and a right tibia (PU 23428).

Humans (Homo sapiens) apparently lived in what is now New Jersey during the latter part of the Pleistocene, perhaps considerably more than 10,000 years ago. Probably some of the extinct large mammals of the Pleistocene were encountered by aboriginal humans at least casually, although there are no sites that demonstrate associations. No Pleistocene human remains have been found in New Jersey, although cultural evidence of Paleoindians is well-known.

Obviously much remains to be learned about Pleistocene occurrences of mammals that occur in the modern fauna. More specimens are needed.

Pleistocene Megafauna

The following animals are commonly considered to be members of the Pleistocene megafauna. Most of these genera are extinct, but several are recent mammals now found in more northerly regions. In an effort to consolidate the published records of these mammals, all known specimens are cited, or previous lists noted. Cetaceans are not treated in this paper, although they are known from numerous fragmentary Quaternary specimens.

Order Endentata

Family Megalonychidae

Genus Megalonyx

Commonly called Jefferson's ground sloth, this large edentate is poorly represented in faunas of the northeastern states, despite a wide range that includes Alaska and the Northwest Territories. The two New Jersey records include, appropriately, a claw similar to those which inspired the generic name "Giant Claw."

ANSP 15232: Five vertebrae and several unidentified bones (Richards, 1951). The locality was at the New Jersey Turnpike crossing of Pennsauken Creek between Mt. Laurel Township, Burlington County, and Cherry Hill Township, Camden County. The specimen was recovered from a gravel, mapped as Cape May Formation. It was compared to M. jeffersonii in Richards' citation.

NJSM 11871: Terminal phalanx of pes. Collected during July, 1973, at the Big Brook locality, in Marlboro Township, Monmouth County, by John Brzostoski. This previously unpublished specimen apparently was eroded from the Pleistocene formation which overlies the Cretaceous Navesink Formation in the brook channel. The Pleistocene bed is a fluvial channel deposit which is traceable downstream into the Cape May Formation and has, in fact, previously been mapped as Cape May Formation. Although older Pleistocene formations are found in the area, it is unlikely that the specimen came from them because of the fragility of the specimen and the distance from outcrops of the other formations. The specimen is well-preserved, but the sheath is missing. It measures approximately 220 millimeters along the dorsal curvature. It is shown in Figure 2, photographed on a centimeter grid. The great depth relative to the length is characteristic of the claws of the pes, of which this specimen would be the third digit on the basis of size. All characteristics support a reference to Megalonyx, but no specific identification is possible. While a precise age determination cannot be made, the bed is believed to have been deposited during the early part of the Wisconsin glacial age. The presence of sloth remains, however, suggests a warmer climate, raising the possibility of correlation with the latter part of the Sangamon interglacial or an interstadial portion of the Wisconsin glacial age instead.

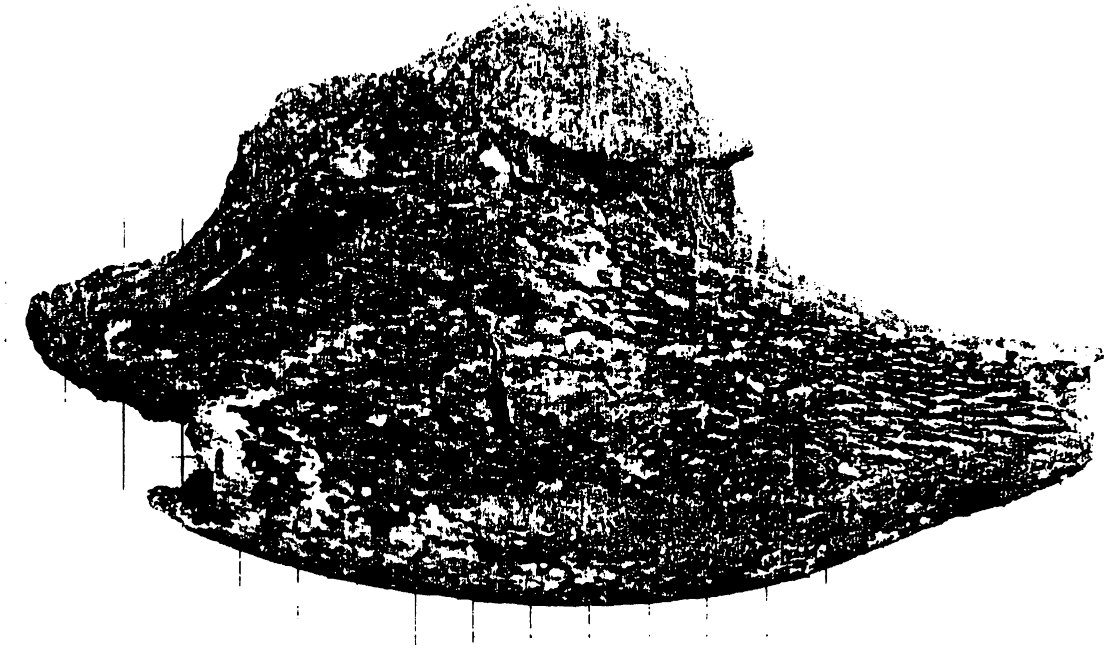

Figure 2. *Megalonyx*, terminal phalanx of pes, from the Big Brook locality, Marlboro Township, Monmouth County (NJSM 11871). Photographed on a centimeter grid.

Family Megatheriidae

Genus Eremotherium

This enormous ground sloth is commonly found in southern states. The New Jersey specimen is considered quite northerly and was possibly near the limits of the range.

AMNH 14443: A right calcaneum, collected at Long Branch, Monmouth County, in 1883, is referred to Eremotherium mirabile (Leidy) (Edmund, 1979, personal communication).

Previous authors listed this specimen as Megatherium (Hay, 1923; Richards, 1951), the customary practice prior to referral of the North American form to Eremotherium. The geologic age of the specimen, unfortunately, cannot be determined precisely.

Order Rodentia

Family Castoridae

Genus Castoroides

This large beaver was apparently common in eastern North America. Although much of the skeleton is known from various specimens, in New Jersey only two teeth have been found, from two widely different sources.

NJSM-ISS-20036: Probably a left lower first molar, was recovered in 1936 during Indian Site Survey excavations at Fairy Hole Rock Shelter, Allamuchy Township, Warren County (Cross, 1941). It is referred to Castoroides ohioensis Foster.

The alleged association of Indian artifacts with this specimen was doubted by Parris and Case (1980). However, James Zamos, of Newton, New Jersey, has recently revealed that he had discovered a fluted projectile point, characteristic of Paleoindian culture, at the same locality. This indicates an earlier human presence at Fairy Hole Rock Shelter than was previously demonstrable, and reopens the possibility of human association with Castoroides. However, no association can be proven.

NJSM 11883: A left upper first molar, was found at the Big Brook locality, Marlboro Township, Monmouth County, by David Markunas in 1977. It was recovered from the fluvial equivalent of the Cape May Formation. It, too, is referred to Castoroides ohioensis. Illustrated in Figure 3.

Order Carnivora

Family Odobenidae

Genus Odobenus

Walruses apparently were common along the Middle Atlantic Coast during the Pleistocene. Numerous specimens have been found, and can scarcely be listed exhaustively. However, several previously unpublished records may be added to those of Ray (1975), Kardas (1965), Richards (1951), Hay (1923), and Leidy (1860). Essentially all recorded specimens were dredged from the continental shelf, and are referred to the living species, Odobenus rosmarus Linnaeus.

NJSM 11260: A skull with left tusk and two other teeth was dredged from the Atlantic Shelf about 40 miles east of Barnegat, according to Harold Francis, who donated the specimen in 1961.

a. Length approx. 50 mm.

b. Occlusal dimensions approx. 15 mm x 17 mm.

Figure 3. Castoroides ohioensis, left upper first molar, from the Big Brook locality, Marlboro Township, Monmouth County (NJSM 11883).

ANSP 15552: A mandible was dredged from the Delaware River near Delair, Pennsauken Township, Camden County, in 1967. The specimen is water-worn, and no traces of alveoli remain, but it is still identifiable. The specimen is of particular interest since it comes from the Delaware River, rather than from marine waters.

PU 21574: A left innominate (pelvis) was recovered by clam draggers off Point Pleasant in 1969. Chris Laskowich and Harold Mendryk donated this specimen in 1972.

NJSM 11906: A water-worn rostrum with fragmentary tusks and vestiges of postcanine alveoli. This specimen was dredged off New Jersey, but no precise locality is known, according to James Hurley who donated the specimen in 1978.

Order Proboscidea

Family Mammutidae

Genus Mammut

Unquestionably the most famous of New Jersey Pleistocene mammals, the mastodons are probably as well-studied as any known fossil mammals. The record of this genus in New Jersey was summarized by Jepsen (1959 and later editions) and offshore records were given by Whitmore et al. (1967), so only some later specimens will be recorded here. All are referred to Mammut americanum (Kerr), except as otherwise noted.

BCM (unnumbered): A major portion of a skeleton was found near Hackensack, Bergen County, in 1962. It is now exhibited in the Bergen County Museum, in a position similar to that in which it was found, and is commonly called the Hackensack mastodon.

Sussex Historical Society: A major portion of a skeleton was excavated in 1962 by the Sussex Historical Society and is exhibited in their museum in the Hill Memorial Building in Newton, New Jersey. It was found in Hampton Township near Don Bosco College.

NJSM 12114: Tusks and a few other bone fragments were recovered near Hackettstown in 1965. The specimens are fragmentary but are identifiably mastodon, rather than mammoth. The material came from the property of William Hulse, on Petersberg Road, in Independence Township.

NSM 109: A major portion of a skeleton (from Blairstown Township, Warren County) is exhibited in the museum of Gary J. Sawyer in Paulina. Mr. Sawyer excavated this specimen in 1969. It was found on the propery to Paul Nehr, about three miles north of the town of Blairstown, on Kerr's Corner Road.

NJSM 11253: A sixth cervical vertebra was dredged from a depth of eleven feet on Catesville Road near Fort Dix (in Pemberton Township, Burlington County, in 1969).

NJSM 11267: A nearly complete skeleton was found on the property of Stanley Bojak in Liberty Township, Warren County, during 1971. This specimen is now mounted in the Natural History Hall at the State Museum. It yielded a radiocarbon date of 10,995 ± 750 radiocarbon years B.P. (Kraft, 1973).

