SOUTH DAKOTA SCHOOL OF MINES

Bulletin No. 13

DEPARTMENT OF GEOLOGY

THE WHITE RIVER BADLANDS

By

Cleophas C. O'Harra, Ph. D., LL. D.,
President and Professor of Geology
South Dakota State School of Mines

Rapid City, South Dakota
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T. W. Dwight, President
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The picture which geology holds up to our view of North America during the Tertiary ages are in all respects, but one, more attractive and interesting than could be drawn from its present aspects. Then a warm and genial climate prevailed from the Gulf to the Arctic Sea; the Canadian highlands were higher, but the Rocky Mountains lower and less broad. Most of the continent exhibited an undulating surface, rounded hills and broad valleys covered with forests grander than any of the present day, or wide expanses of rich savannah, over which roamed countless herds of animals, many of gigantic size, of which our present meager fauna retains but a few dwarfed representatives. Noble rivers flowed through plains and valleys, and sea-like lakes, broader and more numerous than those the continent now bears, diversified the scenery. Through unnumbered ages the seasons ran their ceaseless course, the sun rose and set, moons waxed and waned over this fair land, but no human eye was there to mark its beauty, nor human intellect to control and use its exuberant fertility. Flowers opened their many-colored petals on meadow and hill-side, and filled the air with their perfumes, but only for the delectation of the wandering bee. Fruits ripened in the sun, but there was no hand there to pluck, nor any speaking tongue to taste. Birds sang in the trees, but for no ears but their own. The surface of lake or river whitened by no sail, nor furrowed by any prow but the ~~beast~~ of the water-foul; and the far-reaching shores echoed no sound but the dash of the waves and the lowing of the herds that slacked their thirst in the crystal waters.

J. S. NEWBERRY.

PREFACE

Is it of interest to you that the White River Badlands are the most famous deposits of the kind in the world? Do you know that aside from their picturesque topography they tell a marvelous nature story; a story of strange climate, strange geography, and strange animals; of jungles, and marshes, and tranquil rivers, of fierce contests for food, and life, and supremacy; of a varied series of events through ages and ages of time showing the working-out of well-laid plans with no human being to help or interfere? Most people know something of these things but generally it is in an indefinite piecemeal way. Except to scientific men the Badlands, instead of affording the intellectual delight that they should, are commonly little else than a sterile wonder.

This book is written in order that the intellectually alert, the indifferent thinker, the old and the young, irrespective of educational advantage or technical training may have opportunity to get a clearer and more comprehensive idea of this wonderful part of nature's handiwork.

The landscape views given herein, have never been surpassed, it is believed, for clearness of expression or for detail of configuration and the reproductions of the animals, made by the best vertebrate paleontologists of America, are marvels of beauty and accuracy. Among the pictures of animals both in fossil form and restored to life and activity as they were in their ancient White river home are: Brontotherium, the huge thunderbeast; Metamynodon, the bulky rhinoceros; Moropus, the grotesque chalicothere; Mesohippus, the three toed horse; Oreodon, the ruminating hog; Poebrotherium, the ancestral camel; Protoceras, the six-horned herbivore; Hoplophoneus, the savage-tooth tiger; Stylemys, the large dry land tortoise; Crocodilus, the old-time crocodile; and many others long since vanished from earth's activity. The book indicates why the camel of that time had no pads on his feet and the deer no antlers on his head, why the saber-tooth had his enormously vicious teeth, why dogs had retractile claws like the cat, why the horse had three toes on each foot instead of one, and many other things of like kind.

Geologists and paleontologists have been engaged for three-quarters of a century in unravelling the intricate story of these strange lands and I have drawn liberally from the published works of these men. My gratitude for this material is hereby most gratefully acknowledged. Some of the more important publications consulted are listed under the heading, Bibliography. Those wishing a more complete record of papers with annotations on the same should consult my Bibliography of the Geology and Mining Interests of the Black Hills Region, published as South Dakota School of Mines Bulletin No. 11, 1917. I have endeavored in the text or in the figures and plate descriptions to indicate in proper way the source of material used.

It is an especial pleasure to record here the favors extended by Professor Henry F. Osborn of the American Museum of Natural History, by Professor W. B. Scott of Princeton University, and by The Macmillan Company of New York City in permitting the use of many excellent figures and plates from the two great books, Osborn's Age of Mammals in Europe, Asia, and North America, and Scott's History of Land Mammals in the Western Hemisphere. These books deserve a large audience. They should be consulted by all who wish acquaintance with mammalian progress, and particularly by those interested in our White River Badlands, the classic vertebrate fossil ground of America.

The subject is of absorbing interest but I have endeavored to treat it without exaggeration, sensation or cheapness. The present book while following somewhat closely the plan and wording of the earlier publication is arranged with a little more consideration for the general reader. The revised form freed from technical references and faunal lists in the body of the book and with a more generous use of figures and plates should be readily and entirely assimilated. It is believed especially that the general reader and teachers and high school students interested in natural history subjects should find the information valuable and inspirational.

CLEOPHAS C. O'HARRA.

November 4, 1920.

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ILLUSTRATIONS

Photograph by O'Harra, 1909.

The Gateway, School of Mines Canyon, at northwest base of Sheep Mountain, Pennington County, South Dakota.

The White River Badlands

THEIR IMPORTANCE AND DISTRIBUTION

The White River Badlands constitute the most important badland area of the world. They lie chiefly in southwestern South Dakota but a prominent arm known as Pine Ridge extends through northwestern Nebraska into eastern Wyoming. Most of the drainage is by way of White river, hence the name. The area is very irregular and there are many outliers particularly to the west and northwest of the central portion. Southward geological formations similar to those of White river extend over much of Nebraska and eastern Colorado but here, except along the forks of the Platte the badland feature is not prominent.

Originally the badland formations made up a vast earth blanket stretching for hundreds of miles north and south along the eastern slope of the Rocky Mountain front. Their greatest plainsward extension cannot now be definitely determined, but in South Dakota they reach beyond the Missouri to near the James river valley. They seem to have entirely surrounded the Black Hills and of this uplift only the higher portions remained uncovered. From these restricted areas and from the rising Rocky Mountains detrital materials had opportunity throughout a long period to add their volume to the deposits of the bordering lowlands. Later this vast series of sediments was elevated and was gradually trenched by innumerable streams and most of the material washed away. Along with these changes the badland topography developed and has continued to develop to the present time.

The Badlands do not readily lend themselves to accurate definition nor to brief description. They are in consequence a much misunderstood portion of American territory. The name is a literal translation of the *Mauvaises Terres* of the early French Canadian trappers who had in turn appropriated the still earlier *Mako Sica* (mako, land; sicha, bad) of the Dakota Indians. It signifies a country difficult to travel through chiefly because of the rugged surface features and the general lack of good water. The term is unduly detractive although apt enough in frontier days when hardships of travel were rigorous even under the best of circumstances.

Much the greater portion of the area within the badland region as commonly understood is level and fertile and is covered with rich wild grasses and recent occupation by thousands of settlers has brought out the fact that over large tracts, especially on the higher tables, good refreshing water may be obtained by sinking shallow wells in the soil and gravel mantle that lies rather widespread on the surface. The country has in years gone by been of much value as an open range for the grazing of cattle and horses. Now that it has been made accessible by railway the land has largely passed from the government to private ownership and farming and dairying on an extensive scale are being carried on. Within little more than a stone's throw of where the early explorers spoke of the region as an inferno for heat and drought men have built homes for themselves and their families and are now raising good crops of vegetables, tame grasses and staple grains.

But the purpose of this book is more particularly to indicate the value of the Badlands as an educational asset. Nowhere in the world can the influences of erosion be more advantageously studied or more certainly or quickly understood. Nowhere does the progress of mammalian life reveal itself with greater impressiveness or clearness. Nowhere do long ago days connect themselves more intimately with the present or leave more helpful answers to our wondering questions as to the nature and import of the earth's later development.

The most picturesque portion of the White River Badlands lies between White river and Cheyenne river southeast of the Black Hills. This is known as the Big Badlands, and the chief topographic features, Sheep Mountain and the Great Wall, high remnants of an extensive tableland now reduced to a narrow watershed, are flanked by a marvelous network of rounded hillocks, wedge slopes, grassy flats, and sheer declivites. (For illustrations of these see the views in the plate section). The Great Wall viewed from White river valley presents a particularly rugged aspect and, like the great wall that it is, stretches for many miles in a nearly east-west direction, disclosing for much of the distance a continuous serrated skyline series of towers, pinnacles and precipitous gulches. Sheep Mountain, the cedar covered top of which overlooks all of the surrounding country, presents a view that is hopelessly indescribable. One side leads gently down to a high intricately etched grass-covered flat covering a few cramped square miles. In all other directions everything is strange and wierd in the extreme. Far away cattle or horses may be seen feeding on levels of green and here and there distant dots in ruffled squares indicate the abodes of happy homesteaders. Immediately about all is still. Until recently the sharp eye could occasionally detect a remnant bunch of mountain sheep, once numerous in this locality, but quickly and quietly they would steal to cover among the intricate recesses of the crumbling precipices. Song birds are present but they are prone to respect the solitude. Only an occasional eagle screams out a word of curiosity or defiance as he sails majestically across the maze of projecting points and bottomless pits. Magnificent ruins of a great silent city painted in delicate shades of cream and pink and buff and green! Domes, towers, minarets, and spires decorate gorgeous cathedrals and palaces and present dimensions little dreamed of by the architects of the ancients.

At first as one looks over the strange landscape there may come a feeling of the incongruous or grotesque but studying more closely the meaning of every feature the spirit of this marvelous handiwork of the Great Creator develops and vistas of beauty appear. Here on Sheep Mountain or on the higher points of the Great Wall the contemplative mind weaves its way into the long geologic ages. There are visions of Cretaceous time. A vast salt sea stretches as a broad band from the Gulf of Mexico to the Arctic regions and slowly deposits sediments that are destined to form much of the great western plains of the continent. Strange reptiles sport along the shores of this sea and myriads of beautiful shellfish live and die in its mud laden rush-fringed bays. Changes recur, the salt becomes less pronounced, the sea shallows, brackish conditions prevail but the animals and plants with many alterations and much advancement live on. Deep rumblings in the neighboring Black Hills and in the Rocky Mountains with accompanying intrusions of igneous rocks portend widespread changes, the shallowing sea slips away and fresh water marsh-lands and deltas prevail. The Tertiary comes and with the close of its earlier divisions the White River badland formations begin to be deposited. Barriers somewhere are let down and a great horde of animals higher in type than any known before begins to appear. Here in the foreground gently flowing streams push their muddy way through reedy marshlands and vigorous forests and furnish a lazy playground for countless turtles and occasional crocodiles. In favored recesses groups of rhinoceroses may be seen, some heavy of bulk and water loving, others graceful and preferring dry land. Little fleet-footed ancestral horses with names as long as their legs nibble the grass on the hillsides or, by means of their spreading three-toed feet, trot unhindered across the muddy flats, the nearest restraining rider being more than a million years away. Here and there we see a group of predaceous dogs and not infrequently do we get a glimpse of a ferocious tiger-like cat. On the higher ridges, even far within the distant hills and mountains six horned herbivores reveal their inquisitive pose and perhaps anon, like the antelope, show their puffs of white as they scamper from the nearing presence of some stealthy foe. But the "reigning plutocrat" is the titanothere. In great numbers we see his majestice form as he moves among his kin and crops at his leisure the coarse grasses of the lowlands. Here and there are beavers and gophers and squirrels busy with their toil and their play, and hedgehogs and moles and swine and deer and tapirs and camels, and many other creatures too strange to mention without definition. Although the Badlands as we now know them were until recently little frequented by man except in favored places, do not think the country was in the ages gone by a barren waste or a place of solitude. To all these animals it was home. Here they fought for food and life and supremacy. To them the sun shone, the showers came, the birds sang, the flowers bloomed, and stately trees gave convenient shade to the rollicking young of many a creature.

But "everlasting hills' have their day and rivers do not flow on forever. These animals, under a Guiding Providence, having inherited the more essential characters of their ancestors, in turn transmitted to later individuals the features best fitted to serve their purpose in the winning of life's great race. One by one, group by group, they died, the bodies of most of them quickly feeding the surrounding elements but a chosen few, tucked away by the kindly hand of nature, remaining as unique monuments of the dawning time of the great mammalian races, are now being revealed as gently by nature again in these the days of man.

HISTORY OF EXPLORATION

Our first knowledge of the White River badlands worthy of record dates from 1847. Early in this year Dr. Hiram A. Prout of St. Louis described in the American

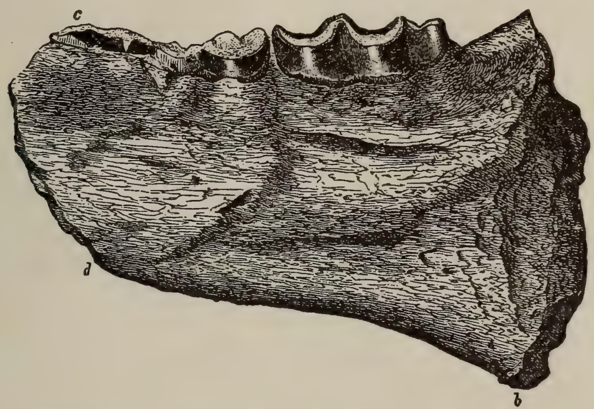


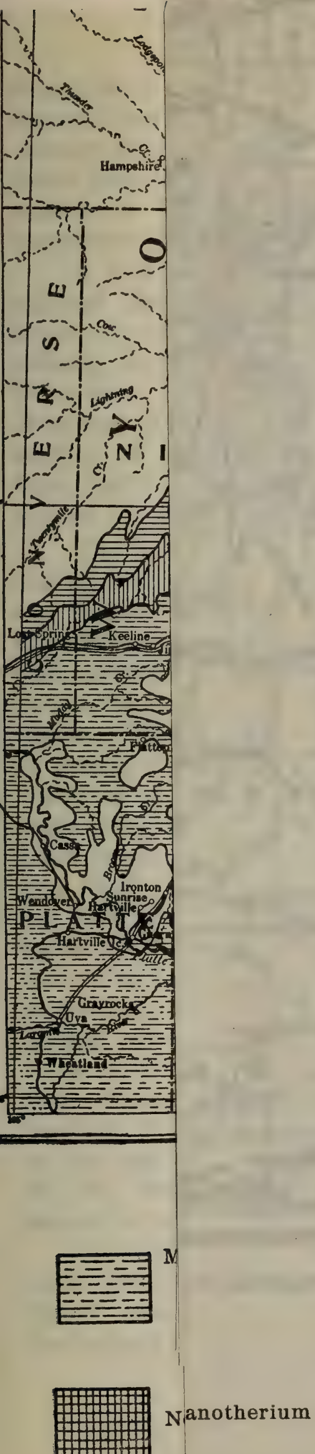
Figure 1—Fragment of the lower jaw of a Titanothere, the first fossil discovered in the Big Badlands. Described by Dr. H. A. Prout of St. Louis, 1846-47.

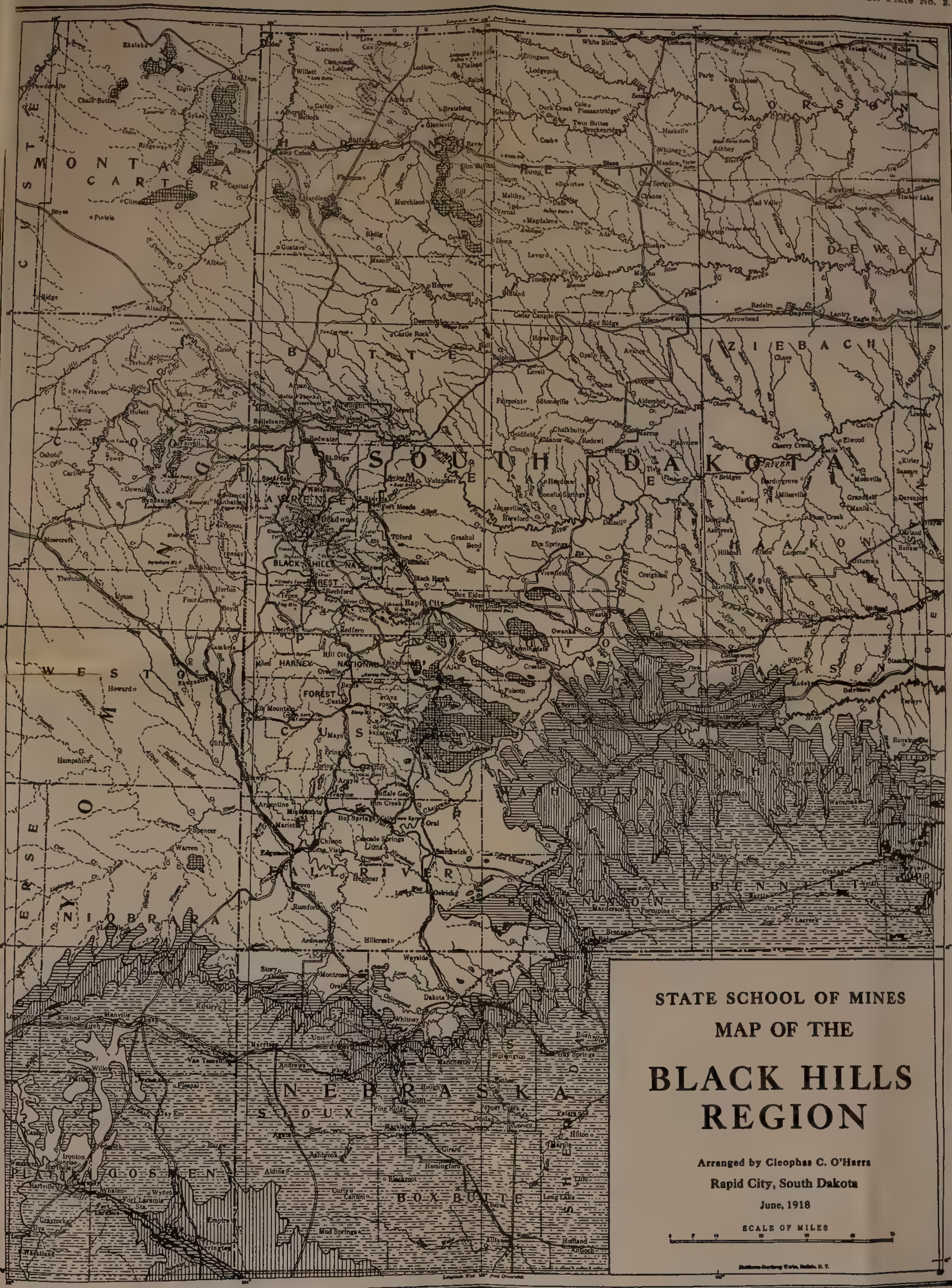
Journal of Science a fragment of the lower jaw of the great Titanothere, he calling it a Paleotherium. A few months later Dr. Joseph Leidy described in the Proceedings of the Academy of Natural Sciences of Philadelphia a fairly well preserved head of what he termed a Poebrotherium. The name implies belief in the ruminating nature of the animal and later investigation, strange as it may seem, showed it to be an ancestral camel. The two specimens referred to were obtained from representatives of the American Fur Company. Their exact locality is not known but it is believed to be somewhere between the present towns of Scenic and Wall.

The descriptions of these specimens aroused much interest among men of science and in 1849, Dr. John Evans in the employ of the government under the direction of David Dale Owen of the Owen Geological Survey, visited the region for the purpose of studying its peculiar features and of collecting additional fossils in order to determine the age of the strata. This visit was of the greatest importance and the results were early published in a most careful scientific manner. The report, chiefly the work of Dr. Leidy, who described the fossils and Mr. Evans who through Mr. Owen reported upon the geography and geology, gave to the world the first authentic description of the nature of the badland country. (Plate 4). Thaddeus A. Culbertson visited the region during the following year, 1850, and obtained at the request of the Smithsonian Institution a small but import-

Figure 2—Head of an ancestral camel, *Poebrotherium*, the earliest Badland fossil described by Dr. Joseph Leidy, of Philadelphia, 1847.

ant series of specimens. F. V. Hayden (Plate 8) of the United States Geological Survey of the Territories made several explanatory trips particularly in 1853, '55, '57 and '66. Often in grave danger and hindered by varied hardships he nevertheless succeeded in unraveling in large measure the main geologic features of the country. Plates 5, 6 and 7). All of these parties collected vertebrate fossils of the greatest scientific value and Dr. Leidy (Plate 8) whom I have already mentioned, being recognized as the best fitted man in America to determine the nature of such fossils, was called upon to write their description. Important papers rapidly issued from his pen and each new description served to point out the need of further exploration. He published in 1869 in the Journal of the Academy of Natural


Hampshire
Lightning
Keeline
Ironton
Sunrise
Hartville
Wendover
Hartville
Grayrocks
Uva
Wheatland
M
Nanotherium



A PRELIMINARY MAP OF THE BADLAND FORMATIONS OF THE BLACK HILLS REGION

Chiefly from the Survey of Darton (1905) as Modified by Matthew and Thomson (1906-07)

Mostly Lower Miocene. Known to contain also some Middle Miocene, Upper Miocene, Pliocene, and Pleistocene.

Middle and Upper Oligocene. Brule Formation (Oreodon and Protoceras Beds).

Non-differentiated Oligocene (Chiefly Chadron formation).

Lower Oligocene. Chadron Formation (Titanotherium Beds).

Sciences of Philadelphia his monumental work "The Extinct Mammalian Fauna of Dakota and Nebraska." In this large volume he brought together the accumulated information of more than twenty years and in consummate manner established the White River badlands as one of the great fossil vertebrate repositories of the world.

A new epoch in the investigation followed. New men entered the field and institutions not hitherto represented began to send out exploratory and collecting expeditions. Among the institutions were Yale University, University of Princeton, United States Geological Survey, American Museum of Natural History, University of Nebraska, University of South Dakota, Carnegie Museum, Amherst College, Field Columbian Museum and the South Dakota State School of Mines.

The first Yale party, under direction of Professor O. C. Marsh (Plate 8) visited the region in 1870. Professor Marsh, not satisfied with the crude methods of collecting with which the earliest investigators had to content themselves, undertook extensive quarrying for the fossils, and developed also more refined methods of utilizing detached and broken pieces. In this way a number of well-preserved, complete, or nearly complete, skeletons were obtained where before the material was weathered and fragmentary. Complete restorations of skeletons disclose structural features much more readily than detached bones and imperfect fragments, and Prof. Marsh first extensively developed this feature for the fossil vertebrates of the White River and other western badlands. He was thus able to emphasize more easily the nature of these animals and to point out more clearly their profoundly significant relation to present-day life. Prof. Marsh continued field work for many years, the collecting being done sometimes by expeditions directly from Yale, some times by collectors hired for the purpose. Following the first Yale expedition of 1870, other Yale expeditions were in the region in 1871, '73, '74 and hired collectors in 1886, '87, '88, '89, '90, '94, '95, '97, '98. The institution was represented in northwestern Nebraska also in 1908.

In this connection it may be stated that during the years 1886-'90, much of the field work directed by Professor Marsh was done under the auspices of the United States Geological Survey, the materials collected being later transferred to the National Museum. Much of this collecting, particularly during the years 1886, '87, '88, was in immediate charge of Mr. J. B. Hatcher, one of the most original and successful collectors that has ever worked in the badlands.

The University of Princeton was first represented by an expedition under direction of Professor W. B. Scott in 1882. Another expedition directed by Prof. Scott came in 1890. A third came in 1893, directed as before by Prof. Scott, with whom was associated Mr. J. B. Hatcher. A fourth party came in 1894, this time under the full direction of Mr. Hatcher. (Plate 8). The results of these expeditions were of very great importance. The abundant fossil remains collected enabled Prof. Scott to describe in most complete manner a number of the more noted extinct animals and to indicate with more certainty their proper classification and relationship.

The American Museum of Natural History entering the field in 1892, was favored from the very first by important discoveries. Since the first expedition, several parties have

Figure 3—Areal distribution of Oligocene and Miocene exposures in South Dakota, Northwestern Nebraska, and Eastern Wyoming. N. H. Darton, modified by Matthew and Thomson, 1909.

represented this institution in its field investigations. Backed by abundant means and made up of capable investigators, they have been able to carry home a large amount of extraordinarily valuable material. This has given opportunity to establish more accurately the details of stratigraphy and correlation and to indicate with greater certainty the characteristics and habits of the various animals while in the living state. The years in which parties have been in the field, either in South Dakota or northwestern Nebraska are 1892, '93, '94, '97, '03, '06, '08, '11, '12, '13, '14, '16. Under the direction of Prof. H. F. Osborn, (Plate 8), Curator of the Department of Vertebrate Paleontology, earlier a co-worker with Prof. Scott in the Princeton investigations, many of the best preserved skeletons complete in practically every detail and mounted with the greatest skill, have been clothed with flesh, life and activity. Reproductions of a number of these, reference to which is made on other pages, are given in this book.

The University of Nebraska sent expeditions into the field, the parties being under direction of Prof. E. H. Barbour in 1892, '94, '95, and '97, '05, '07, '08 and later. Much of their collecting was done in northwestern Nebraska, but a considerable part of it in South Dakota and Wyoming. Prof. J. E. Todd of the University of South Dakota, spent a brief time in the field in 1894. He made a second visit, accompanied by several students in 1896. The University has more recently carried on additional investigations but the publications issued have been largely in connection with the fauna and flora of the present day.

New impetus was given the geological and paleontological work, particularly among the Miocene formations of northwestern Nebraska and eastern Wyoming, by the inauguration in 1902 of explorations by the Carnegie Museum of Pittsburg. This has continued to the present time. Mr. Hatcher directed much of the earlier work, while later, Mr. O. A. Peterson has had charge of it. This museum, as in the case of the American Museum, has been particularly successful, and many new and strange species have been discovered and described. A discovery of special note is that of the rich and important bone deposits near Agate Springs found in 1904.

Amherst College sent a party into the region under directon of Prof. F. B. Loomis in 1903 and another in 1907. Field Columbian Museum was represented by a party under Curator O. C. Farrington in 1904. The United States Geological Survey renewing its investigations in 1897 under Mr. N. H. Darton continued work in the region for several years, the chief purpose being to study the various geological formations with reference to underground water resources.

Reference has been made to the fact that the South Dakota badlands extend across the southern boundary of the state through northwestern Nebraska into eastern Wyoming. The northwestern Nebraska area has in recent years

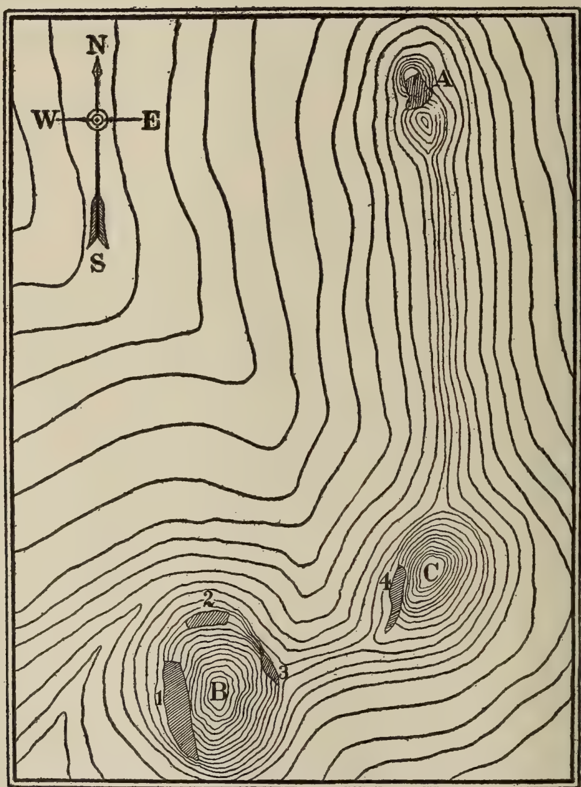


Figure 4—The Agate Spring fossil quarries, Sioux county, Nebraska, and their related topography. Holland and Peterson, 1914. A, First excavation, B, Carnegie hill, C, University hill. Amherst hill lies about two miles east of this.

attracted much attention, due in large measure to the extraordinary deposits found on the James Cook ranch near Agate Springs on the Niobrara river approximately forty miles south of Ardmore, South Dakota. Osborn states that they are the most remarkable deposits of mamalian remains of Tertiary age that have ever been found in any part of the world. It is in connection with these deposits that most of the later White River badland work of the museums and other educational institutions has been done. The bones are not only extremely abundant and well preserved but complete or nearly complete skeletons are fairly common and in several instances considerable groups of good skeletons have been found in little disturbed condition. Three small hills in which quarries have been worked in the search for bones have been designated as Carnegie Hill, University Hill and Amherst Hill, these having been first opened, in the order given, by representatives of the respective institutions, Carnegie Museum, University of Nebraska, and Amherst College.

The South Dakota State School of Mines has nearly every year, beginning with 1899, sent a party into the badlands either to Sheep Mountain or to some place along the Great Wall. Aside from the publication by the institution in 1910 of a summary description under the title "The Badland Formations of the Black Hills Region" the chief purpose of these visits, covering generally only a few days, has been to give students an opportunity to study physiographic processes and topographic types. The visits have served to give name to what is perhaps the ruggedest drainage feature of all the White River badlands, namely, School of Mines canyon. (See Plates 1, 91, 92, 94, 95, 96, and others). This cuts a deep gash into the highest part of Sheep Mountain and connects through a picturesque gateway with Indian creek an affluent of Cheyenne river.

In addition to the expeditions equipped by the several institutions, private collectors have obtained large quantities of valuable material and these specimens, either directly or through dealers, have found their way into the best museums, both at home and abroad. Now that access to every part of the White River badlands is readily gained, investigators are constantly visiting the region and activity in the development of knowledge concerning these wonderful deposits has perhaps never been more vigorous nor better planned than it is at the present time. Each succeeding year enhances the quality and importance of the investigation and doubtless this will continue for many years to come.

Figure 5—North America during the time when the Pierre (Cretaceous) shales in the form of mud were being laid down in the sea. Schuchert, 1908. White represents land areas; diagonal lines Pacific and Atlantic ocean areas; horizontal lines Arctic conditions; vertical lines Gulf conditions; black represents formation outcrops.

CLASSIFICATION AND CORRELATION OF THE DEPOSITS

The history of the earth since the advent of life on its surface is commonly divided into certain time-divisions called eras. Beginning with the oldest, these are the Archeozoic, the Proterozoic, the Paleozoic, the Mesozoic, and the Cenozoic.* Each of these eras is divided into shorter time-divisions known as periods, varying somewhat among authors. For example the Paleozoic may be divided into the Cambrian, Ordovician, Silurian, Devonian, Mississipian, Pennsylvanian, and Permian periods; the Mesozoic into Triassic, Jurassic and Cretaceous; the Cenozoic into the Tertiary and Quaternary. The periods may in turn be divided into epochs, as for example, the Tertiary into the Paleocene, the Eocene, the Oligocene, the Miocene, and the Pliocene epochs; the Quaternary into the Pleistocene, or Glacial epoch, and the Recent or Human epoch. The rocks laid down during the various epochs or periods are spoken of as being grouped into formations (not to be confused with the ill-defined expressions often used for any natural oddity) the name of each formation being usually derived from some town, stream, tribe of people, or other feature of local interest where the formation was first carefully studied and described. The Black Hills and the Badlands together form a nearly continuous series from very old rocks to the very youngest. The following section in order of deposition, the oldest being at the bottom shows the various formations of this part of the country:

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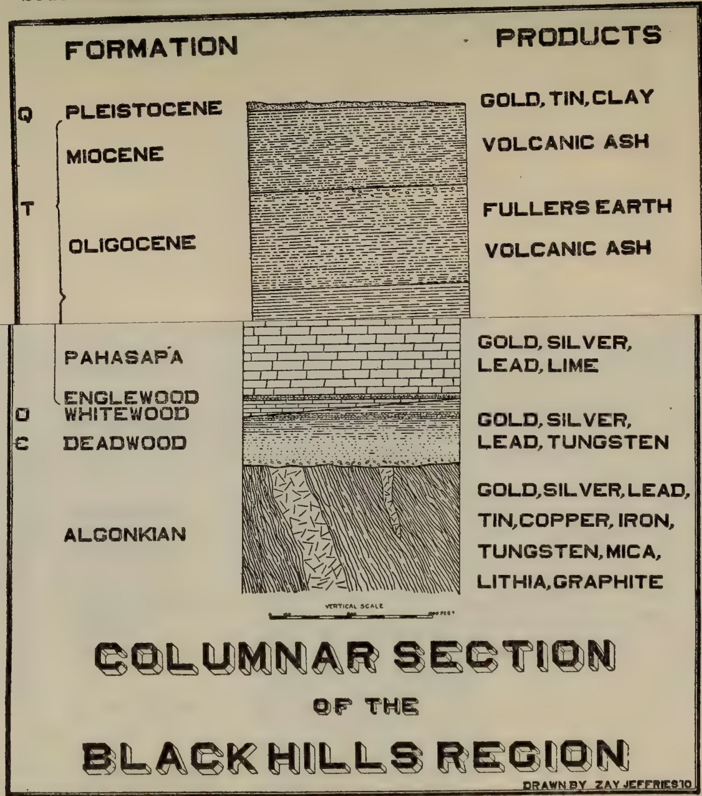
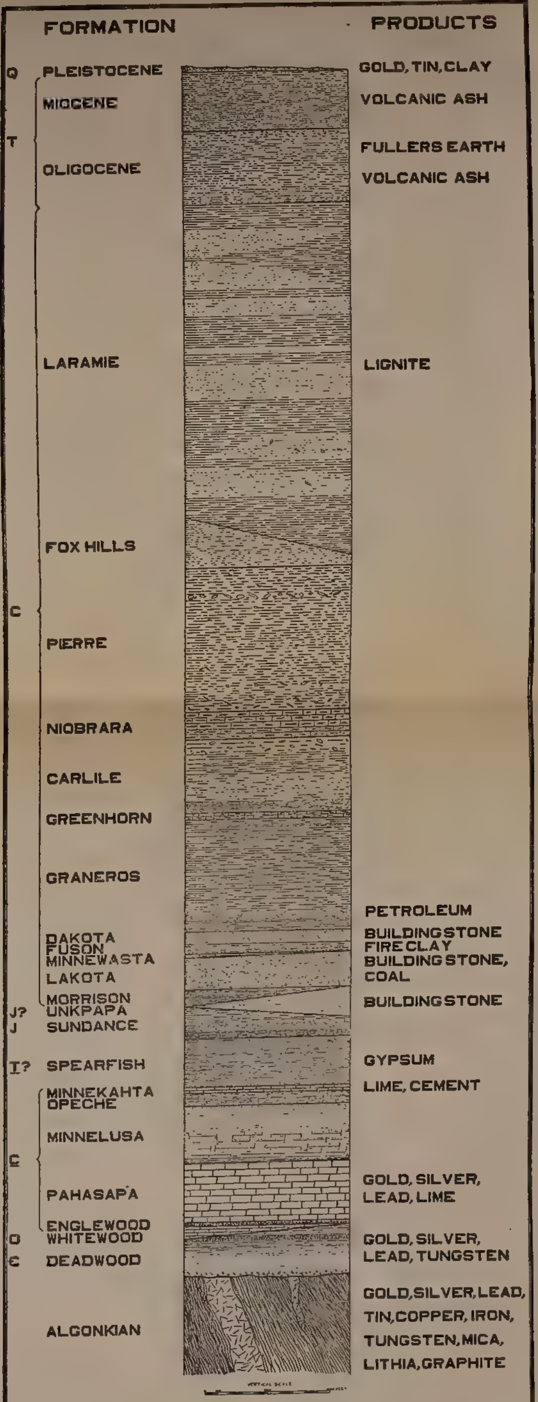
*I regret the apparent advisability of following conservative classification rather than joining present events with anticipated conditions and adding the beautifully expressive term "Psychozoic Era," the Age of Man, introduced by Prof. Joseph LeConte many years ago and used by him in the various editions of his elements of Geology.

Table of Geologic Divisions for Western South Dakota

Cenozoic	Quaternary		Recent alluvial (flood plain) deposits. Older high-level gravels, sands and clays.
	Tertiary	Pliocene	Not sub-divided.
		Miocene	Nebraska Beds Sheep Creek Beds Arikaree
		Oligocene	Brule Chadron
		Eocene	Ft. Union Beds
			? Lance Formation
Mesozoic	Cretaceous		Laramie Fox Hills Pierre Niobrara Carlile Greenhorn Graneros Dakota Fuson Minnewasta Lakota ? Morrison
	Jurassic		? Unkpapa Sundance
	Triassic		? Spearfish
Paleozoic	Carboniferous Permian		Minnekahta Opeche
	Pennsylvanian		Minnelusa
	Mississippian		Pahasapa Englewood
	Devonian		[Not represented?]
	Silurian		[Not represented?]
	Ordovician		Whitewood
	Cambrian (Saratogan)		Deadwood
Proterozoic	Algonkian		Not yet differentiated
Archeozoic			[Not represented]


FORMATION
PRODUCTS
Q
PLEISTOCENE
GOLD, TIN, CLAY
MIOCENE
VOLCANIC ASH
T
FULLERS EARTH
OLIGOCENE
VOLCANIC ASH
PAHASAPA
GOLD, SILVER, LEAD, LIME
ENGLEWOOD
O
WHITEWOOD
C
DEADWOOD
GOLD, SILVER, LEAD, TUNGSTEN
ALGONKIAN
GOLD, SILVER, LEAD, TIN, COPPER, IRON, TUNGSTEN, MICA, LITHIA, GRAPHITE
VERTICAL SCALE
COLUMNAR SECTION
OF THE
BLACK HILLS REGION
DRAWN BY ZAY JEFFRIES '10



COLUMNAR SECTION OF THE BLACK HILLS REGION

DRAWN BY ZAY JEFFRIES

The rock formations of the White River badlands represent a late time in geologic history. From the earliest days of their exploration they have been recognized as of Tertiary age and of non-marine character. The particular horizon within the Tertiary to which the various subdivisions should be referred have been less easy to determine. Leidy in his

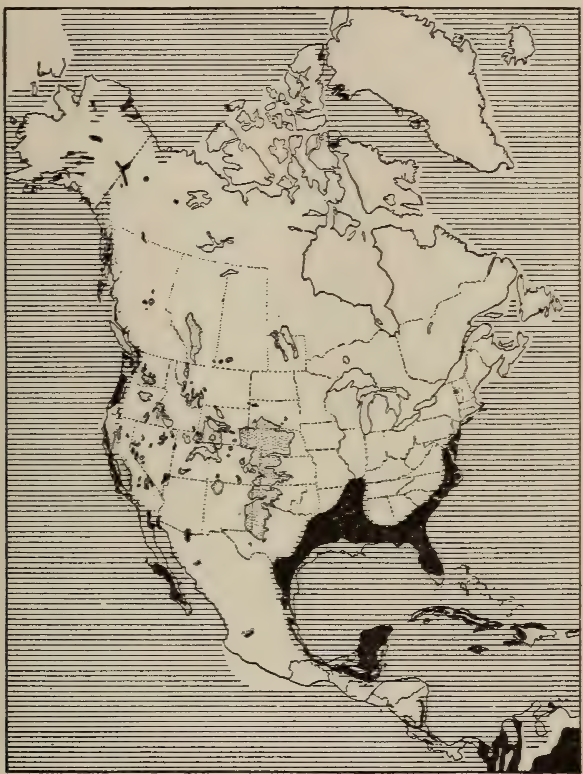


Figure 6—Map of North America in the Tertiary period, Black areas represent known exposures of marine Tertiary; lined areas, sea; dotted areas, non marine formations. Scott.

earliest studies of the extinct animals considered the beds as Eocene. Fuller study indicated to him and others a wider range in age than was first suspected and many features showed a later Tertiary character. As a result they became designated as Miocene and Pliocene, then as Lower Miocene and Pliocene, the Miocene (or lower Miocene) being often referred to as the White River group. Later as the methods of correlation became more refined and as representative fossils came more abundantly and in better condition from the hands of the collectors, giving better opportunity for comparison with similiar fossils in other parts of the world, the lower beds were found to be equivalent to the Oligocene and the upper beds to the Miocene, chiefly Lower Miocene. This is now the accepted correlation. Pliocene deposits are know to occur along and to the

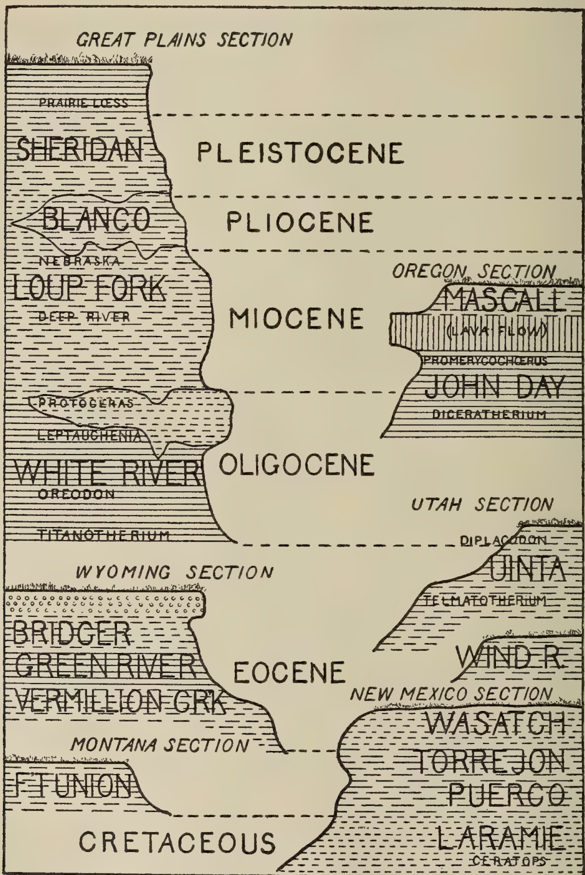


Figure 7—Diagram showing the chronological and stratigraphic succession of the Cretaceous, Tertiary, and Pleistocene formations of the western states, in which fossil mammals are found. Osborn. 1907.

south of the South Dakota-Nebraska boundary line and Pleistocene gravels are found in occasional places.