NJSM 11268: A major portion of a skeleton was recovered during highway construction in Sparta Township, Sussex County, in 1972. This specimen is generally called the Sparta mastodon, and is notable for its radiocarbon dates, described in the Addendum to this paper.

BCM (unnumbered): A major portion of a skeleton was recovered in 1974 in Norwood Borough, Bergen County, on property of the Hackensack Water Company. This specimen is now mounted at the Bergen Community Museum, and commonly called the Dwarskill mastodon.

NJSM 11874: A tooth cusp was found by G. R. Case on 26 April 1975. He donated it to the State Museum. This specimen came from the Big Brook locality in Marlboro Township, Monmouth County, where it had eroded from the Pleistocene beds that overlie the Cretaceous Navesink Formation. It was found about halfway from the Boundary Road Bridge to the Railroad Bridge over the brook.

Unnumbered Specimen: A large sternebra was found in the spring of 1978 by Fred DeHaan on his property in Wantage Township, Sussex County. This bone resembled that of a mastodon in all respects, and is tentatively referred to *Mammut americanum*. The bone is in Mr. DeHaan's possession, but he kindly allowed the State Museum to borrow and photograph it. Precise locality data will not be published at Mr. DeHaan's request.

Family Elephantidae

Genus *Mammuthus*

Pleistocene elephants (or mammoths) are known from only a few New Jersey specimens. Possibly two species are represented by the known materials.

PU 11950: This molar is believed to be the specimen described by Hay (1923), and referred to *Elephas primigenius* (Blumenbach) now in the genus *Mammuthus*, and commonly called the woolly mammoth. The specimen was found in Trenton, Mercer County. This specimen is now on long-term loan to the New Jersey State Museum.

Rutgers University Geological Museum (unnumbered): This is apparently the North Plainfield specimen described by Hay, who referred it to *M. primigenius*. It probably came from Union County, as stated by Hay (North Plainfield is actually in Somerset County). The exact municipality cannot be determined.

Remarks: *Mammuthus columbi* (Falconer), another species of mammoth, is allegedly represented in records from New Jersey, but this is not certain. Hay (1923) reported a specimen from Middletown, Monmouth County, but knew nothing firsthand of the actual specimen. Another specimen was found in 1932 in Gloucester Township, Camden County, and identified as *M. columbi* by Dr. Barnum Brown (Richards, 1951). However, the present location of this specimen is apparently unknown, and the identification cannot be verified. The problems of identification of the various species of mammoths have been discussed by Whitmore *et al.* (1967) and Kurtén and Anderson (1980), and it seems advisable in view of their discussions to avoid specific assignments except for specimens of good quality. Several mammoth teeth cited by Whitmore *et al.* (1967) were from the coast off New Jersey, but no specific assignments were possible. There is considerable overlap of supposed characteristics of the dentitions of the various species.

Order Perissodactyla

Family Equidae

Genus *Equus*

There are few records of Pleistocene horses from New Jersey. Documentation and certain identification remain serious problems for the specimens, since they are distinguished from colonial and recent specimens only with great difficulty. No authenticated specimens have been discovered in recent years. Hay (1923) summarized a small number of earlier records, supposedly including two species, E. complicatus and E. fraternus. The latter species cannot be confirmed, as the specimen was lost.

ANSP 11484: This dentition, described by Woolman (1897) and mentioned by Hay (1923), was referred to Equus complicatus Leidy. Still the best documented Pleistocene horse from New Jersey, it provided critical information in dating the Fish House locality in Camden County.

NJSM 10411: This specimen of right upper molar or premolar from Roxbury Township, Morris County, originally cited by Richards (1951), cannot be identified to species. It may be an authentic Pleistocene record. This specimen is indistinguishable from teeth of domestic horses, however.

Order Artiodactyla

Family Cervidae

Genus Cervalces

One of the most famous New Jersey fossils, and certainly the fossil genus most closely associated with New Jersey, is the so-called elk-moose. Both of the definitive specimens were found in New Jersey, and most specimens from elsewhere are rather poor. The distinctive antlers with their long main beams and palmate tips are truly intermediate between the elk and the moose. Cervalces and Castoroides apparently lived in similar climates and terrain as their ranges coincide rather well.

PU 10648: This excellent skeleton remains the best specimen of the genus. It was found in Mt. Herman, Hope Township, Warren County, and described by Scott (1885).

NSM 264: A major portion of a skeleton of Cervalces scotti Lydekker is presently under study by G. J. Sawyer of Paulina, Blairstown Township, Warren County. The specimen came from a mosquito ditch near Hainesburg River Road in Knowlton Township, Warren County. Although found in 1969 by the property owner, Ralph Babcock, the majority of the specimen was collected in 1973.

NJSM 12109: An antler fragment was found by Scott Velasco in 1978 at the Big Brook locality, in Colts Neck Township, Monmouth County. This specimen adds yet another genus to the considerable record of Monmouth County, which Hay (1923) mentioned as notable. Although fragmentary, the size, the shape of palmation, and the surface textural features indicate a reference to Cervalces.

Genus Rangifer

The living species, Rangifer tarandus Linnaeus, undoubtedly ranged within what is now New Jersey during colder episodes of the Pleistocene epoch. Unfortunately, only an antler fragment serves as evidence of the caribou in this area. Two specimens were noted by Hay (1923), but one of them, a supposed Trenton record, had already been discredited by other authorities. It will not be considered here.

ANSP 11576: A fragment of left antler, found near Vincentown, Southampton Township, Burlington County, appears to be an authentic record of a Pleistocene caribou (Leidy, 1869). It was, however, of rather unusual form as noted by Hay (1923), lacking a brow tine. That condition may be seen in recent individuals, however, so there is no reason not to refer the antler to Rangifer tarandus.

Genus Symbos

This extinct muskox is represented by only one New Jersey record. As discussed below, the supposed ovibovine specimen reported by Volk is not considered a valid record.

PU 16340: A left frontal and horn core, dredged from the continental shelf (Whitmore et al., 1967), belongs to the extinct species Symbos cavifrons (Leidy). Illustrated in Figure 4.

Unsubstantiated and Incorrect Records

A number of genera and species have been reported for the Pleistocene of New Jersey for which records are erroneous or open to serious question.

Ursus sp.: As previously noted, the radius (ANSP 11623) attributed to Ursus sp. by Richards (1951) is actually referable to Canis.

Bison sp.: All previous records of New Jersey Bison specimens are incorrect or very questionable. The specimen reported by Richards (1951), ANSP 15167, cannot be distinguished from domestic Bos. The specimen found by Harold Wooley (NJSM 3838--Archaeology Collection) and reported by Richards (1951) cannot now be located, but another alleged Bison tooth found by Wooley is in the Ocean County Historical Museum. It, too, is indistinguishable from domestic Bos taurus, suggesting that Wooley was unable to differentiate them. Without horn cores or major skull fragments, the identification would be doubtful in any case. The Bison remains reported by Volk (1911) included a femoral fragment found only 2.5 feet from the surface. It is poorly preserved and would not likely have been identified as Bison, but as Bison or Bos, if it had not been assumed that the find was prehistoric. The same can be said of the first right upper molar, also cited by Volk (1911), which was also found in a sand-pit. It was conceded by Dr. G. M. Allen to be indistinguishable between Bison and Bos, and its identification as Bison depended completely on stratigraphy. It is clear from reading Volk's publication that great care had been taken to assure the integrity of his discoveries. However, neither of these two finds can be accepted with confidence. The femur was found in such a shallow position that it could have been a recent intrusive. The tooth was not found by Volk, but by a sandpit worker whose appreciation of stratigraphic precision may have been inadequate. In general, although Volk's work appears to have been carefully performed, it does not add any substantial records of Pleistocene vertebrate genera.

Ovibos sp.: The supposed ovibovine scapula reported by Volk (1911) (AMNH 20/12269) is so poorly preserved that its identification to family does not seem possible. I prefer to cite it as Artiodactyla, indeterminate. Fortunately, the presence of Symbos has confirmed the presence of ovibovines in this area.

Cervus sp.: An alleged elk antler (AMNH 20/12967) reported by Volk (1911) is so poorly preserved that it is difficult to confirm that it is an antler. Even so, it would not be identifiable to genus.

Mylohyus: A questionable record of this Pleistocene peccary was reported by Hay (1923), but no certain record exists. Mylohyus is known from a Pennsylvania cave near the Delaware Water Gap, and undoubtedly ranged into what is now New Jersey, but proof is lacking.