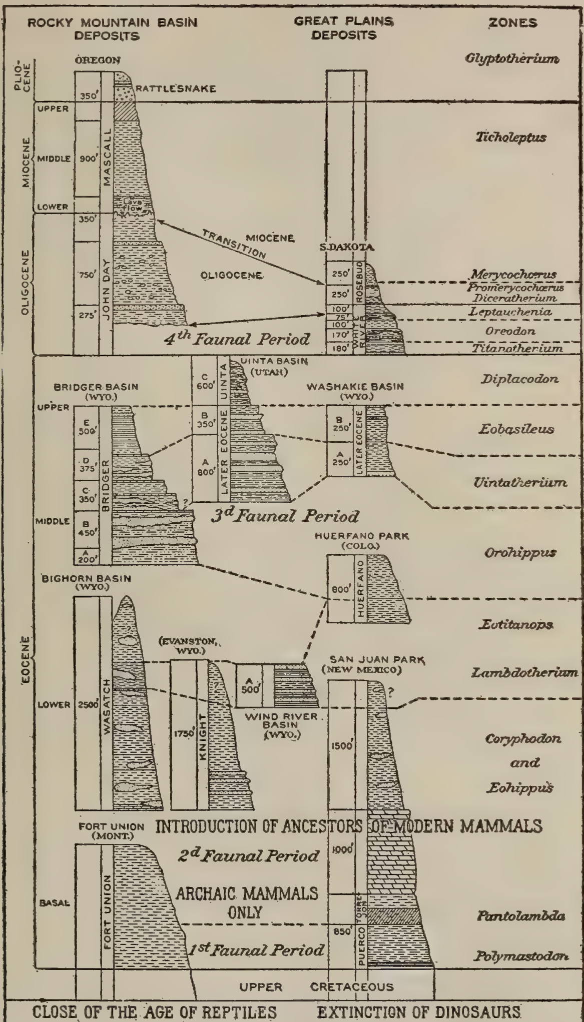


Figure 8—Diagram showing the successive and overlapping Tertiary formations of the Rocky Mountain region, with names of the important life zones. Osborn. 1909.

An important work of investigators has been to further subdivide the deposits and to correlate in so far as possible the resulting subdivisions. Hayden early attempted a subdivision and with marked success so far as information then at hand would allow. Later workers with better means at their command have made corrections and added new features until now the main history is fairly well outlined.

The present classification shown of some local and conflicting peculiarities is given herewith and this is followed by an idealized birdseye view of the Big Badlands by Osborn in which the thickness of the beds and the chief characteristics are given.

GENERALIZED GEOLOGIC SECTION OF WHITE RIVER BADLANDS

Pliocene		Little White River Beds	Hipparion Zone
Upper Miocene—50-200 ft.		Nebraska Beds	Procamelus Zone
Middle Miocene—— ft.		Sheep Creek Beds	
Lower Miocene—600-900 ft.	Arikaree Formation	Harrison Beds	Merycochoerus Zone with Daemonelix Sandstone.
		Monroe Creek Beds	Chiefly Promerycochoerus Zone with Gering Sandstone.
Upper Oligocene—150-250 ft.	Brule Formation	Protoceras Beds	Leptauchenia Zone (Plains fauna) with Protoceras sandstone (Forest and Fluviatile fauna)
Middle Oligocene—200-400 ft.		Oreodon Beds	Oreodon Zone (Plains fauna) with Metamynodon sandstone (Forest and Fluviatile fauna.)
Lower Oligocene 0-180 ft.	Chadron Formation	Titanotherium Beds	Titanotherium Zone

NATURE OF THE DEPOSITS

The rock materials of the White River badlands vary in different localities and in the different beds. The older deposits are chiefly fine partially consolidated clays interlaid with occasional irregular beds of coarse argillaceous sands and gravels. Concretions are abundant and they often grade into fairly continuous sandstone. Clay dikes occur frequently and are widely distributed. In certain localities thin veins of hard bluish-gray chalacedony check the softer sediments in great profusion. Limestones are not common but among some of the marginal outcrops particularly those toward the Black Hills they reach importance. Likewise near the Black Hills conglomerates are occasionally of con-

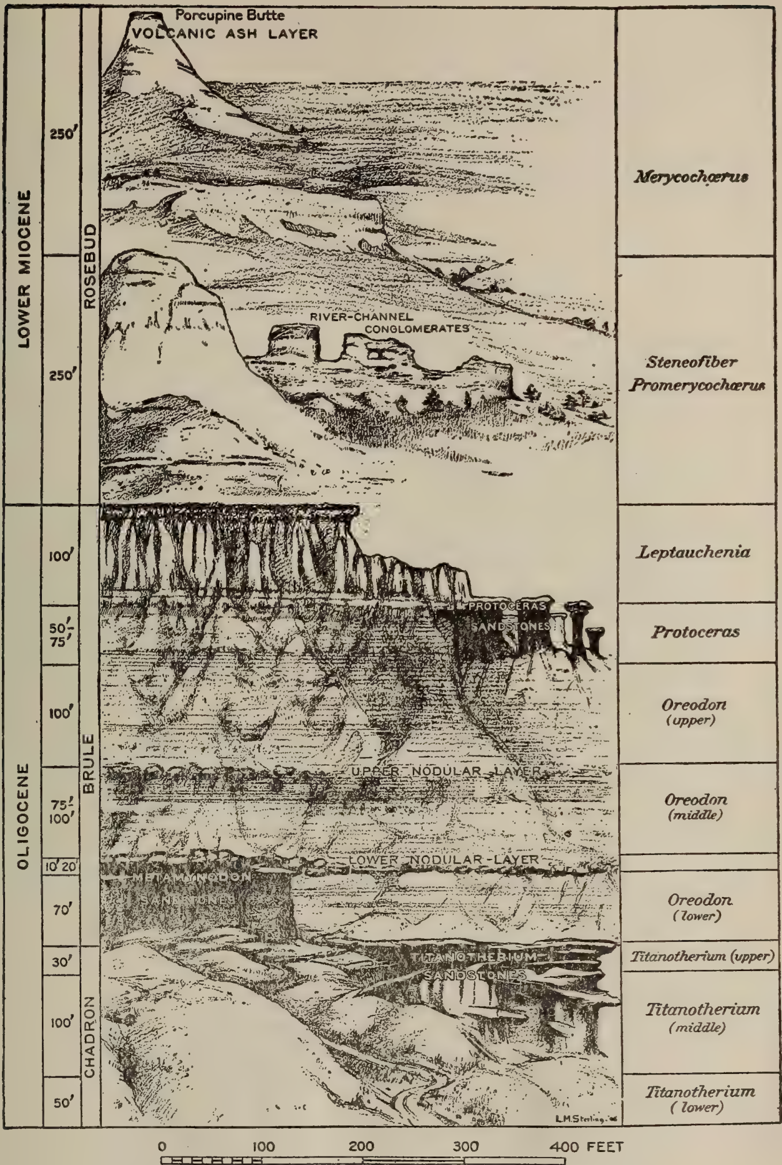


Figure 9—Idealized birds-eye view of the Big Badlands, showing channel and overflow deposits in the Oligocene and Lower Miocene. Looking southeast from the Black Hills. Osborn, 1909.

sequence. Volcanic ash occurs at certain horizons and one or two beds in the later formations cover considerable areas.

The several geological formations have particular characteristics that serve to distinguish them in the field. In view of the importance of these formations the makeup of each is here described in some detail beginning with the Chadron which is the oldest. The others follow in the order of their age.

OLIGOCENE

The Chadron Formation

The Chadron formation, better known by the much older term, the *Titanotherium beds,* from the name of the large extinct animals, whose bones occur in it so abundantly, receives its name from the town of Chadron in northwestern Nebraska. The formation is best developed and has been most studied in and near the Big Badlands of South Dakota, but is of importance along the northerly facing escarpment of Pine Ridge in South Dakota, Nebraska and Wyoming. Owing to the slight dip of the strata away from the Black Hills, the Pine Ridge outcrop, lying as it does at the base of the high escarpment, passes quickly beneath younger formations and leaves only a long narrow east-west band for observation. In and near the Big Badlands the White and Cheyenne rivers and their tributaries have cut deeply into and across the deposits, and there the Chadron is exposed over a large territory. The beds are known to underlie an extensive area of later formations within and beyond the Black Hills region and are well exposed in the valley of North Platte river in western Nebraska, and of South Platte river in northeastern Colorado.

The formation is made up chiefly of a sandy clay of light greenish-gray color, with generally coarser sandy materials at or near the bottom, including sometimes deposits of gravel or conglomerate several feet thick. The beds immediately above the gravels are often of a yellowish, pinkish, reddish, or brownish color, and Mr. Darton states that in northwestern Nebraska, near Adelia, the red color is especially prominent. Aside from this the color in the main is a greenish white, the green showing as a very delicate tinge on weathered slopes, but a distinctly deeper olive green in fresh exposures. The clays sometimes partake of the nature of fullers' earth, but generally they contain more or less sand. In most of the beds little cementing material is present, although the clays are often quite compact. Occasionally thin persistent bands of knotty, grayish limestone or lime clay concretions are found. These weather to a chalky white, and although seldom prominent individual bands may sometimes be traced over considerable areas. Concerning the sandy layers within the Big Badlands, Hatcher says:

"The sandstones are never entirely continuous, and never more than a few feet thick. They present every degree of compactness, from loose beds of sand to the most solid sandstones. They are composed of quartz, feldspar, and mica, and are evidently of granitic origin. When solidified the cementing substance is carbonate of lime.

"The conglomerates, like the sandstones, are not constant, are of very limited vertical extent, never more than a few feet thick. They are usually quite hard, being firmly held together by carbonate of lime. A section of the beds taken at any point and showing the relative position and thickness of the sandstones, clays and conglomerates is of little value, since these vary much at different and quite adjacent localities."*

The total thickness of the formation within the Big Badlands is approximately 180 feet. Hatcher and others subdivide the formation in that locality as follows: Lower, 50 feet; Middle, 100 feet; Upper, 30 feet. The sub-divisions are based on the nature of the Titanotheres found at the various horizons. Along Pine Ridge the formation is much thinner. Darton gives it as approximately 30 to 60 feet.

THE BRULE FORMATION

The Brule formation, like the underlying Chadron formation, outcrops chiefly in the Big Badlands and along the northward facing escarpment of Pine Ridge. As now commonly understood, it may for the Big Badlands be best considered under its two subdivisions, namely, the Oreodon Beds, constituting the lower part, and the Protoceras Beds, constituting the upper part.

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*Hatcher, J. B. The Titanotherium Beds. Am. Nat., Vol. 27, 1893, pp. 204-221.

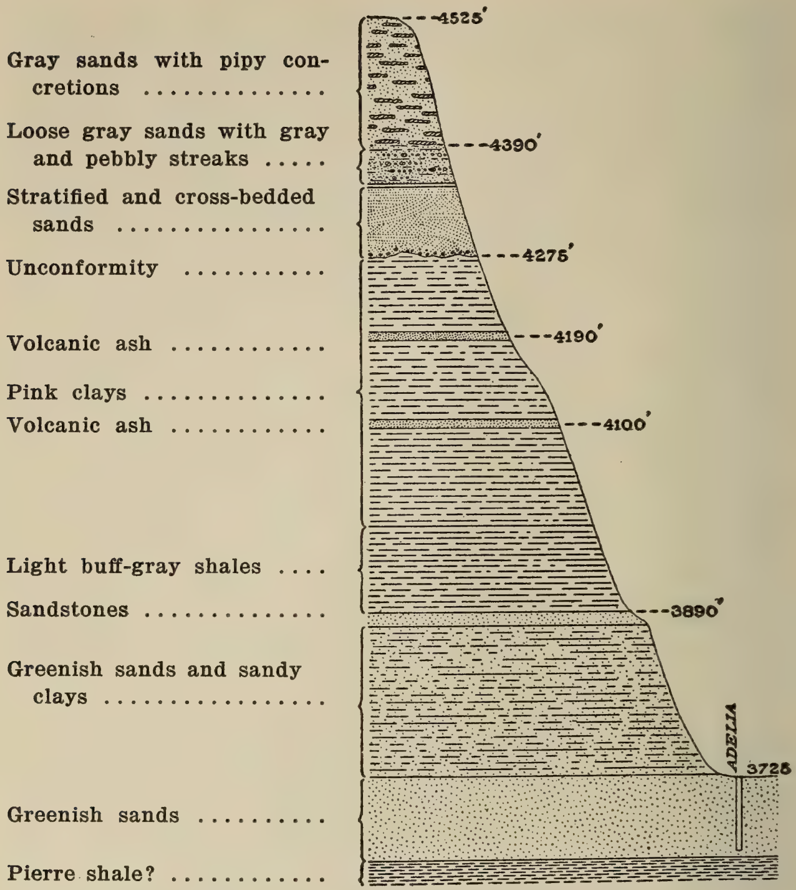

Figure 10—Section from Round Top to Adelia, Sioux county, Nebraska. Above the Pierre shale to 3725 is Chadron formation, 3725 to 4275 is Brule, 4275 to 4390 is Gering, 4390 to 4525 is Arikaree. Darton, 1905.

The Oreodon Beds. The Oreodon beds, so named because of the abundant remains of Oreodons found in them, are made up chiefly of massive arenaceous clays, lenticular sandstones, and thin layers of nodules. A particular feature of the beds is the color banding. The general color is a gray or faint yellow, but this is often much obliterated by horizontal bands showing some shade of pink, red or brown. They are present in greater or less prominence over large areas, particularly in the Big Badlands, and in places become a rather striking feature. Their thickness varies from an inch or less to occasionally several feet. Sometimes they are repeated in rapid succession without great contrasts in color. More often a few bands stand out with prominence, especially if moistened by recent rains and, seen from some commanding point, may be traced for long distances.

The sandstones being of a lenticular nature are often absent or of little consequence, but in many localities they reach considerable thicknesses. One series near the middle of the bed is of particular importance. It reaches in the Big Badlands a thickness of twenty feet or more, and according to Wortman, covers an area approximately twelve miles in length and a mile or a mile and a half in width. It contains fossil remains in abundance of the ancestral rhinoceros, Metamynodon, hence is commonly known as the Metamynodon sandstone.

Of the nodular layers, one just above the Metamynodon sandstone is of paramount importance. For description of this I quote from Mr. Wortman, 1893: "There is one layer found in the Oreodon Beds which is highly characteristic and is perhaps more constant and widely distributed than any other single stratum in the whole White River (Oligocene) formation. This is a buff-colored clay carrying numerous calcareous nodules in which are imbedded remains of turtles and oreodons. The fossils are almost invariably covered with a scale of ferruginous oxide when first removed from the matrix, and are of decidedly reddish cast. Upon this account this stratum is known to the collector as the 'red-layer.' It is situated somewhere between 40 and 50 feet above the top of the Titanotherium beds and can almost always be easily identified. It varies in thickness from 10 to 20 feet, and in some rare instances it is replaced by sandstone. I have also found it without the nodules in places, but this is also quite a rare occurrence."

Another tolerably constant fossiliferous nodular layer occurs at from 75 to 100 feet above the nodular layer just described. This higher horizon was provisionally considered as marking the top of the Oreodon beds. The present tendency is to extend the Oreodon beds upward so as to include the series of non-fossiliferous clays about 100 feet thick, lying just above the upper nodular layer. The total thickness of the beds in the vicinity of Sheep Mountain is from 250 to 300 feet. The stratigraphy in Pine Ridge differs in some important respects lithologically from that of the Big Badlands and the exact equivalent there of the Oreodon beds does not yet seem clear.

The Protoceras Beds. The Protoceras beds, earlier considered as part of the Oreodon beds, were first differentiated by J. L. Wortman as a result of field work done during the summer of 1892 for the American Museum of Natural History. The name is derived from the characteristic and highly interesting extinct animal, the Protoceras, which occurs in the sandstones of these beds in considerable abundance.

Lithologically the beds are made up of isolated patches of coarse, lenticular sandstones, fine-grained clays, and nodular layers. The sandstones occur in different levels and are usually fossiliferous. They are seldom continuous for any great distance and often change abruptly into fine-grained barren clays. Immediately overlying the sandstones there is a pinkish colored nodule-bearing clay, containing abundant remains of Lepthauchenia and other forms, hence the name Leptauchenia zone often used in connection with these beds. The Protoceras beds have been clearly differentiated only in the Big Badlands. Elsewhere the lithologic conditions do not generally serve to indicate their presence, hence if they occur outside of the Big Badlands, the determination of their areal distribution must in a large measure await the study of the paleontologist. The total thickness of the beds, including with them the Leptauchenia clays, is approximately 150 to 175 feet.

LOWER MIOCENE

The Arikaree Formation

The Arikaree formation, first designated as such by Darton, receives its name from the Arikaree Indians, who were at one time identified with the area in which it is most largely developed. Its greatest development is in Pine Ridge and southward. It is of Lower Miocene age and lies uncomformably on the Brule and in places overlaps the margins of that formation.

The Arikaree is largely a soft sandstone, varying in color from white to light gray. Calcareous concretions occur throughout the formation in abundance. They are usually of cylindrical form and are often more or less connected into irregular sheets. It is to this feature especially that the Pine Ridge escarpment and other prominent topographic features of that part of the country are due. For the manner of development of these concretionary forms, the reader is referred to the discussion of concretions and sand-calcite crystals elsewhere in this paper.

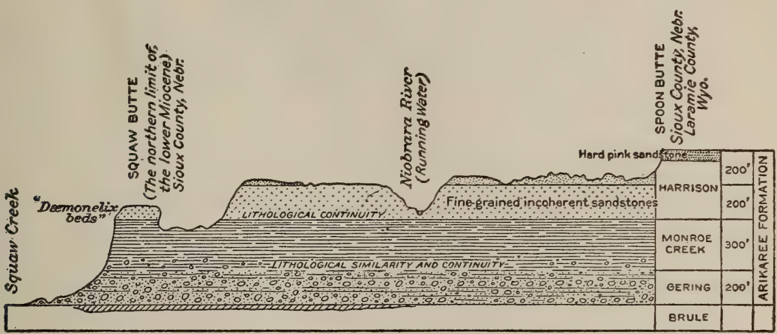

Figure 11—Diagramatic section of the Arikaree on the Nebraska-Wyoming line west of Harrison. Osborn, modified from Peterson, 1906-09.

The Arikaree has not been carefully defined for all the area where it has been found, and owing to the variable nature of the formation in different localities a number of terms in this connection need to be referred to and defined. Darton in his studies in western Nebraska some years ago, differentiated certain sands and standstones, lying below the Arikaree deposits, as the Gering formation. More recent study seems to show that much of this material is little more than non-continuous river sandstones and conglomerates that traverse the lower Arikaree clays and occupy in places irregular channels in the partly eroded upper Brule formation, the relation to the Arikaree clays being in such places much as that of the Titanotherium, Metamynodon and Protoceras sandstones to the clays in which they severally occur. The general tendency at present seems to be to consider them as a special depositional phase of the lower part of the Arikaree. According to Hatcher, the Arikaree in Sioux County, Nebraska, and Converse County, Wyoming, is lithologically and faunally divisible into two easily distinguishable horizons, namely, the Monroe Creek beds, below, and the Harrison beds above.

The Monroe Creek Beds. The Monroe Creek beds, Hatcher states, are well shown in the northern face of Pine Ridge at the mouth of Monroe Creek Canyon, five miles north of Harrison, where they overlie the Gering sandstones, and are composed of 300 feet of very light colored, fine-grained, not very hard, but firm and massive sandstones. The thickness decreases rapidly to the east and increases to the west. The beds are generally non-fossiliferous, though remains of Promerycochoerus are found in it, hence the name Promerycochoerus zone.

The Harrison Beds. The Harrison beds receive their name from Harrison, in the vicinity of which town the beds are well exposed. As stated by Hatcher, they are composed of about 200 feet of fine-grained, rather incoherent sandstones, permeated by great numbers of siliceous tubes arranged vertically rather than horizontally. They are further characterized by the presence, often in great abundance, of

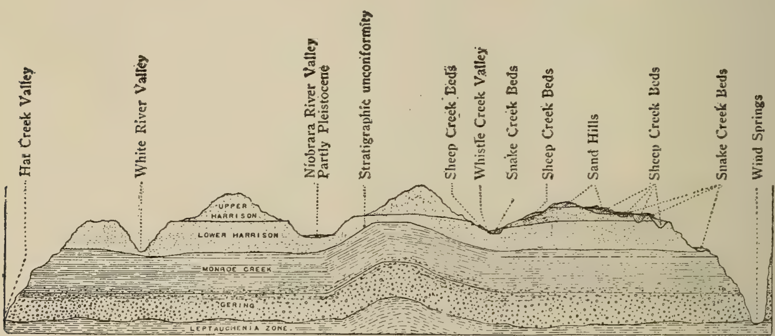

Figure 12—Section from Hat creek south through Sioux county to Wind Springs, a distance of approximately fifty miles. Cook, 1915.

those peculiar and interesting, but as yet not well understood, fossils known as Daemonelix, (hence called Daemonelix beds by Barbour, who first studied them), and by a considerable variety of fossil mammals belonging to characteristic Miocene genera.

Later investigation has shown that in some places the division is not readily made on lithologic features alone, but that the formation can in all places be separated faunistically into lower and upper levels as indicated. The section by Osborn, modified from Peterson, shows the relations of the Nebraska-Wyoming line west of Harrison. (Figure 15).

The Rosebud Beds. The Arikaree has been studied with much care near Porcupine Butte and farther east on White river by representatives of the American Museum of Natural History. Matthew and Gidley, who first collected fossils there, designated the series of strata as the Rosebud beds. These beds are believed to be approximately equivalent to the Arikaree formation as the latter is now coming to be understood, but exact relations have not yet been fully determined over any very large section of the country. Matthew describes the beds in their typical eastern locality as follows: "The western part of the formation attains a thickness estimated at 500 feet on Porcupine creek, a southern tributary of White river. The base is taken at a heavy white stratum which appears to be identical with the stratum capping the White River formation on Sheep Mountain in the Big Badlands. This stratum can be seen extending interruptedly across the river to Sheep Mountain, about twenty miles distant, capping several intervening buttes and projecting points of the underlying formation. The Rosebud beds at the bottom approximate the rather hard clays of the upper Leptauchenia beds, but become progressively softer and sandier towards the top, and are capped at Porcupine Butte by a layer of hard quarzitic sandstone. Several white flinty, calcareous layers cover the beds, one of which, about half way up, was used to divide them into Upper and Lower. The stratification is very variable and inconstant, lenses and beds of soft fine-grained sandstone and harder and softer clayey layers alternating with frequent channels filled with sandstones and mud-conglomerates, all very irregular and of limited extent. The hard calcareous layers are more constant. A bed of volcanic ash lies near the top of the formation, and there may be a considerable percentage of volcanic material in some of the layers further down. These volcanic ash beds should in theory be of wide extent, and may be of considerable use in the correlation of the scattered exposures on the heads of the different creeks—a very difficult matter without their aid.

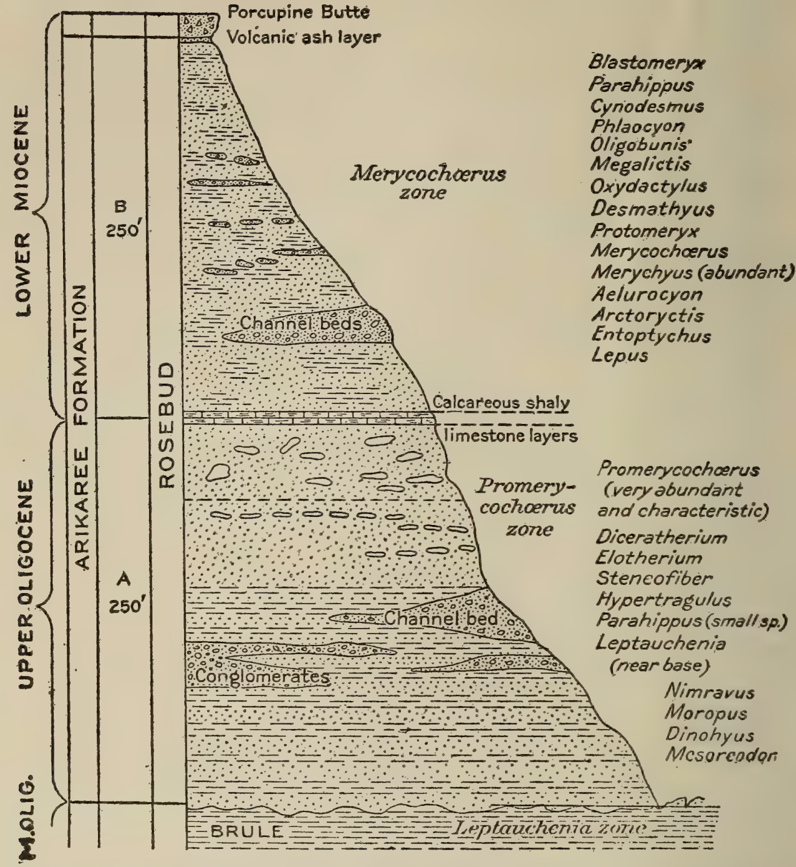

Figure 13—Columnar section from Porcupine Butte northward toward White river as observed by Matthew and Thomson in 1906. Osborn, 1912.

The beds form the upper part of the series of bluffs south of White river on the Pine Ridge and Rosebud Reservations, and are exposed in the upper part of the various tributary creeks."*

For a section of these beds see Figure 13, from U. S. Geol. Survey Bulletin No. 361, p. 70, Cenozoic Mammal Horizons of Western North America, etc., by Osborn and Matthew.

*Matthew, W. D. A Lower Miocene Fauna from South Dakota. Am. Mus. Nat. Hist., Bull., Vol. 23, 1907, pp. 169-219.

MIDDLE MIOCENE

The Middle Miocene, so far as I am aware, has not been identified within the area covered by the Black Hills map, except in the southern part, chiefly in Nebraska. Strata of this age have been studied fifteen or twenty miles south-southwest of Agate Springs, and they have there yielded a limited fauna. Matthew and Cook designate them as the *Sheep Creek beds,* and describe them briefly, as follows: "They consist of soft fine-grained sandy 'clays' of a light buff color, free from pebbles, and containing harder calcareous layers. Their thickness is estimated at 100 feet. Near the top is a layer of dark-gray volcanic ash, two feet thick."

UPPER MIOCENE

The Nebraska Beds. The Nebraska beds, Nebraska formation as designated by Scott, are represented in various areas not yet carefully mapped along the Niobrara river, where, as widely scattered river channel and flood plain deposits, they immediately overlie the Harrison beds. Further south they pass beneath or blend into the Oglalla formation, which covers so much of western and southwestern Nebraska. They have been studied by Hatcher and by Peterson. Hatcher describes them as consisting of a series of buff colored sandstones of varying degrees of hardness and unknown thickness, with occasional layers of siliceous grits, which protrude as hard undulating or shelving masses from the underlying and overlying softer materials. Peterson states that the thickness cannot be greater than 150 or 200 feet, and he gives a section near the Nebraska-Wyoming line showing only 70 feet. The beds have afforded many interesting fossils of vertebrates, some of which are described elsewhere in this publication.

PLIOCENE

Pliocene strata are found irregularly distributed on the eroded surfaces of Upper Miocene beds bordering Little White river valley and the valley of the Niobrara. They contain important fossils but the beds have not been carefully mapped. As a consequence local names have been used to designate the beds in the several localities where fossil hunting has been carried on. Among these names are Snake Creek, Oak Creek, Little White River, Niobrara River and Spoon Butte.

The beds are of Lower Pliocene age and are of especial stratigraphic value in that Pliocene mammals are not well known in North America and the mammalian fauna which the beds have yielded has helped materially in filling in the gap.

GEOLOGIC SECTION OF THE BIG BADLANDS

	Approximate estimate thickness of the beds	Characteristic Species and General Nature of the Rock
Protoceras Beds	100 feet	Leptauchenia layer; nodule-bearing, pink-colored clays widely distributed.
	50-75 feet	Coarse sandstones, occupying different levels, not continuous.
Oreodon Beds	100 feet	Light colored clays. Few fossils.
	75-100 feet	Nodulous clay stratum. Bones white. Sandstones and clays. Bones rusty colored.
	10-20 feet	Oreodon layer; nodule-bearing, very constant and widely distributed. Numerous Oreodons and turtles imbedded in nodules. Bones always covered with scale of ferruginous oxide. "Red layer" of collectors.
	70 feet	Metamynodon layer; sandstones, sometimes replaced by light colored barren clays. Bones usually rusty colored. Reddish gritty clay, sometimes bluish, Bones white.
Titanotherium Beds	30 feet	Clays, sandstones and conglomerates.
	100 feet	Clays, toward the base often reddish, or variegated. The prevailing color, however, is a delicate greenish white. Bones are always light colored or white, sometimes rusty. Clays and sands, sometimes fullers earth.
	50 feet	

MANNER OF DEPOSITION

Geologists who first studied the badland formations of the western plains early formulated the theory that the deposits were collected by streams from the highlands of the Rocky Mountains and the Black Hills and were laid down as sediment in great fresh water lakes. These lakes were thought to have varied in position and extent in the different periods of time during which the several formations were being deposited. They were believed in general to have had their origin in certain structural changes, either a slight depression along the western side or the elevation of some drainage barrier on the east, and to have been obliterated by the development of new drainage channels accompanied possibly by general uplift, and by the progressive aridity of the climate.

More recently doubts began to be entertained as to the accuracy of this attractive lacustrine theory, more detailed study disclosing many facts at variance with the usual conditions of lake deposition, both with reference to the physical character of the deposits and to the nature, condition, and distribution of the fossil remains found in them. There now seems to be abundant evidence for the belief that the deposits were of combined lagoon, fluviatile, floodplain and possibly eolian origin instead of having been laid down over the bottom of great and continuous bodies of standing water as was first supposed.

The lacustrine theory originated in the earlier accepted idea that all horizontally bedded sedimentary rocks were deposited in bodies of comparatively still water, either marine, brackish, or fresh. It was believed that the fine-grained banded clays were deposited in the quiet deeper waters of the lake, that the sandstones and conglomerates were deposited along the shores and about the mouths of tributary streams, and that the wide distribution of the animals now found as fossils was accomplished by the drifting about in the lake of the decaying bodies washed down by the inflowing streams. The fossils obtained by the earlier students of the region showed a general lack of an aquatic fauna. As a result the idea developed that the waters of this great lake although receiving the drifting bodies of land animals were themselves of such a saline or alkaline nature that they were incapable of supporting life.

It has more recently been shown that the waters were not only not saline, but that they were eminently fitted for the support of aquatic life and in fact in some localities did support such life, both plant and animal in great abundance.

It seems that the topography of the plains region during deposition of the badland materials was nearly level, the slope then as now being very gentle from the Rocky Mountains and the Black Hills. Broad streams found their way slowly across this great tract and developed upon it a net work of changing channels, backwaters, lagoons and shallow lakes interspread here and there with reed-bearing marshes and grass-covered flats. Climatic changes gradually brought about conditions of aridity, the rivers and other water bodies dwindled and wind-driven materials began to assert their prominence. Thus the clays, sandstones, conglomerates, fullers earth, eolian-sands and even the volcanic dust, wind-borne from far away craters in the Rocky Mountains or the Black Hills, are all accounted for and the life conditions of the time are in reasonable measure made plain.

GEOLOGIC HISTORY

The rocks of the earth's crust retain to a marked extent a record of their history. Sometimes this is indicated by composition, sometimes by manner of erosion, sometimes by relation to one another, sometimes by fossil contents, et cetera. Often several such characters are available in the same formation. In such cases the history may be unraveled with much fulness.

A detailed history of the Tertiary of the Black Hills region may not be entered upon here, but a brief review of the general physical changes is desirable in order that the setting of conditions and activities discussed elsewhere may be better understood.

Preceding the deposition of the Tertiary rocks, that is during the Cretaceous period, the Black Hills region had for a long time been surrounded and largely if not wholly covered by a great sea. In this sea countless marine organisms flourished and died. The sea from time to time, and particularly near the close of the period, tended through a brackish to a fresh water nature. Approximately coincident with the full development of fresh water conditions the Black Hills region was subjected to disturbance, profound elevation took place and a more active erosion was inaugurated. The history here for a time is not well disclosed but beginning with the Oligocene the conditions become more evident. By that time the streams had become sluggish and muddy and by meandering had developed vast flood plains across which they shifted their lazy way and deposited and redeposited the debris obtained from the higher lands to the west· Following the Oligocene there was further uplifting and erosion was correspondingly quickened but the general history continued much as before.

The climate for a considerable time in the history of the deposition seems to have been moist to a marked degree. Later a more arid condition prevailed and it was then that transportation and deposition by wind became a feature of importance.

The great disturbances in the early part of the Tertiary resulting in the pronounced doming of the Black Hills region and the uplifting of the Rocky Mountain front were accompanied and followed by profound igneous intrusion. The White River region was influenced only in a general way by the disturbances and no volcanic outbursts occurred there. However some of the igneous material within the Rockies and possibly some also in the northern Black Hills connecting with the throats of vigorous volcanoes was from time to time hurled high above the surface. Here favorable winds, catching up the finely divided fragments, bore them far to the eastward and there gently dropped them as thin widespread ashen blankets to become an integral and interesting portion of the general badland deposits.

Subsequent to the Pleiocene the history of the White River badlands is largely one of rapid weathering and vigorous erosion.

PHYSIOGRAPHIC DEVELOPMENT

The White River badlands are the result of erosion, controlled in part by climatic conditions and in part by the stratigraphic and lithologic nature of the deposits. There is a too frequent lack of appreciation of the work of common disintegrating and carrying agents and many an individual speculates upon the mighty upheavals and the terrific volcanic forces that to him have produced the wonderful ruggedness of the badlands, when the real work, so far at least as immediate topography is concerned, wholly apart from the forces of vulcanism, have been performed under a kindly sun and through benevolent combination by ordinary winds and frosts and rains, and to a lesser degree by plants and animals. What the earliest beginning may have been is not known. Suffice it to say that then, as now, the sun shone, the winds blew, and the rains came, and such irregularities as may have existed influenced in some degree the earliest run off. Season by season the elements weakened the uplifted sediments, and little by little the growing streams cut the yielding surface. In time lateral tributaries pushed their way into the interstream areas and these tributaries in turn developed smaller branches, the series continuing with ever increasing complexity to the delicate etching at the very top of the highest levels. All the important streams give indications of an eventful history, but for this there is little opportunity for discussion here. Cheyenne river and White river are the chief factors today in the production and continuation of the badland features, and of these, White river clings most closely to its task. The Cheyenne has already cleared its valley of the badland deposits except in the important locality southeast of the Black Hills and in the western Pine Ridge area beyond the headwaters of White river and even in these areas the main stream has cut entirely through the formations and in most places deeply into the underlying black Cretaceous shales. White river, on the other hand, for more than fifty miles of its middle course, meanders across a wide alluvial bottom, underlain by badland sediments, while its many branched head and all of the larger tributaries from the south and many from the north continue to gnaw vigorously into deposits that retain much of their original thickness.

Among the innumerable tributaries within the badlands proper, few are of great length, but many are of note in the physiography of the region, in the history of early day travel, and in the yielding of important specimens to the fossil hunter. Of those leading from the Badlands to the Cheyenne river, the following are important and often referred to in the scientific literature: Bull creek, Crooked creek, Sage creek, Hay creek, Bear creek, Spring crek, Indian creek, Little Corral draw, Big Corral draw, Quinn draw, and Cedar draw. Nearer the head of the river are Hat creek, Old Woman creek, Lance creek, and others. Three streams rising east of the Big Badlands and north of the Great Wall flow eastward between Cheyenne river and White river and form the head of Bad river. These are Cottonwood, White Water and Buffalo creeks. The White river tributaries from the north are short, and of these Cain creek, Cottonwood creek, and Spring creek rising near the heart of the Big Badlands are the most important. The White river tributaries on the south are numerous, and of considerable size. Well known ones within the Pine Ridge Indian reservation, are: Pass creek, Eagle Nest creek, Bear in the Ledge creek, Corn creek, Pumpkin creek, Yellow Medicine creek, Medicine Root creek, Porcupine creek, Wounded Knee creek, and White Clay creek. Little White river is the most important of all the streams flowing into White river. It rises west of Manderson in the southern part of Pine Ridge reservation and flows eastward and northward into and through the Rosebud Indian reservation. Many valuable fossils have been found among the outcrops exposed along its valley.

The southern slopes of Pine Ridge are drained by Niobrara river. This river rises in Wyoming and flowing eastward approximately parallels Pine Ridge and the South Dakota-Nebraska state line. It may for our purpose here serve to mark the southern limit of the area described.

In addition to the streams certain features need mention because of their commanding position. These are Pine Ridge, Porcupine Butte, Eagle Nest Butte, Sheep Mountain, and The Wall," the latter being more fully designated by the various local names: Sage creek wall, White Water wall, and Big Foot wall. Besides these, the following passes or natural roadways, well known to all the travelers within the Big Badlands, are of historic importance and of physiographic significance: Sage Creek pass, Big Foot pass, Cedar pass, Chamberlain pass, et cetera.

Less noted in the literature, but of much importance, are the numerous mesas or tables. They stand at various heights up to three hundred feet or more above the basins or valleys. Some of these are of large size and those east of the Cheyenne river have been given individual names by the people who have settled upon them. The larger ones are Sheep Mountain table, about six miles south-southwest of Scenic; Hart table, between Indian creek and Spring creek; Kube table, between Spring creek and Bear creek; Seventy-one table, between Bear creek and Hay creek; Quinn table, between Hay creek and Sage creek; Crooked Creek table, between Sage creek and Bull creek; Lake Flat between Bull creek and the headwaters of Cottonwood creek; White River table, at head of Quinn draw. The last named lies within the Pine Ridge Indian reservation and is of historic interest in that it was used as a fortress by the Indians during the Indian outbreak of 1891.