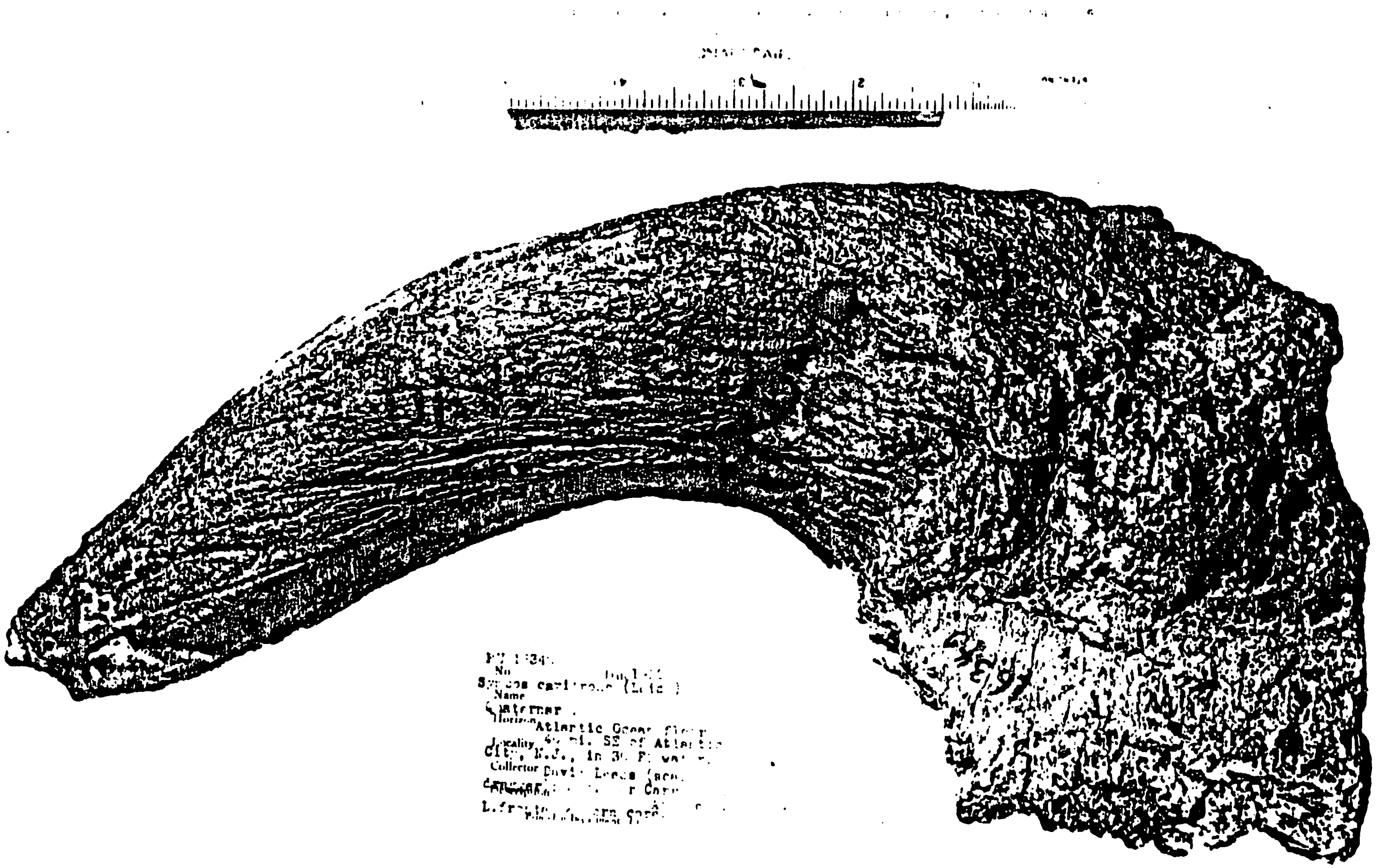

Figure 4. Symbos cavifrons, left frontal and horn core, dredged from the continental shelf 40 miles southeast of Atlantic City, N.J. (PU 16340). Scale in centimeters and inches.

Current Investigation

A particularly interesting specimen, NMNH 214459, is now being studied by Dr. Roger C. Wood of Stockton State College. This specimen is a horn core referable to the genus Bos. Its large size suggests comparisons with Bos primigenius, the Urus. It was found in peats off Brigantine. Dr. Wood has a paper in preparation that includes a complete description of this specimen and a discussion of its probable affinities.

Current Discoveries

Two additional specimens of Rangifer tarandus, the caribou, have been found within the last few years. Both were found at the Big Brook locality in Marlboro Township, Monmouth County, and are now in the personal collections of Frank Yuro of Edison and Andy Dillman of Perth Amboy. Both collectors kindly allowed me to examine and record the specimens.

The Yuro specimen is a basal fragment of a shed right antler with a portion of brow tine and main beam with some palmation.

The Dillman specimen is a basal fragment of a shed left antler with a portion of brow tine and over thirty centimeters of main beam, including some palmation and another tine.

Both specimens are large antlers, comparable in size to those of a trophy mount Alaskan specimen in the New Jersey State Museum taxidermy collections and more massive than ANSP 11576, the other New Jersey Pleistocene specimen. No reference to any living subspecies can be made, however.

Conclusions

The Pleistocene faunal record of New Jersey, which seems so promising, is actually rather poor. Reexamination of previously reported materials has actually reduced the number of genera and species reported from the area (Table 1). However, the presence of numerous Pleistocene deposits in New Jersey still suggests that fine discoveries may yet come. If deposits yielding multiple numbers of specimens and precise dates can be found, New Jersey may yet attain its deserved place in studies of Pleistocene Vertebrata, as Hay supposed so many years ago.

Table 1. New Jersey Pleistocene Megafauna

Megalonyx cf. jeffersonii Desmarest
Eremotherium mirabile (Leidy)
Castoroides ohioensis Foster
Odobenus rosmarus Linnaeus
Mammut americanum (Kerr)
Mammuthus primigenius (Blumenbach)
Equus complicatus Leidy
Cervalces scotti Lydekker
Rangifer tarandus Linnaeus
Symbos cavifrons (Leidy)

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ADDENDUM

RADIOCARBON DATES FOR THE SPARTA MASTODON

Introduction

Although mastodons, Mammut americanum (Kerr), are rather common fossils in New Jersey, Pennsylvania, and New York, relatively few specimens have been dated by radiocarbon. This is unfortunate since dates could provide information helpful not only to studies of extinctions of Pleistocene megafauna but also of the retreat of continental glaciation.

Although radiocarbon dates on bone are controversial (Martin, 1967), theoretically there is no more satisfactory way to obtain a date for an individual than by valid determinations on its bones, and it is desirable that validity be confirmed by independent determination methods. In the case reported here two distinct methods yielded dates of remarkable similarity.

Specimen

The Sparta Mastodon (NJSM 11268) was discovered in 1972 during construction of New Jersey State Route 15 on property formerly belonging to C. H. Habbart of Sparta Township, Sussex County, New Jersey (approximately 41° 0' 48" N., 74° 36' 58" W., Franklin quadrangle). Other locality information may be obtained from the New Jersey State Museum, Bureau of Science.

The specimen, a substantial portion of a skeleton, was dredged from a depth of about four meters, according to crane operator Ramon Casal, and other workers at the scene. The Habbart family, other local residents, amateur fossil collectors, and New Jersey State Museum employees collected the bones. They chose bone samples for potential radiocarbon dating, and sealed the specimens immediately in airtight containers.

NJSM 11268 had young adult dentition (with the second and third molars erupted, but the latter essentially unworn), and epiphyses were unfused in the femora, scapulae, and vertebral centra. It was a large individual, about one-fifth larger than the Bojak Mastodon (NJSM 11267), which is a mounted skeleton with a mature adult level of tooth wear, and complete epiphyseal fusion. Dental age estimates are based on the criteria of Saunders (1977).

The spoil piles consisted primarily of peat, muck, and gray clay, typical of the sediments of a mastodon site in this area (Drumm, 1963; Dumont and Ehlers, 1973). The bones had muck matrix adhering to them but could not be observed in place. The excavation area was essentially saturated with groundwater, again typical of mastodon sites. Although similar deposits yield numerous shells of freshwater gastropods and pelecypods, these were not in evidence at this site. The underlying lithology is gneiss of Precambrian age, apparently referrable to the quartz-oligoclase gneiss unit of Buddington and Baker (1961), although the locality is slightly outside the surface area of that unit as published. The site is just north of the Portland moraine (Wolfe, 1977).

Radiocarbon Test Results

Two analyses were performed by Geochron Laboratories Division of Krueger Enterprises, Inc., on the Sparta Mastodon bone sample, GX-5742-A. The apatite fraction gave an age of 12,320 ± 410 C^{14} years B.P. (A C^{13} analysis indicated that the bone apatite was uncontaminated.) A sample of bone gelatin from the specimen yielded a second date of 12,730 ± 360 C^{14} years B.P. The two samples thus showed excellent concordance.

Discussion

Pleistocene mammals from bogs in the area in question often yield well-preserved bone collagen. Radiocarbon dates from the collagen seem consistent with determinations on materials other than bone (Table 1). These dates are also consistent with determinations on bog sediments from the region (Buckley and Willis, 1970; Spiker _et al._, 1978) and determinations on coastal occurrences (Whitmore _et al._, 1967). The bog deposits of the region yield major proportions of mammalian skeletons, suggesting quick burial of the individuals, before decay and scattering could occur. Unquestionably, these bogs provide great protection against oxidation; decomposition of the materials, both plant and animal, proceeds rapidly upon exposure. It is therefore not surprising that NJSM 11268 yielded collagen sufficient for a date determination, particularly in view of its depth of burial, which was somewhat greater than those of most previous mastodon discoveries.

The lack of contamination of the bone apatite is unusual, however. There is no secure explanation for this lack of contamination. This bog deposit was located over Highland gneissic terrain, rather than Valley and Ridge terrain (which includes many carbonate rocks). This could have resulted in low levels of carbonate in the groundwater. The lack of molluscan shells in the bog sediments is also perhaps indicative of a low amount of carbonate in the depositional environment.

Conclusion

There is reason to believe that Wisconsin megafaunal specimens from peat bogs overlying gneissic terrain will yield consistent radiocarbon dates for bone collagen and bone apatite. The Sparta Mastodon is a specimen demonstrating such concordance, and testing of other specimens from the region could conclusively establish a method for cross reference of radiocarbon determinations on similar specimens.

Table 1. Radiocarbon Dates from the Atlantic Region
(Region delimited by Dreimanis, 1968)

Specimen	Approximate Location	Laboratory No.	Material	Date*	Reference
Marshalls Creek *Mammut*	Marshalls Creek, Pa.	I-3929	Wood	12,160 ± 180	Buckley and Willis (1970)
		I-3930	Wood	12,020 ± 180	Buckley and Willis (1970)
Bojak *Mammut* (NJSM 11267)	Liberty Twp., N.J.	GX-2675	Bone collagen	10,995 ± 750	Kraft (1973)
Ohberg *Mammut*	Vernon Twp., N.J.	L-231	Peat	10,890 ± 200	Dreimanis (1968)
Arborio *Mammut*	Montgomery, N.Y.	I-3785	Bone	10,000 ± 160	Funk *et al.* (1970)
Sugar Loaf *Mammut*	Middletown, N.Y.	I-6634	Bone	9,860 ± 225	Dumont and Ehlers (1973)
Dutchess Quarry *Rangifer*	Florida, N.Y.	I-4137	Bone collagen	12,530 ± 270	Buckley and Willis (1972)
Dewey-Parr *Cervalces*	W. of Florida, N.Y.	I-4016	Bone	10,950 ± 150	Buckley and Willis (1970)
Sparta *Mammut* (NJSM 11268)	Sparta Twp., N.J.	GX-5742 A	Bone apatite	12,320 ± 410	This report
			Bone collagen	12,730 ± 360	This report

* Radiocarbon years B.P.

Acknowledgements

I thank Daniel Dombroski (N.J. Bureau of Geology and Topography) and Shirley S. Albright (N.J. State Museum) for information on lithologies of the Precambrian gneiss. This note was suggested by Dr. Henry Krueger of Geochron Laboratories, who deserves credit for initiating the dual date determination.

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Pleistocene Edentates of Dallas County

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The Edentates of present times are a relatively insignificant group of mammals represented by the tree sloths, anteaters, and armadillos. These extant forms have been classified into 14 genera and 31 species, Vaughan, 1972. In Pleistocene times, however, this order included a great variety of species such as the ground sloths, glyptodonts, and pampatheres whose often large and bizarre remains are well documented in the fossil record of the new world.

Although both modern and fossil forms appear quite diverse, all exhibit distinctive morphological characteristics. There are extra zygapophysis type articulations present on the lumbar vertebrae (xenarthrous) and the sacrum is elongated. There are no incisors or canines and the perpetually growing cheek teeth (absent in the anteaters) are open rooted and lack enamel. Instead of seven cervical vertebrae as in other mammals, the edentates have from six to nine. The limbs are relatively short and the claws are often enormously developed. The overall structural trends exhibited by edentates is for an increase in stability of the axial skeleton, a reduction of the dentition, and short, powerful limbs specialized for digging or climbing although the formidable claws of some of the Pleistocene forms probably served as food gathering tools or defensive weapons.

Early edentate ancestry has been taken back as far as the Cretaceous by McKenna, (1975). The known fossil record, however, is to the late Paleocene in South America. This continent was separated from North America near the end of the Cretaceous and was not rejoined with the latter until the late Pliocene. This separation from the North American mammalian fauna allowed the edentates to evolve undisturbed by competition throughout the Tertiary. These Paleocene forms classified in the suborder Xenarthra belong to the Dasypodidae (armadillos) and are represented by a diverse group. By the Pleistocene, one of these creatures attained the size of a rhinoceros. Vaughan (1972), suggests that the other Tertiary xenarthrans may have evolved from this early Dasypodid stock. Evidence for this idea may be found in the similar ossified dermal scutes so characteristic of the Dasypodids also found in other successive xenarthran families (ie., the Glyptodontidae - Eocene to Pleistocene and Mylodontidae - Oligocene to Pleistocene).

Successive to the rejoining of the Americas by the Pliocene land bridge, the xenarthrans were able to move northward and had established themselves quite well by the Pleistocene. One species, Megalonyx jeffersoni, ranged as far north as Alaska. Xenarthran families represented by fossils in the North American Pleistocene are the Dasypodidae (armadillos), the Glyptodontidae (glyptodonts), and the ground sloths Megalonychidae, Megatheriidae, and

Mylondontidae. Bones and teeth are the most abundant fossils from these creatures, however, mummified carcasses with well preserved hair and soft parts and large numbers of coprolites are known from western states.

Pleistocene edentate material in Dallas county is extremely rare and is represented by isolated bones and fragments found in commercial sand and gravel operations along major drainages. As these sedimentary formations are the result of river point bar type deposits, the material is often water abraded and tumbled. Recognized families in these Dallas county deposits are the Dasypodidae, Glyptodontidae, Megalonychidae, and the Mylodontidae.

The Dasypodids here include the pampathere Holmesina septentrionalis (Leidy) of the subfamily Pampatheriinae and Dasypus bellus (Simpson) of the subfamily Dasypodinae. These species are typically represented by scutes which comprised the body armor in life. Dasypus bellus (Simpson) was very similar to our present nine-banded armadillo Dasypus novemcinctus except for its larger (double) size. Pampatheres like Holmesina were somewhat more specialized than their smaller armadillo cousins and reached sizes up to three meters, Edmund (1987).

Glyptodonts were very specialized edentates of large (up to three meters) size and, like their armadillo cousins, possessed a carapace comprised of hundreds of scutes. The carapace on these creatures, however, had no flexible joints as in the armadillos, and the back and legs were overly developed to support the weight of this structure. Probably clumsy and slow, glyptodonts have been referred to as the mammalian version of the turtle and were vegetarians with weak, flat-crowned teeth. Authors like Gillette (1973), feel the glyptodonts possessed a short trunk like snout that may have been useful in food gathering. A single scute is confirmed from just outside Dallas county and is assigned to the species Glyptotherium floridanum (Simpson).

The ground sloths from Dallas include the Megalonychid Megalonyx jeffersoni (Desmarest) and the Mylodont Glossotherium harlani (Owen). Megalonyx was a cow sized animal and rather abundant as far as the edentates are known from the North American Pleistocene. It ranged throughout much of our country including points as far north as Canada and Alaska. This is the only gound sloth with canine-like (caniniform) teeth in the anterior of both upper and lower jaws. A near complete lower jaw, isolated teeth, claws and assorted post cranial elements are known from Dallas county. Glossotherium formerly Paramylodon is known from a few teeth, dermal scutes and bone fragments attributed to this species. This was a larger animal than Megalonyx with a massive skeleton, caniniform teeth in the upper jaw, and ossified dermal scutes embedded in the back for protection. The Pleistocene grasslands of much of North America was the habitat of Glossotherium and it has been found in sites from Florida to California.

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PLATE I

Edentate fossil specimens from Dallas County vicinity. All illustrations by author. All specimens X.50.

1. a, b - Megalonyx jeffersoni (Desmarest). Lower jaw of young animal. a - left lateral view, b - occlusal view.
2. a, b, c. - Megalonyx jeffersoni (Desmarest). Claw core, second digit, left manus. a - lateral view, b - dorsal view, c - ventral view.
3. a, b, c. - Glossotherium harlani (Owen). Second upper left cheek tooth. a - lingual view, b - occlusal view, c - anterior view.
4. Megalonyx jeffersoni (Desmarest). Second metacarpal, second digit, right manus. Lateral view.
5. Holmesina septentrionalis (Leidy). Buckler scutes. Dorsal view.
6. Glyptotherium floridanum (Simpson). Dermal scute. Dorsal view.