The chief factors in badland development are these: first, a climate with a low rainfall more or less concentrated into heavy showers; second, scarcity of deep rooted vegetation; third, slightly consolidated nearly homogenous fine-grained sediments lying at a considerable height above the main drainage channels, the occasional hard layers or beds that may be present being thin and in horizontal position. All of these favor rapid, steep, and diversified sculpturing. As already stated, the White and the Cheyenne rivers, not far separated from each other, serve as the main drainage channels for the Badlands and, having cut far below the topmost mesas or tables, afford abundant opportunity for rapid run off. The vegetation is scanty. Rich, short grasses are abundant over large areas, but these have not sufficient root-strength to prevent cutting. The gnarled cedars of the higher points also lack such strength, for even these often wage a losing fight and especially in the elongating gulches and on the narrowing tables they progress toward inevitable destruction.

The rock material is largely an excessively fine clay, not thoroughly indurated, sometimes massive, sometimes laminated. Sandstones occur locally in some abundance, especially in the upper beds, but never of great thickness and seldom of much lateral extent. Concretions are common and these as well as the sandstones accentuate the irregularity of erosion. The bare clay slopes under the influence of occasional rains and the beating suns, generally show a spongy surface, the loosening porous clay often extending to a depth of several inches. This feature is common on the sloping surface of the Oreodon beds and is especially characteristic of the rounded hillocks of the Titanotherium beds. This preliminary loosening of the clay, explains perhaps more than any other one feature, the surpassing ease with which the countless tiny channels are formed and how it is that the streams become turbid with every passing shower.

Any hard layer that may be present tends to resist erosion and this at once initiates surface irregularities. The unconsolidated clays being more rapidly removed, the harder stratum soon stands out in distinct relief and later by undercutting, a precipice develops. Joints often accelerate the erosion along certain vertical planes and the result is the development sometimes of cave-like excavations and sometimes of columnar masses. Columns are likely to develop also in connection with hard strata made up of concretionary masses. They are especially abundant in the Protoceras beds, where concretionary masses and jointed sandstones are both abundant.

Generally the transportation lags perceptibly behind the disintegration and as a consequence a thin fan of sediment clings to the base of every pillar, mound or table. The full extent of these alluvial fans is often not fully discerned. Being formed by the conjoint action of many little streams and made up of excessively fine sediment, their surface slope is low and one readily confuses the alluvial materials with the undisturbed beds on which they lie. As may be readily inferred, there is much transient carrying of sediments and much meandering of maturer streams. A single season or even a single freshet often makes important changes in a stream's position and there is a decided tendency in the medium sized streams to quickly develop box-like trenches. Cheyenne river and White river are active throughout the year, and during the rainy season they flow in large volume, but the tributary streams coming from the badlands are dry much of the time. Some are able to struggle along in continuous flow for a little while after the rainy reason, but later in most of them little is left but dusty sands and stingy pools of water, the latter clear if strongly alkaline, otherwise turbid to the consistency of mud porridge.

CONCRETIONS, SAND CRYSTALS, DIKES, VEINS AND GEODES

Concretions. A concretion is a spherical, cylindrical, elliptical, or nodular body produced by the tendency of certain mineral constituents to orderly aggregate about a common center within an embedding rock mass. The discovery in the White River badlands several years ago of what are known as sand or sand-calcite crystals has added much to our knowledge of concretionary development and has served well to indicate the local conditions with reference to these abundant and interesting forms.

Concretions vary greatly in size, shape, composition, manner of distribution and method of growth. They are common in the Great plains formations. In some of the Cretaceous and Tertiary beds they may be found in prodigious numbers. They occur in many places and in various horizons and of all sizes up to several feet in diameter. Any horizon which contains the concretions at all is likely to contain many of them and often they coalesce horizontally and form continuous strata. More frequently they are separate and, being harder than the surrounding material, they often tend under the influence of erosion to become the caps of earth pillars. The material of which they are made is generally an arenaceous clay with calcium carbonate as a cementing material, but iron oxide is often times present in considerable quantity.

Sand Crystals. The sand crystals are made up of approximately sixty per cent of sand and about forty per cent of calcium carbonate. The former occurs as an inclusion, while the latter, the mineralizing agent, is the crystal proper. The size varies in length from a quarter of an inch or less to fifteen inches. They occur chiefly in the Arikaree formation, which is largely a soft sandstone. Much of the rock is concretionary, and not a little of it is in cylindrical or pipe-like masses, often many feet or yards in length. These often disclose evidence of some internal molecular or crystalline arrangement and weathered specimens not infrequently show a radiate or rosetted structure, due to the tendency of lime-salts to crystallize according to the laws governing calcite as far as the interference in the part of the sand grains will allow. (Plate 52).

The first discovered and most noted locality is on Pine Ridge Reservation at Devils Hill, near Corn creek, about twenty miles south of White river. Concerning their occurrence here, Prof. Barbour, who has visited the locality, says: "The mode of occurrence of these crystals seems most unusual and remarkable. In a bed of sand scarcely three feet thick, and so soft as to resemble the sand on the seashore, occur these crystals in numbers which can best be figured in tons. We dug them out with our bare hands. They are mostly single crystals, with numerous doublets, triplets, quadruplets and multiplets. In other words every form from solitary crystals to crowded bunches and perfect radiating concretions were obtained. It was a matter of special interest in the field to note that at the bottom of the layer the bulk of these sand-lime crystals are solitary; one foot higher there is an evident doubling of the crystals, until within another foot they are in loosely crowded clusters, a little higher in closely crowded continuous clusters, pried out in blocks with difficulty; still higher they occur in closely crowded concretions in contact with one another, making nearly a solid rock. A little higher this mineralizing process culminates in pipes, compound pipes and solid rocks composed wholly of crystals but so solidified that their identity is lost, and is detected only by a certain reflection of light, which differentiates the otherwise invisible units by showing glistening hexagonal sections. There could not have been a more gradual and beautiful transition, and all confined to a bed six or eight feet in thickness."

The relation of the crystals to concretions, as indicated above, discloses an important step in the development of concretions in general, and doubtless to some such cause as this crystallographic tendency is due the development of all of the concretions of the Badland strata.

Dikes and Veins. Dikes and veins are ordinarily elongate, vertical, or nearly vertical rock or mineral masses occupying fissures in a pre-existing rock. The filling body, if intruded as an igneous rock while in the molten condition, is commonly referred to as a dike. If filled in by a slow process of deposition from aqueous solution it is known as a vein. It is now recognized that fissures sometimes become filled with broken (clastic) material derived from adjacent or nearby rock masses without any immediate influence either of heat or of solvent action. These clastic bodies are known as dikes also.

Many writers have commented upon the nature and abundance of the dikes and veins in the Badlands. Although constituting minor features of the landscape they are nevertheless extremely abundant in places and not infrequently they display themselves in an interesting and complicated manner. The dikes are made up generally of a soft greenish sand or sandy clay. This usually wears away a little more readily than the enclosing strata but sometimes it resists weathering better and then the dike projects above the general surface. The prevailing attitude is nearly perpendicular and the dike outcropping in a straight line may occasionally be traced across gulches and draws and over ridge and pinnacle and mound for a mile or more. The thickness is commonly not more than a few inches but it sometimes reaches two or three feet. The dikes are supposed to occupy preexisting cracks, the material having been forced in from below by hydrostatic pressure or by the weight of the superincumbent strata. It is possible that in some cases the material may have come from above.

The veins are chiefly chalcedony. They resemble the dikes so far as concerns position and form and, aside from the fact that they were deposited from solution, are believed to have much the same history. They average thinner than the dikes, are much harder, and are in many places more abundant. They resist weathering much better than the enclosing clays, hence commonly present a jagged line above the surface. As the supporting clay becomes loosened and is carried away the thin chalcedony breaks into platy angular fragments and these falling upon the surrounding surface protect it from further erosion much as would a shingle roof.

Geodes. Geodes are spheroidal masses of mineral matter formed by deposition of crystals from some mineral solution on the walls of a rock cavity. The growth is constantly inward toward the center. If the process of deposition has continued sufficiently long, the crystals reach across the depositional space, interlock with each other, and the geode becomes solid. Often the crystals project only part way, leaving a considerable cavity and then the geode when broken presents a crystal lining of much beauty and interest. Commonly the geodes are more or less siliceous, especially in the outer portions and, resisting weathering better than the enclosing rock mass, may often be found freed from the matrix lying on the disintegrating surface. Not infrequently crystal fragments become detached within the shell, and these, striking against the inner walls when the geode is shaken, serve to make a sound. For this reason the geodes are often referred to locally as rattle stones.

Many geodes have been collected from the Big Badlands. The diameter varies from one inch or less to several inches. The prettiest ones of rather small size are found near Imlay. They have commonly an irregular shell of chalcedony more or less filled with bright clear-cut white or colorless quartz crystals, the latter varying from microscopic size to one-half inch or more in length. The finer white crystals much resemble white sugar, hence the name sugar geodes. Selenite (crystalized gypsum) is occasionally present. The origin of the geodes is doubtless closely connected with the origin of the chalcedony veins described above.

DEVIL'S CORKSCREWS (*Daemonelix*)

Among the interesting materials of the badland deposits few have given rise to more speculations as to their origin than what are known as the Devil's Corkscrews of the Harrison beds. Devil's Corkscrews, or Daemonelix, as they are technically called, have been known by the early residents of northwestern Nebraska for many years but it was not until 1891 when Prof. Barbour made a collecting trip to Harrison and the Badlands that these strange objects were brought to the attention of scientific men. What they really represent or how they were formed is still a matter of conjecture. The more typical forms are upright tapering spirals and they twist to the right or to the left indiscriminately. The spiral sometimes encloses a cylindrical body known as the axis but it is more often without the axis. Sometimes the spiral ends abruptly below but more often there projects from the lower part one or two obliquely ascending bodies placed much as the rhizomes of certain plants. The size of the well developed form varies considerably. The height of the corkscrew portion often exceeds the height of a man while the rhizome portion is ordinarily about the size of one's body.

They are known to occur especially between the head waters of White and Niobrara rivers chiefly in Sioux county, Nebraska, but extend westward to Lusk, Wyoming, and eastward to Eagle Nest Butte, South Dakota. The vertical range of strata carrying them is approximately 200 feet. In certain localities they are found in the greatest profusion, sometimes stretching like a forest over many acres and sometimes so closely placed that they are inextricably entangled and fused together. (Plate 47).

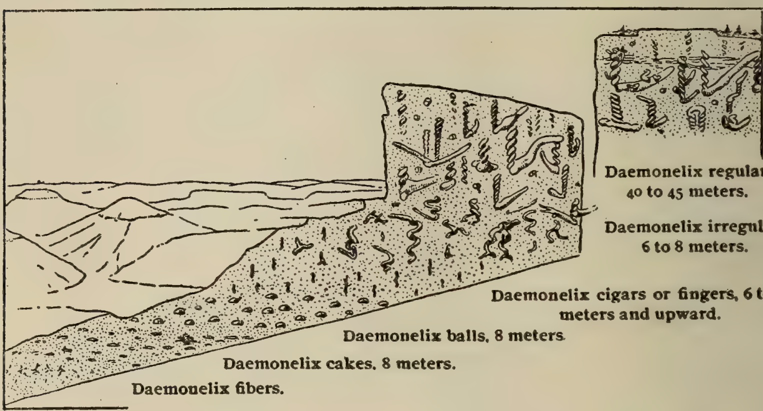

Figure 14—Diagramatic section showing the relative positions of the several forms in the Daemonelix series according to Barbour, 1896.

Prof. Barbour who has given these interesting forms most study considers them as representing some kind of plant life and has apparently found much to corroborate this view. Some have considered that they represent low plant organisms such as algae, others that they may be remains of higher plants, in which all has decayed away except the cortical layer. Still others and these with much reason have considered them as casts of well preserved burrows of animals. Among the earliest to suggest the latter idea were Dr. Theodore Fuchs of Germany and Prof. Cope. More recently Mr. O. A. Peterson emphasized the latter view as a result of the finding of numerous fossils of burrowing rodents within the corkscrews. (See Figures 15 and 53).

Figure 15—Field sketch of a weathered rhizome containing the type specimen of the burrowing rodent, *Steneofiber barbouri*. Peterson, 1905.

ECONOMIC MINERAL PRODUCTS

The White River badlands have not attracted particular attention as a source of mineral wealth. Sandstones and limestones are found in various places but they seldom meet the requirements of a high grade building stone. They are nearly always thin-bedded and generally are more or less argillaceous. The sandstones are often of coarse or irregular texture and poorly cemented.

Clays occur in unlimited abundance and analyses show that they could be utilized if desired, in various ways, particularly in the manufacture of brick and cement. Some of the clays especially those near the bottom of the Titanotherium beds have the property of decolorizing or clarifying oils, hence are known as fullers earth.

Prof. Heinrich Ries of Cornell University, gives the following analyses for the localities mentioned, analyses 1, 2, 3, 6 being of material from near Fairburn, and analyses 4 and 5 of material from near Argyle.

Analyses of Fullers' Earth From the Titanotherium Beds.

Constituent	1	2	3
	Per cent	Per cent	Per cent
Silica (SiO_2)	68.23	60.16	56.18
Alumina (Al_2O_3)	14.93	10.38	23.23
Ferrous oxide (FeO)	3.15	14.87	a 1.26
Lime (CaO)	2.93	4.96	5.88
Magnesia (MgO)	0.87	1.71	3.29
Loss on ignition	6.20	7.20	b 11.45
Total	96.31	99.28	101.29

a—Fe_2O_3 b—H_2O.

Constituent	4	5	6
	Per cent	Per cent	Per cent
Silica (SiO_2)	55.45	57.00	58.72
Alumina (Al_2O_3)	18.58	17.37	16.90
Ferrous oxide (FeO)	3.82	2.63	4.00
Lime (CaO)	3.40	3.00	4.06
Magnesia (MgO)	3.50	3.03	2.56
Loss on ignition	8.80	9.50	8.10
Volatile	5.35	5.85	....
Alkali	....	....	2.11
Moisture	....	....	2.30
Total	98.90	98.35	98.45

Volcanic ash has been mentioned in the description of the deposits. It occurs rather widely distributed over the country. A prominent bed lies near the top of Sheep mountain and extends outward from it for many miles along the walls and the remnant buttes that are high enough to retain it. Other beds are found near and within the neighboring Black Hills and here some effort has been made to place the material upon the market. Deposits of a similar nature in Nebraska have been worked for many years. The ash when not mingled with other sediment is nothing more than minute angular fragments of natural glass and these having sharp cutting edges give to the ash a value as a polishing powder or in the prepared state is an important constitutent of abrasive soaps.

The fossil bones found in the badland deposits, like the bones of present day animals, generally contain much phosphate. There is little reason, however, to believe that the phosphate can be utilized commercially. Men speak of the abundance of the fossil bones, but it should be stated that this is more particularly from the viewpoint of the scientist interested in their educational value rather than that of the manufacturer of commercial bone products. There seems never to have been any very great tendency for the phosphate to leach out from the bones and concentrate into beds.

For those interested in the chemical nature of the bones, I give the following analyses made many years ago by Dr. Francis V. Greene from material collected by the Owen Survey and published in the American Journal of Science, 1853, also analyses made recently in the State School of Mines laboratories by Mr. George Enos.

Analyses of Badland Fossils (Greene)

Constituent	1	2	3	4
	Per cent	Per cent	Per cent	Per cent
Phosphoric Acid (P_2O_5)	33.98	39.15	35.97	31.19
Silica (SiO_2)	0.09	0.48	0.79	0.26
Ferric Oxide (Fe_2O_3) ..	1.77	....	....	....
Fluorine (F)	0.40	0.04	1.42	2.46
Magnesia (MgO)	0.33	0.22	0.53	1.14
Lime (CaO)	49.77	51.80	51.23	50..83
Potash (K_2O)	0.31	0.24	0.23	0.28
Soda (Na_2O)	1.13	1.28	0.75	1.57
Baryta (BaO)	0.36	....	....	1.10
Chlorine (Cl)	....	....	....	0.02
Sulphuric Anhydride (SO_3)	0.88	1.01	1.51	2.19
Carbonic Acid (CO_2) ..	4.08	3.17	2.83	2.77
Water (H_2O)	2.04	0.62	2.10	1.97
Organic Matter	5.67	2.54	2.66	4.09
Total	100.81	100.55	100.02	99.87

In the above anaylses, No. 1 is that of a Titanothere bone, No. 2 of a Titanothere tooth (enamel), No. 3 of a Titanothere tooth (dentine), No. 4 of an Archaeotherium (Elotherium) bone.

Analyses of Badland Fossils (Enos)

Composition	1	2	3	4
	Per cent	Per cent	Per cent	Per cent
Silica (SiO_2)	8.96	2.10	23.78	71.80
Phosphoric Anhydride (P_2O_5)	46.30	33.40	20.00	4.34
Iron and Aluminum Oxides	1.97	2.80	5.00	.18
Lime (CaO)	27.17	20.00	24.10	8.80
Magnesia (MgO)	.50	32.36	1.44	3.22
Soda (Na_2O)	6.08	.14	.04	2.80
Potash (K_2O)	.65	.80	.72	1.16
Baryta (BaO)	.08	....	3.80	....
Chlorine (Cl)	Trace	....	....	....
Fluorine (F)	....	....	....	....
Sulphuric Anhydride (SO_3)	.56	.97	.42	.25
Carbon Dioxide (CO_2)..	4.65	5.90	18.70	7.19
Water at 110°C	1.40	1.32	2.04	....
Organic Matter	1.17	....	....	....
Total	99.49	99.79	100.04	99.74

Remarks:—

No. 1 is part of the upper tooth of a brontothere.

No. 2 is part of lower tooth of a young titanothere.

No. 3 is part of lower jaw with teeth (oreodon) and matrix.

No. 4 is a coarse sandstone with clay pebbles and bone fragments from Protoceras beds.

The above specimens are all from the Big Badlands of South Dakota.

FOSSILS

Fossils as generally understood are the parts of animals and plants living before the present era that have been buried in the rocks and preserved by natural causes. The manner and degree of preservation vary greatly. The essential thing is the sealing up of the remains in the rocks so that destruction and decay may be prevented. Animals such as the ice-entombed mammals of Siberia and the amber enclosed insects of the Baltic, are practically perfect as the day they were buried, but they are exceptional. Generally only the hard parts, such as bones or teeth, or shells remain. Not infrequently these are replaced particle by particle by new mineral matter of some kind, particularly silica or pyrite, then they become petrifactions. Sometimes only the form, or the impression of the original parts are preserved, hence the terms molds and casts. Occasionally the relics are limited to footprints, or trails, or burrows, or borings or eggs.

Animals living in the water or frequenting marshy places for food and drink are more easily and more quickly buried beneath sediments, hence their fossils are usually more abundant. The bodies of dry land animals are subjected to the vicissitudes of sun and rain and wind, and frost, and are often feasted upon by scavenger birds and beasts and insects. Furthermore their burial is commonly brought about only during flood season. All of these tend to the destruction or dismemberment of the various parts. Again, even if once nicely buried, they may later be obliterated by metamorphism or be destroyed by disintegrating and denuding agencies. As a result of all this, the history of certain groups of animals is meagre in the extreme and doubtless hordes of species have left no worthy evidence of their ever having lived.

EXTINCTION, EVOLUTION AND DISTRIBUTION OF ANIMALS

The progress of animal organisms is constantly directed toward the goal of perfection. Each individual shares in the improvement but the perfection to be attained consists not so much in the exquisite relation the various organs bear to one another as it does in the harmony that the animal in all its characters shows to its environment.

When life began, and how, no one knows. It is evident that in the beginning it was represented by very simple forms. These, because of varying conditions, were followed in orderly sequence by creatures of growing complexity. All animals pass through innumerable vicissitudes and existence is a constant struggle. Those best fitted to meet difficulties tend to survive and leave posterity. It thus happens that advantageous variations are perpetuated and those of less use are eliminated. In this way changes occur, characters are modified, and life forms sooner or later take on an appearance and a nature quite different from their ancestors.

Just as individuals suffer distress and destruction so, sometimes, entire animal groups battling for position in life's long race and gaining for a time supremacy in their field are in turn oppressed and in the end obliterated by the contending forces. Of the animals described in this book several groups are wholly extinct, no relatives of any reasonable nearness being found living today. Notable among such are the Titanotheres, the Oreodons and the Moropus. Reference to the extinction of others is given in connection with their description.

Often extinction is apparent rather than real and the seeming obliteration may be only the normal expression of constant change. For example, in the horse, camel, rhinoceros and other families the consecutive changes may be traced through a long continued series of replacements by the process of gradual development. Again the seeming extinction may be only a migration from the locality in

Figure 16—Land areas of the world during Late Cretaceous and Basal Eocene time. Period of extinction of the great Reptilia. A time of elevation, favoring an interchange of archaic life between South and North America, also between North America and Europe. South America probably united with Australia via Antarctica, allowing an interchange of carnivorous and herbivorous marsupials. A partial community of fauna between North America and Eurasia with Africa. Rearranged from W. D. Matthew, 1908. H. F. Osborn: The Age of Mammals in Europe, Asia, and North America, 1910. Published by The Macmillan Company. Reprinted by permission.

question and in the new environment activity may continue as favorable as before.

In case of actual extinction it is often not possible to ascertain the immediate causes. Sometimes the extinction is due wholly to conditions external to the animals themselves, such as unfavorable climate, alteration of food sup-

Figure 17—Land areas of the world during Oligocene time. A period of continental elevation and reunion followed by the reestablishment of connections between the life of the New and Old Worlds. Central Europe submerged or partly archipelagic. African mammals and birds partly similar to those of Europe. Madigascar united with Africa. South America entirely separated, its mammals developing independently. Australia entirely separated. Closing the Oligocene, another long interval of separation between North America and Europe. Rearranged after W. D. Matthew, 1908. H. F. Osborn. The Age of Mammals in Europe, Asia and North America, 1910. Published by the Macmillan Company. Reprinted by permission.

ply, ravages of disease, encroachment of hostile species, insect pests, et cetera. Again extinction may be due largely to lack of internal adaption or adaptability, for example, the teeth may be fitted for too little variation of food, or the brain may be deficient in size or quality so that the animal lacks resourcefulness, alertness and enterprise.

The distribution of animals is closely related to their development and has been in large measure controlled by geographical conditions. A study of paleogeography shows that the several continents have had a varied career. Changes have taken place in them through all the ages and migration roads and barriers, in long procession, have

Figure 18—Land areas of the world during Miocene time. A period of continental elevation and emergence, consequently of renewed land connections and migrations. Africa broadly united with Europe across the Arabic peninsula, and a typical Asiatic fauna roaming westward into Europe and Africa. Asia connected with the East Indies and the Philippine Islands. Florida elevated at the close of the Miocene. South America divided into northern and southern halves by a broad gulf, the northern half perhaps connected with North America. Australia entirely separated from Asia. Rearranged after W. D. Matthew, 1908. H. F. Osborn: The Age of Mammals in Europe, Asia and North America, 1910. Published by The Macmillan Company. Reprinted by permission.

formed and disappeared. With the advent of mammalian life interest in these physiographic changes increases and their interpretation is made with greater assurance of accuracy.

Life in the older geologic time was simple. The forms increased in complexity as the ages came and passed. Primitive mammals appeared during the Mesozoic but not until the

Cenozoic did they reach importance. They then became the ruling type and the Cenozoic, for this reason is often called The Age of Mammals. (See Plate 9).

In early Tertiary time North America was apparently not connected by land with South America. It was, however, connected with Asia by way of Alaska and with Europe by way of Greenland and Iceland. These land bridges and the Panama region are known to have changed greatly during and subsequent to the Tertiary and a fair understanding of their influence will explain many perplexing features of animal and plant distribution.

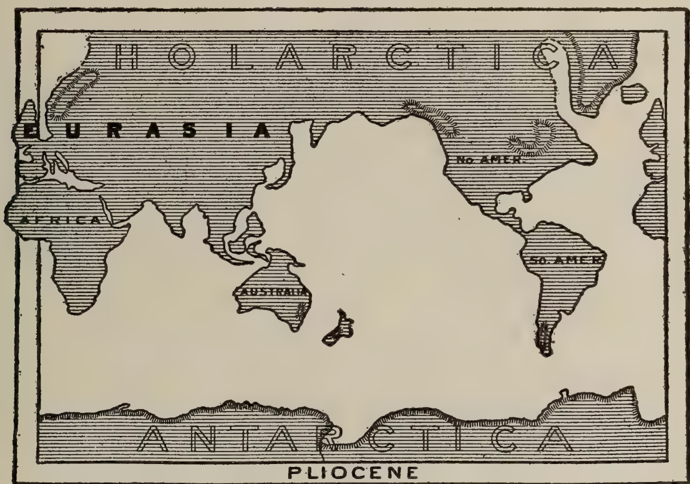

Figure 19—Land areas of the world during Pliocene time. A period of continued continental elevation especially in Europe and Eastern North America. Seasons of aridity or summer drought, increased aridity of the Great Plains of North America. South America connected with North America by migration routes which allowed free interchange of mammals. Australia still united with New Guinea and Tasmania. Rearranged after Matthew, 1909. H. F. Osborn. The Age of Mammals in Europe, Asia and North America, 1910. Published by The Macmillan Company. Reprinted by permission.

THE COLLECTING AND MOUNTING OF FOSSIL BONES

In the earliest explorations in the Badlands little careful effort was made to secure complete skeletons, the explorer apparently contenting himself with securing only the better heads or other fragments lying on or near the surface. Later extensive digging was resorted to, but for some years this was done in a crude way. The bones are generally more or less broken and disarticulated and when once the fragments become separated the proper assembling of the pieces again becomes a difficult task. In course of time a method of bandaging developed. Now the fragments

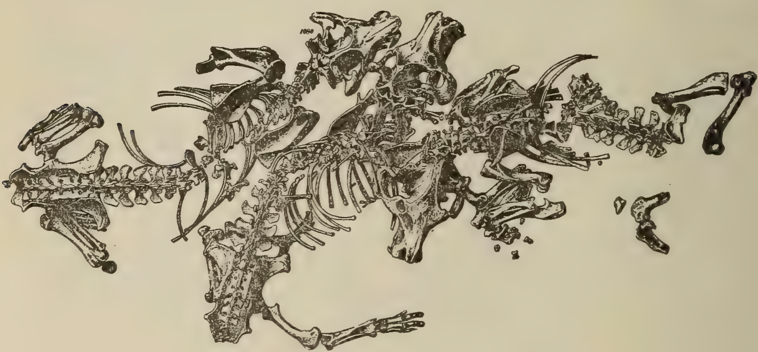

Figure 20—Group of three *Promerycochoerus carrikeri* skeletons in position as found. Showing the disturbed conditions of the specimens even when the bones are well preserved and the skeletons fairly complete. Peterson, 1914.

while being excavated are kept together by laying on with flour paste strips of muslin or burlap or other coarse, loose-woven cloth. Plaster of paris may also be used especially where heavy pieces are involved or where extreme care is necessary. Soft bones are treated with some preparation of shellac or gum to harden them for transportation· Exact location of the skeleton and the relative position of every bone in the skeleton is of the greatest importance. Sketches and photographs are made as the work progresses and all pieces removed are carefully labelled. A knowledge of the stratigraphical horizon is essential to determining much of the relationship and life history of the animal and the proper location of each bone with reference to neighboring bones of the same excavation may serve greatly in the

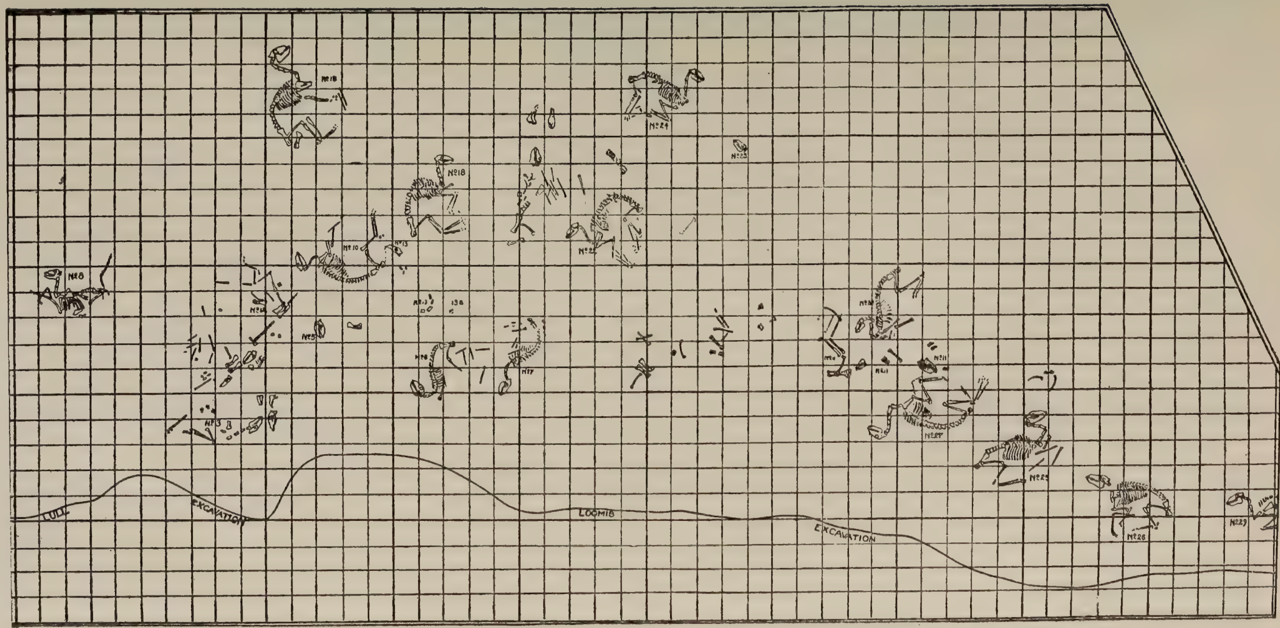

Figure 21—Plan of the Carnegie Museum Stenomylus quarry, Sioux county, Nebraska, showing the remarkably fine array of complete or nearly complete skeletons of ancestral camels excavated there. Peterson, 1911. (Each square represents one square foot.)

mounting of the restored skeleton. Often considerable masses of the enclosing earth or stone are quarried out and shipped to the museum where time and proper instruments will permit a more satisfactory extraction of the bones. (See Plate 10 and Figures 20 and 21).

Reaching the preparator's laboratory the bandages are carefully removed, all useless matrix cleared away and the bone fragments assembled and cemented together. Injured bones are then repaired and missing bones reproduced in some suitable artificial preparation. The mounting is often facilitated by study of the living relatives of the fossil form. Where there is no living animal nearly related, recourse is had to the studies of the rugosities of the bones where the main muscles were attached in life, the facettes of the joints and the general shape and character of the various bones.

All this work, if properly done, requires much patience and skill in manipulation as well as intelligent insight into the general nature of the animal to be mounted. Many weeks or months may be required in the laboratory work alone, the expense of preparation usually far exceeding the time and money spent in collecting the specimens in the field. It may be readily inferred that the money value, to say nothing of the educational importance of the completed skeleton, particularly if it is the type specimen of a new series, is often very great. (Plate 50).

THE CLASSIFICATION AND NAMING OF EXTINCT ANIMALS

The naming of animals, both living and extinct is closely interwoven with their classification. Classification is a process of comparison. Its object is to bring together the like forms and to separate the unlike. This is best accomplished by comparing the various characters which are the most constant. The natural result is the arrangement of groups within groups in a continuous manner, the various groups being given particular names, as, Kingdom, Subkingdom, Class, Order, Family, Genus, Species, et cetera. The scientific name by which any animal is indicated is formed by combining the generic and specific names much as we combine our own family and Christian name except that in the scientific nomenclature the specific term comes last. To illustrate: The scientific name of the domestic dog is *Canis familiaris* Linnaeus, *Canis* being the name of the genus and *familiaris* the name of the species. The third non-italicized portion may be considered a part of the name although this really refers only to the naturalist who first carefully described and properly named the creature. It is often omitted, especially in the case of fairly common or well known animals or where there is no mistaking the individual who gave the name. In scientific literature, however, and particularly in paleontology where, on account of imperfect material, there is liability of error in determination this is usually given as it not infrequently becomes essential for clearness in referring to the species. Omitting it from the name for the time being, the complete classification of the dog may be represented as follows:

Kingdom, Animalia.
  Sub-kingdom, Vertebrata.
    Class, Mammalia.
      Sub-class, Eutheria.
        Infra-class, Monodelphia.
          Cohort, Unguiculata.
            Order, Carnivora.
              Sub-order, Fissipedia.
                Family, Canidae.
                  Genus, Canis.
                    Species, Familiaris.
                      Variety, "Shepherd."
                        Individual, "Shep."

Continuing the illustration the scientific name of the tiger is *Felis tigris* Linnaeus; of the ox, *Bos taurus* Linnaeus; of man, *Homo sapiens* Linnaeus. These names are simple enough when once understood and indeed many names we now look upon as common have been transferred bodily from the scientific generic nomenclature, as for example, rhinoceros, hippopotamus, bison, and mastodon.

It is well known that the common names by which animals now living are designated are often not sufficiently accurate. The name in order to be properly useful must be sufficiently distinctive to indicate clearly the animal to which reference is made. For example, there are five existing species of rhinoceroses, the clear definition of which by common names is perhaps difficult enough, to say nothing of the score or more of fossil forms besides a still larger number of extinct animals closely allied to the rhinoceroses and falling under the general Class, Rhinocerotoidae. Again sometimes the common name is deceptive. For example the well known pronghorn antelope, *Antilocapra americana,* of our western plains is considered by some zoologists as not being an antelope at all. On the other hand our Rocky Mountain goat *Oreanus Montanus* is a member of the true antelope family. True antelopes at the present day inhabit chiefly Europe, Asia and Africa. They include many species, the better known ones being designated in common speech as hartebeests, gnus, elands, gazelles, klipspringers, gemsbocks, springboks, waterbucks, duickerboks, saigas, etc. Several of these are subdivided. For example the duickerboks alone are credited with thirty-eight species. If, therefore, we are going to name animals in conformity with their recognized distinctions, and for clearness of conception there is generally no alternative, then the various duickerbok species must each be given a name—thirty-eight in all. Thus antelope being in reality a misnomer here in this country and losing much of its distinctive significance even in the old world, becomes little more than a loose expression for a great group of animals, some of them no larger than a jack-rabbit, and others comparable in size to a horse.

Generally, in designating the species, the words of the scientific name refer to some important character, or they express some relationship or resemblance, or indicate some fact of distribution or discovery. Sometimes the meaning is obscure in which case it may be necessary to consult the work of the original author for the interpretation. Often, however, the name needs little explanation other than that given by a good comprehensive dictionary.

The generic names are usually of classic origin, most of them being Latinized forms of Greek names. They may be either simple or compound words and they often have modifying or descriptive prefixes or suffixes. The specific names show a somewhat wider latitude of origin than the generic names. Sometimes they are geographical, sometimes personal, oftentimes descriptive. The following names of badland fossils may serve to illustrate the principle: *Procamelus occidentalis* Leidy, an ancestral camel of the new world, described by Leidy; *Magacerops brachycephalus* Osborn, a short headed animal with a great-horned appearance, described by Osborn; *Neohipparion whitneyi* Gidley, a new world, small horse described by Gidley and named in honor of W. C. Whitney; *Protoceras celer* Marsh, a fleet-footed first-horned animal described by Marsh; *Protosorex crassus* Scott, a large sized primitive shrew, described by Scott.

It would lead us too far away to go into the full details of this nomenclature. One additional feature, however, deserves notice in view of its not infrequent perplexity. The individual who first describes a new species is supposed to give it a name which must not conflict with any name used previously for another species. According to the rules governing the matter the name by reason of its priority can not be changed subsequently except for cause. Often in paleontological work where poor or insufficient or aberrant material has been first studied later discoveries have shown errors of description or improper identification in which case a new name may become necessary. The new name, if properly given becomes the accepted name while the old name is referred to as a synonymn. In not a few cases there are several synonyms and not infrequently it is a matter of some conjecture as to just which is the most appropriate under the circumstances.

With rare exceptions the animal life of the White River badlands is restricted to the Vertebrata—the backboned animals. Aside from turtles of which there are many, and a few crocodiles, lizards, and birds eggs, all of the fossil remains of the vertebrates thus far found within the area belong to the great class "Mammalia." The term "Mammalia" includes all hair-clad, vertebrated animals, the females of which are provided with glands for secreting milk for the early nourishment of the offspring. They are the highest of the vertebrates, possessing that happy combination of anatomical and physiological simplicity and complexity tending toward highest efficiency as organisms. They are not only the most important animals of today, but they have been the rulers of the animal world since early Tertiary time. Continuing back in geological history with ever increasing simplicity toward a generalized, omnivorous, allotherian ancestry they may be traced with certainty to Triassic time. Since their beginning multitudinous changes have taken place in the structure and activity of the many species that have originated, developed and died and, as a result, the expression of relationship must often be indefinite or uncertain.

Following the custom of many authors three main subclasses of the Mammalia may be recognized, namely, the Prototheria or primitive mammals, the Metatheria or pouched mammals and the Eutheria or perfect mammals.

The Prototherian mammals are restricted to a few simple forms such as the Echidna (Australian Ant Eater) and the Ornithorynchus (Duck-billed Platypus) which lay large yolked eggs much after the fashion of reptiles and birds. They are not represented in the White River badlands either living or fossil, hence need no further consideration here.

The Metatheria are those intermediate, marsupial mammals which, having only a rudimentary or primitive placental structure, bring forth their young in a very immature state and carry them for a considerable time in a pouch provided for the purpose. The opossum, the kangaroo and the Tasmanian "wolf" are well known representatives. Like the Prototheria the Metatheria are not found in the White River badlands.

The Eutheria include a vast assemblage of forms of all sorts of perfection of development from lowly primitive creatures to man. These are grouped somewhat differently by different authors but all of the fossil forms obtained from the region under discussion fall naturally into four main divisions, namely, the Insectivora (insect eaters) the Carnivora (flesh eaters), the Rodentia (gnawers), and the Ungulata (hoofed mammals), the Ungulata (Herbivora) being represented by two orders, the Perissodactyla (~~even~~ odd toed mammals) and the Artiodactyla (~~odd~~ even-toed mammals).

The Insectivores include moles, hedgehogs, shrews and other small animals of antiquated structure. They are generally plantigrade (walking upon the sole of the foot), the snout is often prolonged into a short proboscis, and their chief food is insects. The Carnivores include animals whose chief food is flesh. They may be terrestrial, arboreal, or aquatic. They have a simple stomach, a well developed brain, toes provided usually with long, sharp claws, and generally they have a body capable of much agility in the capture of prey. They walk either upon the entire sole of the foot or upon the under surface of the toes but never upon the tips of the toes as do the Ungulata. The carnivorous structure is common to all of the class but the carnivorous habit, though general is not universal. Living representatives vary in size from the little active ermine to the powerful grizzly bear. The Rodents include a group of small to moderately large animals the most prominent and universal character of which is their dentition. Canine teeth are absent. The deeply set incisors, separated by a considerable vacant interval from the molars, are long and flat edged and are of paramount importance. Since they lengthen by persistent growth they serve admirably for vigorous chisel-like cutting of hard materials, hence the name "gnawers." The animals are usually plantigrade, often burrowing, not infrequently arboreal, and occasionally acquatic. They are today represented by the squirrels, prairie dogs, rabbits, rats, mice, beavers, porcupines, and a host of others. The Ungulates (Herbivores) are plant-feeding animals with hoofs rather than claws or nails, and with limbs perfected for running and not for climbing and grasping. Viewed from the point of usefulness to man they are the most important of all animals in that they furnish him with food, clothing and working assistance.

CARNIVORES

The Carnivora may be conveniently divided into three sub-divisions (sub-orders), namely, the Creodonta or primitive carnivores, the Fissipedia or true carnivores, and the Pinnipedia or aquatic carnivores. Of these the Creodonts are found only in the fossil state; the Fissipedes include our common carnivorous animals such as the Canidae (dogs or dog-like creatures) and the Felidae (cat family), and are both fossil and living. They are found in large numbers among the fossils of the badlands. The Pinnipedes include the aberrant animals, the seals and walruses. The Creodonts are represented in the White River badlands by but one family, the Hyaenodonts. The Pinnipedes are not found there at all.