PLATE I

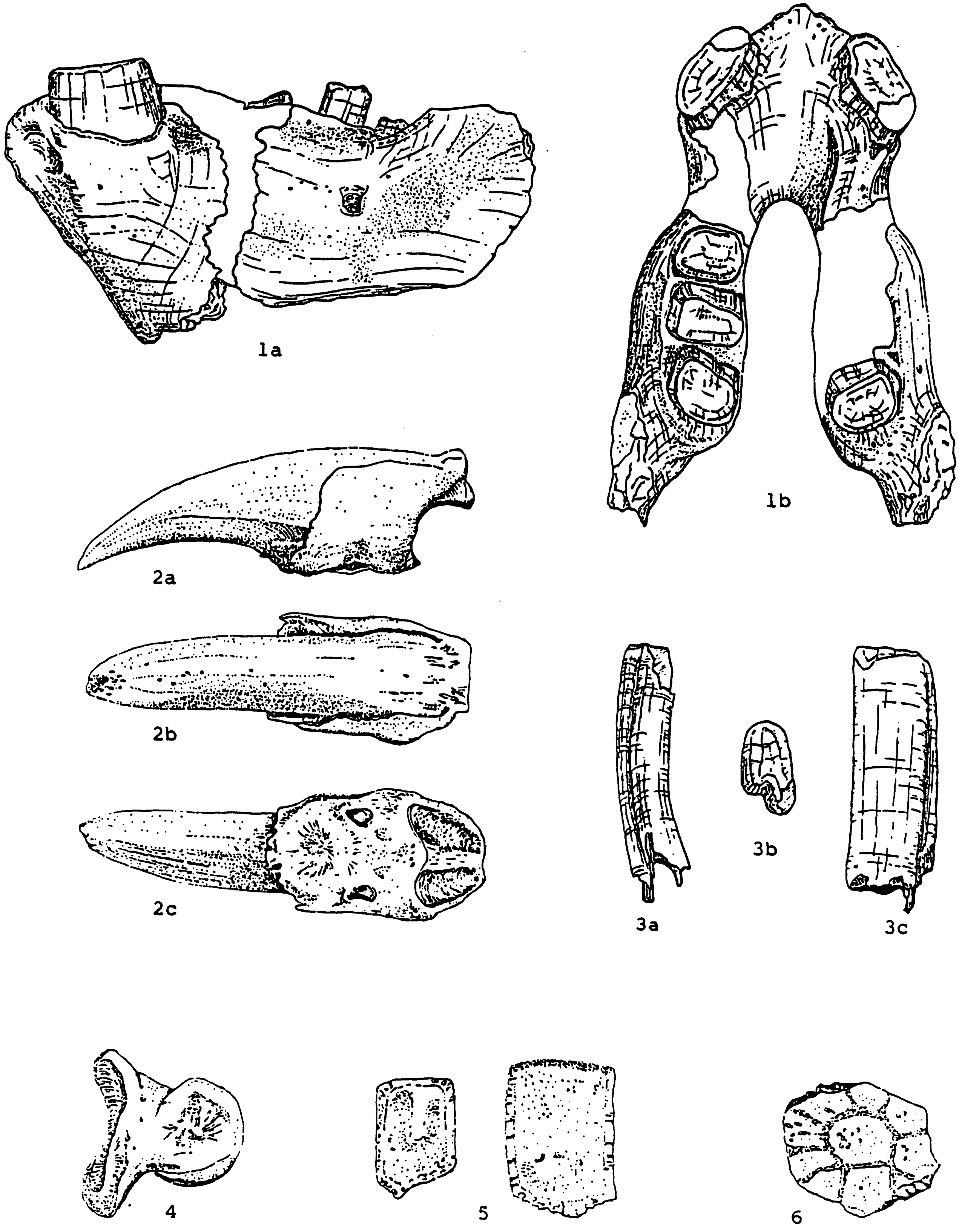


PLATE II

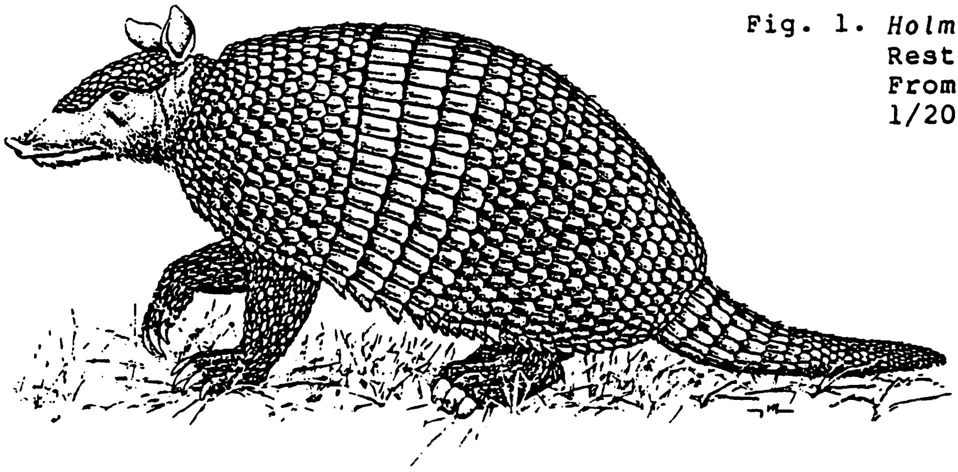
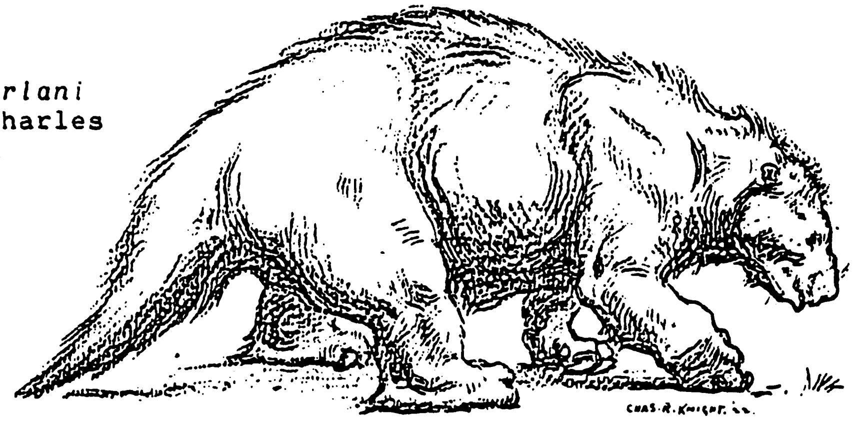


Fig. 1. *Holmesina septentrionalis*
Restoration composite.
From Edmund, 1985.
1/20 scale.

Fig. 2. *Glossotherium harlani*
Restoration by Charles
R. Knight. From
Stock, 1925.
1/24 scale.



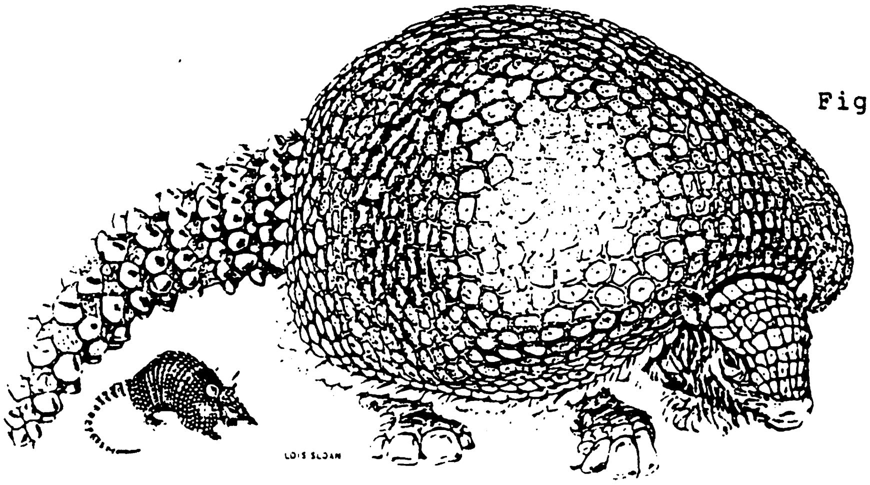
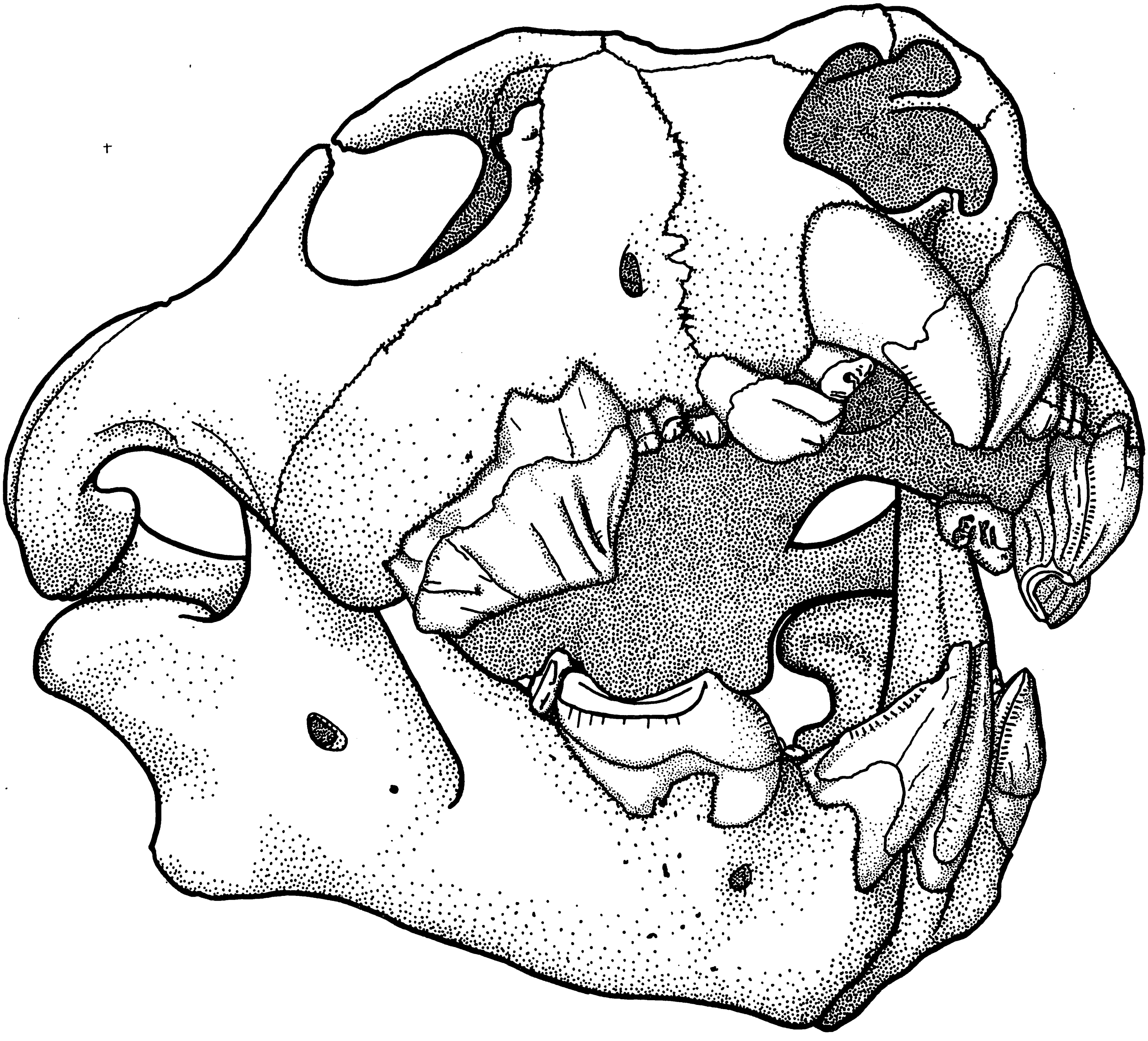
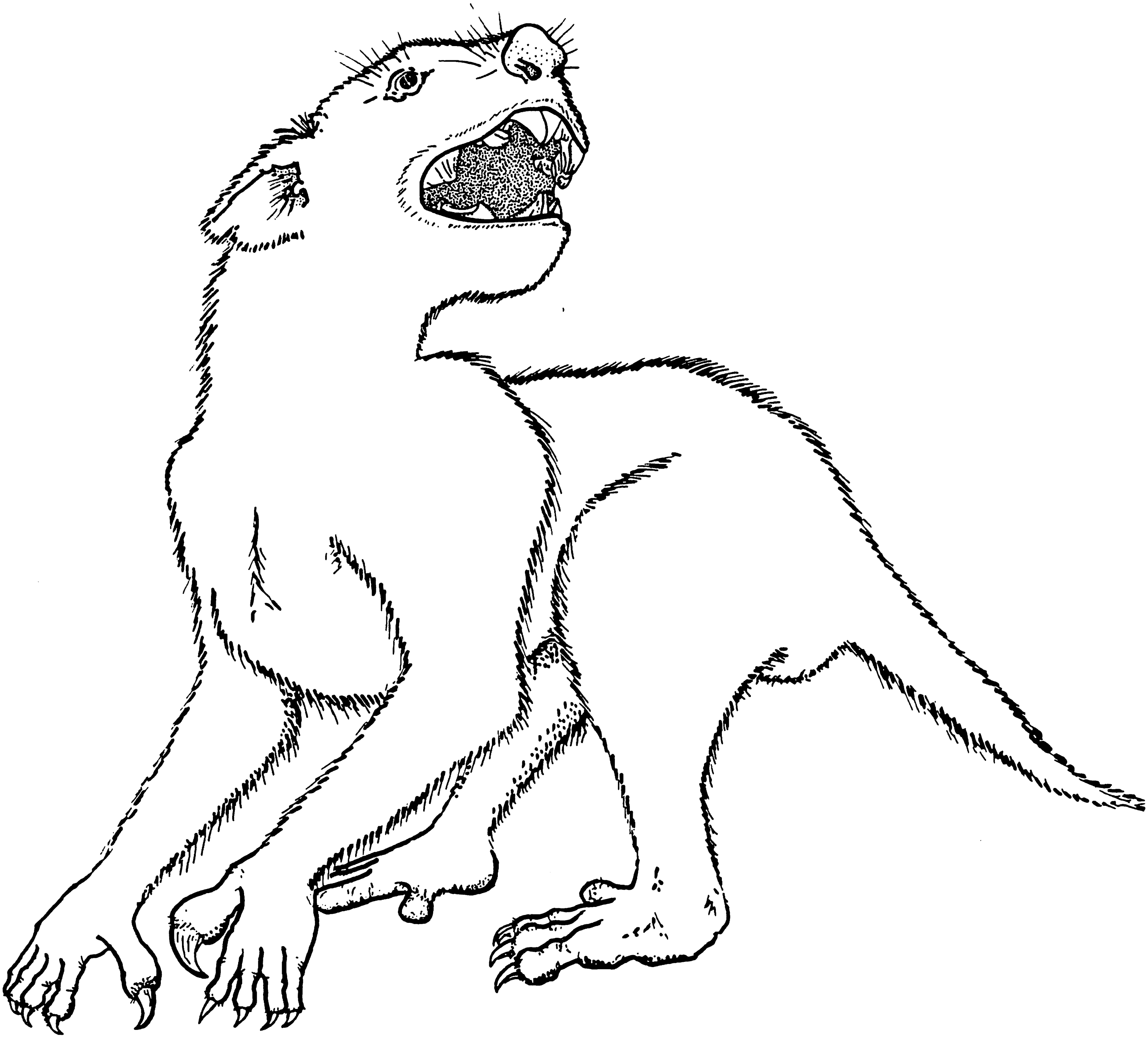


Fig. 3. Glyptodont species
compared to modern
armadillo. From
From Nat. Geo. Soc.,
1983. 1/20 scale.





The Large Extinct Carnivore from Pleistocene Australia *Thylacoleo carnifex* (Owen)

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Private collecting of vertebrate fossils has not been encouraged in Australia and their rarity and fragmentary nature gives the average fossicker little chance of establishing a worthwhile collection. It is encouraging to note that some paleontologists recognize the contribution that can be made by amateurs and give encouragement and guidance with regard to preserving the scientific significance of specimens.

My family, friends, and I were fortunate to have the opportunity to spend our spare time over the last eight years rescuing the remains of Pleistocene creatures from a cave being exposed, and destroyed, by commercial quarrying. We have contributed more than 10,000 hours collecting, cleaning, sorting, preserving, cataloguing, and studying this material. As a result, we are researching snakes' ancestors around the world, and finding evidence to support Continental drift through their apparent migration routes and evolution.

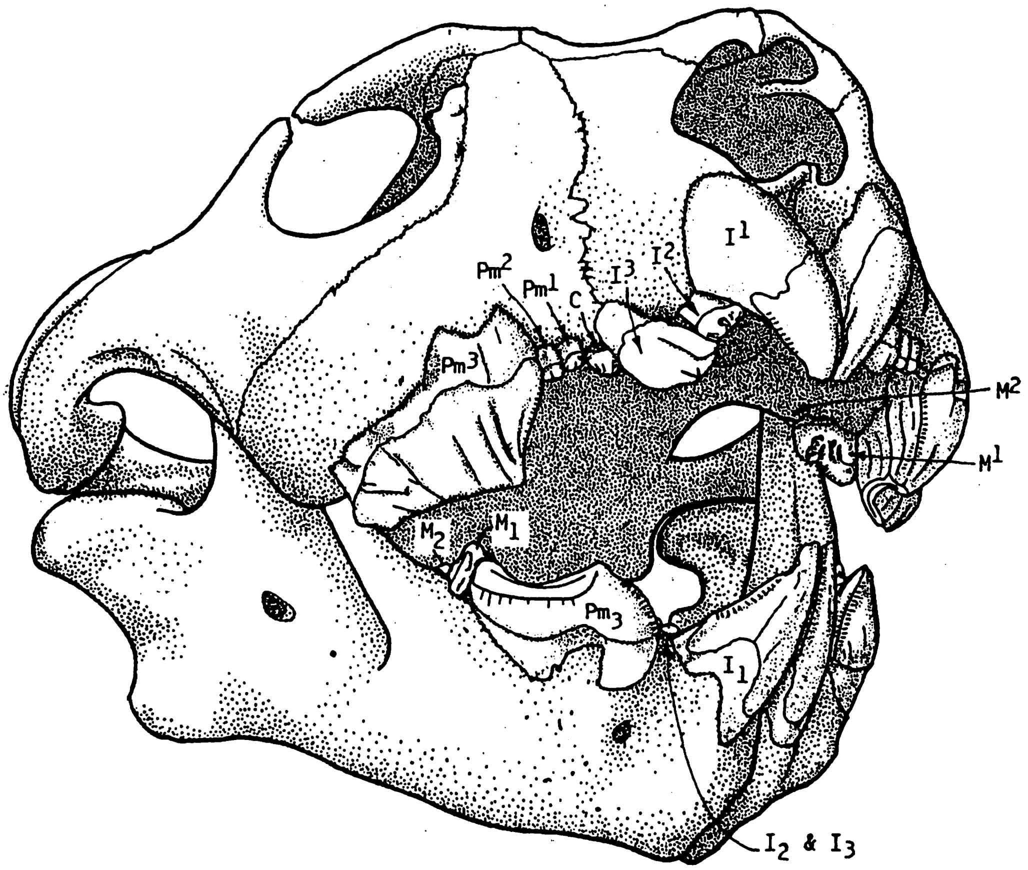
Significant remains of *Wonambi naracoortensis*, a large boid possibly the Rainbow Serpent of aboriginal mythology, having its closest relatives of Cretaceous age distributed across what was Gondwanaland, has been the highlight of our research.

The remains of other creatures collected include hippopotamus-sized herbivores to mouse-sized insectivores, numerous birds and reptiles, and a diversity of carnivorous marsupials. The most outstanding carnivore is undoubtedly the leopard-sized *Thylacoleo carnifex*.

Thylacoleo was strongly built as is evidenced by the degree of sculpture on its bones. The pressure of muscles working against bone causes displacement and redeposition in areas of least pressure, thus creating ridges along the bone surface. These ridges maintain both the strength of the bone and the free action of the muscle. Conversely, slow moving or slightly built animals have rather rounded bones.

The fore-arms of *Thylacoleo* show particular evidence of strength, being quite long and ideally suited for climbing. The skull and jaws were also very robust with room for heavy, muscular structure.

The animal's dentition is arguably one of the most unique in the world, past and present, and has created much speculation as to its diet. It is now considered beyond doubt that it was a carnivore (Wells et al., 1982).



THYLACOLEO CARNIFEX OWEN (THYLACOLEONIDAE) x 0.65. Juvenile specimen of skull and jaws agape showing full dentation notations on right side except M^1 and M^2.

Cont...

The dental formula, as evidenced by specimens examined, is as follows:

$$I\,\frac{1.2.3.}{1}\qquad C\,\frac{1}{0}\qquad Pm\,\frac{1.2.3.}{1.2.3.}\qquad M\,\frac{1.2.}{1.2.}$$

The most spectacular teeth are the upper and lower third pre-molars (PM3's), which are large guillotine-like blades with concave surfaces.

Occlusion caused food to be drawn towards the center of the teeth where it was sheared off with the keen serrate edge of the blades. The other major teeth are the first incisors (I1), both upper and lower, which would have been for piercing, holding, and stabbing.

It is interesting to compare the relationship of upper and lower dentition. The skull is very broad and certainly lion-like as is witnessed by Sir Richard Owen's given name. The mandibles do not fuse at the symphysis, but form a hydraulic joint. The lower jaws are narrow and, when closed, fit high against the palate between the upper teeth, the lower PM3's resting inside the upper ones. Similarly, the lower incisors rest with their tips at the base of the upper incisors.

To effectively bite, *Thylacoleo*, in using its PM3's which invariably show great evidence of wear, must roll the jaw sideways. To avoid dislocating the opposite side condyle, the hydraulic symphysis must flex and allow the lower front incisors to cross the upper incisors. This action allows the PM3's to occlude and effectively shear. On specimens from young animals, a very sharp edge is present on these PM3's and the bite is near vertical. With maturity, the shearing surface becomes more obtuse and the bite apparently developed somewhat more horizontal.

It is of note that on crossing the paired incisors during occlusion of the left PM3's, the left upper incisor meets the right lower incisor (and vice versa) creating a notch in the lower I1 near the tip.

The manus and pes have been described in detail by Wells and Nichol, 1977, but no complete articulated specimen of pes has yet been recovered, consequently, areas of doubt will exist.

It is also interesting to note that several artists in reconstructing the *Thylacoleo* choose to show a clawless metatarsal 1 on the pes. While agreeing with this assumption, proof is elusive. A bone that may well be metatarsal 1 has been found in association with pes material, however, there is no clear articular point of attachment. With *Phascolarctos* (koala) having a similar pes, it is suggested that the degree of articulation may be small, even if *Thylacoleo* was arboreal as is *Phascolarctos*. Consequently, one would not expect the rounded surfaces to compare with the highly articulate clawed first phalange.

The hooded claws of both manus and pes are unusual. Studying the feet of cats, one finds retractable claws that literally fold back askew to rest between the digits, thus enabling cats to keep sharp claws from interfering with objects as they walk. Thylacoleo has a straight alignment along the bones to the distal phalanges and to avoid getting tangled up while walking, must have had much less curvature on the claws. Generally, claws are quite small judging by the distal phalange that supports them, although the thumb (distal phalange 1) is enormous by comparison. The syndactylous toes (generally used for grooming) are consistent with other syndactylids and are rather curved and slender.

The thumb has promoted great interest because of the size of the sheath housing the claw and the degree of articulation. In the manus, the thumb is supported from the scapholunar via the trapezium, metacarpal and proximal phalange to the distal phalange (hooded claw), the latter two bones being very diagnostic and highly articulate. The proximal end of the proximal phalange is trumpet shaped, fitting snugly against the blocky metacarpal while the distal end is highly rounded with a rather deep "V" providing a highly articulate joint in flexion but with great resistance to twisting. The thumb does not oppose the "index finger" as in humans, but the opposite side of the hand in the area of the pisiform (wrist). Wells and Nichol suggest that this would be the primary grasping movement. It may also be related to the manner in which Thylacoleo was able to run without the claw hindering its movement. This claw, no doubt, was an important element in Thylacoleo's hunting, its strength and mobility making it a formidable weapon. The purpose of the hood over the claw, particularly the thumb, is believed to be a mould from which the claw grows, and an anchor to give it tremendous support.

Studying the curvature lines inside the hood, it is difficult to visualize the claw retracting within it. To do so it would need a fulcrum about which to rotate, yet the arcs evident on the inner surface of the hood indicate the fulcrum would be well below the digit. In addition, to be retractable, it would need to act as a hydraulic ram, although the hood does not appear to be strong enough, or the amount of travel available, sufficient to support and permit the effective use of such a sturdy claw.