CREODONTA

The Cerodonts originated in the earliest Tertiary and were evidently the predatory flesh eaters of their time. They were the primitive ancestors of the true carnivores and they held a position relative to contemporary animals similar to that which the true carnivores hold among the animals of today.

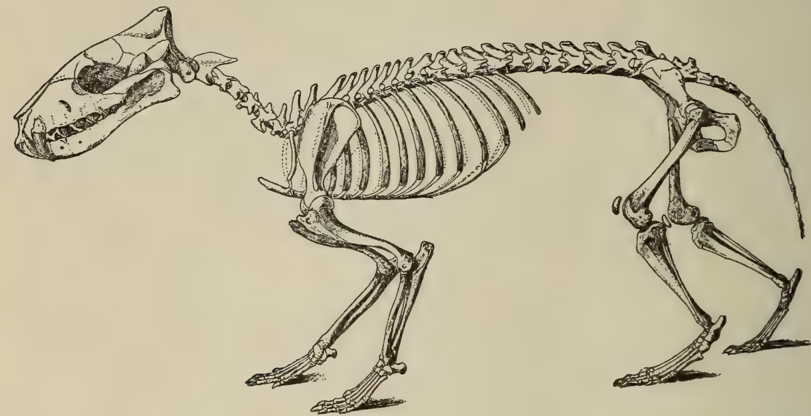

Figure 22—Skeleton of the Oligocene creodont *Hyaënodon cruentus* Scott. 1895.

There were numerous families but of all these only the Hyaenodons, the latest and most specialized are found in the White River badlands. (See Plate 25). The individual fossils are not abundant although several species are represented. The skull of the largest *Hyaendon horridus* indicates an animal of wolf-like appearance approaching in size the present day black bear. The life habits of these animals are not entirely clear. It is not even known whether they were digitigrade or plantigrade. They may have been semi-plantigrade. It has been suggested that they were semi-acquatic but this is quite uncertain. The Hyaenodons, unlike most of the class, seem to have lived on carrion.

CANIDAE

The Canidae are abundantly represented in the White River badlands. More than twenty species are known. The earliest North American Canidae recognized as such are found in the Upper Eocene. They first appeared in Europe at about this time also and were abundant in both Europe and North America during Oligocene and Miocene times. They are known to have reached India by the early part of the Pliocene and seem to have migrated along the Isthmus of Panama to South America as soon as it emerged from the sea at the dawn of Pliocene time. It is of interest to note in this connection that the nearest living allies of the

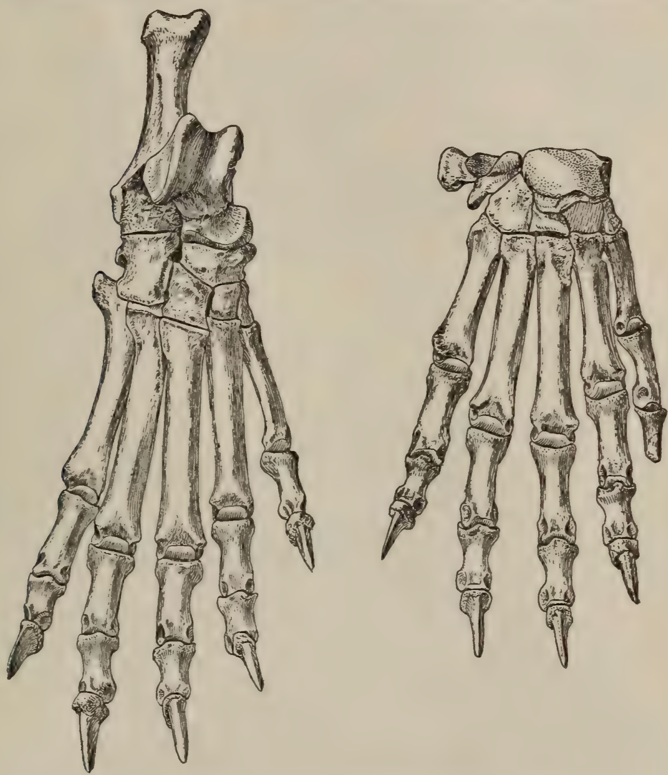

Figure 23—Dorsal view of the hind foot and the fore foot of *Daphoenodon superbus*. Peterson, 1910.

White River Oligocene and Miocene forms are certain foxes now inhabiting South America.

According to Cope, the Canidae, so far as concerns structure, occupy a position intermediate between the generalized carnivores, such as the raccoons, and the highest specialized forms, the cats; but in brain character they display superiority to all of the other carnivore families. The chief difference between the Tertiary and the living forms lie in the higher specialization of the latter, particularly as regards foot structure and brain character.

The Canidae seem almost certainly to have descended directly from the early Eocene Creodonta, but so undoubtedly did the Felidae. During the Oligocene time the two families were much generalized and had many characters in

Figure 24—Skull of *Daphoenodon superbus*. Peterson, 1906.

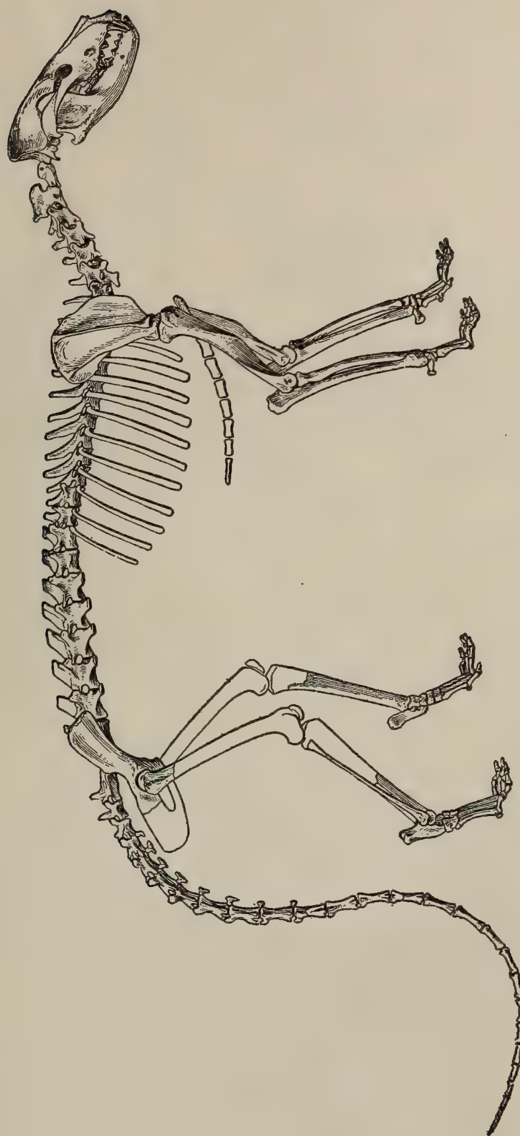

Figure 25—Skeleton of the Oligocene bear dog, *Daphoenodon superbus*. Peterson, 1910.

common, particularly in the dentition, the structure of the skull, the vertebrae, the limbs, and the feet. One feature of surprising interest, first indicated by Prof. Scott, is that some at least of the Canidae had sharp pointed, high, compressed, hooded claws, as in the cats, instead of curved, cylindrical cones, as in the dogs, and had the unmistakable ability of retracting the claws to a greater or less extent.

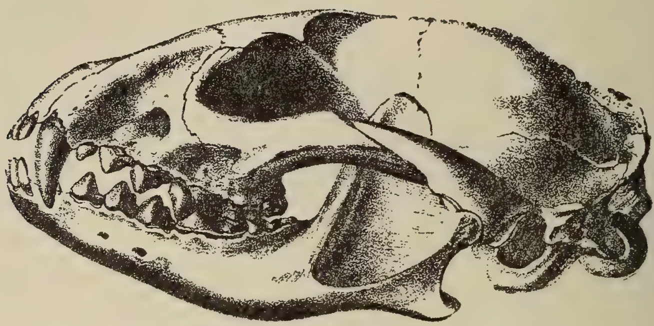

Figure 26—Skull of *Cynodictis gregarius.* Scott, 1898.

Although many specimens of the Canidae have been found in the White River badlands, few complete skeletons have been obtained. Until recent years little had been collected but heads. Of the several species *Cynodictis gregarius, Daphoenus felinus* and *Daphoenus superbus* are the best known. *Cynodictis gregarius* was most abundant and as the name implies seems to have roved the country in packs. It was smaller than the common red fox of the eastern states. *Daphoenus felinus* reached approximately the size of the coyote, while *Daphoenus superbus* was as large as a full grown gray wolf. (See Plate 26). One species, *Ischyrocyon hyaenodus,* includes individuals of larger size. Partial remains of a young individual seem to indicate that the full grown animal would compare favorably with the modern grizzly bear.

Daphoenus seems to represent in pretty fair manner the ancestral stage of the present-day wolf. Cynodictis has many characters resembling those of the modern fox but close relationship has not been proven. A small brain was characteristic of all of the Canidae and this was particularly true of Daphoenus.

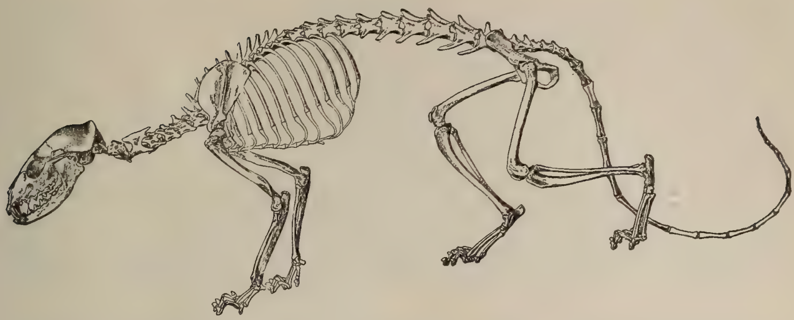

Figure 27—Skeleton of the Oligocene dog, *Cynodictis gregarius*. Matthew, 1901.

FELIDAE

The cat family is well represented in fossil form in the White River region, although neither the species nor the individuals were so numerous as were the Canidae. Two genera are of particular prominence, namely, Hoplophoneus and Dinictis. These are early forms of what are commonly known as saber-tooth cats or tigers (Machaerodonts), a name given them by reason of two great sword or saber-like canine teeth of the upper jaw. They were not so large as certain later forms of this great group, nevertheless they were vicious creatures and Hoplophoneus, the larger of the

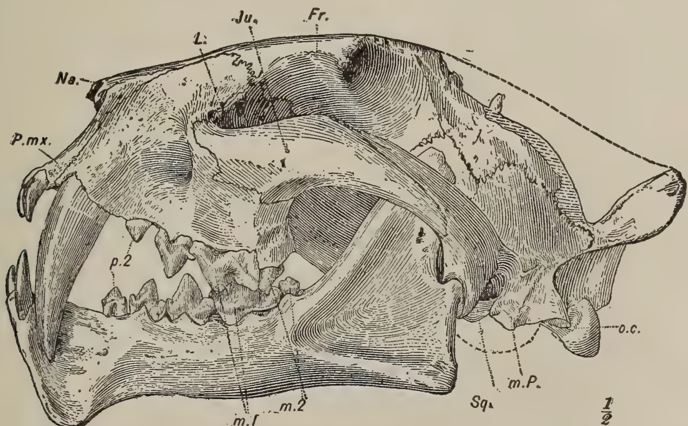

Figure 28—Skull of the Saber-tooth tiger, *Dinictis squalidens*. Matthew, 1905.

two, was doubtless fully as large as the present day leopard and apparently much more powerful. (Plates 27 and 28). The two represent well separated stages in the evolution of saber-tooth cats, and while Dinictis seems to have reached as high a stage of specialization as Hoplophoneus, it was evidently fitted to a somewhat different life.

An important feature of the lower jaw is the extreme downward projection of its anterior portion. This seems to be a co-incident feature necessitated by the unprecedented development of the powerful canine teeth already mentioned.

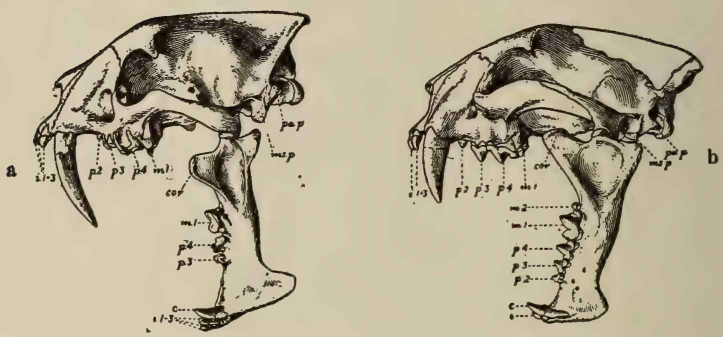

Figure 29—Heads of White River Saber-tooth tigers showing open jaws ready for attack. (a) *Hoplophoneus primaevus* (b) *Dinictis squalidens*. Matthew.

These upper canine teeth curve forward and downward nearly parallel with each other, and passing behind the much smaller lower canines, continue approximately to the lowest portion of the anterior downward prolongation of the chin. In general they are laterally compressed and the edges are more or less serrulated. They are implanted by a strong fang and reach two and one-half or three inches in length. In Hoplophoneus, these fangs were very long and slender and the protecting jaw flange was correspondingly deep. Dinictis had shorter canines and a less prominent jaw flange.

The cause of the development of the abnormally powerful upper canines and the uses to which they were put have been the cause of much speculation. (Plates 11 and 12.) W. D. Matthew of the American Museum of Natural History in discussing this indicates that in his opinion there is definite evidence of the adaptation of the canines to a particular method of attack. The head is so shaped that good attachment is allowed for strong muscles, enabling the animal to strike downward with its saber teeth with enormous power and the changes in the cranial por-

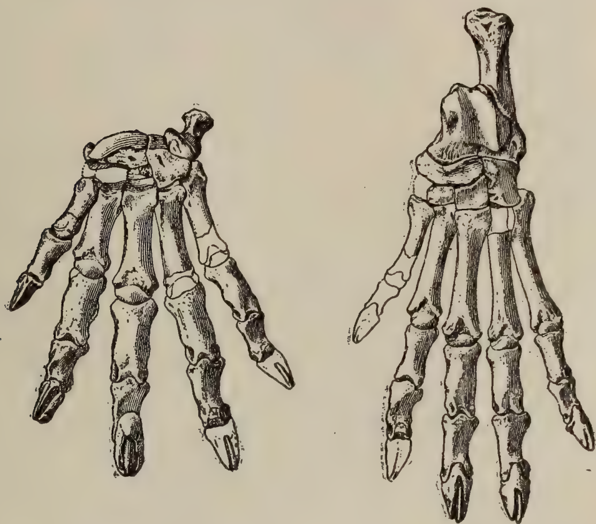

Figure 30—Dorsal view of the fore foot and the hind foot of *Hoplophoneus primaevus*. Adams 1896.

tion allowing for the attachment for the increasingly powerful muscles were in strict correlation with the development of the saber-teeth. Along with these changes was the degeneration and change in shape of the lower jaw, allowing the mouth to be opened to an unusual extent so as to give greatest freedom to the saber-teeth in stabbing the prey. Hoplophoneus in addition to his terrible teeth had a strong body, stout neck and legs and highly developed strong retractile claws. His food must have been in large measure the thick skinned rhinoceroses, elotheres, oreodonts, and other similar animals of the time. The lighter proportioned

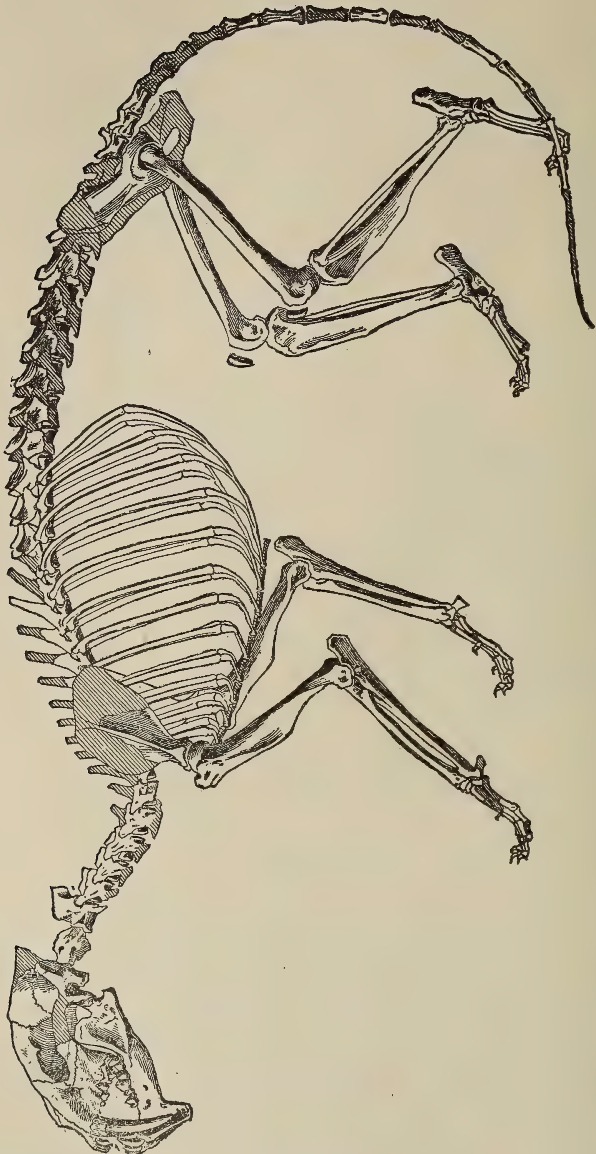

Figure 31—Skeleton of the Oligocene Saber-tooth tiger *Hoplophoneus primaevus*. Scott and Osborn, 1887.

Dinictis, with its less powerful canines, doubtless preyed more successfully on the smaller swift-footed animals, the securing of which demanded superior speed and endurance.

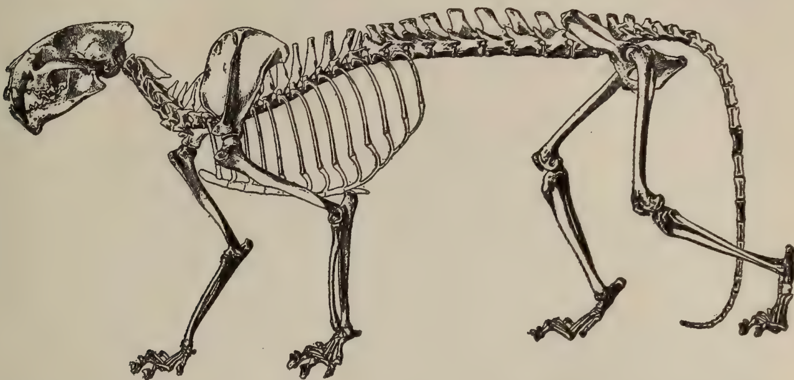

Figure 32—Skeleton of the Oligocene saber-tooth tiger ***Dinictis squalidens.*** **Matthew, 1901.**

The White River badlands furnished the earliest discovered remains of Saber-tooth cats in America. Leidy who described the first species gave it the name *Machaerodus primaevus.* Later this was changed to *Depranodon primaevus,* and still later to *Hoplophoneus primaevus,* the name it now bears. From time to time other species have been discovered until now about a dozen are known. They were all most terrible beasts of prey and one of them *Eusmilus dakotensis,* approaching the size of the African lion was the largest carnivore of its time.

MUSTELIDAE

The Mustelidae of the present day include such animals as the badgers, minks, martens, weasels, ermines, skunks, otters, and ratels· Fossil members of the family have been found in some abundance. The more ancestral forms continue back to Eocene time, but no clearly defined species have as yet been identified in the White River badlands in rocks older than the Miocene.

None of the remains discovered are complete, and nearly all are more or less mutilated. Those of *Megalictis ferox,* however, are sufficiently characteristic to indicate much of the nature of the animal. They represent a very large musteline. The head is short, wide, and massive, brain small, tail long and powerful, limbs short and stout, feet plantigrade, number of toes five, claws large and non-retractile. The animal is characterized as a gigantic wolverine, equalling a jaguar or a black bear in size, but in proportion more like the ratel. It was evidently predaceous like the wolverine, but seems to have been to some degree of burrowing disposition.

INSECTIVORES

Remains of insectivorous animals are recognized as far back as earliest Tertiary time, but the fossils are not abundant. The White River badlands have yielded several species, but they are fragmentary. They belong to several families, particularly the hedgehogs, the shrews and the golden moles. The identification of fossil remains of the golden mole in South Dakota brought up certain important questions and speculations. True moles (Talpidae) are now found in the subarctic or temperate zones of all the northern continents, but not in or south of the tropics. However, in the south temperate zone, there are animals which have adopted mole-like habits and superficially resemble the true moles to a greater or less degree. The Chrysochloridae or golden moles of South Africa are of this nature. A similar animal in fossil form has been found in the Upper Miocene of southern South America. The peculiar geographical distribution of certain animals and plants of southern lands has long been a source of speculation and study and this finding of a fossil golden mole in South Dakota so far removed from its present day and fossil relatives, adds a new feature of interest.

RODENTS

The rodents or gnawers as regards numbers are overwhelmingly predominant among living mammals. Their most prominent and universal character, the dentition, shows the absence of canine teeth and the paramount importance of front teeth or incisors. They appear to have originated in North America in early Eocene time and to have been rather rapidly distributed to the other great land masses of the earth. In the White River region they appear first in the Middle Oligocene, ancestral squirrels, rabbits, beavers, and rats, being represented. The beavers or beaver-like animals continue into the Upper Oligocene, the Lower Miocene and the Upper Miocene. They are particularly abundant in the Lower Miocene. Rabbits occur also in the Lower Miocene as well as certain poorly preserved forms supposed to be related to pocket gophers.

The number of specimens found indicates a considerable abundance of rodents in the region during Tertiary time, and the number of species adds emphasis to this. It happens, however, that but few complete skeletons have been obtained, the best material consisting largely of skulls and lower jaws, and in several of the species named, the description has been based on still more fragmentary material.

The earliest specimens of the rodents obtained were found by Hayden in the Big Badlands, and described by Leidy. With the exception of two other species described many years ago by Cope, little further information became available until the last few years, during which time Mr. Peterson of the Carnegie Museum, and Mr. Matthew of the American Museum of Natural History, each described a number of species. The Carnegie Museum material has come chiefly from northwestern Nebraska and eastern Wyoming, the American Museum material from Little White river.

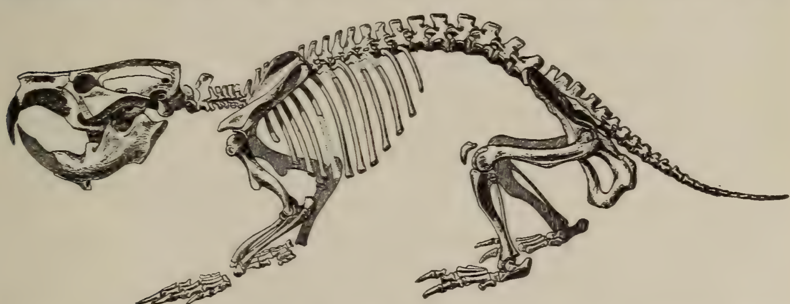

Figure 33—Skeleton of the Lower Miocene burrowing rodent *Steneofiber fossor.* Peterson, 1905.

The commonest fossil is Steneofiber. This is especially abundant in the Lower Rosebud beds of Little White river and in the Harrison (Daemonelix) beds in northwestern Nebraska and in eastern Wyoming. Entoptychus, the gopher-like rodent, seems to be fairly common in the Little White river area also. Peterson found many specimens of

Steneofiber fossor in close association with the Devil's Corkscrews of the Harrison beds and, as referred to elsewhere, suggests the reason for the association. This animal was smaller generally than the present day beaver. Its skull is comparatively large, the lower jaws heavy, neck short, limbs and feet powerful, tail round, rather heavy and of moderate length. Peterson states that the limb presents a striking similiarity to that of other burrowing rodents and approaches that of the mole in its position. The elongated and narrow scapula of the mole, the heavy clavicle, the strongly built humerus, and the broad foot with the long and powerful unguals, is rather suggestive of the habits of this animal, which was probably burrowing to a considerable degree. The animal is related to the beaver, but is evidently not in the direct line of ancestry.

UNGULATES

The order Ungulata (Herbivores) as now constituted includes the mammals once loosely classed as Ruminants, and Pachyderms. The earliest known forms much resemble the primitive Carnivores. The ancestors of both seem to have been omnivorous.

For some reason there appeared very early among the Ungulates a tendency to develop the herbivorous type of tooth and the digitigrade foot (walking upon the tips of the toes). The change in the foot from the five toed plantigrade form progressed along two different lines and thus there were produced two very different types, ,namely, the odd-toed type and the even-toed type. In the odd-toed type the axis of the foot is in the third or middle digit (mesaxonic). Animals of this type are known as Perissodactyls. In the even-toed types the axis of the foot is between the third and fourth digits (paraxonic). Animals of this type are known as Artiodactyls. The horse, the tapir, and the rhinoceros are well known representatives of the perissodactyls. Among Artiodactyls are the camel, lama, deer, giraffe, antelope, ox, sheep, goat, and bison.

PERISSODACTYLS

Perissodactyls, as above stated, have the axis of the foot in the third or middle digit. They are generally odd toed, the third toe being the largest and sometimes the only functional one. The tapir, an anatomically unprogressive creature, is a partial exception in that it has four toes on the front foot and three toes on the hind foot. Similar exceptions or seeming exceptions occasionally existed in the evolutionary development of other perissodactyls, nevertheless the bisection of the third toe by the median plane of the foot early asserted itself and has continued with firm persistence.

Existing perissodactyls include animals of greatly differing appearance and habits but their skeletal characters indicate with certaintly their relationship and skeletal characters indicate also the wide gap between them and other hoof-bearing creatures.

The perissodactyls constitute a restricted group and although many prehistoric forms are known—in all about five hundred species—living species are confined to the three well known families, rhinoceroses, tapirs, and horses. Of fossil forms the following families are represented in the White river badlands: Titanotheridae, Equidae, Tapiridae, Lophiodontidae, Hyracodontidae, Amynodontidae, and Rhinocerotidae.

The living forms so far as concerns their present natural habitat, with the exception of the American tapirs, are all confined to the Old World. Gidley calls attention to the fact that this is the more interesting since North America seems to have been the birth place or at least the stage for the development, not only of the early representatives of all the living Perissodactyls, but of most of the extinct groups of the order as well and that half the total number of perissodactyl species described have been founded on specimens from the Tertiary and Quaternary formations of this country.

RHINOCEROTOIDEA

The finding of fossil bones of true rhinoceroses in the Big Badlands by Alexander Culbertson in 1850, and their prompt and accurate identification by Leidy, constitute one of the most interesting, unexpected, and instructive paleontological discoveries of America.

Existing rhinoceroses are confined to Africa, the Indian Archipelago and the southern parts of Asia. These form but a small representation of the numerous ancestry that abounded in North America from Middle Eocene to late

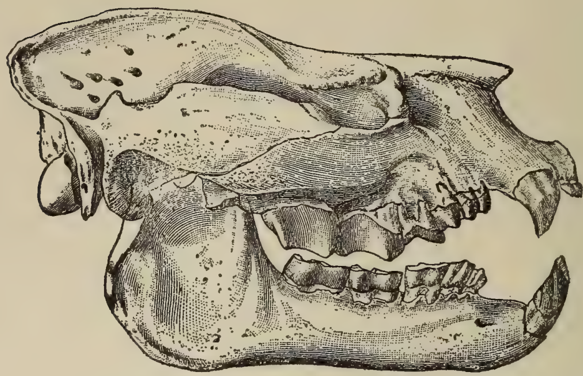

Figure 34—Skull of *Metamynodon planifrons*. Osborn, 1896.

Miocene time and in Europe from Eocene to Pliocene time. There is much reason for believing that the rhinoceros family originated in North America and subsequently spread to the old world but this has not as yet been proven.

All rhinoceroses, living and extinct, are divided by Osborn into three subdivisions, as follows. The Hyracodontidae or cursorial (upland) rhinoceroses; the Amynodontidae (aquatic) rhinoceroses, and the Rhinocerotidae or true (lowland) rhinoceroses. Of these the first two are found only in

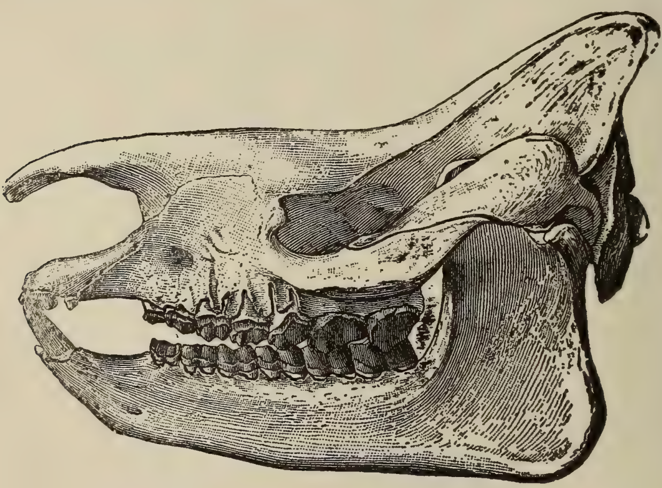

Figure 35—Skull of *Caenopus tridactylus*. Osborn, 1898.

the fossil state, the third is found both fossil and living. In America, the cursorial rhinoceroses are found first in the Middle Eocene, the aquatic rhinoceroses in the Upper Eocene, and the true rhinoceroses in the Lower Oligocene. The first two became extinct here in the Oligocene, but the true rhinoceroses endured until after the close of the Miocene. All three occur in fossil form within the area described in this paper, the cursorial and aquatic species in the Oligocene, chiefly in the Middle Oligocene, the true rhinoceroses throughout both the Oligocene and the Miocene.

The three families differed greatly from one another, both in exterior form and in dental and skeletal structure. The Hyracodonts were small, light chested, swift footed,

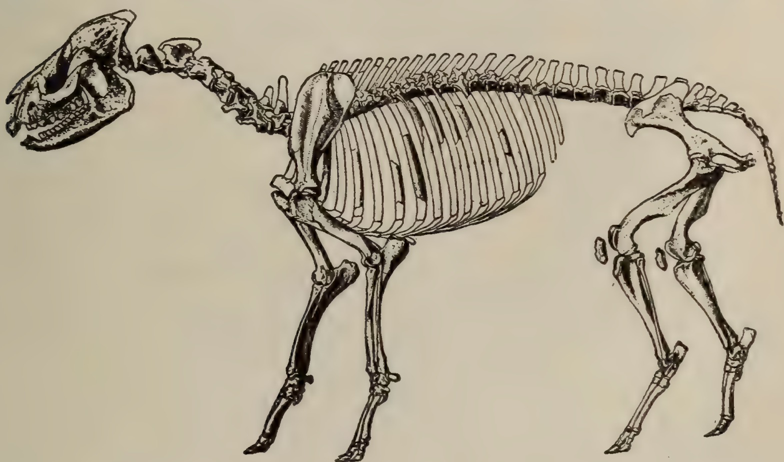

Figure 36—Skeleton of the small, swiftfooted Oligocene rhinoceros, *Hyracodon nebrascensis*. Osborn, 1898.

hoofed, hornless creatures, much resembling the Miocene horses and evidently well-fitted for living on the grass-covered higher lands. (Plates 30 and 38). The Amynodonts were heavily built, short-bodied, hornless animals, with spreading padded feet, four functional toes in front, eyes and nostrils much elevated supposedly for convenience in swimming, canine teeth enlarged into recurved tusks, and a prehensile upper lip, apparently tending toward proboscoid development. (Plates 29 and 30). The animal evidently much resembled the present day hippopotamus, both in build and in habit. One adult skeleton, that of *Metamynodon planifrons* in the American Museum of Natural History, measures nine and one-half feet long and four and one-half feet high at the shoulders. The true rhinoceroses began as light limbed, hornless animals, intermediate in proportion between the two just mentioned, and in size and structure were not greatly unlike modern tapirs. During much of their early life history they, like the more primitive Hyracodonts and Amynodonts, were entirely without horns.

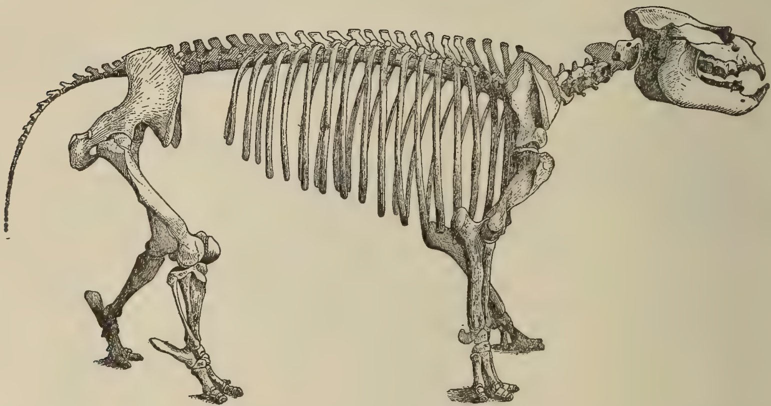

Figure 37—Skeleton of the heavy, marsh loving Oligocene rhinoceros, *Metamynodon planifrons*. Osborn, 1898.

The true rhinoceroses constitute in many respects the most important of the three subdivisions and to the paleontologist are of profound interest. They lived in great numbers in the region of the Black Hills during Oligocene and Miocene time, and their skeletons in certain favored localities, particularly in the Big Badlands and in Sioux County, northwestern Nebraska, have been collected in abundance. The Oligocene forms are especially characterized as being without horns, hence the old name Acerathere. (Plate 15). The Miocene forms have generally, but not always, a rudimentary or fairly well developed pair of horns placed transversely across the anterior part of the head, hence the name Dicerathere. (Plate 26). Present day rhinoceroses, it should be remembered, have either no horn or one or two horns, but the arrangement when horns are present is always medial, never transverse. It is of in-

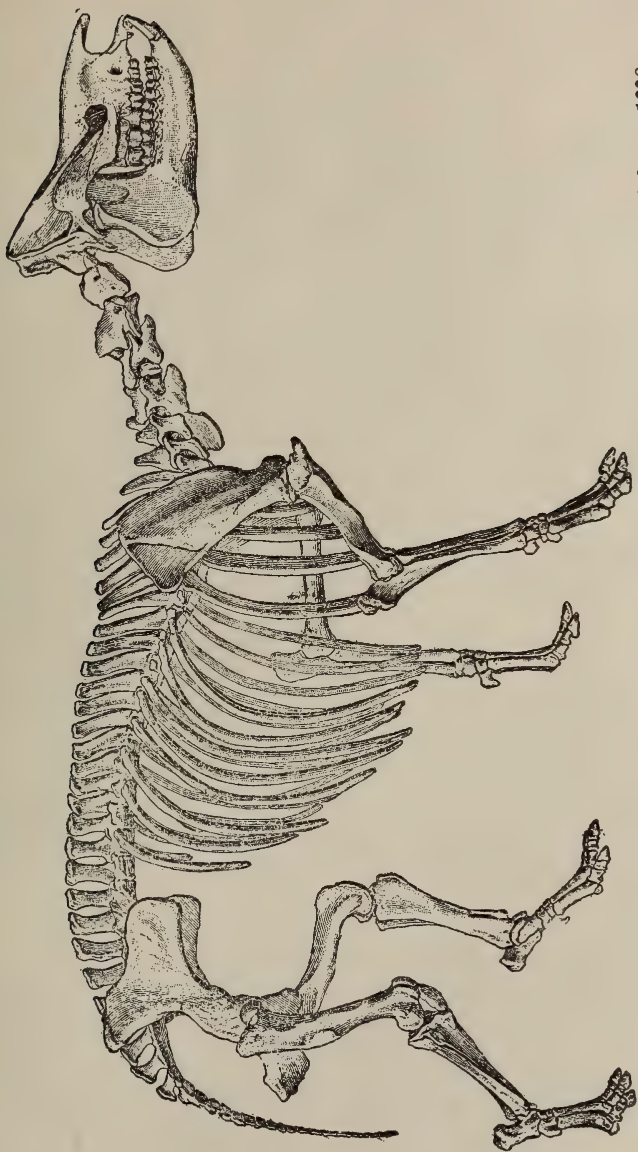

Figure 38—Skeleton of the Oligocene true rhinoceros, *Caenopus tridactylus*. Osborn, 1898.

terest to note also that while all living rhinoceroses have feet that are functionally tridactyl, some of the ancestral true rhinoceroses, at least so far as concerns the front feet, were functionally tetradactyl. This is known to be true of *Trigonias osborni* and is suspected of others. This lessening of the number of functional toes corresponds to similar alterations in other animals and indicates progressive change. Indeed, the rhinoceroses show in many ways gradual transformations, particularly with reference to the feet, the teeth, and the development of horn cores.

Among the Aceratheres *Caenopus mitis* was the smallest, its height at the shoulders being approximately twenty-eight inches. Among the Diceratheres *Diceratherium schiffi* was the smallest. It was also most specialized. The largest of the Aceratheres, in fact the largest of all the true rhinoceroses, seems to have been *Caenopus platycephalus.* It considerably surpassed the present day Sumatran rhinoceros. Among the others *Caenopus copei* was about the size of the American tapir and *Caenopus tridactylus*, measuring seven feet, nine inches in length, and four feet high to top of the rump, was nearly as large as the Sumatran rhinoceros.

LOPHIODONTIDAE

The lophiodonts, closely related to the ancestral tapirs, are the most generalized of all known perissodactyls. The fossils that have been found are in general very fragmentary but they indicate a group of animals of great interest. Much uncertainty prevails as to the exact relationship of the Lophiodonts, but they are known to have many of the primitive characters of the tapir, the hyracodont, and the horse.