Several authors have documented markings on bones attributing these to being caused by the feeding action of Thylacoleo. Invariably, these markings attributed to Thylacoleo are opposing, that is on both sides of the bone. A curious variation to this prompted a close study of Thylacoleo's teeth and their action.

The proximal end of a femur was collected from a small cavern amongst various cranial and post-cranial remains that proved to be of a wombat.

Marks on the femur indicate it had been subjected to a very aggressive chewing action which, closer examination suggests, may

F. x2

have been caused by Thylacoleo carnifex. In cross-section, the bone has been abraded deeply, leaving facets at approximately 60 degrees to each other. Comparisons were made by studying the marks on other bones, available literature (Horton and Wright, 1981 and Wells, Horton, and Rogers, 1982) and bones from King Creek on the Darling Downs, Queensland and Naracoorte, South Aust. which show only opposing marks attributed to the cutting action of upper and lower P3.

By occluding a maxilla and mandible specimen, there appeared to be no way in which the bone could have been marked by the action of upper and lower P3. as shown on the comparative material.

Investigation of a mandible revealed that the angle formed between I1 and P3 is approximately 60 degrees. Placing the marked bone carefully between these teeth, an incredible fit resulted.

The triangular shaped cross-section of I/1 is rather unusual in Thylacoleo, detailed examination disclosing a very definite and slightly serrated auxiliary ridge along the labial edge. Similarly, the posterior edge of P/3 has a ridge also serrated and somewhat opposing I/1.

The marks on the bones commence with a shallow scrape close to the swelling at the proximal end of the femur, then became 3 to 4mm deep as they extend 20mm along the shaft to end in a sharp angular edge. This process is repeated on the other side of the femur.

The second set of gouges penetrates the bone at the deepest point, 15mm from the point at which the bone has been severed. Gashes, but no drawn out gouge marks are associated with the broken edge. This break does not appear to have been the result of a holding grip becoming too deeply incised. Maybe it was a method used by Thylacoleo to disable its prey. Each set of gouge marks is paired. One produced by I/1 has a smooth, slightly convex surface, while the other, produced by P/3, has more irregular grooves, some of which are individually concave. It has been established that both sets of marks were made by the left mandible, indicating that the prey was dragged, both on its back and on its belly. Had both the left and right mandible been used, the relationship of the marks would have been reversed.

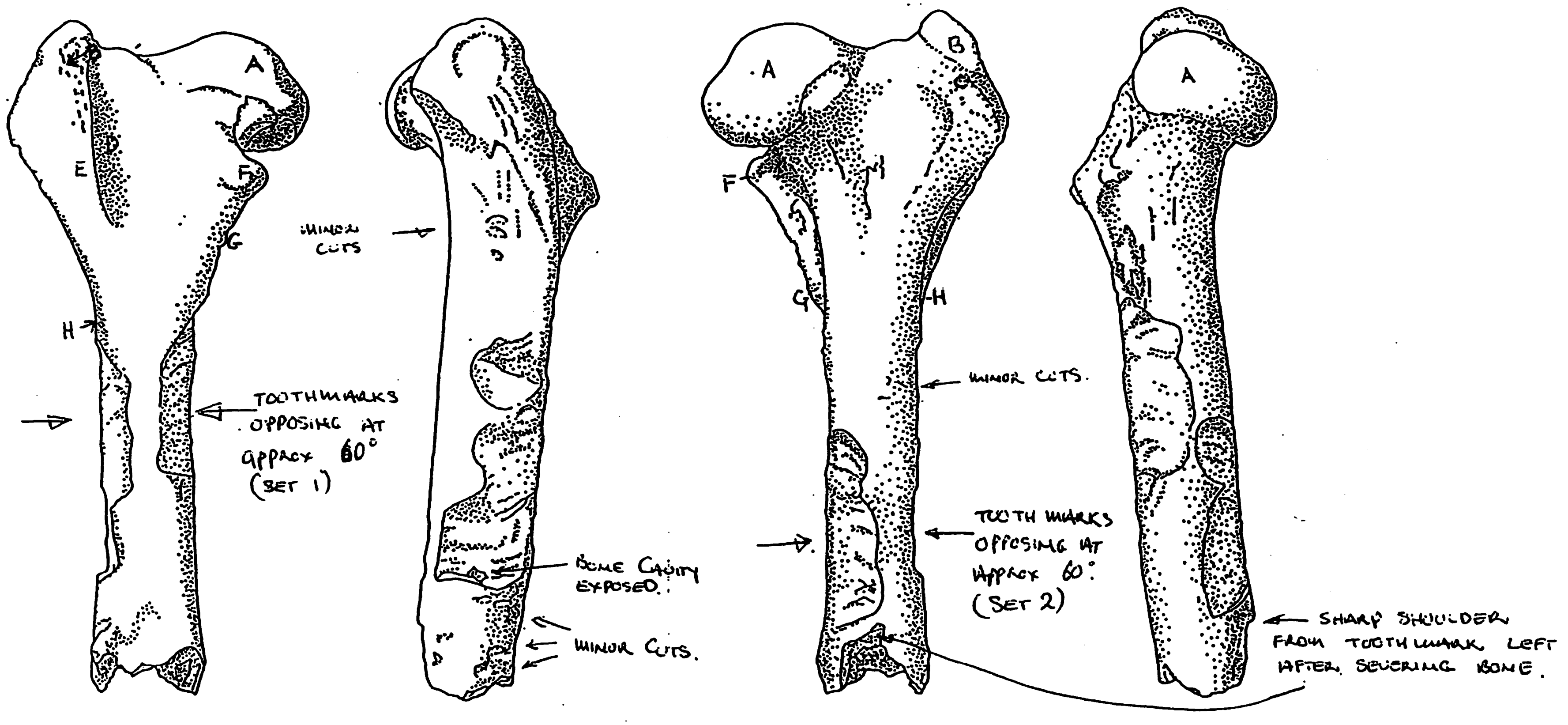
The degree of marking on this bone infers a considerable effort was involved in holding the prey. This could indicate the prey was dragged over a long distance or was almost too large to move. In any case, it implies that Thylacoleo was able to transport a carcass to the shelter of a cave. Assuming that such a carcass was relatively complete, a fact supported by the skull elements and sacral vertebrae found with the associated bones, it could have weighed in excess of 30kg.

The lower incisors 2 and 3 are absent in all specimens collected. They may perform a particular function in a juvenile Thylacoleo, however, these teeth may be easily dislodged by prey being grasped.

A HEAD.
B GREAT TROCHANTER.
C EPIPHYSIAL LINE OF HEAD.
D TROCHANTERIC FOSSA
E POSTERIOR BORDER OF TROCHANTERIC FOSSA.
F LESSER TROCHANTER.
G RIDGE DESCENDING FROM LESSER TROCHANTER.
H MUSCULAR INSERTIONAL TRACT.

PROXIMAL END OF VOMBATUS LEFT FEMUR × 1.
DISPLAYING TOOTH MARKS.

REFERENCES FROM. MEMOIRS OF THE ROYAL S OF SA:
PART II. BY. E.C. STIRLING.
PLATES LIII, LIV, LV.



POSTERIOR ASPECT. G1
INTERNAL ASPECT. G2
ANTERIOR ASPECT. G3
EXTERNAL ASPECT. G4

The continuing eruption of I/1 in the juvenile reduces the alveoli of I/2 and I/3, which may be sufficient to dislodge them.

With the mature animal, many teeth exhibit some damage in the grasping area of the lower I/1. This damage is in addition to and behind the notch caused by contact with the upper I/1 from the opposite side during occlusion of the P/3's.

Conclusions

1. The tooth marked bone adds further support to the theory that Thylacoleo was carnivorous.

2. The functions of I/1 and P/3 also include being a well developed anchoring mechanism enabling quite large prey to be moved.

3. The degree of gouging indicates Thylacoleo chewed vigorously on the bone, probably in an attempt to move a carcass.

4. Tooth marks at the break may indicate that Thylacoleo was capable of crushing a bone to disable its prey.

5. General lack of tooth marks on associated bones suggests that feeding may not produce frequent gashes on bones, and that tooth marks on the femur may have resulted from the disabling, killing, and transportation of the prey.

6. It may not have been necessary to transport prey to a cave unless young were present. General predation may have been much less demanding in regards to transport of prey and no such distinctive bone has been found before.

The bone was collected in the extreme upper levels of the deposit which may indicate a fairly recent specimen. It is of note that approximately 50% of Thylacoleo fossils are of very juvenile animals. The task of providing for them may have been too much in a changing ecosystem.

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Glossary of Terms

alveoli - The socket in which tooth roots are supported.

arboreal - Adapted to living in trees.

browsing 'roos - Extinct, generally short-faced kangaroos that feed on leaves.

condyle - The hinge joint each side at the rear of the lower jaws (dentary or mandible).

distal - The bone or end of a bone furthest from the body.

flexion - The movement of bones at a joint or joints.

mandibles - The lower jaws (dentaries).

manus - The forehead.

maxilla - The upper jaw.

metacarpals - The larger bones of the hand proximal to the phalanges.

occlusion - The contacting of the teeth in the upper and lower jaws.

phalange distal - The bone in the finger tip.

phalange proximal - The finger bone between metacarpals and distal phalanges.

pisiform - A wrist bone opposite the base of the thumb.

proximal - The end of a bone closest to the body.