CHALICOTHERIDAE

The study of fossil bones has oftentimes brought out very unexpected information. The unravelling of the story of the Chalicotheres is a good illustration of this in that it presents a pronounced exception to Cuvier's law of correlation. Certain peculiar foot bones found at Eppelsheim, nearly one hundred years ago were pronounced by Cuvier to be those of a gigantic pangolin (an edentate). These were described by Lartet under the name Macrotherium (Big Beast). Later some skull fragments with teeth found in the same Eppelsheim locality were described under

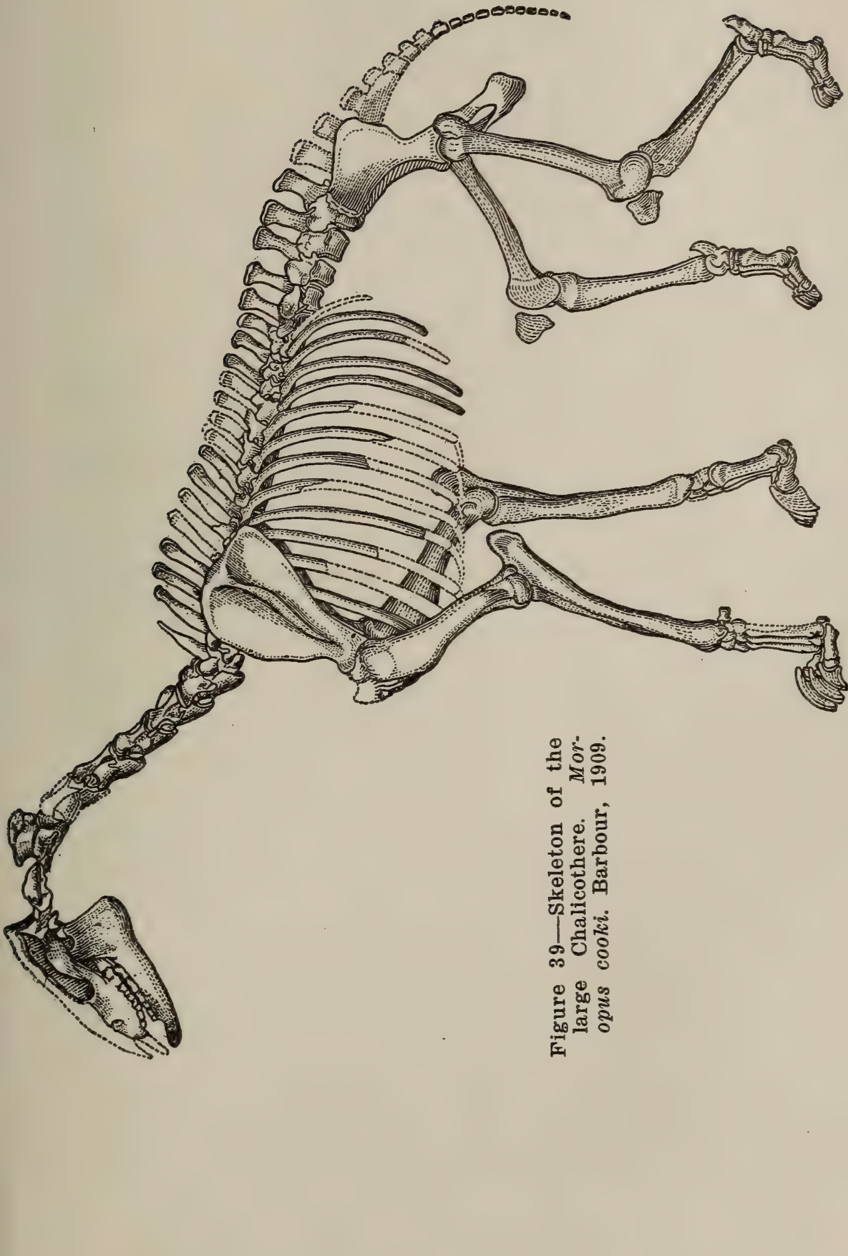

Figure 39—Skeleton of the large Chalicothere. *Moropus cooki.* Barbour, 1909.

the name Chalicotherium (Beast of the Gravel). The teeth were somewhat similar to those of the rhinoceros hence these head parts were regarded as belonging to one of the ungulates. Some paleontologists believed at first that they represented the artiodactyles but later they were generally considered as representing the perissodactyls. The foot bones continued to be regarded as belonging to the Edentates. Filhol, a French paleontologist, in 1887 reflecting upon the fact that Macrotherium foot bones were not uncommon and that Chalicotherium teeth were pretty well known but that no one had discovered feet of the latter nor head of the former, began to suspect that the two represented the same creature. The discovery a little later of nearly complete skeletons under favorable conditions definitely established the correctness of this supposition. It is of interest that in more recent years American discoveries have added greatly to our knowledge of these strange creatures. Several localities have afforded remains of which the most important has been the famous Agate Springs locality in northwestern Nebraska. The deposits are known as the Harrison beds. Director W. J. Holland and Mr. O. A. Peterson of the Carneige Museum in 1909 described in elaborate manner some of the best Agate Springs material found up to that time and summarized in good form the descriptions given in the publications of other investigators. Later the American Museum of Natural History made important discoveries in the Agate Springs locality and in their five summers (1911-1914, 1916) of excavation unearthed there within an area of about thirty-six feet square nearly complete skulls of ten individuals and skeletal parts of seventeen individuals. This material added new information of importance until now the size and nature of the animal are known to a high degree of certainty.

All of the chalicotheres found in the Agate Springs quarries have been designated as belonging to the genus *Moropus*. Several species have been described. The largest is *Moropus elatus,* an animal as large or larger than the African rhinoceros. (Plate 31). Others are considerably smaller.

Moropus in life was evidently very grotesque in appearance. The head resembles not a little that of the horse, or the primitive rhinoceros. The neck is heavier than that of the horse although very similar in shape, while the body has some resemblance in general outline to the rhinoceros. The head is small but the body is heavy and is supported by heavy limbs and feet. The fore limbs are larger than the hind limbs and this gives to the animal a corresponding pose. The feet, terminating in bifid, clawlike bones are especially distinctive, combining in peculiar manner characteristics of the ungulates and apparent characteristics of the Carnivores, and of animals accustomed to digging. (Plates 17 and 32). Osborn says, "Moropus may be characterized as a forest-loving, slow moving animal, not improbably frequently rather swampy ground. The small head, relatively long neck, high fore quarters, short, downwardly sloping back, straight and elongated limbs, suggest a profile contour only paralleled by the forest-loving okapi among existing mammals. The foot structure, of course, is radically different from that of the okapi, but we should not regard it as fossorial, or of the digging type, because it is not correlated with a fossorial type of fore limb. It would appear that these great fore claws, in which the phalanges were sharply flexed, were used in pulling down the branches of trees and also as powerful weapons of defense." The illustrations give a better idea of the animal than can readily be obtained by simple description.

TAPIRIDAE

The present day tapirs, like the horse, are the descendants of a very ancient family. Unlike the horse, however, specialization in the tapir has not advanced to a high degree, and so far as foot structure is concerned, and to a considerable extent tooth structure also, the modern representatives of the tapir are in much the same condition as the early ancestral horses. They are very similar to the Lophiodonts just mentioned. Indeed, these animals and the ancestral tapirs show so many characteristics of such decided similarity or of such a vague nature as to render their separation and classification a matter of difficulty and some uncertainty.

Fossil remians of the Tapiridae are comparatively rare. They, however, have had a wide geographical distribution and are known to be present in rocks of nearly every period since earliest Tertiary time. Three species, described from the Big Badlands, all belonging to the genus Protapirus, are believed to be in the direct line of ancestry from the modern tapirs. (Plate 14). All of the specimens secured have come from within or near the Big Badlands. The material is not abundant and consists chiefly of skulls, lower jaws, and certain limb bones.

Prof. Scott suggests that the scarcity of the remains is probably because tapirs have always been forest-haunting animals, hence their habits must have kept them in places remote from areas where the accumulation of sediments was in progress and thus only occasional stragglers were buried and preserved.

EQUIDAE

Of all the fossils of the White River badlands perhaps none have elicited more genuine interest than those of the Equidae, or horse family. The ancestry of the horse is in full harmony with the proud position he holds among present day animals. No other mammal displays such a lengthy, well connected lineage, nor discloses a more beautiful handiwork in the well-ordered development of structure and habits. For perhaps three million years or more, members of the family have roamed the hills and dales of the earth, molding their nature to an ever changing environment, discarding many things inherited from their evident Cretaceous five-toed progenitors, and taking on new features leading to the exquisite relation of organs and actions in the finely-built horse of today.

The earliest known members of the family is the little Hyracotherium, or Eohippus of the Eocene, less than one foot in height, with four well developed toes on each front foot, and three on each hind foot. Splint bones indicate the earlier presence of five toes on the front foot and four on the hind foot, and there is good reason for believing that at some still earlier stage the pentadactyl nature was complete. In connection with the progressive enlargement of the middle toe, profound alteration also took place in other parts of the anatomy, particularly the lengthening of the jaws, increasing complexity of the teeth, pronounced elongation of the lower part of the limbs, and the degeneration of the ulna and fibula.

Figure 40—Skeleton of the three-toed Oligocene horse. *Mesohippus bairdi.* Farr, 1896.

The phylogeny of the horse was first suggested by the great French paleontologist, Cuvier. The earliest attempt at its expreession was made by Kowalevsky, the Russian. He was followed in succesive order by Huxley of England, Marsh, Cope, Wortman and Scott of America, and Schlosser of Germany, and more recently by Osborn and others. Interpretation by the earlier men showed inconsistencies and omissions, but with increasing collections of well-preserved material it has been possible to eliminate aberrant forms and to add needful material, until now the genealogical series is fairly complete. In the unraveling of the relationships the monophyletic origin theory has seemed to lose much of its earlier supposed significance as supported by Marsh.

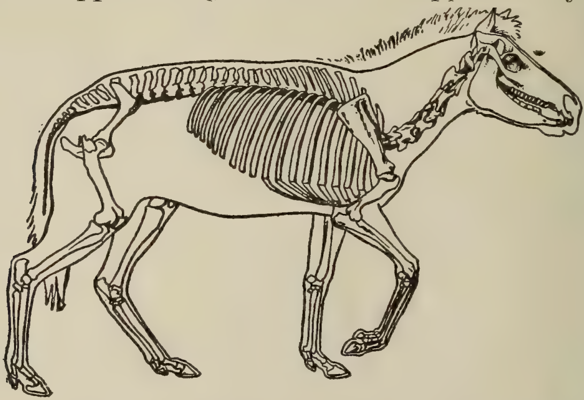

Figure 41—Skeleton of the beautifully preserved Upper Miocene three-toed horse. *Neohipparion whitneyi.* Original now in the American Museum of Natural History. W. B. Scott, A History of Land Mammals in the Western Hemisphere, 1913. Published by The Macmillan Company. Reprinted by permission.

Later paleontologists, particularly those following the work of Osborn in his study of the Titanotheres and Rhinoceroses and Osborn and Gidley in their study of the Equidae inclined to the polyphyletic theory, that is, that the representatives of a family instead of being necessarily derived from a single Eocene ancestor may be representative of several contemporaneous phyla represented by as many distinct types of the Eocene. For a diagrammatic representation of the more important evolutionary changes see Figure 48.

Fortunately the fossils representing the extinct horses are abundant and often well preserved. For some years the Peabody Museum of Yale University excelled all others in the extent and importance of its collections, but more recently the American Museum of Natural History has surpassed it. Gidley stated in 1907 that the latter collection then contained several thousand specimens—Eocene to Pleistocene, inclusive. Granger, 1908, says that the Hyracotheres (Eocene) alone were represented by several hundred specimens. Matthew and Cook, 1909, add the information that in their recent work in the Pliocene of northwestern Nebraska, they collected some hundreds of incomplete jaws and about ten thousand separate teeth, besides great numbers of limbs and foot bones. While it should be borne in mind that the above collections represent to a large extent fragmentary material, Osborn states, that in all the museums of the world there were in 1904 only eight complete mounted skeletons of fossil horses, but that of these, five were in the American Museum.

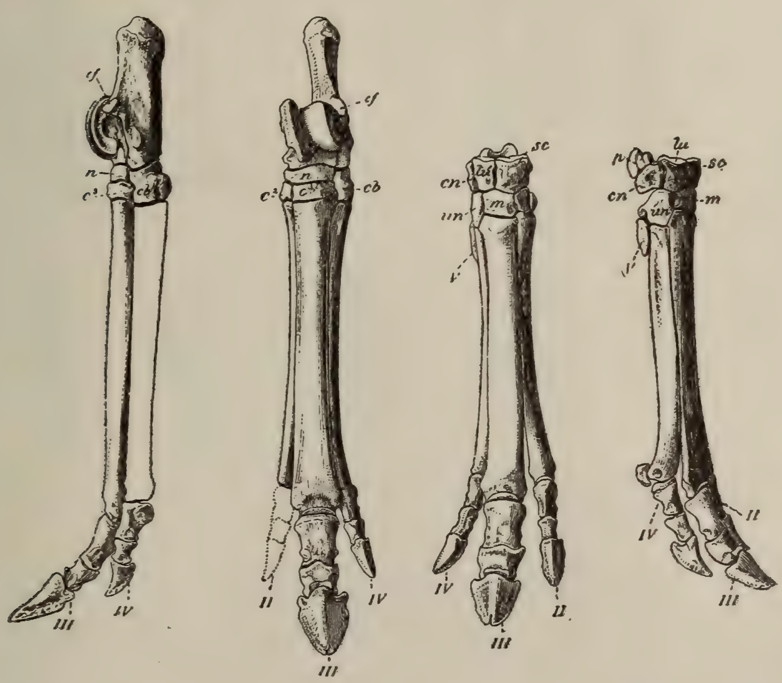

Figure 42—Right hind foot and left fore foot of the three-toed horse, *Mesohippus intermedius,* front and side views. Osborn and Wortman. 1895.

The abundance of the fossil remains and their widespread distribution geologically and geographically, clearly indicate that for ages members of the horse family ranged over the country in countless numbers. They were numerous in both North America and South America. Beginning, as they evidently did, in the earliest Tertiary or late Cretaceous in some generalized form of small height, probably no greater, according to Marsh, than a rabbit, they continued in increasing size to individuals larger than the largest draft horses of the present day. The earliest and the latest known members of the family do not occur in the deposits described in this paper, but intermediate forms are found in considerable numbers. These intermediate forms merit our chief attention.

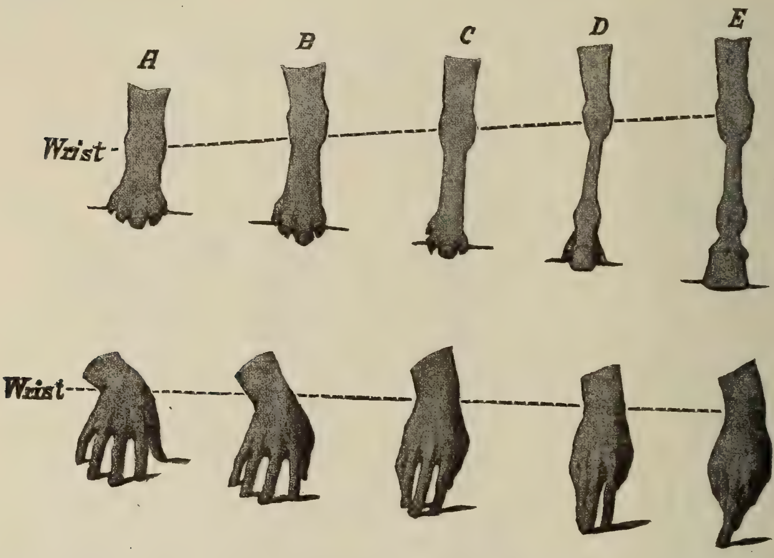

Figure 43—Illustration to show evolution of the fore foot in the Horse family. Osborn.

With one exception all horses of the White River badlands had three toes on each foot. Those of the older formations, particularly of the Oligocene, stand approximately midway in the genealogical line and show characters of absorbing interest.

It may be noted here that Eocene horses are four toed, with short crowned teeth; Oligocene horses are three toed with short crowned teeth; Miocene horses are three toed with progressively long-crowned teeth; Pliocene horses are sometimes three toed and sometimes one toed, with long crowned teeth; and Pleistocene horses are one toed with very long crowned teeth.

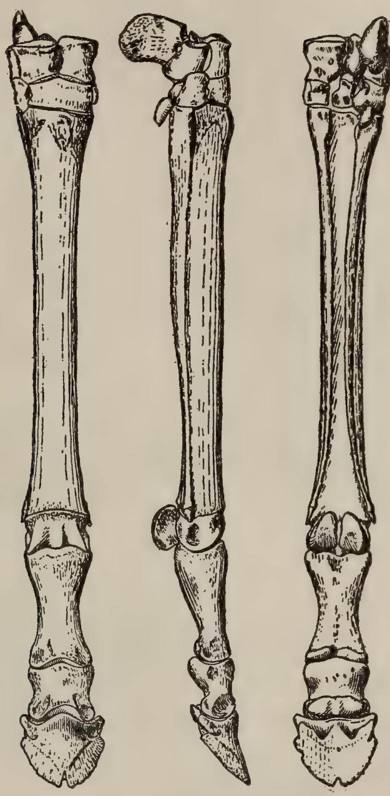

Figure 44—Right fore foot of the earliest known one-toed horse, *Pliohippus lullianus*. Front, side and back views. Troxell, 1916.

The earliest one toed horse of which we have knowledge is *Pliohippus lullianus* Troxell, a ten months old colt, a considerable part of the skeleton of which was found in the summer of 1916 in the valley of Little White river near the town of Mission in the eastern part of the Rosebud Indian Reservation. Remains of another monodactyl species *Pliohippus pernix* found somewhere on the Niobrara river was described in 1874 by Marsh.

Of the many species discovered, the commonest and most noted one is *Mesohippus Bairdi* of the Middle Oliocene. (Plates 16 and 33). In consequence of the fact that all of the earlier skeletons found were much broken and poorly preserved, and only the best bones saved, for forty years little was known of this animal except what could be learned from the foot bones and the head. Since 1890 several well preserved, nearly complete sketletons have been found and some of these have been dscribed in much detail. The adult animal averaged about eighteen inches in height, approximately the height of the coyote. It was a slender-limbed creature, very well adapted for speed. The hind limbs were much longer than the fore limbs, more so proportionately than in the present day horse, and the spines of the lumbar vertebrae were nearly if not quite as high as those of the dorsal region, so that, according to Farr, the rump must have been much elevated above the withers if the different parts of the limbs were not very much more

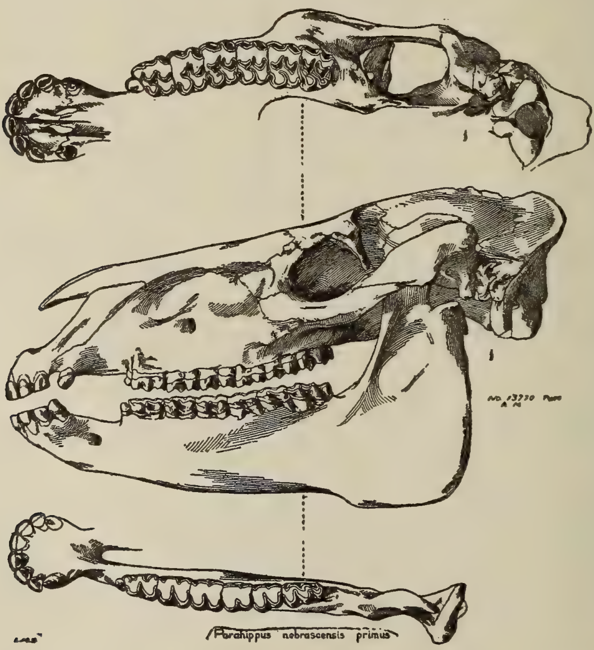

Figure 45—Skull of the browsing three-toed horse *Parahippus nebrascensis*. Osborn 1918. (Lower Miocene.)

flexed on each other than would seem justifiable, judging from recent animals. Scott states that the obliquity of the faces of the dorsal and lumbar vertebrae show that the back was decidedly arched.

The skull was about seven inches in length. The brain was large and apparently well convoluted. It weighed about one-third as much as the brain of the average present day horse. The number of teeth was forty-four, the arrangement on each side, above and below, as follows: Incisors, three;

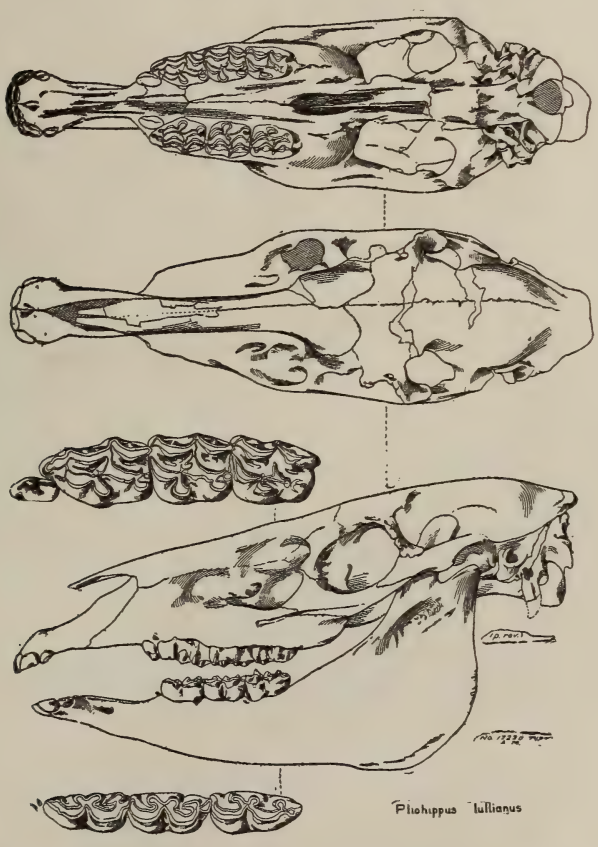

Figure 46—Skull of the earliest known one-toed horse *Pliohippus lullianus*. (A colt ten months old.) Named by Troxell and found near Mission, on the Rosebud Indian Reservation, South Dakota in beds of probably Lower Pliocene age. Osborn, 1918.

canines, one; pre-molars, four; molars, three. They were of the crested or lophiodont type and show the intermediate stage in the conversion of the short, round-knobbed and enamel covered crown, into the long, sharp-crested crown of cement, dentine, and enamel, as in the present day horse, so arranged that the unequal density of these tissues produces a hard, uneven grinding surface at all stages of wear.

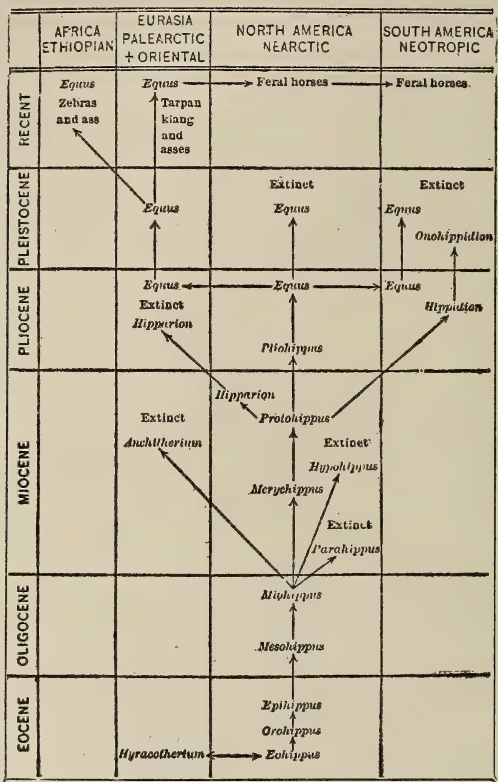

Figure 47—Phylogeny of the Horses. R. S. Lull Organic Evolution, 1917. Published by The Macmillan Company. Reprinted by permission.

The animal, unlike its present day representative evidently had to limit its food to soft vegetable tissue. Indeed it is of interest that the magnificent tooth battery of the horse developed pretty much in unison with the incoming of the hard grasses.

The most striking feature is the tridactyl nature of the feet. There were three well-developed toes on each foot, fore

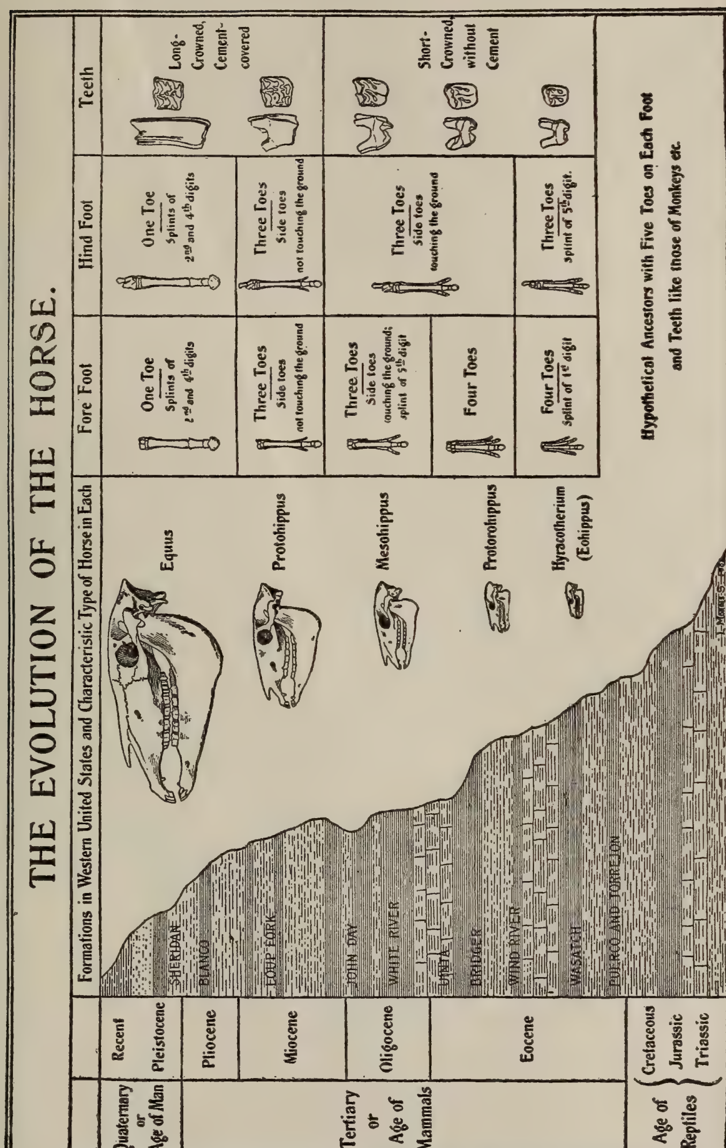

Figure 48—The successive changes in the development of the Horse, arrayed stratigraphically. Matthew, 1905.

and hind. These represent the second, third and fourth toes of five-toed animals. In addition to these, a splint bone on each fore foot represents the fifth toe, and a small nodule of bone is recognized as being the last lingering remnant of the first toe. The middle or third toe is longer and larger than the lateral ones and terminates in an enlarged, somewhat triangular bone, corresponding to the hoof bone of the present horse.

Among the later horses from the badland formations, *Neohipparion whitneyi* of the Upper Miocene is noteworthy. The type specimen found on Little White river by Mr. H. F. Wells of the American Museum expedition in 1902, and described by Mr. Gidley in 1903, is the most perfect fossil horse skeleton ever discovered. (Plates 24 and 34) The preservation of the skeleton is extraordinary, even the rib cartilages being found in place as well as the tip of the tail. The skeleton, approximately forty inches high, was that of a mare, and was found in association with the incomplete skeletons of five colts. It was proportioned like the Virginia deer, "delicate and extremely fleet-footed, surpassing the most highly bred modern race-horse in its speed mechanism, and with a frame fashioned to outstrip any type of modern hunting horse, if not thoroughbred."

Notwithstanding the highly developed nature of its skeleton Neohipparion represents a side branch of the horse family and for some reason, like Hypohippus, the "forest horse" and Parahippus, became extinct. Protohippus, an animal of about the same size as Neohipparion, survived and established for itself, as did the earlier Mesohippus, a definite place in the genealogical line leading to Equus of today.

TITANOTHERIDAE

The Titanotheres are the largest animals found in the White River badlands. With the exception of turtles and Oreodons they are also the most abundant. The family was a comparatively short-lived one but it has proven to be one of the most interesting known to vertebrate paleontology.

Dr. Hiram A. Prout of St. Louis, in 1846 and 1847, described briefly in the American Journal of Science a portion of the lower jaw of one of these animals, the first specimen ever obtained from the White River badlands, and called

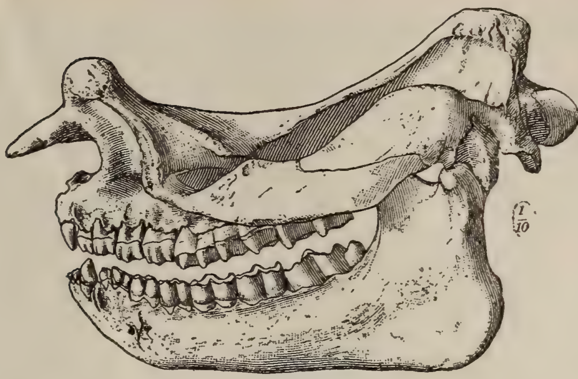

Figure 49—Skull of the Titanothere *Megacerops marshi.* Osborn, 1902.

it a Paleotherium. Later the true character of the specimen was recognized, a new name was necessitated, and Titanotherium (Titanbeast) suggested by Dr. Leidy in 1852, came into use. Since the finding of the earliest specimen many species have been described. The following White River phyla are now recognized: Menodus, Allops, Brontops, Megacerops, Brontotherium. They are distinguished from one another by differences in tooth and horn structure, the shape of the head, and the relative length and massiveness of the limbs. They are all included under the general term Titanotheres. Of these the Brontotheres were the latest and the largest.

Figure 50—Skull of the Titanothere *Brontotherium platyceras.* Osborn, 1896.

Mr. Hatcher in 1886, while searching for Titanothere remains in South Dakota and northwestern Nebraska, discovered that certain forms of the skulls of the Titanotheres are charactertistic of certain horizons in the beds, and this indicated to him the importance of keeping an exact record of the horizon from which each skull or skeleton was taken. Continued search showed that a regular and systematic development took place in these animals from the base to the top of the beds. The most notable change was a gradual and pronounced increase in size. Hatcher says: "This increase

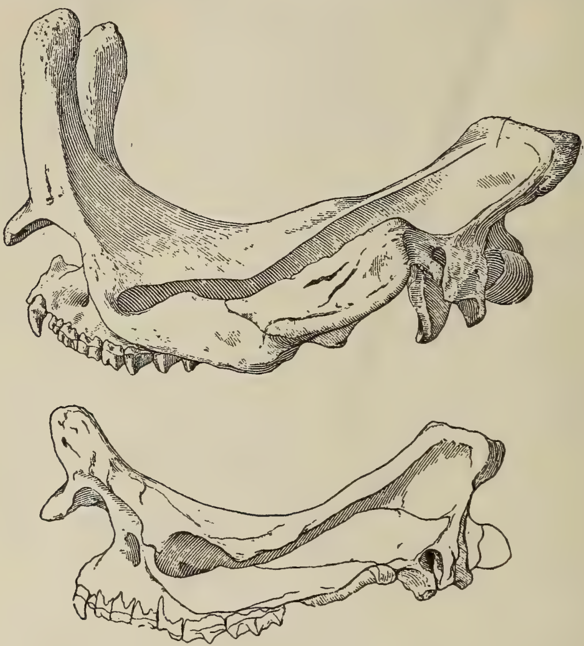

Figure 51—Skulls of *Titanotherium elatum*. Upper skull, male; lower skull, female. Osborn, 1896.

in size from the base to the summit of the beds was attended by a very marked development in certain portions of the skeleton, noticeable among which are the following: A variation in shape and an increase in the size and length of the horncores as compared with the size of the skulls was attended, near the summit of the beds at least, by a decided shortening of the nasals. There were also changes taking place in the dentition of these animals, especially in the number of incisors and in the structure of the last, upper, true molar. The number of incisors, though probably never constant, even in the same species, shows a tendency to decrease in skulls found near the summit of the beds.

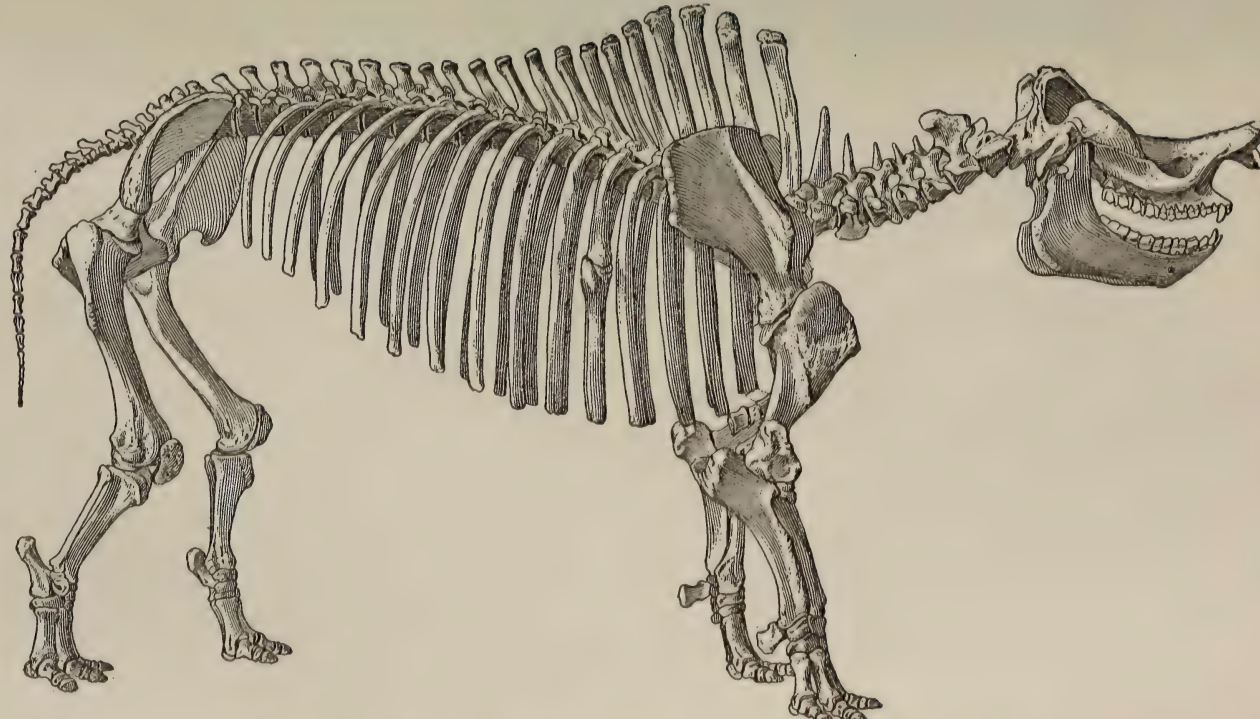

Figure 52—Skeleton of the large Lower Oligocene Titanothere, *Megacerops robustus* from Corral Canyon, approximately one twenty-fifth natural size. Original in the American Museum of Natural History. Osborn and Wortman. 1895.

At the base of the beds the number of incisors is from one to three on a side, while at the top there are never more than two on a side, often only one, sometimes none. In skulls from the very lowest beds the incisors have already become so rudimentary as to be no longer functional. As would be expected, the number of incisors decreased after they became of no functional value. In the matter of incisors the Titanotheridae at the time of their extermination, were in a fair way to accomplish just what the somewhat related, but more persistent, Rhinocerotidae have nearly succeeded in doing, namely: the elimination of the incisor dentition. In view of this weak frontal dentition it would seem that for the securing of its food, the animal must have been provided with a long tongue and a prehensile lip.

The Titanothers had their origin in early Eocene time, were of considerable importance throughout the Bridger and Uinta periods, reached their culmination during Lower Oligocene time, and became wholly extinct at the close of the latter period. (See Fig. 53). They present one of the most interesting illustrations known of rapid evolution in size and special characters followed by quick extinction. They developed slowly at first, and although they may be traced for perhaps half a million years, they seem to have left absolutely no descendants. Outside of North America the Titanotheres have been recognized only in Hungary and Bulgaria, these latter localities have but one representative each.

During the time of their greatest development the Titanotheres were the largest of all the mammals in the localities where they lived. They were well prepared by size and offensive weapons for combating the attacks of predaceous animals and they were possessors of perhaps the most efficient dental equipment ever developed for masticating coarse vegetable food, such as evidently flourished in abundance in the region at that time. Their size was comparable to that of the present day elephant, averaging slightly smaller. One of the best known skeletons, that of *Megacerops robustus* found in Corral Canyon and restored in 1895 by Osborn and Wortman of the American Museum of Natural History measures thirteen feet, eight inches in length, seven feet, seven inches in height, and breadth across the pelvis three feet, ten

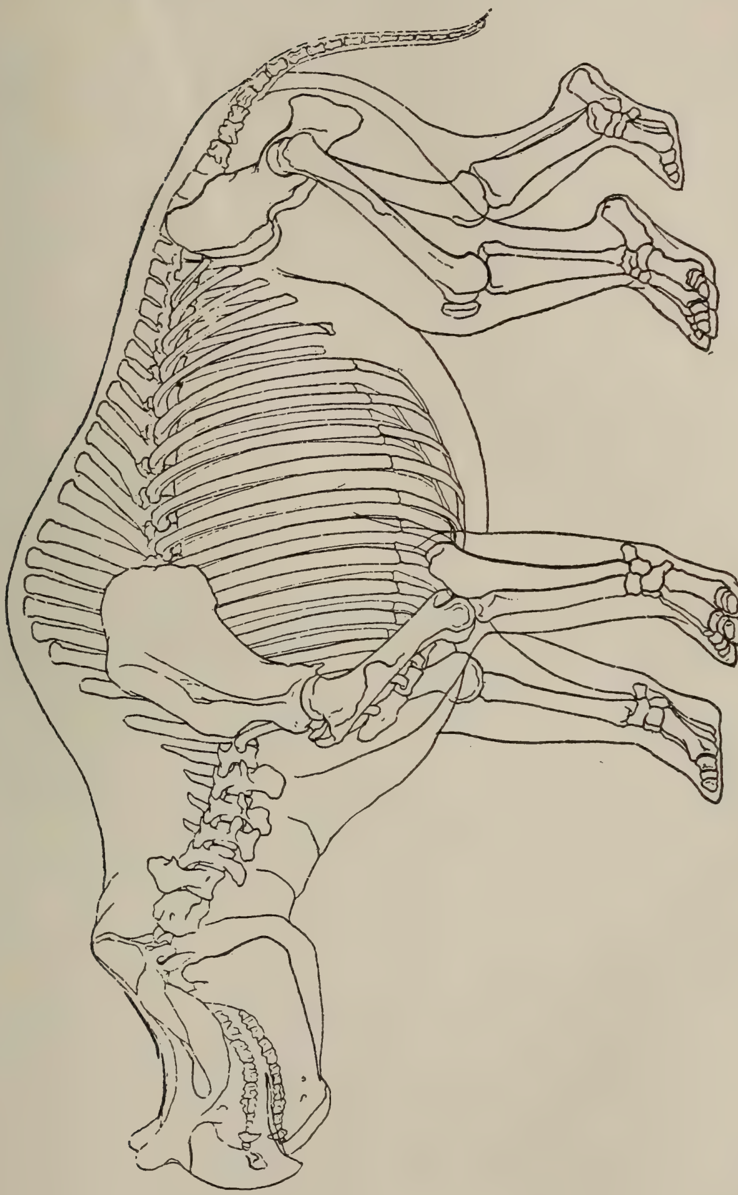

Figure 53—Skeleton of *Titanotherium prouti* of the Lower Oligocene. Scott and Osborn, 1887. Later modified, 1895 by Osborn and Wortman.

inches. This would indicate an animal fourteen feet or more in length and fully eight feet high.

In general appearance the Titanothere showed some resemblance to the rhinoceros, particularly as to the head. The limbs are stouter than in the rhinoceros, the fore limbs especially so. The limbs have some likeness to those of an elephant, but are shorter and apparently more supple. There are four short thick hoofed toes on the front foot corresponding to the second, third, fourth and fifth of five toed animals. (Plate 18). On the hind foot only the second, third, and fourth are present. The body of the animal is short, as in the elephant, and the shoulder is conspicuously high, much as in the bison. (Plates 35 and 36). This is caused by the great elongation of the spinous process of the anterior dorsal vertebrae. The projecting parts have well roughened extremities and doubtless served to support in great measure the stout muscles required to manipulate the powerful head in feeding and to give opportunity for its aggressive use.

The skull is particularly grotesque and noteworthy. It is a long, low, saddle-shaped affair, with remarkable nasal prominences at the extreme end, bearing in most species, (Plate 20) especially the later ones, powerful bony protuberances. These protuberances are commonly spoken of as horns or horn cores, but there is much doubt as to their ever having been sheathed in horn. The skull varies much in the different genera and species, considerably in the different sexes, and individual variation is not uncommon. Its full length in some of the larger species reaches as much as three feet or even more. The width is generally less than two feet, although in occasional skulls, especially of Brontotherium, it may reach more than thirty inches. (Plate 36).

The horn-cores are more or less cellular at the base and are placed transversely and project upward and outward. Their size, shape and position, like other parts of the skull, vary much with species and sex. The ears are placed far to the rear, while the eyes are surprisingly near the front. The brain, like the brain of nearly all early mammalian types, was very small. It was scarcely as large as a man's fist, and the living animal was evidently a very stupid creature. The teeth, usually thirty-eight, were large. This is particularly true of the grinders in the upper jaw. (Plate 19). Not infrequently in the larger species the well-fanged, nearly square upper molars measured more than four inches in diameter. The neck was short and stout and the head in ordinary position was evidently held declined. The Titanothere was a perissodactyl and a pachyderm. The nature of its thick skin is not positively known, but relying on skeletal characters common to thick-skinned animals, the restorations that have been made are believed upon considerable evidence to be within reasonable limits of accuracy. (Plates 35, 36).