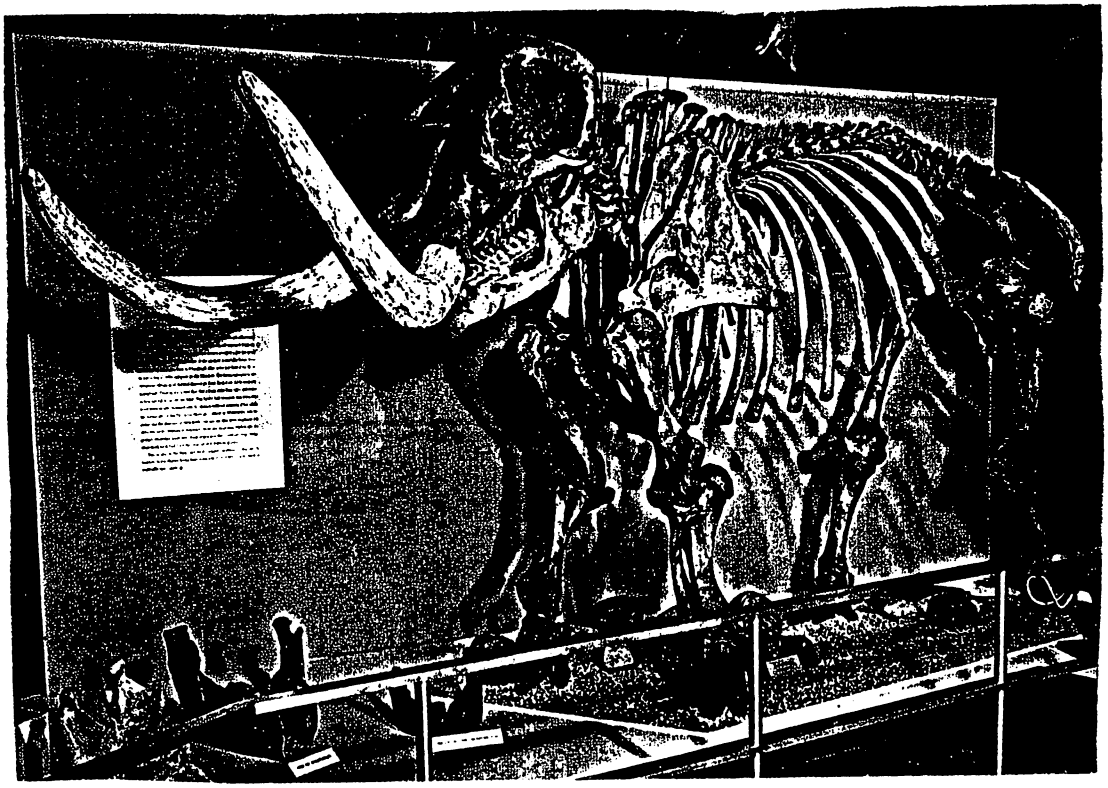
scapholunar - A fusion of the scaphoid and the lunar articulating with the distal end of the radius. The thumb develops from the scapholunar.

symphysis - (relating to the mandibles) the union of the mandibles.

syndactylous - The condition in which metatarsals 2 and 3 are sheathed in common sheath of skin. Used principally in grooming.

trapezium - Distal to the scapholunar in the thumb.

"OHIO MASTODON"



OHIO'S MASTODON

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This skeleton of an American Mastodon was discovered at Johnstown, Ohio, and when found, was one of the three most complete mastodon skeletons in the world.

This fossil animal skeleton has long been one of the favorite exhibits in the Cleveland Museum of Natural History. This elephant was a male whose backbone and ribs reveal that he had been gored in a fight, and subsequently suffered from an ailment that is quite common to modern mammals--arthritis.

Skeletal remains of many mastodons have been removed from what were Post-Glacial bogs in the north and central parts of Ohio. These bogs are believed to have been formed 13,000 years ago, toward the end of the last ice age, as glaciers moved through northern Ohio depositing huge blocks of ice into depressions in the ground, here and there, forming "Kettle Hole Bogs."

Jackpine, tamarack trees, cranberries, orchids, poison sumac, and many other unusual luch vegetation grew around the borders of the bogs. Sphagnum moss percolated in a floating mass, dying off by generations, part of it falling to the bottom of the acid waters, and also making floating peat packed 1- to 15 meters in depth in a cushiony mass, that were called "Quaking Bogs."

The mastodon being a true vegetarian, with a huge appetite, was attracted to the lush vegetation around these bogs, and due to its enormous size and weight, was evidently trapped in the mire of quicksands in these locations. The Ohio climate rose by 10 to 20 degrees. Deciduous trees began making incursions, shrinking the bogs and turning wetlands into forests, allowing farmers--much later in time to "Mine"--some of these areas for peat, resulting in some of these fossil remains being discovered along with fossils of giant beavers and "Cervalces," a rare Pleistocene moose.

The elephants, first appearing in the Late Eocene, seem to have developed along the same lines as the horse. Early elephantlike animals were about the size of a small modern elephant, but had longer heads and shorter trunks. As the development of the group continued, there resulted in an increase in size, a change in skull and tooth structure, and an elongation of the trunk. The Mammoth and the Mastodon are well known fossil forms. The latter resembled the modern elephant, but the structure of their teeth were quite different. In addition the mastodon skull was lower than that of an elephant and the tusks were exceptionally large, with some reaching a length of nine feet, and that is a lot of ivory to lug around day after day!!!

In America the fossil remains of these huge mammals have been found in many of the Pleistocene deposits, from Alaska through many states down through Florida.

ESCONI PALEONTOLOGY MEETING MINUTES -- NOVEMBER

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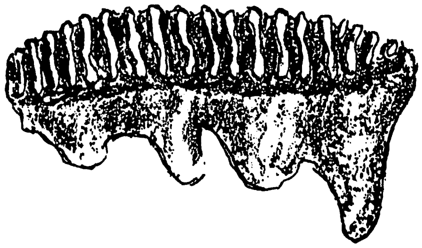
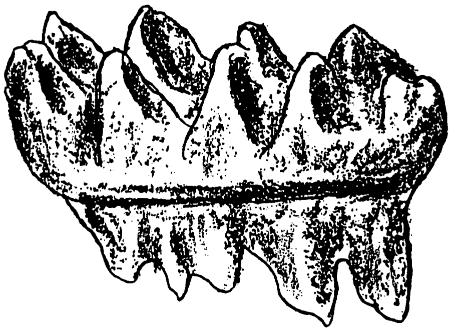
". . . Mammoths and Mastodons are grouped as sub-ungulates with such seemingly unrelated animals as conies and sea cows. The order Proboscidea is composed of the modern elephants, mammoths, mastodons dinotheres and moeritheses. Most of the earliest fossil subungulates are found in Africa with a number of important finds in Egypt. Dinotheres were contemporary with the mammoths and mastodons but followed a separate line of development. By the Pleistocene some variety of mammoth and/or mastodon roamed every continent except Australia and Antarctic.(sic) Mastodons followed two lines of development from a primitive ancestor, the Trilophodon. The North American species Mastodon americanus was a heavily built animal with long reddish hair. Mastodons were distinguished from mammoths by the fact that the teeth were low crowned with few ridges, most or all were in place at the same time and both lower and upper jaws had tusks.



Mammoth Tooth



Mastodon Tooth

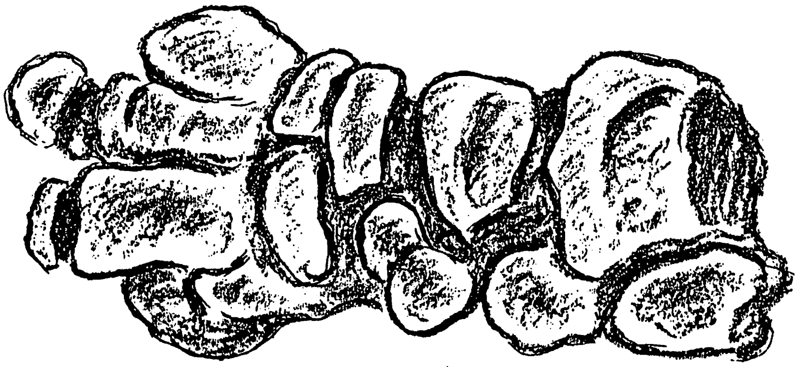
Mammoths flourished in the Ice Age. The Wooly mammoth is the best known North American form. The first fossils of the elephant-mammoth group are found in India in the late Miocene. Three basic types evolved: 1. The imperial mammoth group. 2. The wooly mammoth, Indian elephant group, and 3. The African elephant group.

Mammoths are found in many places. By chance the Aulers found a spectacular mass burial site in Hot Springs, South Dakota. In June 1974, a contractor was leveling a hill in a housing development when he uncovered large bones. Experts worked till November on the site without completing the excavation. In 1976-1979 over 30 mammoths were uncovered. A non-profit organization was formed that enclosed the site in a church-like building and funded further research. Over 100 mammoths are expected to be unearthed at the site plus a cave bear, beaver, coyote, fish and rodents. Originally Hot Springs was a sinkhole in Triassic age rock that filled in with eroding Cretaceous age sediments during the Pleistocene. Young male mammoths wandering off from the herd were trapped in the soft mud and buried. This was repeated numerous times to form a series of layers containing mammoth bones. Most fossils are complete but disarticulated, perhaps from the struggle of more recently trapped animals. The layers are exposed forming a stairlike exposure. No human artifacts are known from Hot Springs, a site anyone heading to the Black Hills should visit.

Early reports of fossils bones of mastodons and mammoths came from Vienna, Germany, France, Italy, Sweden, New York, and Mexico. Many interesting and inventive stories were told to explain these huge bones and teeth, both by native peoples and scholars.

Russia became a source for ivory in the late 1800's. One thousand six hundred and thirty tusks from fossil animals were shipped to London in 1873 and 1,140 in 1874. The mongols kept the source of the ivory a secret. Whole animals with skin and hair intact were found in ice blocks. Bones from Big Bone Lick, Kentucky were sent to Encland while Ben Franklin was there. A reconstructed mastodon skeleton was sent to London by a Mr. Cook using bones found in Missouri. A Danube farmer used mammoth bones to make fertilizer till an archaeologist purchased the land which contained over 1,000 specimens. Four Ice Ages occurred with warmer periods in between. During the 4th Ice Age man stayed in the cold with the mammoths. We know man co-existed with these creatures till they became extinct 8,000 - 10,000 years ago. Finally, in the 1920's a Siberian hunter reported following tracks which lead to a huge hairy beast too big for him to shoot.

Specimens of femur ends and rib bones from a mammoth from Florida were brought in by Roger Bohn. Also a pigmy mammoth tooth from the Netherlands. Robert also had an ivory cab made from fossil ivory from Florida. Dawn Silfies had a mastodon tooth from the Phosphate pits of Florida. Dentine and enamel were present, but no root. John Ade had wood found in the skull of the Perry Mastodon collected by Wilbert Rath while he worked at the dig. Gastropods from the same site were from Jim Konecny. It was thought that the mastodon was found in a beaver pond from marks on the woods. . ."



Articulated Mammoth Foot