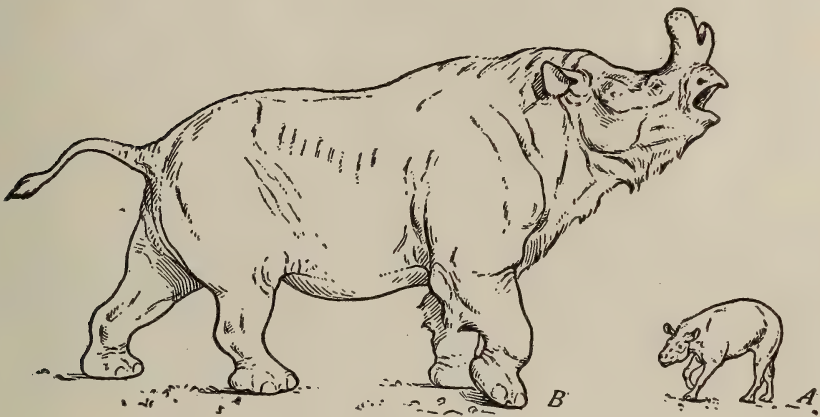

Figure 54—First and last known stages in the evolution of the Titanotheres. (a) *Eotitanops.* (b) *Brontops robustus.* Believed to be the most accurately restored Titanotheres published. Osborn, 1914.

Titanothere remains are abundant and several hundred heads have been found but complete skeletons are rare. Hatcher in 1902, gives the total number in the whole country as four, as follows: One in the Carnegie Museum, from War Bonnet creek, northwestern Nebraska one at Yale University, from near Chadron; one in the American Museum of Natural History, from the Big Badlands; and one in Princeton Museum from the Big Badlands. Of these the Carnegie Museum skeleton is from the Lower Titanotherium beds, the other three from the Upper Titanotherium beds.

ARTIODACTYLS

As previously indicated the artiodactyls include those herbivores in which the axis of the foot is between the third and fourth digits. They nearly always have an even number of toes on each foot, either two or four. None have less than two. Occasionally three or five are present but this is distinctly exceptional.

Artiodactyls have a long time constituted the dominant ungulate order. They include a great assemblage of creatures of many types but with marked unity of structure, the size varying from the little chevrotain to the huge hippopotamus. They have always been most abundant in the old world, nevertheless they have had from near their beginning a good representation in North America and the White River badlands have disclosed a remarkably interesting series. Practically all of these White River forms are described in the following pages.

ELOTHERIDAE AND DICOTYLIDAE

Few fossil animals of the White River badlands have afforded more real puzzling features than the ancestral swine (giant pigs). Several genera and a number of species have been identified, including several classed as ancestral peccaries, but usually the material is fragmentary and confined mostly to the head and lower jaws. Elotherium is the best known genus, its skeleton being represented by considerable material. It was evidently a very grotesque animal.

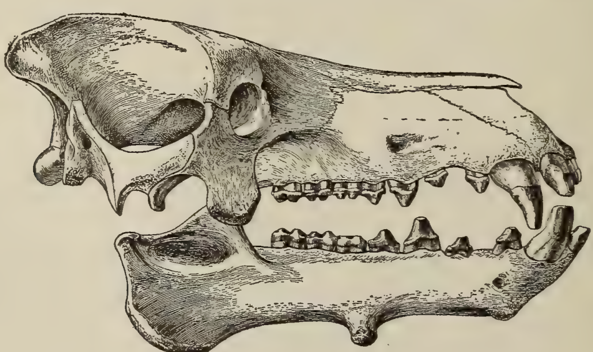

Figure 55—Skull and lower jaws of *Dinohyus hollandi*. Peterson, 1906.

Considered as indirectly ancestral to present day swine, it nevertheless showed few of the distinct suilline characters. In not a few respects it resembled the hippopotamus. Its size varied considerably, ranging in some species to near the

Figure 56—Palatal view of skull of *Dinohyus hollandi.* Peterson, 1906.

size of the present day rhinoceros, the head alone reaching sometimes more than three feet in length. *Dinohyus hollandi,* a nearly related genus, had a skull whose length, according to Peterson, reached more than thirty-five inches. (Plates 37 and 39). The Elothere skull is remarkable in many ways. The muzzle is long and slender, the eyes

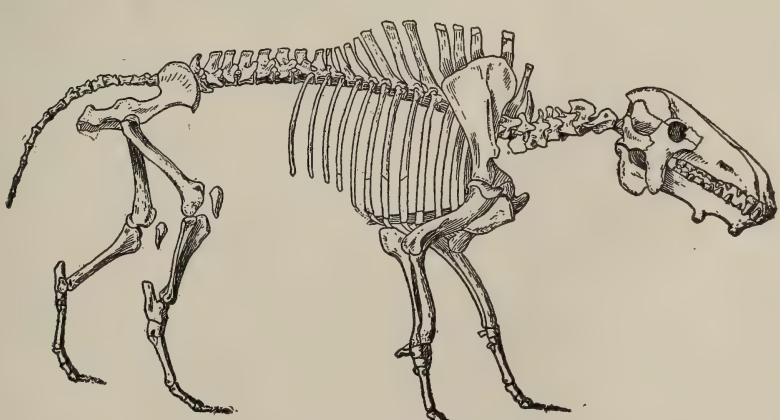

Figure 57—Skeleton of the giant Oligocene pig *Elotherium* (*Entelodon*) *ingens.* Peterson, 1909.

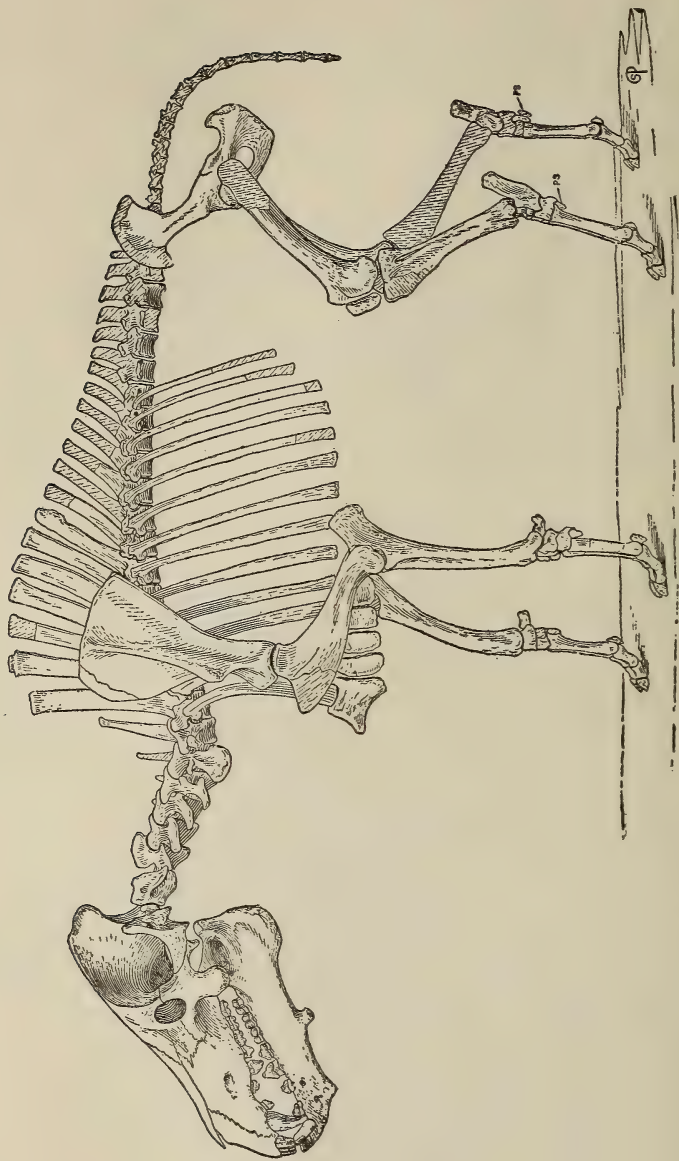

Figure 58—Skeleton of the Lower Miocene pig *Dinohyus hollandi*. Peterson, 1909.

shifted far back, the cranium short, brain cavity absurdly small, the sagittal crest high and thin and the zygomatic arches enormously developed. Other odd features are the pendant compressed plates given off from the ventral surface of the jugals and two pairs of knob-like processes on the ventral borders of the lower jaw. In young individuals the knob-like processes are only rough elevations, in some adults, especially the smaller species, they are little more than rounded knobs, but in the larger forms they become greatly elongated and club-shaped. Their use seems to be wholly unknown. The dentition above and below on each side is as follows: Incisors, three; canines, one;

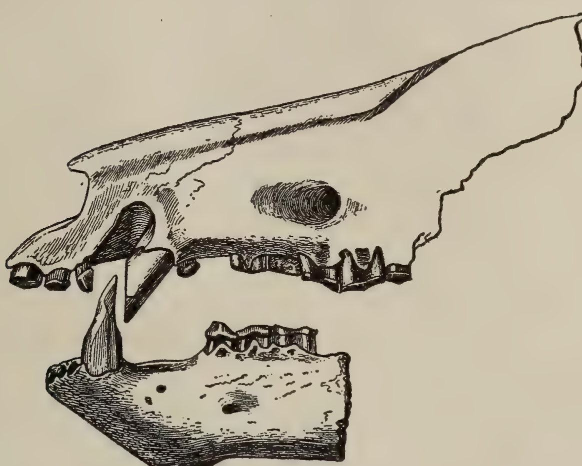

Figure 59—Anterior portions of the upper and lower jaws of the ancestral peccary. *Desmathyus* (*Thinohyus*) *Siouxensis*. Peterson, 1905.

pre-molars, four; molars, three; total, fourty-four. The canines both above and below are large and powerful. They do not appear to be of any sexual significance as the females developed them as fully as the males. Their use seems to have been that of digging up roots, in view of the fact that certain well preserved specimens show deep grooves on the posterior side of the lower teeth near the gums, grooves that could not have been caused by the attrition of the other teeth. The neck is short and massive and well arranged for the attachment of strong muscles necessitated by the great length and weight of the head. The limbs are long, particularly the fore limb, and this in connection with the high shoulder prominence, gives to the animal a peculiar stilted appearance. The foot, fore and hind, has two functional toes corresponding to the third and fourth of five toed animals. The second and fifth are present, but only in rudimentary form. Much that has been said in regard to the structural features of the Elotheres applies also in a general way to the Dicotylidae, but the latter represent a later development and tend more definitely toward the modern peccaries.

Figure 60—Skull of *Hyopotamus* (*Ancodus*) *brachyrhynchus.* Scott, 1895.

Concerning all of the forms, it may be said that they with the Suidae were apparently derived from a common Eocene ancestry. According to Matthew and Gidley the peccaries originated in the new world and have always remained here, while the true pigs (suinae) originated in the old world and never of their own accord reached the new world, their presence here now of the latter being due solely to introduction by man since the discovery of America by Columbus.

ANTHRACOTHERIDAE

The Anthracotheridae include species of an extinct family of stoutly built, generalized, primitive animals, evidently resembling to some extent the present day pig but having some characters possessed by the hippopotamus. Their nearest important relatives of White River time were apparently the Oreodontidae. These they resembled very closely. Scott states that the likeness as shown in the skull, teeth, vertebrae, limbs, and feet, is fundamental and indicates a common pentadactyl ancestry of perhaps middle Eocene time.

Fossils representing various species of the family are widely distributed over the earth, more particularly in the old world. The name Anthracotherium (Coal-beast) arises from the fact that their remains were first discovered in coal

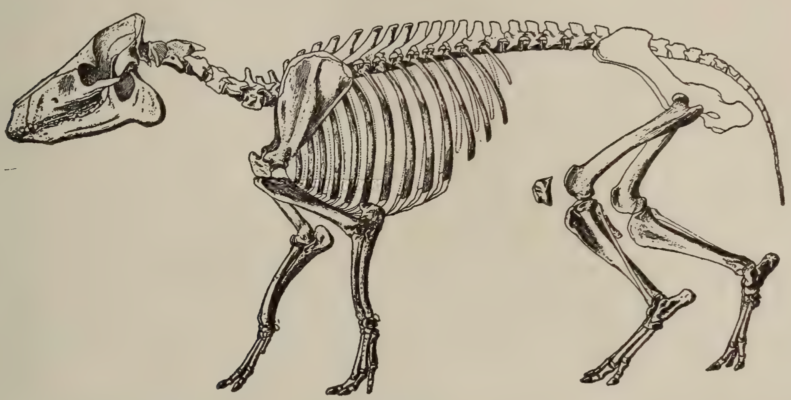

Figure 61—Skeleton of the Oligocene Anthracothere, *Hyopotamus (Ancodus) brachyrhynchus*. Scott, 1895.

deposits,—the brown-coal deposits of Savoy. A few nearly complete skeletons of Bothriodon the commonest Oligocene form have been obtained from the channel sandstones of the Big badlands.

OREODONTIDAE

The Oreodontidae include the commonest fossil mammals of the White River badlands. Representatives of the family are found only in North America. They originated in the Eocene, ranged through the Oligocene and Miocene and became extinct in Lower Pliocene. They are distinguished by many primitive characters and according to Cope they constitute one of the best marked types of Mammalia the world has seen. They occupy a position somewhat intermediate between the ruminants (cud-chewing animals) and the suilline pachyderms (pig-like thick-skinned animals).

The skull has to some extent the form of the present day peccary. The cranial portion is much like that of the camel. The skeleton as a whole more nearly resembles that of the pig, but the number, general proportions, relative position and plan of construction of the teeth are more nearly those of the ruminants and it is this relationship to the ruminants that has governed the classification of the family. Leidy in his description of the Oreodon suggested that it might very appropriately be called a "ruminating hog." One remarkable feature is the highly developed canine teeth in both jaws. These teeth or tusks are three sided with round borders, the upper pair curving forward, downward and slightly outward, the lower pair nearly or quite straight and pointing upward, forward and outward. They give to the jaws something of the appearance of the wolf's jaws but it is only a resemblance and does not indicate any close relationship. (Plates 21 and 22). As in the pigs the eyes were small, the neck and legs short. With the exception of the older forms all of the Oreodontidae had four toes on each foot. These represent the second, third, fourth, and fifth of five toed animals. Agriochoerus and the

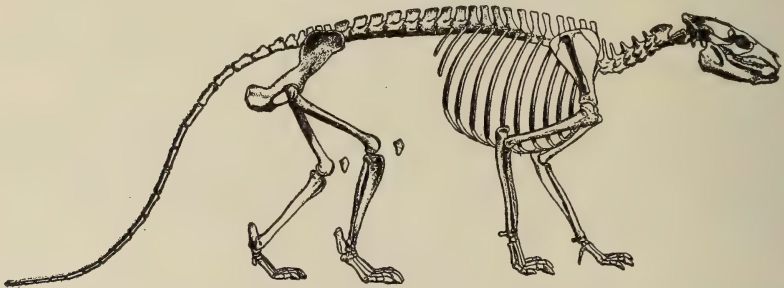

Figure 62—Skeleton of the Oligocene Oreodont, *Agriochoerus latifrons*. Wortman, 1896.

far commoner Oreodon had five on the front feet. The tail was long and slender. The animals varied considerably in size but the common forms were about the size of the peccary. Promerycochoerus, the largest, was about the size of the wild boar.

Of the several genera, Oreodon, Leptauchena, Agriochoerus, and Promerycochoerus are the best known. Oreodon is by far the most abundant but the others are found in considerable numbers. (Plates 40 and 41). They seem to

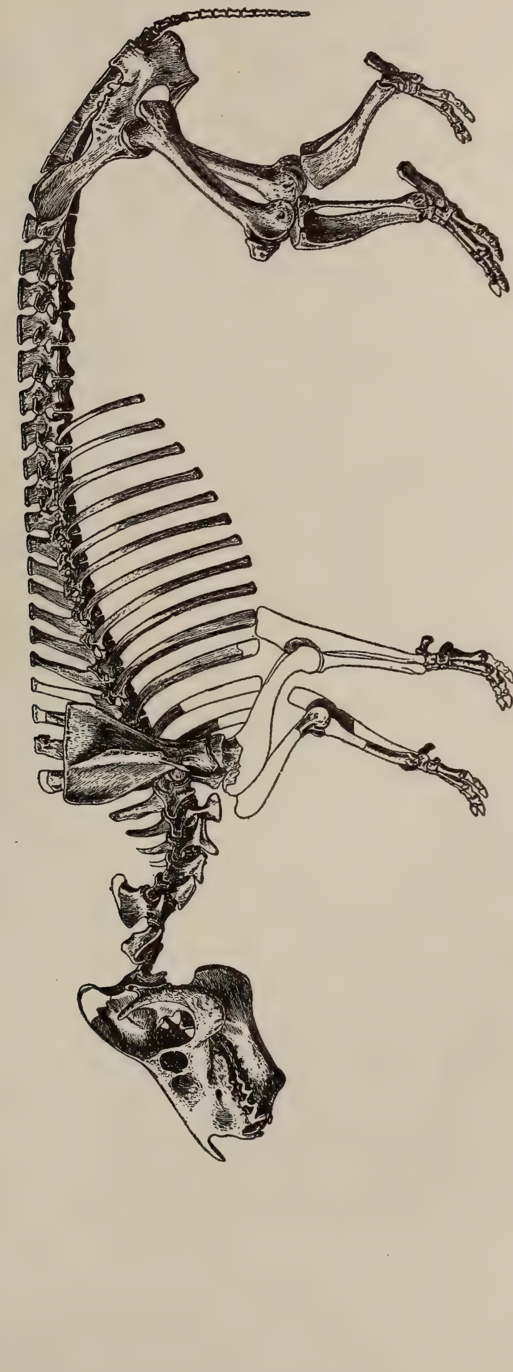

Figure 63—Skeleton of the Lower Miocene Oreodont, *Promerycochoerus carrikeri*. Peterson, 1906.

have ranged in great herds over the Oligocene and Miocene lands of South Dakota, Nebraska, Colorado, Wyoming, Montana and North Dakota. It is interesting in this connection to note that the Oreodontidae, in addition to giving their name to the Oreodon beds of the Middle Oligocene furnished names also for three of the zones above the Middle Oligocene, namely, the Laptauchenia zone, the Promerychocrus zone, and the Merycochoerus zone.

Leptauchenia was founded on fossil remains obtained by Prof. Hayden in 1855 from near Eagle Nest butte. This animal is of interest in that its structure seems to indicate an acquatic habit. (Plate 42). The teeth resemble somewhat those of the llama (Auchenia) hence the name Leptauchenia. Agriochoerus, is remarkable in that its toes were apparently armed with claws instead of hoofs and the first toe (thumb) of the fore foot seems to have been opposable. Aside from its foot structure the animal was much like the Oreodon. (Plate 42). It was approximately three feet long not including the rather long tail. Mesoreodon is likewise remarkable in that the thyroid cartilage of the larynx was ossified much as in the howling monkey and according to Prof. Scott it must have had most unusual powers of voice.

Promerycochoerus, a larger and heavier animal than those of the earlier genera, has been found in considerable numbers in northwestern Nebraska and eastern Wyoming. The restored skeleton of *Promerycochoerus carrikeri* is more than five and one-half feet long and evidently indicates a large bodied slow moving animal, the habits of which as has been suggested were perhaps somewhat the same as those of the hippopotamus. Peterson described the animal briefly as having a massive head, a short, robust neck, dorsal vertebrae, provided with prominent spines, lumbar vertebrae heavy, thoracic cavity capacious, and the feet large. (Plate 38).

The Oreodons are found in the Lower and Middle Oligocene and are particularly common in what is known as the "lower nodular layer" (red layer) of the Middle Oligocene fifteen or twenty feet above the Titanotherium beds. It is on account of the abundance of these fossils and their early discovery in the Middle Oligocene that this division of the badland formations was by Hayden given the name of Oreodon beds. Leidy tells us that as early as 1869 he

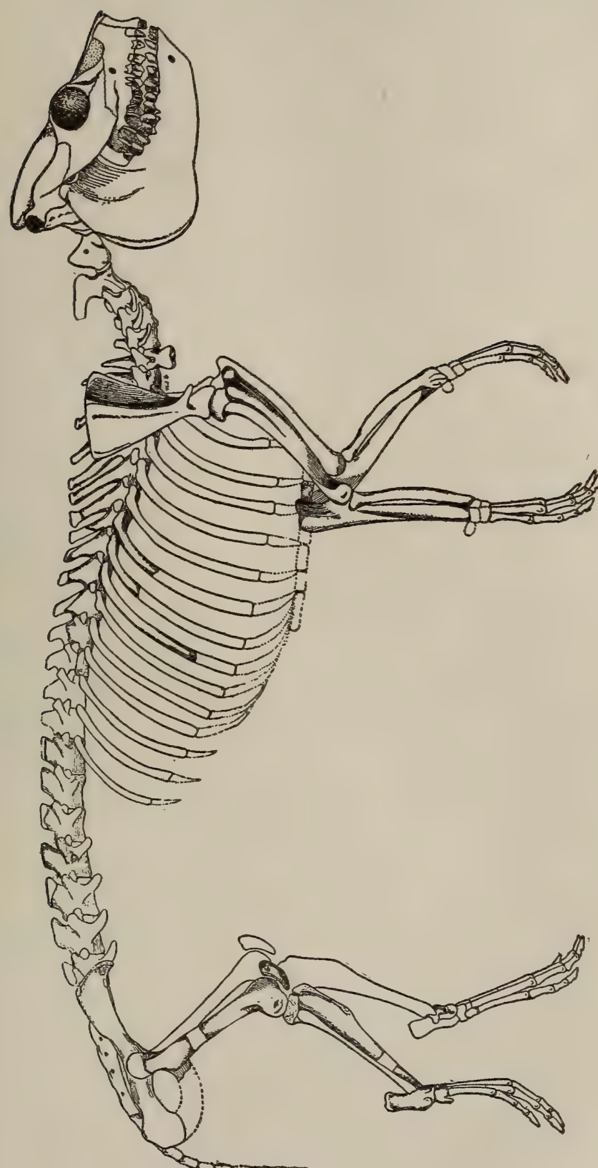

Figure 64—Skeleton of the Lower Miocene Oreodont, *Leptauchenia decora*. Sinclair, 1910.

had observed fossils of approximately five hundred individuals among the collections sent him for study. Few general badland collections fail to show specimens of these interesting creatures, but most of the material is made up of skulls and detached bones. Few complete skeletons have been obtained and until recent years little attempt was made at restoration. The dentition is remarkably complete, the total number of permanent teeth being forty-four arranged in nearly unbroken series in both jaws. Of the Oreodons *Oreodon clubertsoni* is by far the most common. Leidy says that of the five hundred he had observed about four hundred and fifty were of this species. *Oreodon gracilis,* about two-thirds as large as *Oreodon culbertsoni* was perhaps the next in abundance. Its skull was about the size of the red fox and a skeleton mounted by Mr. C. W. Gilmore of the U. S. National Museum measured twenty-seven inches in length and is twelve and one-half inches high at the shoulders. *Eporeodon major,* earlier called *Oreodon major* is still rarer. It is about one-fifth larger than *Oreodon culbertsoni* or nearly twice as large as *Oreodon gracilis.*

HYPERTRAGULIDAE

The Hypertragulidae include some of the most interesting fossil mammals ever discovered. They are ancient selenodonts (ruminants) resembling in a way the little chevrotain or "deerlet" of India and the musk deer of the Asiatic highlands but they are in reality not closely related to either. They seem to represent an independent offshoot of the primitive ruminant stock but near relatives, either ancestral or descendent are not known.

They are distinguished from all other American ruminants by the combination of functionally tetradactyl front feet with didactyl hind feet. Of the seven genera thus far recognized from the White River region, Protoceras is the most interesting and the best known. (Plate 43). It is found only in the Upper Oligocene and because of its importance the strata containing it are known as the Protoceras beds. Of the other genera Leptomeryx has been most carefully described but with the exception of one find of twenty-six skeletons in one associated group and described by Riggs, Bull. G. S. A., vol. 25, p. 145, the materials available have not been so abundant nor so complete as in the case of Protoceras.

The first Protoceras specimen was obtained by Mr. J. B. Hatcher in 1890. It, like all subsequent material of this kind, was found near the highest part of the Big Badlands, where the Protoceras beds are well exposed. In January, 1891, Prof. Marsh described the animal in the American Journal of Science under the name *Protoceras celer* in allusion to the early appearance of horns in this fleet-footed group of artiodactyls. Before this discovery no horned artiodactyls were known to have lived earlier than Pliocene time. Marsh states it as an important fact that while all existing mammals with horns in pairs are artiodactyls and none of the recent perissodactyls are thus provided, the reverse of this was true among the early forms of these groups.

The head is especially unique. (Plate 23). It displays in many ways the modernized type of structure, and shows

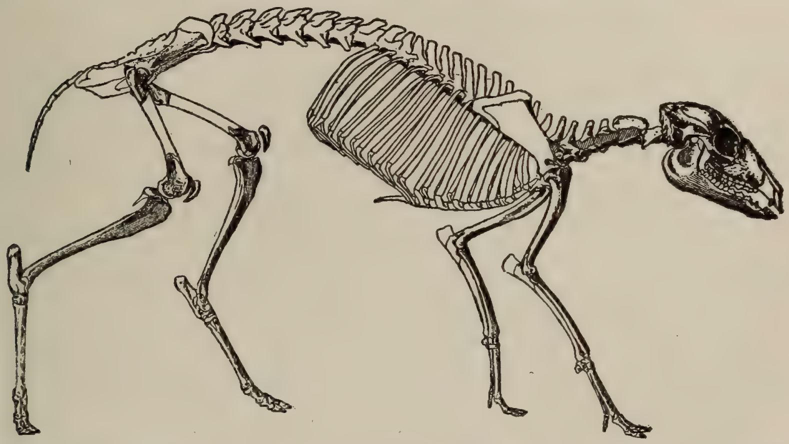

Figure 65—Skeleton of the Oligocene ruminant, *Leptomeryx evansi*. Scott, 1891.

sexual differences unparalleled among the ancient artiodactyls. The most obvious characters are the bony protuberances from various parts of the head in the male. In the female these are only faintly indicated. In the male a pair of protuberances project upwards from the rear part of the head in much the same position as the horns of the present day pronghorn antelope. Near the anterior end of the face there is a second pair, laterally compressed and more prominent than the first pair. Over the eyes there is a third pair serving as a sort of protective awning for the eyes. In front of these and slightly nearer the median line of the face there is a fourth pair. These are much less prominent than the others mentioned but their presence is clearly indicated. Finally a fifth pair, slightly more prominent than the last, but less prominent and especially less horn-like than the others, is placed at the side of the face nearly above the anterior molar tooth.

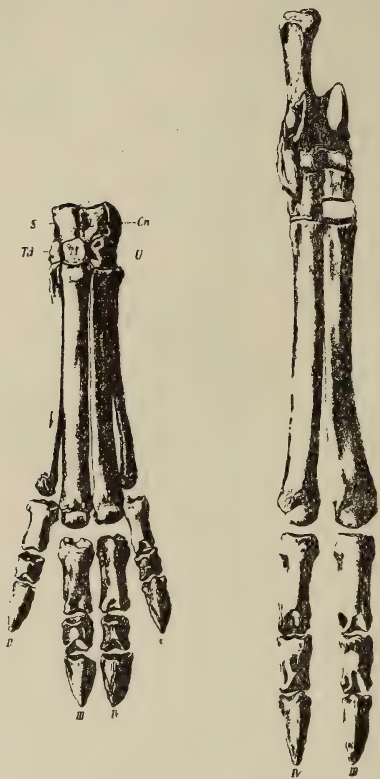

Figure 66—Fore and hind foot of Protoceras, the six-horned ruminant of the Upper Oligocene, Scott, 1895.

The head is long and narrow, tapering rapidly toward the anterior end, where the muzzle becomes extremely slender. The cranium is capacious and well formed. The brain case is of good size and indicates a brain fairly well convoluted, in fact the brain development of Protoceras seems to have been more advanced than any other animals of the time. The nasals are remarkable in that they indicate a long flexible nose if not a true proboscis. Among recent ruminants such a proboscidiform muzzle is found only in the saiga antelope and to a less extent in the moose.

The four toes of the front foot are functional and correspond to thé second, third, fourth, and fifth, of five-toed animals. The hind foot shows only two toes, the third and fourth. Small short splint-like processes disclose, however, the rudimentary second and fifth. The hind limb compared with the fore limb, is large and long. The tail is larger and better developed than in the present day deer.

Figure 67—Skull of the ruminant *Syndyoceras cooki* of the Lower Miocene. Barbour, 1905.

The size of Protoceras is practically that of the sheep, but the general build seems to have corresponded more nearly to that of the pronghorn antelope. (Plate 44). The animal is, however, not very closely related to either. Syndyoceras had a head that in the male was as fantastic as that of Protoceras. There were two pairs of horns or horn-like outgrowths,—one pair situated above the eyes and curving toward each other, like those of the present day cow and one pair arising anteriorily nearly midway between the eyes and nostrils and curving outward away from each other. (Plate 45.

CAMELIDAE

The camel originated in North America. The earliest and most primitive ancestors are found here and the evidence shows that the family had traveled far on its road toward modern camels before conditions became favorable for their migation to other continents.

At present the family consists of but two phyla, Camelus and Llama. Of the camels proper there are but two species, *Camelus dromedarius* or Arabian (one-humped) camel, and *Camelus bactrianus* or Bactrian (two-humped) camel. They inhabit the desert regions of Northern Africa, Arabia, and Central Asia. The llamas, including alpacas, guanacos, and vicunas, live only in the arid highlands of South America.

Figure 68—Skull of the Oligocene camel, *Poebrotherium wilsoni.* Wortman, 1898.

The camels are among the earliest domesticated animals of which we have knowledge and since the dawn of human history they seem not to have been known in the truly wild state. We lose ourselves in meditation as we think of the position these stupid ungainly creatures have made for themselves in the history of old world transportation but let us not fail to reflect that their earliest ancestral history lies at our own door-way. Ages before Joseph was sold by his brethren to the Ishmaelitic caravan from Gilead the forerunners of these useful beasts of burden were roaming in great numbers the wilds of what we now know as South Dakota and neighboring states seeking the comforts of a primitive living and looking forward in some mysterious way to the convenience of elastic pads for their feet, fleshy humps for their backs and water pockets for their stomachs. Concerning their distribution Scott says:

Figure 69—Skeleton of the Lower Miocene camel, *Oxydactylus longipes*. Peterson, 1904.

"Under modern conditions, no mammals could seem more completely foreign to North America than those of the camel family, which, now restricted to two well-defined genera, inhabit central Asia and the colder parts of South America. Yet, as a matter of fact, this family passed through nearly the whole of its development in North America and did not emigrate to the other continents before the late Miocene or early Pliocene, and it is this North American origin of the family which explains its otherwise inexplicable distribution at the present time. To all appearances, the whole family had completely disappeared from this continent in the later Pleistocene, but in the middle and earlier portions of that epoch both true camels and large llama-like animals were very abundant. * * *

"The most ancient known camels of the Old World are found in the Pliocene of India, and the first llamas recorded in South America are also Pliocene. Since both camels and llamas existed together in North America, it may be reasonably asked why only one phylum migrated to Asia and only the other to South America. Why did not each continent receive migrants of both kinds? Without knowing more than we are ever likely to learn about the details of these migrations, it will not be possible to answer these questions, though plausible solutions of the problem suggest themselves. It is to be noted, in the first place, that a migration from the central portion of North America to Asia was by way of the far north and thus involved very different climatic conditions from those which must have been encountered in passing through the tropics to South America. It is perfectly possible that animals which lived together in temperate North America should have had very different powers of adaptation to heat and cold respectively, and the northern route may have been impassable to one and the southern route to the other. To this it might perhaps be objected that llamas are cold-country animals, but this is true only of the existing species, for fossil forms are found abundantly in the Pleistocene of Ecuador, Brazil and Argentina. Another possibility is that both phyla did actually migrate to both continents and that only the camels succeeded in permanently establishing themselves in Asia and only the llamas in South America, though for this solution the fossils afford no evidence."

Within the area described in this book, a number of ancestral species have been identified, some from the Oligocene and some from the Miocene. These are preceded elsewhere by still older forms, the oldest of all so far as yet known being *Protylopus petersoni* a little four toed creature scarcely larger than a jackrabbit, found a few years ago in the Upper Eocene beds of the Washaki basin, Wyoming, and

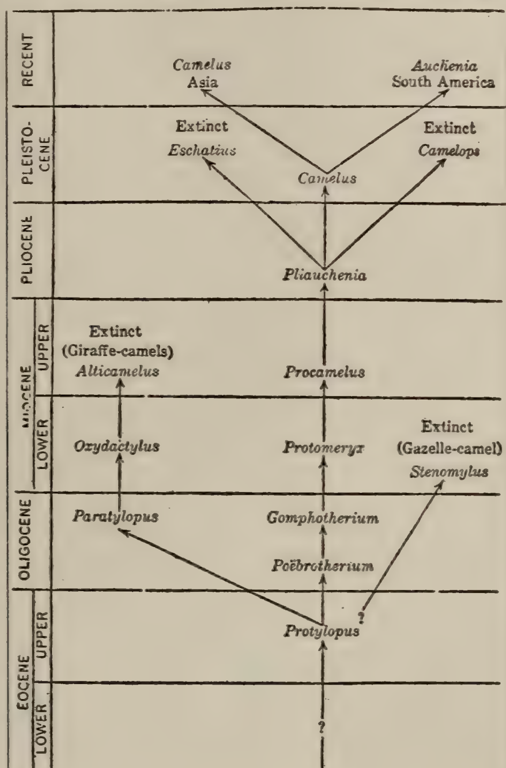

Figure 70—Phylogeny of the Camels. R. S. Lull; Organic Evolution, 1917. Published by the Macmillan Company. Reprinted by permission.

described by Mr. W. B. Matthew of the American Museum of Natural History.

The best known South Dakota species, the one first discovered, and the one that has received the most merited recognition is *Poebrotherium wilsoni.* (Plate 46). The collection of Big Badland material given by Mr. Alexander Culbertson in 1847 to the Academy of Natural Sciences of Philadelphia contained a broken skull of this animal and Dr. Leidy in describing the specimen, the first of the many South Dakota badland fossible vertebrates studied by him, gave it the name it bears. (See Figure 2). He first regarded the animal as allied to the musk deer but later indicated its cameloid nature. Since the description of this earliest Poebrotherium skull abundant other remains have been found but generally they have not been complete. In 1890 the Princeton expedition was fortunate in securing a very excellent skeleton of *Poebrotherium wilsoni* almost entire and Prof. Scott has described this in a most careful manner. It is not possible, nor would it be profitable to go into the details of this description here. Briefly it may be said that the animal was a lightly built, graceful creature with apparently some external likeness to the llama but of about the size and build of the existing gazelle. It shows its relationship in many features of its skeleton but as in many extinct animals the bones show a primitive or generalized nature, and its connection with the llamas is perhaps as close as with the true camels. The eyes are farther back than in the present day camel, the ribs are more slender, and the foot, armed with small pointed hoofs was apparently without a pad. Like the existing camel the foot has only two toes, the third and fourth, but traces of the second and fifth remain as evidenced by the metapodial nodules. The metatarsal bones are separate but pressed closely together and plainly anticipate the definite union into a "cannon bone" during the subsequent Miocene. The animals varied considerably in size, the larger individuals reaching a height of twenty-four inches.

Among the Miocene forms Procamelus has long been known. This genus is of interest in that the camels and llamas of today seem to have descended directly from it. The gazelle camel, Stenomylus, and the giraffe camel, Oxydactylus, were discovered later but they have received full description. Their remains have been found in particular abundance in northwestern Nebraska. Several dozen skeletons of Stenomylus, were obtained from one excavation near Agate Springs. Peterson says it is seldom that the complete knowledge of the osteology of a genus has been acquired so rapidly after its discovery as that of Stenomylus and that

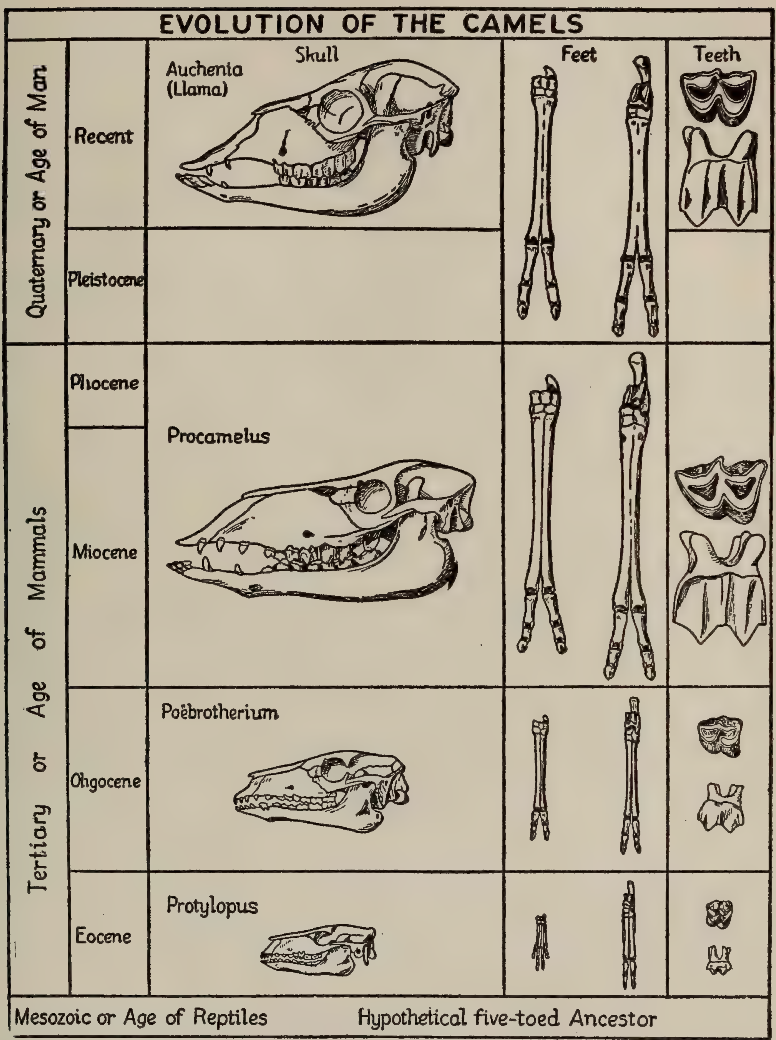

Figure 71—The evolution of the camel as indicated by the skull, feet and teeth. (Modified from Scott) R. S. Lull: Organic Evolution, 1817. Published by The Macmillan Company. Reprinted by permission.

more complete remains of this genus have been found than that of any other Miocene camel. The accompanying sketch by Peterson, page 71, shows a number of the skeletons as they were found in the quarry. These graceful llama-like little camels lived apparently in herds in an upland country where hard grasses constituted their chief food. In general it may be said that the Miocene forms became increasingly more cameloid in that they are larger, the side toes disappear, the metatarsal bones become more fully united and rugosities of the hoof bones indicate the presence of a small foot pad.

With the close of the Miocene important geographical changes came about including the raising of the isthmus of Panama above sea level and the forming of a land connection across Behring Strait. In this way widespread migration became possible. The camels during and immediately subsequent to the development of these land bridges were especially abundant and diversified throughout North America, hence readily took advantage of the opportunity to enter South America in the one direction and Asia and thence to Europe and Africa in the other. Later during Pleistocene time by reason of unfavorable climate or other conditions the North American branches of the family all died out while some at least of the more favorably situated foreign members lived on. Thus in the light of their ancestral history the wide separation of such nearly related animals as the camel and the llama, so long a perplexing question, is readily understood.

CERVIDAE

Until 1904 nothing was known of the ancestral deer within the region of the White River badlands. In that year Mr. Matthew described a fragmentary jaw, *Blastomeryx wellsi* from the Upper Miocene. Since then several other species have been noted.

The earliest material obtained gave little information as to the definite relation of Blastomeryx to present ruminants but in the study of the later collections Mr. Matthew discovered it to be a primitive deer approximately ancestral to the American Cervidae and derivable in its turn from the Oligocene genus Leptomeryx whose relation to the Cervidae had not before been suspected. Its nearest relative structurally among the present day Cervidae is the musk deer. The general proportion of the skull is much as in the musk deer and like that animal it has no trace of horns or antlers such as gradually developed in later times and the upper canines are in the form of long, slender, recurved tusks. The skeleton as a whole has many primitive characters but the various species all show the general cervid affinities. The animal in life stood from one to one and a half feet high at the shoulders.

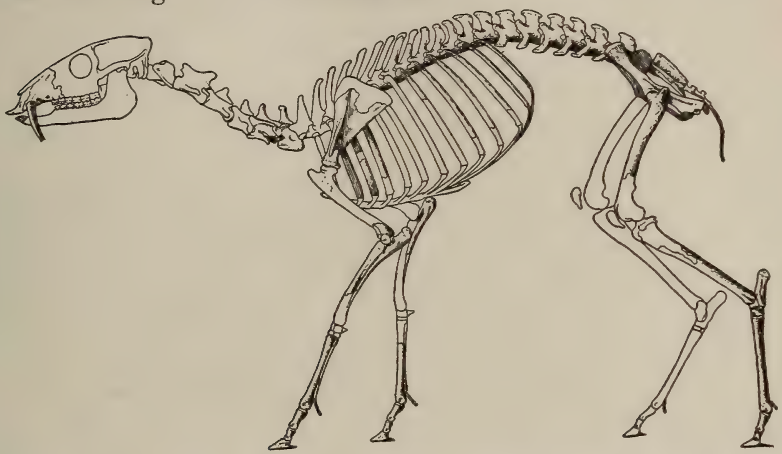

Figure 72—Skeleton of the primitive Lower Miocene deer, *Blastomeryx advena.* Matthew, 1908.

REMAINS OF ANIMALS OTHER THAN MAMMALS

As indicated elsewhere fossil remains of backboned animals other than mammals in the Badlands are in general of little numerical consequence. Only in the case of turtles is there a decided exception. Occasional fragmentary remains of lizards and crocodiles are found and a few petrified birds eggs have been picked up but these are all that are worthy of mention. Shelled animals lived in the region but their remains are generally rare and of little consequence except from the standpoint of refined science. The beautiful and well known invertebrate shells from southwestern South Dakota so often seen in museums are from older geological formations. Coming chiefly from the Cheyenne river and its tributaries they are erroneously supposed by many to be of the same age as the mammal-bearing beds of the Tertiary.

Interest naturally attaches to the turtles, crocodiles and birds eggs, the first because of their size and abundance, and the second because of their having lived in this latitude and the third because of the general rarity of fossil eggs. These may be briefly described.

TURTLES

Few Badland fossils are more abundant or more widely distributed or better preserved than the turtles. The size of the individuals varies from a few inches in length to more than two feet. Specimens three feet long are occasionally observed. These large sized Tertiary forms should not be confused with the far larger Cretaceous turtles found in the black Pierre shales near the Big Badlands. These Cretaceous turtles became veritable monsters and reached a greater size than any others yet found anywhere in the world, either living or fossil. The type specimen, found near Railroad Buttes, southeast of the Black Hills and described by Mr. Wieland in 1896, had a total length of approximately eleven feet, and fragmentary portions of a still larger individual showed a length of forty inches for the head alone.

From the various Badland formations in the White River region ten species of turtles have been described. Of all these only *Stylemys nebrascensis* occurs in abundance. (Plate 48). So far as I have learned each of the other species is known by only one or two specimens. Published reference to these latter is meagre and confined in the main to brief scientific description.

Stylemys nebrascensis, the common form, was first described in 1851 by Dr. Joseph Leidy, and is the earliest discovered fossil turtle in America. The first specimens were obtained by Dr. John Evans of the Owen Geological Survey in 1849 and since then hundreds of specimens have found their way into the museums of the world. The visitor in the Badlands can scarcely fail to find them if he walks along the outcrops of the containing strata and in favorable localities he may see them with surprising frequency. I myself have observed many dozens of them in a few hours walk in Indian draw and there are other places where they seem to be as abundant. They are found particularly in the Oreodon beds but occur in the Protoceras beds also. As yet none have been found in the Titanotherium beds.

The shell body is often preserved with remarkable perfection but owing to the fact that weathering readily separates the bones, specimens exposed on the surface are usually more or less disintegrated. The head and feet are rarely found. Dr. Leidy, who first described the species stated that he had seen hundreds of shells but no skull. Even today there is record of only two skulls. One of these in the Carnegie Museum of Pittsburg is accompanied by the shell. The other is in the Princeton Museum but the body to which it belonged was not found. The general absence of the head is due perhaps to the fact that Stylemys was a dry land tortoise and any freshet that might be able to carry or roll the heavy decaying body into water where deposition was taking place would wrench the head away. This, separate from the body, would be inconspicuous and hence fail of ready detection.

Several fossil turtle eggs have been found in the Badlands and they are regarded as belonging to the common

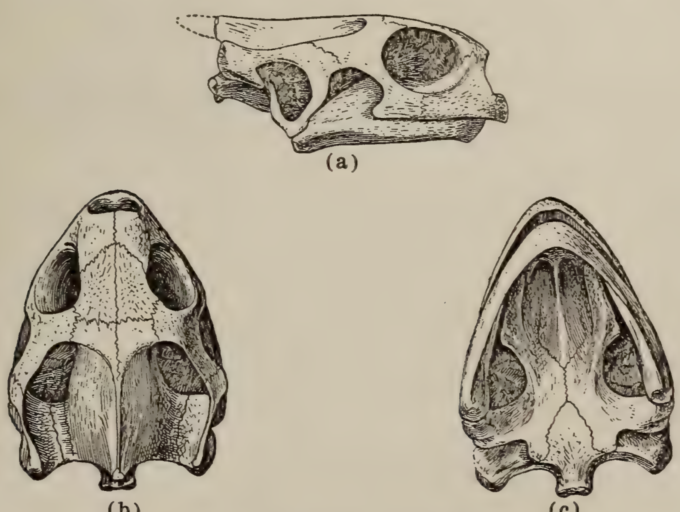

Figure 73—Head of the abundant Oligocene dryland tortoise, *Stylemys nebrascensis*. Natural size, (a) view of right side; (b) view from above; (c) view from below. Hay, 1906.

species just described. Hay states that they are slightly elongated but he indicates that this is perhaps due to deformation by pressure from an original globular form. They are a little less than two inches in diameter. They were formerly in the James Hall collection but are now in the American Museum of Natural History.

CROCODILES

Two species of crocodiles have been described from the White River badlands. These were found near Sheep mountain. Fragments of others have been obtained from the Finney breaks near Folsom. All of the specimens are from the Titanotherium beds. Besides other parts each species is represented by a considerable portion of the head.

Figure 74—Anterior portion of head of the Oligocene crocodile, *Crocodilus prenasalis* found in Indian draw, (a) view from above; (b) view from below. Loomis, 1904.

The author found the first of these, *Crocodilus prenasalis,* in 1899. (Plate 47). In this the nasal opening is placed forward hence the specific name. The part of the head that is preserved is broad and short and contains the root portions of eighteen teeth, two of which retain the nearly complete crowns. These are conical and slightly recurved and the longest is approximately one half inch in length. The portion of the head preserved shows a width of

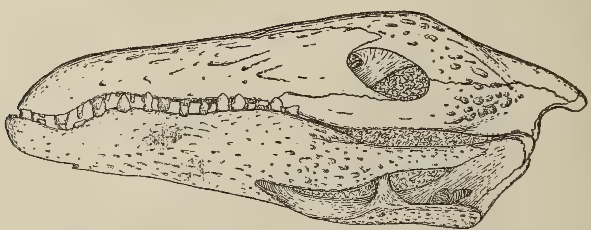

Figure 75—Head of the Oligocene crocodile *Caimanoides visheri.* Mehl, 1916.

two and five-eights inches within two inches of the nasal end. The animal in life was perhaps six feet long. The second species, *Caimanoidea visheri,* found in 1911, shows characters tending toward the alligators. Its length in life was about five and one half feet.

These fossils are of interest in showing in striking manner the Floridian character of the climate in the White River region during early Oligocene time and they add to other evidence that the country was then a land of inundation.

BIRDS EGGS

Several fossil birds eggs have been found in or near the Big Badlands. Unlike eggs found elsewhere as fossils the badland birds eggs are distinctly petrified, that is they show a practically complete replacement of the original matter by mineral material. Soft animal tissues quickly decay and only exceptional conditions allow for their preservation or petrefaction. Turtle eggs are occasionally found filled with hardened mud and eggs of certain extinct birds have been preserved by reason of the thickness of their shells but the Badland birds eggs show not only the thickness of the original shell but apparently also the position of the white and the yolk of the egg.

One of the Badland eggs found by Mr. Kelly Robinson in 1896 has been carefully described by Dr. O. C. Farrington of the Field Museum. The shell portion is made up of dark colored chalcedony, the color being due to organic matter. The portion representing the white of the egg is gray translucent chalcedony with occasional black blotches the exact nature of which was not determined. The yolk is replaced by opal in two portions of about equal size but with different texture. The egg measures 2.03 inches by 1.49 inches, long and short diameters, conforming in size and general shape to that of the present day Florida duck (*Anas fulvigula*). Plate 48.)

Since the publication of the paper by Mr. Farrington other birds eggs from the Badlands, perfect in outline and similar in size and shape to the one described have been found. One of these is now in the geological museum of the South Dakota State School of Mines.

THE BADLAND LIFE OF TODAY

Conditions for present day animal and plant life in the Badlands are fairly favorable. The average annual rainfall is approximately seventeen inches. Of this amount about thirteen inches comes during the five crop growing months, April, May, June, July and August. The average annual temperature is about 44 deg. Fahrenheit.

The soil varies considerably. Much of the flatter country is covered by a silty or sandy loam which nourishes rich, native grasses and it has proven under cultivation to be favorable for the growing of vegetables and grains.

The native plants incline toward the hardy semi-arid types. Annuals are conspicuous in many places especially where moisture lingers longest. Pubescent-leaved perennials with their well-anchored roots are widely distributed. There is a surprising abundance of flowers and they appear in tenaceous succession through the summer. Grasses are the predominant plants over much of the country. Chief among the many species are buffalo grass, grama grass, wheat grass, needle or spear grass, blue stem and wire grass. Of these the buffalo grass and grama grass have been of the greatest value in making of the region a great cattle range. Cacti and yuccas among the gorgeously blooming plants and sage brush among the woody shrubs are abundant and conspicuous but they are by no means uniformly distributed. The chief wild fruits are plums, chokecherries, sandcherries, buffalo berries, gooseberries, currants, wild grapes, raspberries and service berries.

Trees are abundant in places but well wooded areas are greatly restricted. Cottonwoods are common along some of the alluvial flats and red cedar and the western yellow pine form considerable of a forest growth among the higher breaks. Pine Ridge, a prominent irregularly etched escarpment and an integral part of the area under discussion owes much of its picturesque nature to the presence of the pines and cedars scattered so promiscuously among its otherwise nearly bare slopes and precipices. In addition to these there are in much less abundance the box elder, ash, elm, hackberry, stunted oak, and willow.

There are or were until recently more than forty native mammals frequenting the Badlands. Approximately three hundred species of birds have also been found visiting or making their homes in the region· The commonest of the birds are the cliff swallow, the rock wren, the meadow lark and the chikadee but others may be found in considerable numbers. Mammals once occupying the country in an important manner but now nearly or wholly dispersed are the bison, elk, deer, bear, antelope, mountain sheep and puma. Among those that are yet to be found in abundance or in considerable numbers are the following: Coyote, gray wolf, gopher, jack rabbit, cottontail rabbit, prairie dog, badger, skunk, porcupine, raccoon, bobcat, kitfox, weasel, mice and shrews.

RECENT HISTORY

The history of the White River Badlands in so far as it relates to man before the advent of the white settler has to do chiefly with the Teton Indians. When white men first penetrated the region they found Indians frequenting the country and calling it a part of their possessions. In the earliest days the Crows, (Absarokas) controlled the country and later the Cheyennes but sometime before the close of the eighteenth century the lands passed into the possession of the Tetons of the Dakota Sioux. The claims of the several Teton tribes shifted from time to time, the Brules and the Minneconjous for a while occupying much of the country but later the Oglalas assumed a large control. (Plate 49).

The earliest white men to see the Badlands were traders and trappers in search of furs. Their coming led in due course to military and exploratory expeditions. Conflicts of diverse kinds occurred between the Indians and the newcomers and for a number of years an irritating warfare prevailed. However, most of the actual fighting took place outside the region under consideration. The severest conflict in the Badlands proper occurred during the Messiah Craze of 1890. This is commonly known as the Wounded Knee affair. It was an unfortunate clash between federal troops and the Indians in which 200 Indians, men, women, and children, and sixty soldiers were killed.

During the last quarter of a century, with the growing preponderance of white people the Indians have progressed toward civilization and many of their homes show semblance of comfort, stability and wealth. The traveller finds them today kind and considerate and many a white settler has reason to rejoice in their friendship. The fathers and mothers, notwithstanding their disadvantages, have generally a fair knowledge of English and most of the children are receiving training in good elementary and industrial schools. The expansive reservations established years ago have nearly disappeared. In opening up these reservations the Indians first receive liberal individual allotments of land, then that which remains is available for settlement by the whites. Opportunity for good financial returns from a large part of the Badlands, notwithstanding their detractive name, has been abundantly proven and with better understanding of conditions, the wealth of the region will greatly increase.

HOW TO SEE THE BADLANDS

The White River Badlands are readily accessible. Many of their features may be observed with pleasure and satisfaction from a Pullman window. Well-travelled wagon roads connect the better known passes and these give opportunity through much of the year for delightful automobile drives. Off-the-road places may be reached by saddle or in pedestrian boots.

Railroads cross the country in several places and give abundant opportunity to visit almost any desired locality. The Pierre, Rapid City and Northwestern railroad now merged with the Chicago and Northwestern system, going up Bad River valley and thence over into the Cheyenne valley crosses a narrow northerly projecting arm at the town of Wall, South Dakota. The Chicago and Northwestern railroad from Omaha crosses Pine Ridge from southeast to northwest at Chadron, Nebraska. The connecting Chadron-Lander line, following up the head of White River cuts Pine Ridge from northeast to southwest near Crawford and again farther west in a nearly east-west direction in Converse county (now Converse and Albany counties) Wyoming. The Chicago, Burlington and Quincy railroad from Lincoln traverses the Crawford locality from southeast to northwest, it being nearly at right angles to the Chadron-Lander connection of the Chicago and Northwestern.

The Chicago, Milwaukee and St. Paul railroad gives to the car window sightseer the best and most abundant opportunity to view the general ruggedness of the Badlands and affords also a very good opportunity to study close at hand, though in hasty manner, many things of interest. For many miles this railroad winds its way up White River valley along the southern face of the Great Wall, then plunges into the very heart of the picturesque Big Badlands the culminating feature of all the area included under the name, White River Badlands. From near Kadoka to Scenic there is a never ceasing array of those topographic peculiarities that make the region famous and, in the Big Badlands, they are placed together in most fantastic manner. Sheep Mountain (Cedar Point), the most famous locality of all this wonderful country lies a few miles south of Scenic. It may be seen from the car window but its strange grandeur can be understood only by a special visit and its chief feature—School of Mines canyon—should be traversed only with proper equipment and guide. Those wishing to study the Great Wall will find it accessible from any of the nearby railway towns. Interior is the largest and in some respects the most convenient place from which to drive or walk but there are facilities at every station and at some of them they are nearly or quite as good as at Interior.

Those desiring to visit remote areas either in southwestern South Dakota, northwestern Nebraska or southeastern Wyoming will have little difficulty in obtaining direction and suggestion. The people generally will be found accommodating to the point of urgent hospitality. One needs of course to bear in mind that much of the country is still sparsely settled and that as in any other place annoying weather conditions may at times prevail but the real lover of the great out-of-doors, man or woman, will usually find little of real hardship. He who has opportunity to ramble over this strange country in the bright mornings of early summer when the short grasses are brilliant green or who in the on-coming autumn can camp near some good spring and enjoy the beauty of the prairie evening and the stillness of the arid night is blest with a golden privilege.

The Badlands are strange, and inspirational and good. For many years only those technically trained in nature's ways could appreciate them but now in these days of wider opportunity with railway facilities, good roads, numerous settlers and the omnipresent automobile every one can cultivate a growing comprehension of their meaning. Even the name is rapidly losing its forbidding aspect. Until recently the country was to the causal visitor but a grotesque quarry for dry bones. It should be to all men a living storehouse of wonderful works.

A List of the Fossil Mammals Found in the White River Badlands*

LOWER OLIGOCENE (TITANOTHERIUM ZONE.)

Carnivora (Fissipedia).
 Canidae.
  Daphoenus dodgei Scott. Am. Phil. Soc., Trans., vol. 19, 1898, p. 362. Nw. Neb.
 Felidae.
  Dinicitis fortis Adams.
Perissodactyla.
 Rhinocerotidae.
  Trigonias obsborni Lucas. U. S. Nat. Mus., Proc., vol. 23, 1900, pp. 221-223. So. Dak.
  Leptaceratherium trigondum Osborn and Wortman. Am. Mus. Nat. His., Bull., vol. 6, 1894, pp. 201-203, (Aceratherium). So. Dak.
  Caenopus cf. platycephalus Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 6, 1894, p. 206, (Aceratherium). So. Dak.
  Caenopus mitis Cope.
 Lophiodontidae.
  Colodon (Mesotapirus) occidentalis Leidy.
 Equidae.
  Mesohippus proteulophus Osborn.
  Mesohippus hypostylus.
  Mesohippus celer Marsh. Am. Jour. Sci., vol. 7, 1874, p. 251, (Anchitherium). Nw. Neb.
 Titanotheridae (Brontotheridae).
  Titanotherium prouti Leidy.
  Titanotherium helocerus (Cope).
  Titanotherium trigonoceras (Cope).
  Megacerops dispar (Marsh). Am. Jour. Sci., vol. 34, 1887, p. 328, (Brontops). So. Dak.

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*Fossil forms too poorly preserved to admit of careful description and naming have been omitted from this list. In compiling the list I have made extensive use of Matthew's Faunal Lists of the Tertiary Mammalia of the West as given in U. S. Geological Survey Bulletin No. 361, 1909. I have made no effort on my own part to indicate the relative value of synonyms where synonyms exist, but have endeavored to follow closely the nomenclature as given by Matthew and by later authors. For additional convenient helpful literature the reader is referred to Hay's Bibliography and Catalogue of the Fossil Vertebrata of North America, U. S. Geological Survey Bulletin No. 179, 1902, and to Palmer's Index Generum Mammalium; a list of the Genera and Families of Mammals, U. S. Department of Agriculture, Division of Biological Survey, 1904.

Effort has been made to indicate the scientific paper in which each form was first described and named, its year of publication, also the approximate locality within the area covered by the accompanying map of the Black Hills region where the earliest or type specimen was found. Such reference is omitted in a few instances where I have not had opportunity to examine the original publication. In a few instances fossils found south of the Niobrara-Platte river divide and fossils found near and to the east of Ft. Niobrara are included but generally such forms are not considered as coming within the scope of this paper. So. Dak| means in all cases the southwestern part of the state. Mauv. Terres where used corresponds fairly well to the Big Badlands, hence refers generally to fossils from South Dakota.

Megacerops tichoceras Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, pp. 159-160, (Menodus). So. Dak.
Megacerops robustus (Marsh). Am. Jour. Sci., vol. 34, 1887, pp. 326-327, (Brontops). Nw. Neb.
Megacerops brachycephalus Osborn. Am. Mus. Nat. Hist., Bull., vol. 16, 1902, pp. 97-98. So. Dak.?
Megacerops bicornutus Osborn. Am. Mus. Nat. Hist., Bull., vol. 16, 1902, p. 99. So. Dak.?
Megacerops marshi Osborn. Am. Mus. Nat. Hist., Bull., vol. 16, 1902, pp. 100-101. So. Dak.?
Allops serotinus Marsh. Am. Jour. Sci., vol. 34, 1887, p. 331. So. Dak.
Allops crassicornis Marsh. Am. Jour. Sci., vol. 42, 1891, pp. 268-269. So. Dak.
Allops amplus (Marsh). Am. Jour. Sci., vol. 39, 1890, pp. 523-524, (Diploclonus). So. Dak.
Symborodon montanus (Marsh). Am. Jour. Sci., vol. 9, 1875, p. 246, (Anisacodon). Nw. Neb.
Symborodon copei Osborn, Am. Mus. Nat. Hist., vol. 24, 1908, pp. 616-617. So. Dak.
Brontotherium ramosum (Osborn).
Brontotherium dolichoceras (Scott and Osborn). Mus. Comp. Zool., Bull., vol. 13, 1887, pp. 160-161, (Menodus). So. Dak.
Brontotherium leidyi Osborn. Am. Mus. Nat. Hist., Bull., vol. 16, 1902, pp. 105-106. So. Dak.
Brontotherium hatcheri Osborn. Am. Mus. Nat. Hist., Bull., vol. 24, 1908, pp. 615-616. So. Dak.

Artiodactyla.
Elotheridae (Entelodontidae).
Elotherium (Entelodon) crassum Marsh. Am. Jour. Sci., vol. 5, 1873, pp. 487-488.
Anthracotheridae.
Hyopotamus (Ancodon) americanus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 59. So. Dak.
Oreodontidae (Agriochoeridae).
Oreodon (Merycoidodon) hybridus Leidy. Ext. Mam. of Dak. and Neb., 1869, pp. 105-106. Mauv. Terres.
Oreodon (Merycoidodon) affinis Leidy. Ext. Mam. of Dak. and Neb., 1869, p. 105. Mauv. Terres.
Oreodon (Merycoidodon) bullatus Leidy. Ext. Mam. of Dak. and Neb., 1869, p. 106. Mauv. Terres.
Hypertragulidae.
Heteromeryx dispar Matthew.

MIDDLE OLIGOCENE (OREODON ZONE.)

Carnivora (Creodonta).
Hyaenodontidae.
Hyaenodon horridus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853, pp. 392-393. Mauv. Terres.
Hyaenodon cruentus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853, p. 393. Mauv. Terres.
Hyaenodon crucians Leidy. Acad. Nat. Sci., Phila., Proc. vol. 6, 1853, p. 393. Mauv. Terres.
Hyaenodon paucidens Osborn and Wortman. Am. Mus. Nat Hist., Bull., vol. 6, 1894, pp. 223-224. So. Dak.

Hyaenodon leptocephalus Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, p. 152.
Hyaenodon mustelinus Scott. Acad. Nat. Sci., Phila., Jour., vol. 9, 1894, pp. 499-500. So. Dak.

Carnivora (Fissipedia).
Canidae.
Daphoenus vetus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853, p. 393, Mauv. Terres.
Daphoenus hartshornianus (Cope).
Daphoenus felinus Scott. Am. Philos. Soc., Trans., vol. 19, 1898, pp. 361-362. Nw. Neb.
Daphoenus nebrascensis (Hatcher). Carnegie Mus., Mem., vol. 1, 1902, pp. 95-99, (Proamphicyon). Nw. Neb.
Daphoenus inflatus (Hatcher). Carnegie Mus., Mem., vol. 1, 1902, pp. 99-104, (Protemnocyon). Nw. Neb.
Cynodictis gregarius (Cope).
Cynodictis lippincottianus (Cope).

Felidae.
Dinictis felina Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 91, Mauv. Terres.
Dinictis squalidens (Cope).
Dinictis paucidens Riggs.
Hoplophoneus primaevus (Leidy).
Hoplophoneus occidentalis (Leidy). Acad. Nat. Sci., Phila., Jour., vol. 7, 1869, pp. 63-64, (Depranodon). Mauv. Terres.
Hoplophoneus oreodontis Cope.
Hoplophoneus marshi Thorpe. Am. Jour. Sci., vol. 50, 1920, pp. 211-214. Nw. Neb.
Hoplophoneus molossus Thorpe. Am. Jour. Sci., vol. 50, 1920, pp. 220-224. Nw. Neb.

Insectivora.
Erinaceidae.
Proterix loomisi Matthew.
Leptictidae.
Leptictis haydeni Leidy.
Ictops dakotensis Leidy.
Ictops bullatus Matthew. Am. Mus. Nat. Hist., Bull., vol. 12, 1899, p. 55. So. Dak.
Ictops porcinus (Leidy).
Soricidae.
Protosorex crassus Scott. Acad. Nat. Sci., Phila., Proc., 1894, pp. 446-448. So. Dak.

Rodentia.
Castoridae.
Eutypomys thomsoni Matthew.
Ischyromyidae.
Ischyromys typus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 89, Mauv. Terres.
Muridae.
Eumys elegans Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 90, Mauv. Terres.
Leporidae.
Palaeolagus haydeni Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, pp. 89-90, Mauv. Terres.
Palaeolagus turgidus Cope.

Perissodactyla.
- Hyracodontidae.
  - Hyracodon nebrascensis Leidy.
  - Hyracodon major Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, p. 170. So. Dak.?
- Amynodontidae.
  - Metamynodon planifrons Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, pp. 165-169. So. Dak.

Rhinocerotidae.
  - Caenopus (Subhyracodon) occidentalis Leidy.
  - Caenopus (Subhyracodon) copei Osborn. Am. Mus. Nat. Hist., Mem., vol. 1, 1898, pp. 146-150, (Aceratherium). So. Dak.
  - Caenopus (Subhyracodon) simplicidens Cope.
  - Leptaceratherium trigonodum (Osborn and Wortman).
  - "Hyracodon" planiceps Scott and Osborn. Mus. Comp. Zool., Bull., vol. 13, 1887, pp. 170-171. So. Dak.
- Lophiodontidae.
  - Colodon (Mesotapirus) procuspidatus Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 7, 1895, pp. 362-364. So. Dak.
  - Colodon (Mesotapirus) dakotensis Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 7, 1895, pp. 362-364. So. Dak.
  - Colodon (Mesotapirus) longipes Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 7, 1895, p. 366. So. Dak.
- Tapiridae.
  - Protapirus simplex Wortman and Earle. Am. Mus. Nat. Hist., Bull., vol. 5, 1893, pp. 168-169. So. Dak.
- Equidae.
  - Mesohippus bairdi Leidy.
  - Mesohippus obliquidens Osborn. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, p. 173. So. Dak.
  - Mesohippus trigonostylus Osborn. Am. Mus. Nat. Hist., Mem., vol. 2, pt. 1, (new series) 1918, pp. 47-48. So. Dak.

Artiodactyla.
- Elotheridae (Entelodontidae).
  - Elotherium (Enteloden) mortoni Leidy.
  - Elotherium (Entelodon) ingens Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, pp. 164-165. Mauv. Terres.
- Dicotylidae (Tagassuidae).
  - Perchoerus probus Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 165. Mauv. Terres.
  - Perchoerus nanus (Marsh). Am. Jour. Sci., vol. 48, 1894, p. 271, (Thinohyus). So. Dak.
- Anthracotheridae.
  - Anthracotherium curtum (Marsh). Am. Jour. Sci., vol. 47, 1894, p. 409, Heptacodon. So. Dak.
  - Hyopotamus (Ancodon) rostratus Scott. Acad. Nat. Sci., Phila., Jour., vol. 9, 1894, Appendix, p. 536. So. Dak.
- Leptochoeridae.
  - Leptochoerus spectabilis Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 88. Mauv. Terres.
  - Lepthochoerus gracilis Marsh. Am. Jour. Sci., vol. 48, 1894, pp. 271-273. So. Dak.

Stibarus quadricuspis (Hatcher). Carnegie Mus., Ann., vol. 1, 1901, pp. 131-134, (Leptochoerus).

Oreodontidae (Agriochoeridae).

Agriochoerus antiquus Leidy.

Agriochoerus latifrons Leidy. Ext. Mam. of Dak. and Neb., 1869, pp. 135-141. Mauv. Terres.

Oreodon (Merycoidodon) culbertsoni (Leidy).

Oreodon (Merycoidodon) gracilis Leidy.

Oreodon (Merycoidodon) sp. cf. bullatus Leidy.

Hypertragulidae.

Hypertragulus calcaratus Cope.

Leptomeryx evansi Leidy. Acad. Nat. Sci., Phila., Proc., vol. 6, 1853, p. 394. Mauv. Terres.

Hypisodus minimus Cope.

Hypisodus alacer Troxell. Am. Jour. Sci., vol. 49, 1920, pp. 393-396.

Camelidae.

Poebrotherium wilsoni Leidy. Acad. Nat. Sci., Phila., Proc., vol. 3, 1847, pp. 322-326. Mauv. Terres.

Poebrotherium labiatum Cope.

Poebrotherium eximium Hay. U. S. Geol. Surv., Bull. No. 179, 1902, p. 67. This was first described by Wortman as Poebrotherium wilsoni Leidy. See Am. Mus. Nat. Hist., Bull., vol. 10, 1898, pp. 111-112. So. Dak.

Poebrotherium andersoni Troxell. Am. Jour. Sci., vol. 43, 1917, pp. 381-389.

Paratylopus primaevus Matthew. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 211-213. So. Dak.

UPPER OLIGOCENE

(Protoceras and Lower Leptauchenia Zones.)

Carnivora (Fissipedia).

Canidae.

Cynodictis temnodon Wortman and Matthew. Am. Mus. Nat. Hist., Bull., vol. 12, 1899, p. 130.

Felidae.

Dinictis bombifrons Adams.

Hoplophoneus insolens Adams. Am. Jour. Sci., vol. 1, 1896, p. 429. So. Dak.

Eusmilus dakotensis Hatcher. Am. Nat., vol. 29, 1895, pp. 1091-1093. So. Dak.

Rodentia.

Castoridae.

Steneofiber nebrascensis (Leidy). Acad. Nat. Sci., Phila., Proc., vol. 8, p. 89. Mauv. Terres.

Perissodactyla.

Rhinocerotidae.

Caenopus tridactylus Osborn. Am. Mus. Nat. Hist., Bull., vol. 5, 1893, pp. 85-89, (Aceratherium). So. Dak.

Caenopus platycephalus Osborn and Wortman.

Tapiridae.

Protapirus obliquidens Wortman and Earle. Am. Mus. Nat. Hist., Bull., vol. 5, 1893, pp. 162-169. So. Dak.

Protapirus validus Hatcher. Am. Jour. Sci., vol. 1, 1896, pp. 162-168. So. Dak.

Equidae.

Mesohippus intermedius Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 7, 1895, pp. 334-356. So. Dak.

Mesohippus meteulophus Osborn. Am. Mus. Nat. Hist. Bull., vol. 20, 1904, pp. 174-175. So. Dak.

Mesohippus brachystylus Osborn. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 175-176. So. Dak.

Miohippus validus Osborn. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, p. 177. So. Dak.

Miohippus gidleyi Osborn. Am. Mus. Nat. Hist., vol. 20, 1904, p. 178. So. Dak.

Miohippus crassicuspis Osborn. Am. Mus. Nat. Hist., Bul., vol. 20, 1904, pp. 178-179. So. Dak.

Colodon copei Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 7, pp. 356-358, 1895. So. Dak.

Parahippus cognatus Leidy. Acd. Nat. Sci., Phila., Jour., vol. 7, p. 314, 1869. Nw. Neb.

Artiodactyla.

Elotheridae (Entelodontidae).

Elotherium (Entelodon) cf. ingens Leidy.

Elotherium (Entelodon)? crassus Marsh.

Elotherium (Entelodon) bathrodon Marsh. Am. Jour. Sci., vol. 7, 1874, p. 534. So. Dak.

Dicotylidae (Tagassuidae).

Perchoerus robustus (Marsh). Am. Jour. Sci., vol. 48, 1894, p. 94, (Thinohyus).

Perchoerus platyops (Cope). Hayden Surv., Bull., vol. 6, pp. 174-175, (Palaeochoerus). So. Dak.

Anthracotheridae.

Anthracotherium karense Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 6, 1894, pp. 222-223. So. Dak.

Hyopotamus (Ancodon) brachyrhynchus Osborn and Wortman. Am. Mus. Nat. Hist., Bull., vol. 6, 1894, pp. 220-221. So. Dak.

Oreodontidae (Agriochoeridae).

Agriochoerus major Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 164. Mauv. Terres.

Agriochoerus gaudryi (Osborn and Wortman). Am. Mus. Nat. Hist., Bull., vol. 5, 1893, pp. 5-13, (Artionyx). So. Dak.

Agriochoerus migrans (Marsh). Am. Jour. Sci., vol. 48, 1894, pp. 270-271, (Agriomeryx). So. Dak.

Eporeodon (?Eucrotaphus) major (Leidy). Smithson. Contr. to Knowl., vol. 6, p. 55, (Oreodon). So. Dak.

Eucrotaphus jacksoni Leidy.

Hypertragulidae.

81-82. So. Dak.

Protoceras comptus Marsh. Am. Jour. Sci., vol. 48, 1894, pp. 93-94. So. Dak.

Protoceras nasutus Marsh.

Calops cristatus Marsh. Am. Jour. Sci., vol. 48, 1894, p. 94. So. Dak.

Calops consors March.

Camelidae.

Pseudolabis dakotensis Matthew. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, p. 211. So. Dak.

LOWER MIOCENE.

Carnivora.

Canidae.

Nothocyon gregorii Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 183. So. Dak.

Nothocyon vulpinus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 183-184. So. Dak.

Nothocyon annectens Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 53-54. Nw. Neb.

Nothocyon? lemur Cope.

Daphoenodon superbus Peterson. Carnegie Mus., Ann. vol. 4, 1908, pp. 51-53. Nw. Neb.

Daphoenodon periculosus Cook. Neb. Geol. Surv., vol. 3, 1909, pp. 268-270. Nw. Neb.

Mesocyon robustus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 185. So. Dak.

Enhydrocyon crassidens Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 190-193. So. Dak.

Cynodesmus thomsoni Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 186-188. So. Dak.

Cynodesmus minor Matthew. Am. Mus. Nat. Hist. Bull., vol. 23, 1907, p. 189. So. Dak.

Temnocyon venator Cook. Neb. Geol. Surv., vol. 3, 1909, pp. 262-266. Nw. Neb.

Temnocyon percussor Cook. Neb. Geol. Surv., vol. 3, 1909, p. 266. Nw. Neb.

Borocyon robustum Peterson. Carnegie Mus., Mem., vol. 4, 1910, pp. 263-267. Nw. Neb.

Paroligobunis simplicidens Peterson. Carnegie Mus., Mem., vol. 4, 1910, pp. 269-278. Nw. Neb.

Mustelidae.

?Brachypsalis simplicidens Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 44-46. Nw. Neb.

Oligobunis lepidus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 194-195. So. Dak.

Megalictis ferox Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 197-204. So. Dak.

Aelurocyon brevifacies Peterson. Carnegie Mus., Ann., vol. 4, 1908, 68-72. Nw. Neb.

Felidae.

Nimravus sectator Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 204-205. So. Dak.

Insectivora.

Chrysochloridae.

Arctoryctes terrenus Matthew.

Rodentia.

Castoridae.

Euhapsis brachyceps Peterson. Carnegie Mus., Mem., vol. 2, 1905, pp. 179-184, (platyceps). Nw. Neb.

Euhapsis gaulodon Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 208-210. So. Dak.

Steneofiber? pansus Cope.

Steneofiber fossor Peterson. Carnegie Mus., Mem., vol. 2, 1905, pp. 140-166. Nw. Neb.

Steneofiber barbouri Peterson. Carnegie Mus. Mem., vol. 2, 1905, pp. 166-171. Nw. Neb.

Steneofiber simplicidens Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 205-207. So. Dak.
Steneofiber sciuroides Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 207. So. Dak.
Steneofiber brachyceps Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 208. So. Dak.
Geomyidae.
Entoptychus formosus Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 212-213. So. Dak.
Entoptychus curtus Matthew. Anm. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 213-214. So. Dak.
Leporidae.
Lepus primigenius Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 216. So. Dak.
Lepus macrocephalus Matthew. Am. Mus. Nat. Hist., vol. 23, 1907, pp. 214-216. So. Dak.
Perissodactyla.
Rhinocerotidae.
Diceratherium cooki Peterson. Science, vol. 24, 1906, pp. 282-283. Nw. Neb.
Diceratherium niobrarense Peterson. Science, vol. 24, 1906, pp. 281-282. Nw. Neb.
Diceratherium arikarense Barbour.
Diceratherium petersoni Loomis.
Diceratherium schiffi Loomis.
Metacaenopus egregius Cook. Neb. Geol. Surv., vol. 3, pp. 245-247. Nw. Neb.
Metacaenopus stigeri Loomis.
Epaiphelops virgasectus Cook.
1908, pp. 245-247. Nw. Neb.
Chalicotheridae.
Moropus? elatus Marsh. Am. Jour., Sci., vol. 14, 1877, pp. 250-251. So. Dak.
Moropus cooki Barbour. Neb. Geol. Surv., vol. 3, 1908, (Considered by Holland and Peterson as Moropus elatus). Nw. Neb.
Moropus petersoni Holland. Science, vol. 28, 1908, p. 810. Nw. Neb.
Moropus hollandi Peterson. Science, vol. 38, 1913, p. 673. Nw. Neb.
Moropus matthewi Holland and Peterson. Carnegie Mus., Mem., vol. 3, 1914, pp. 230-231. Ne. Colo.
Moropus parvus Barbour.
Equidae.
Miohippus equinanus Osborn. Am. Mus. Nat. Hist., Mem., vol. 2, pt. 1 (new series), 1918, pp. 65-66. So. Dak.
Miohippus gemmarosae Osborn. Am. Mus. Nat. Hist., Mem. vol. 2, pt. 1 (new series), 1918, pp. 66-68. So. Dak.
Parahippus pristinus Osborn. Am. Mus. Nat. Hist., Men. vol. 2, pt. 1 (new series), 1918, pp. 76-77. So. Dak.
Parahippus pawniensis atavus Osborn. Am. Mus. Nat. Hist., Mem. vol. 2, pt. 1 (new series), 1918, pp. 79-80. Nw. Neb.
Parahippus nebrascensis primus Osborn. Am. Mus. Nat. Hist., Mem. vol. 2, pt. 1 (new series), 1918, pp. 80-82. Nw. Neb.
Parahippus aff crenidens Scott.

Parahippus nebrascensis Peterson. Carnegie Mus. Ann., vol. 4, 1908, pp. 57-60. Nw. Neb.
Parahippus tyleri Loomis. Am. Jour. Sci., vol. 26, 1908, pp. 163-164. Nw. Neb.
Kalobatippus agatensis Osborn. Am. Mus. Nat. Hist., Mem. vol. 2, pt. 1 (new series), 1918, pp. 71-73. Nw. Neb.

Proboscidea.
Gomphotherium conodon Cook. Am. Jour. Sci., vol. 28, 1909, pp. 183-184. Nw. Neb.

Artiodactyla.

Elotheridae, (Entelodontidae).
Dinohyus hollandi Peterson. Science, vol. 22, 1905, pp. 211-212.

Dicotylidae (Tagassuidae).
Desmathyus siouxensis (Peterson). Carnegie Mus., Mem., vol. 2, 1906, pp. 308-320, (Thinohyus). Nw. Neb.
Desmathyus pinensis Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, pp. 217-218.

Anthracotheridae.
Ancondon (?Bothodon) leptodus Matthew. Am. Mus. Nat. Hist., Bull., vol. 26, pp. 1-7. So. Dak.

Oreodontidae, (Agriochoeridae).
Mesoreodon megalodon Peterson. Carnegie Mus. Ann., vol. 4, 1908, pp. 24-26. Nw. Neb.
Promerychochoerus carrikeri Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 26-29. Nw. Neb.
Promerychochoerus vantasselensis Peterson. Carnegie Mus. Ann., vol. 4, 1908, pp. 36-37. Nw. Neb.
Phenacocoelus typus Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 29-32. Nw. Neb.
"Merychyus elegans Leidy."
"Merychyus" harrisonensis Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 37-40. Converse Co., Wyo.
Merychyus minimus Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 41-44. Nw. Neb.
Leptauchenia decora Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 88. So. Dak.
Leptauchenia major Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, pp. 163-164. Mauv. Terres.
Leptauchenia nitida Leidy. Acad. Nat. Sci., Phila., Jour., vol. 7, 1869, pp. 129-131. So. Dak.

Camelidae.
Stenomylus gracilis Peterson. Carnegie Mus., Ann., vol. 4, 1908, pp. 41-44. Nw. Neb.
Stenomylus hitchcocki Loomis. Am. Jour. Sci., vol. 29, 1910, pp. 298-318. Nw. Neb.
Stenomylus crassipes Loomis. Am. Jour. Sci., vol. 29, 1910, pp. 319-323. Nw. Neb.
Protomeryx halli Leidy. Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 164. So. Dak.
Protomeryx leonardi Loomis. Am. Jour. Sci., vol. 31, 1911, pp. 68-70. S. E. Wyo.
Protomeryx?cedrensis Matthew.
Oxydactylus longipes Peterson. Carnegie Mus., Ann., vol. 2, 1904, pp. 434-468. Nw. Neb.

Oxydactylus brachyceps eterson. Carnegie Mus., Ann., vol. 2, 1904, pp. 469-471, (brachyodontus). Nw. Neb.
Oxydactylus longirostris Peterson. Carnegie Mus., Ann., vol. 7, 1911, pp. 260-266. Nw. Neb.
Oxydactylus lulli Loomis. Am. Jour. Sci., vol. 31, 1911, pp. 66-68. S. E. Wyo.
Oxydactylus gibbi Loomis Am. Jour. Sci., vol. 31, 1911, pp. 67-68. S. E. Wyo.
Oxydactylus campestris Cook, Am. Nat., vol. 43, 1909, pp. 188-189.
Oxydactylus brachyodontus Peterson.

Hypertragulidae.
Syndyoceras cooki Barbour. Science, 1905, vol. 33, pp. 797-798.
Hypertragulus "calcaratus Cope."

Cervidae.
Blastomeryx advena Matthew. Am. Mus. Nat. Hist., Bull., vol. 23, 1907, p. 219. So. Dak.
Blastomeryx primus Matthew. Am. Mus. Nat. Hist., Bull., vol. 24, 1908, p. 543. So. Dak.
Blastomeryx olcotti Matthew. Am. Mus. Nat. Hist., Bull., vol. 24, 1908, p. 543. So. Dak.

UPPER MIOCENE

Carnivora.
Canidae.
Aelurodon saevus (Leidy). Acad. Nat. Sci., Phila., Proc., 1858, p. 21. Nw. Neb.
Aelurodon haydeni (Leidy). Acad. Nat. Sci., Phila., Proc., 1858, p. 21. Nw. Neb.
Ischyrocyon hyaendus Matthew. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 246-249. So. Dak.

Mustelidae.
Potamotherium lacota Matthew. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 254-255. So. Dak.
Lutra pristina Matthew. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 256-257. So. Dak.

Rodentia.
Castoridae.
Eucastor (Dipoides) tortus Leidy. Acad. Nat. Sci., Phila., Proc., 1858, p. 23. Nw. Neb.
Mylagaulidae.
Mylagaulus monodon Cope.

Perissodactyla.
Rhinocerotidae.
?Aphelops brachyodus Osborn. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, p. 322. So. Dak.

Equidae.
Hypohippus affinis Leidy. Acad. Nat. Sci., Phila., Proc., 1858, p. 26. Nw. Neb.
Protohippus perditus Leidy. Acad. Nat. Sci., Phila., Proc., 1858, p. 26. Nw. Neb.
Protohippus placidus Leidy. Acad. Nat. Sci., Phila., Jour., vol. 7, 1869, pp. 277-279. Nw. Neb.

Protohippus supremus Leidy. Acad. Nat. Sci., Phila., Jour., vol. 7, 1869, p. 328. Nw. Neb.
Protohippus pernix (Marsh). Am. Jour. Sci., vol. 7, 1874, pp. 252-253. Nw. Neb.
Protohippus simus Gidley. Am. Mus. Nat. Hist., Bull., vol. 22, 1906, pp. 139-140.
Neohipparion whitneyi Gidley. Am. Mus. Nat. Hist., Bull., vol. 19, 1903, pp. 467-476. So. Dak.
Neohipparion occidentale (Leidy). Acad. Nat. Sci., Phila., Proc., vol. 8, 1856, p. 59, (Hipparion). So. Dak.
Neohipparion dolichops Gidley. Am. Mus. Nat. Hist., Bull., vol. 22, 1906, pp. 148-151. So. Dak.

Artiodactyla.

Dicotylidae (Tagassuidae).

Prosthemnops crassigenis Gidley. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 265-267. So. Dak.

Camelidae.

Procamelus occidentalis Leidy. Acad. Nat. Sci., Phila., Proc., 1858, pp. 23-24. Nw. Neb.
Procamelus robustus Leidy. Acad. Nat. Sci., Phila., Proc., 1858, p. 89. Nw. Neb.

Cervidae.

Blastomeryx wellsi Matthew. Am. Mus. Nat. Hist., Bull., vol. 20, 1904, pp. 125-126. So. Dak.
Blastomeryx marshi Lull. Am. Jour., Sci., vol. 50. 1920, pp. 125-130. Nw. Neb.
Aletomeryx gracilis Lull. Am. Jour. Sci., vol. 50, 1920. pp. 85-124. Nw. Neb.

PLIOCENE*

Perissodactyla.

Equidae.

Pliohippus lullianus Troxell. Am. Jour. Sci., vol. 24, 1916, pp. 335-348. So. Dak.
Pliohippus pernix Marsh. Am. Jour. Sci., vol. 7, 1874, pp. 252-253. Nw. Neb.
Pliohippus robustus Marsh. Am. Jour. Sci., vol. 7, 1874, p. 253. Nw. Neb.
Pliohippus leidyanus Osborn. Am. Mus. Nat. Hist., Mem., vol. 2, pt. 1 (new series), 1918, p. 162. Nw. Neb.

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*For a faunal list of beds of this age found in Southern Sioux County, Nebraska, see: Matthew, W. D. and Cook, H. J. A Pliocene Fauna from Western Nebraska. Am. Mus. Nat. Hist., Bull., vol. 26, pp. 361-414, 1909.

A List of Fossil Vertebrates Other Than Mammals Found in the White River Badlands.

TURTLES*

LOWER OLIGOCENE

Graptemys inornata Loomis. Am. Jour. Sci., vol. 18, 1904, p. 429. So. Dak.
Testudo brontops Marsh. Am. Jour. Sci., vol. 40, 1890, p. 179. So. Dak.
Xenochelys formosa Hay. Am. Mus. Nat. Hist., Bull., vol. 22, 1906, p. 29. So. Dak.

MIDDLE AND UPPER OLIGOCENE

Stylemys nebrascensis Leidy Acad. Nat. Sci., Phila., Proc., vol. 5, 1851, p. 172. So. Dak.
Testudo laticunea Cope.
Testudo thomsoni Hay. Hay's Fossil Turtles of North America, 1908, pp. 400-401. So. Dak.

LOWER MIOCENE

Testudo arenivaga Hay. Carnegie Mus. Ann., vol. 4, 1906, pp. 16-17, Nw. Neb.
Testudo emiliae Hay. Hay's Fossil Turtles of North America, 1908, pp. 419-420. So. Dak.

UPPER MIOCENE

Testudo edae Hay. Carnegie Mus., Ann., vol. 4, 1906, p. 19. Nw. Neb.
Testudo hollandi Hay. Carnegie Mus., Ann., vol. 4, 1906, p. 18. Nw. Neb.
Testudo niobrarensis Leidy. Acad. Nat. Sci., Phila., Proc., 1858, p. 29, Nw. Neb.

LIZARDS

Aciprion formosum Cope.
Rhineura hatcheri Bauer. Am. Nat., vol. 27, 1893, p. 998.
Hyporhina antigua Bauer. Am. Nat., vol. 27, 1893, p. 998.

CROCODILES

Crocodilus prenasalis Loomis. Am. Jour. Sci., vol. 18, 1904, pp. 427-429. L. Olig. of So. Dak.
Caimanoidea visheri Mehl Jour. Geol., vol. 24, 1916, pp. 47-56. So. Dak.

BIRDS

Birds egg (Anatidae?) Farrington. Field Mus., Geol. Ser., vol. 1, 1899, pp. 193-200. L. Olig. of So. Dak.

*The nomenclature here given for the turtles is that of O. P. Hay in his work, The Fossil Turtles of North America, 1908.

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GREENE, FRANCIS V. Chemical Investigation of Remains of Fossil Mammalia. Am. Jour. Sci., 2d. ser., vol. 16, 1853, pp. 16-20. Acad. Nat. Sci., Phila, Proc., vol. 6, 1853, pp. 292-296.

LEIDY, JOSEPH. The Ancient Fauna of Nebraska, or a Description of Remains of Extinct Mammalia and Chelonia from the Mauvaises Terres of Nebraska. Smithsonian Contributions to Knowledge, vol. 6, 1853, pp. 1-126, 24 pls. 1 map.

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*The plates are not indexed.

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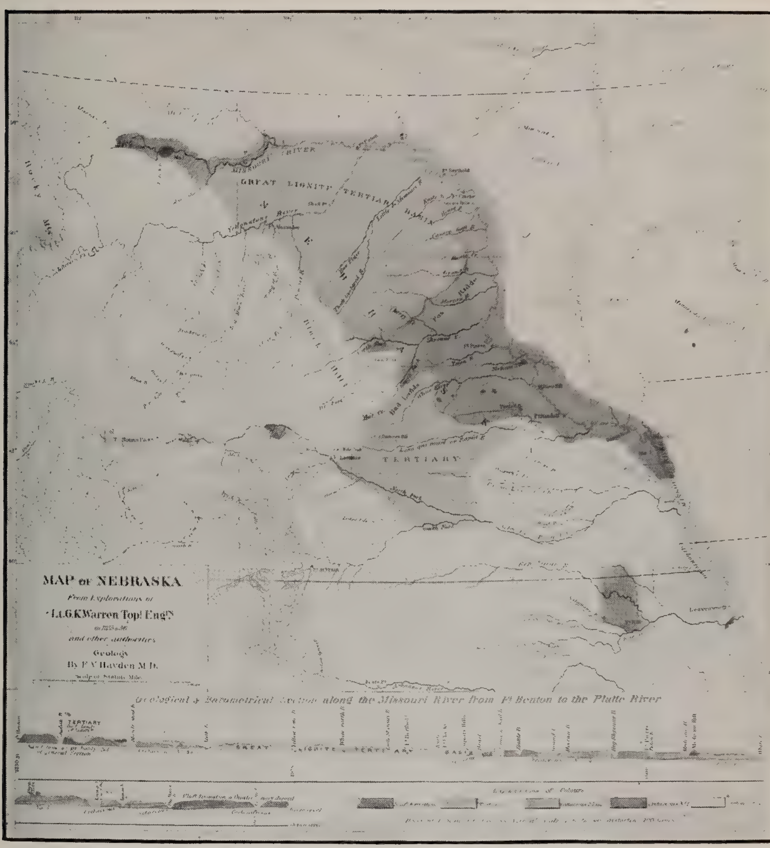
PLATES

Earliest published view of the White River Badlands, Sketched by Dr. John Evans in the field, 1849. Owen Geolog. Survey, 1852.

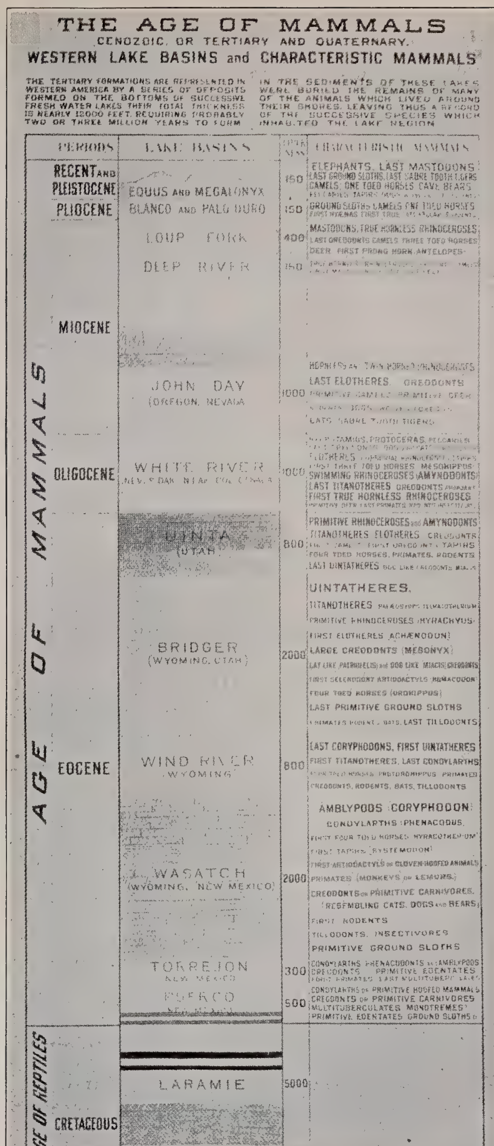
Reproduction of one of the early views of the Big Badlands by Dr. F. V. Hayden, Am. Nat., 1882.



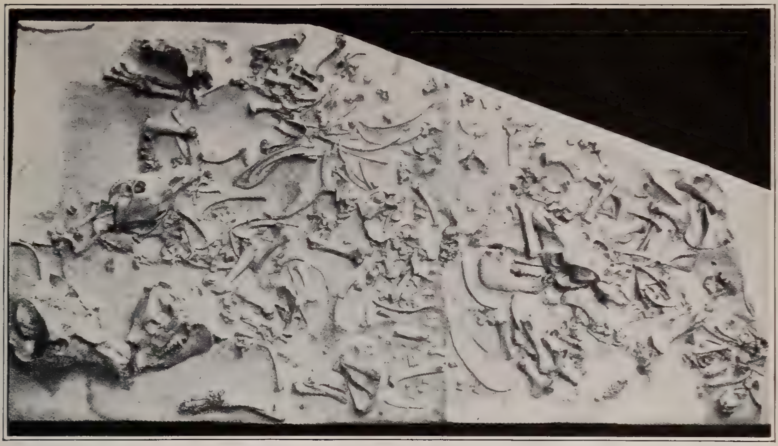
Reproduction of Hayden's Earliest Geological Map of the Upper Missouri country. The original map is colored to show the several rock divisions as then known. Note the erroneous extension of the Black Hills to the Yellowstone river, Hayden, 1857.

Reproduction of Hayden's second Geological Map of the Upper Missouri country. This map is the first ever published showing any details of the geology of the Black Hills. The geology of the surrounding country, including the Badlands, is more fully indicated than in Hayden's earlier map. Hayden, 1858.

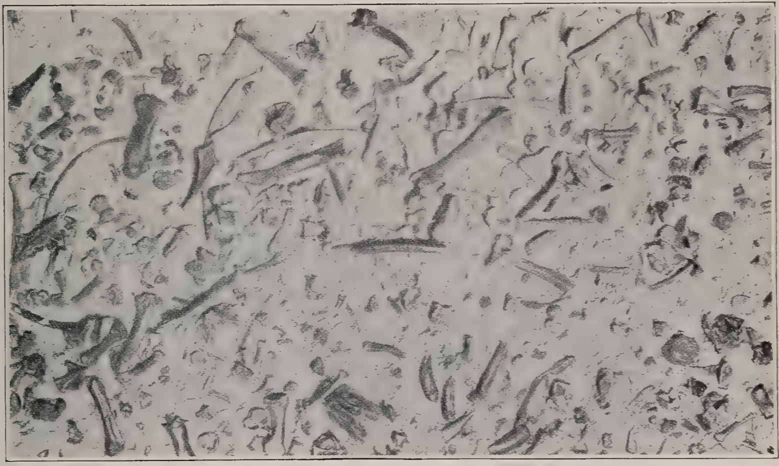
Some of the men who have done noteworthy work in unravelling the history of the White River Badlands. For description of their work see the text pages.



Divisions of the Age of Mammals. Characteristic fossil mammals, and the geological formations in which they are found. Matthew, 1903.



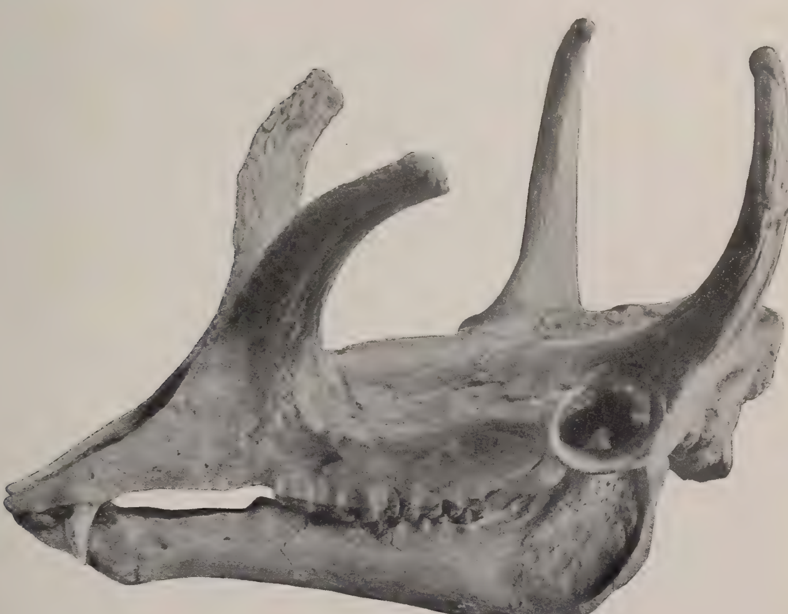
A. Matrix contains skeletons of one adult and four young individuals of *Merycochoerus proprius.* Matthew, 1901.



B. Bones are chiefly those of *Diceratherium, Moropus, Dinohyus,* and *Dinocyon.* Barbour, 1909.

Rock slabs showing abundance and arrangement of fossil bones as found in the quarry and indicating some of the difficulties of restoration.

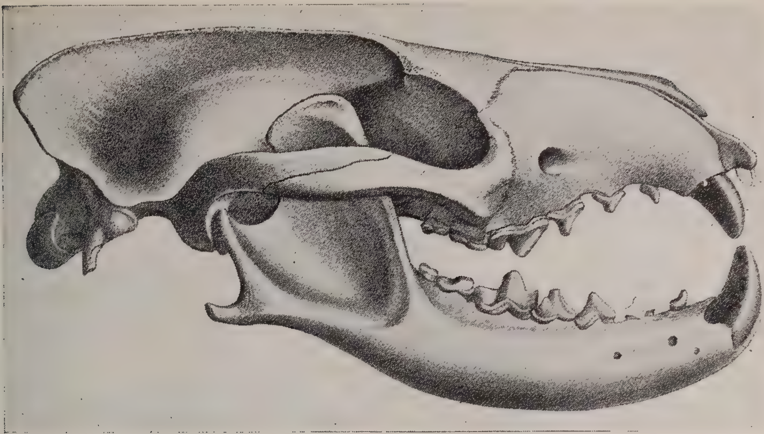
A. Head of *Hoplophoneus primaevus*, Leidy 1869.



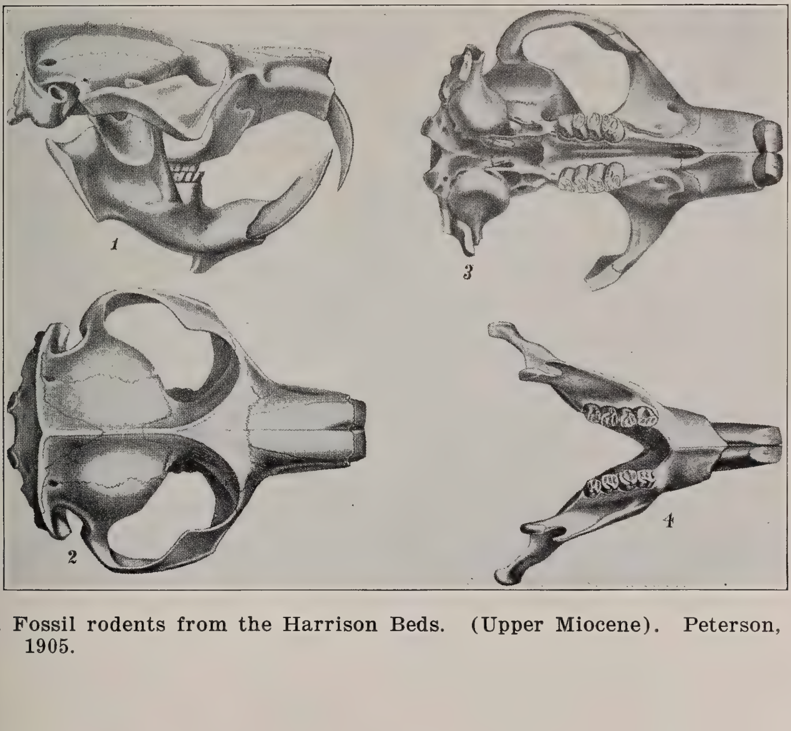
B. Head of *Syndyoceras Cooki*. Barbour. 1905.

A. Restoration of head of the Titanothere Megacerops. Lull, 1905.

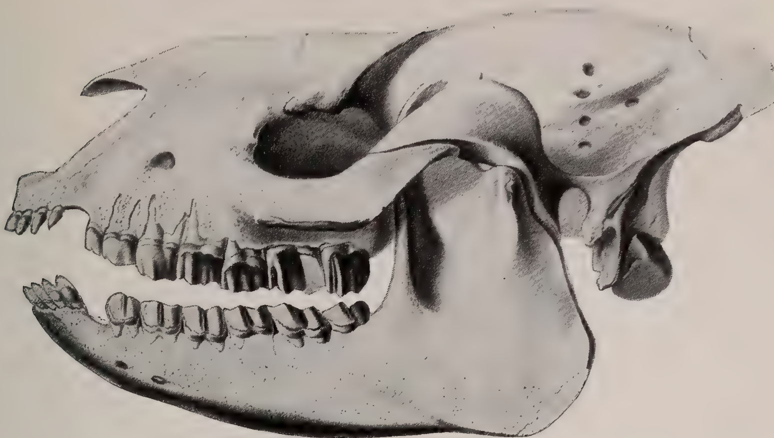
B. Outline restoration of head of the Saber-tooth tiger, *Smilodon*, to show the wide open jaw and the opportunity the animal had of using the great canine fangs for stabbing and ripping its prey. Matthew, 1905.



A. Head of *Daphoenus felinus*. Hatcher, 1902.

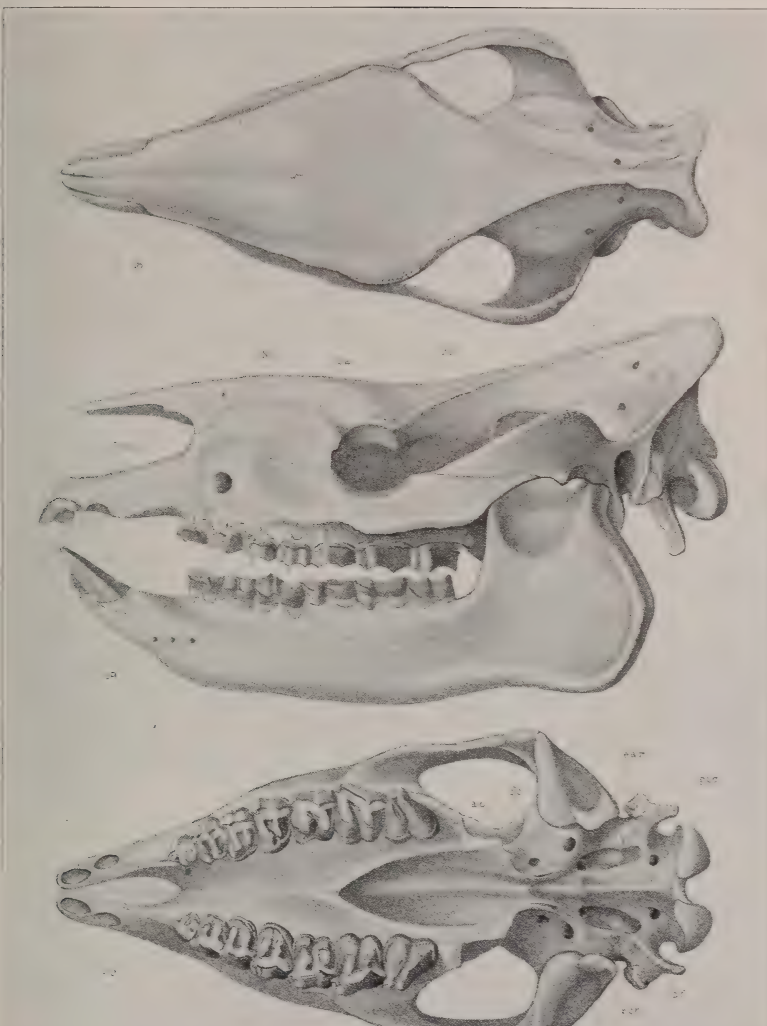


B. Fossil rodents from the Harrison Beds. (Upper Miocene). Peterson, 1905.

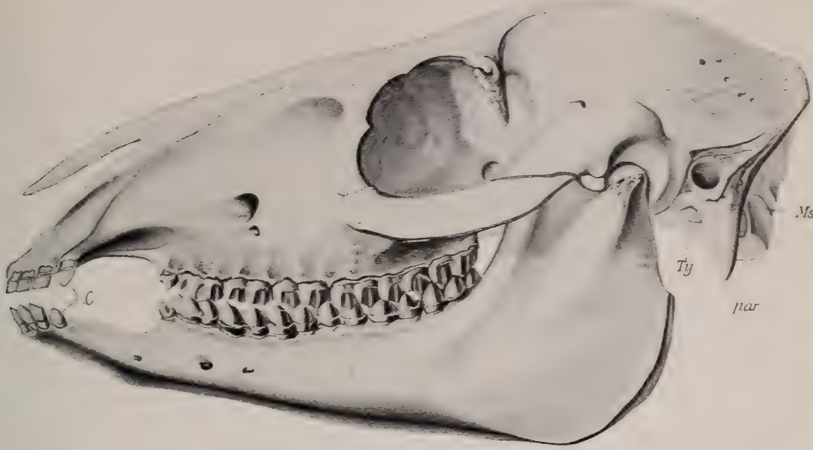


A. Head of *Hyrocodon nebrascensis*. An oligocene rhinoceros. Scott, 1896.

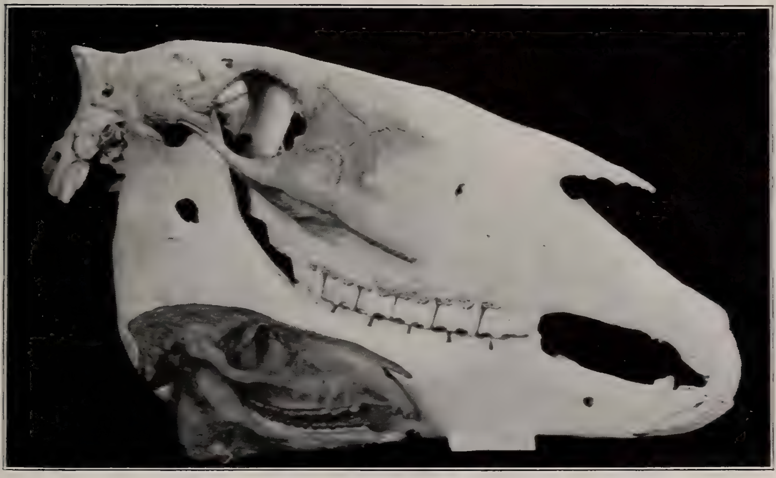
B. Head of the White River tapir, *Protapirus validus*. Restored from a skull in the museum of Princeton University. W. B. Scott, A History of Land Mammals in the Western Hemisphere, 1913. Published by the Macmillan Company. Reprinted by permission.



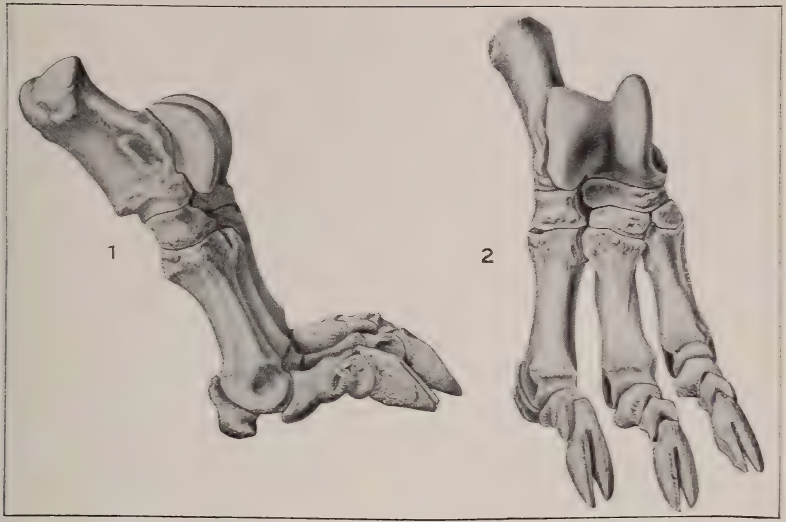
Skull of White River rhinoceros, *Caenopus* (*Aceratherium*) *occidentalis*. Upper view, side view, and palatal view. Osborn, 1898.



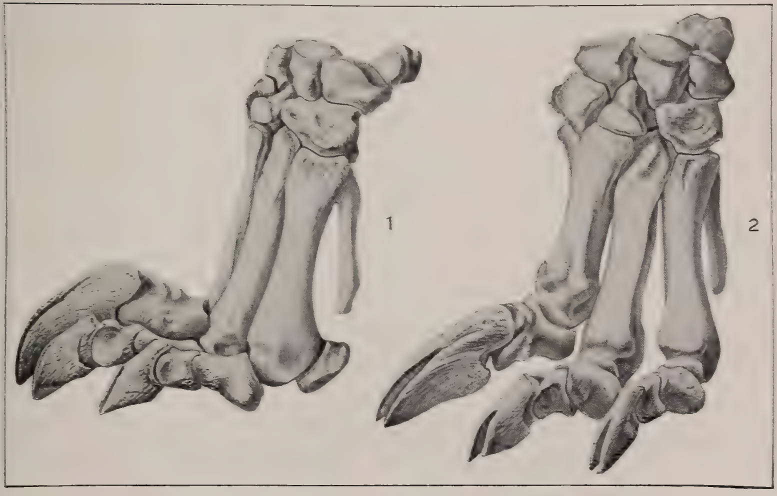
A. Head of *Mesohippus bairdi*. Scott, 1891.



B. Head of the Oligocene three toed horse, *Mesohippus bairdi* compared with that of the present day horse *Equus caballus*.

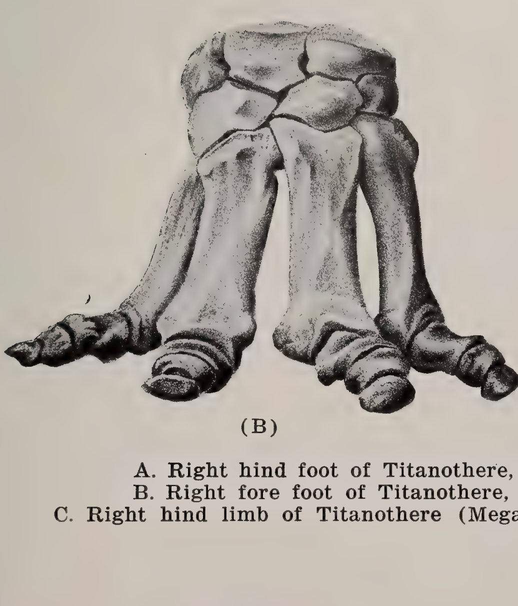


A. Right hind foot of *Moropus elatus* 1. External view. 2. Anterior view. Holland and Peterson, 1914.



B. Fore foot of *Moropus elatus.* 1. Ulnar view. 2. Anterior view. Holland and Peterson, 1914.

(A)



(B)

(C)

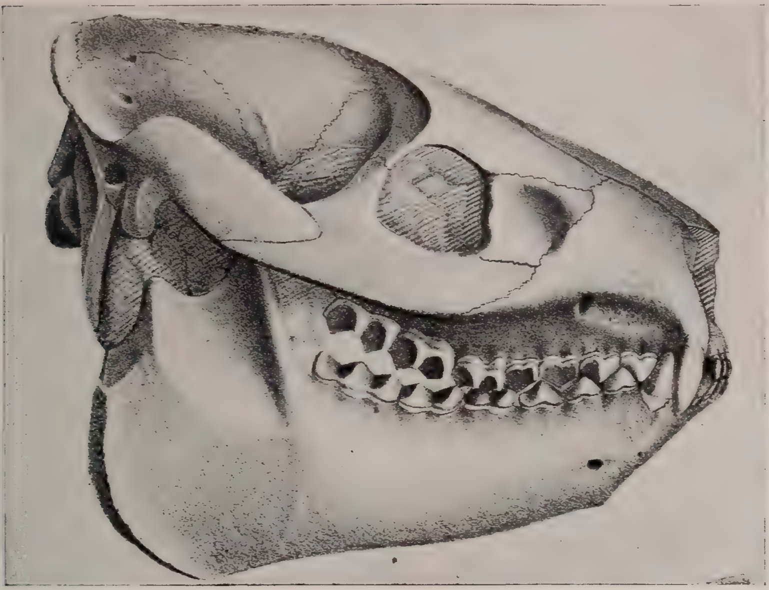
A. Right hind foot of Titanothere, Marsh, 1876.
B. Right fore foot of Titanothere, Marsh, 1876.
C. Right hind limb of Titanothere (Megacerops), Lull, 1905.

A. Upper teeth of Titanothere. Marsh, 1876.

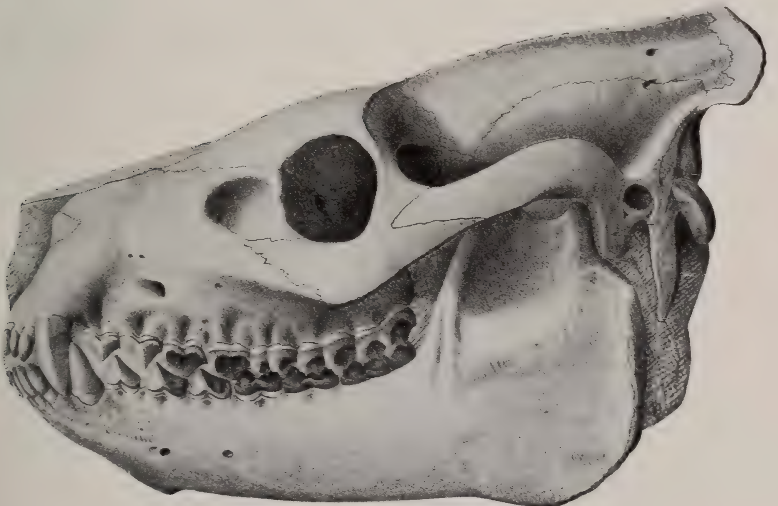
B. Lower jaw of Titanothere. Marsh, 1876

Both figures much reduced. B is reduced more than A.

Skull of *Titanotherium ingens* viewed from above. The anterior end is toward the top of the plate. Marsh, 1874.

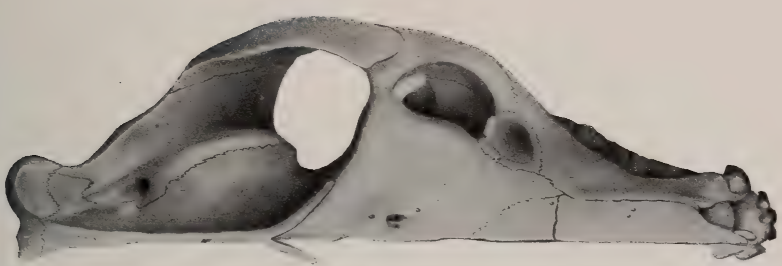


A. Head of *Merycoidodon* (*Oreodon*) *gracile*, Leidy, 1869.

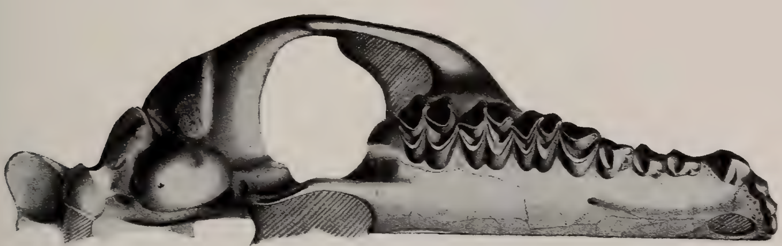


B. Head of *Merycoidodon* (*Oreodon*) *culbertsoni*. Leidy, 1869.

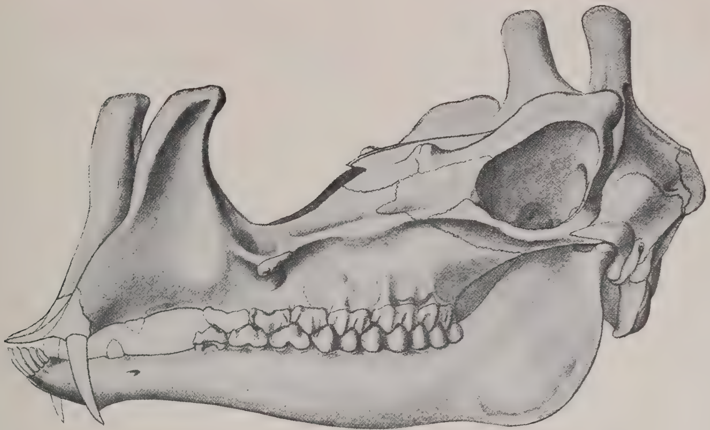
A. Skull of *Eporeodon major*. Leidy, 1869.



B. Left half of skull of *Eporeodon major*, as seen from above. Leidy, 1869.

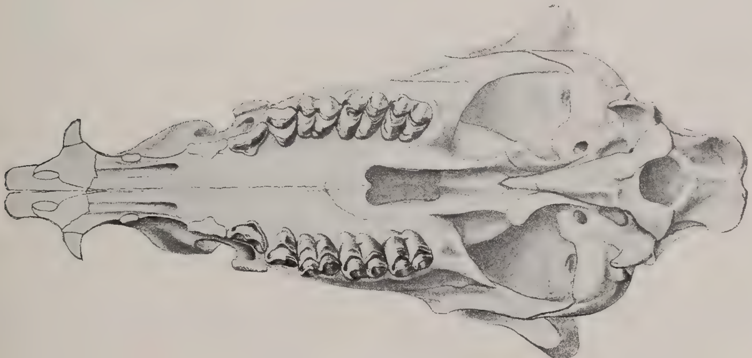


C. Right half of skull of *Eporeodon major*, as seen from below. Leidy, 1869.

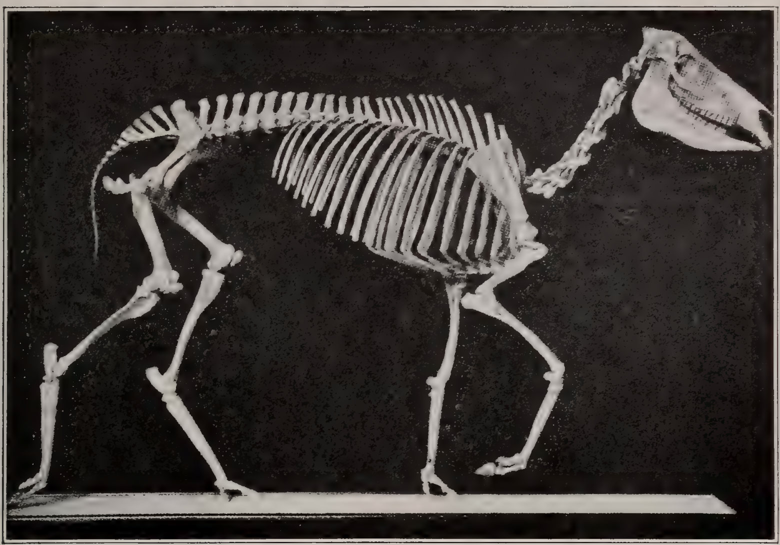


A. Head of *Protoceras celer.* Marsh, 1897.

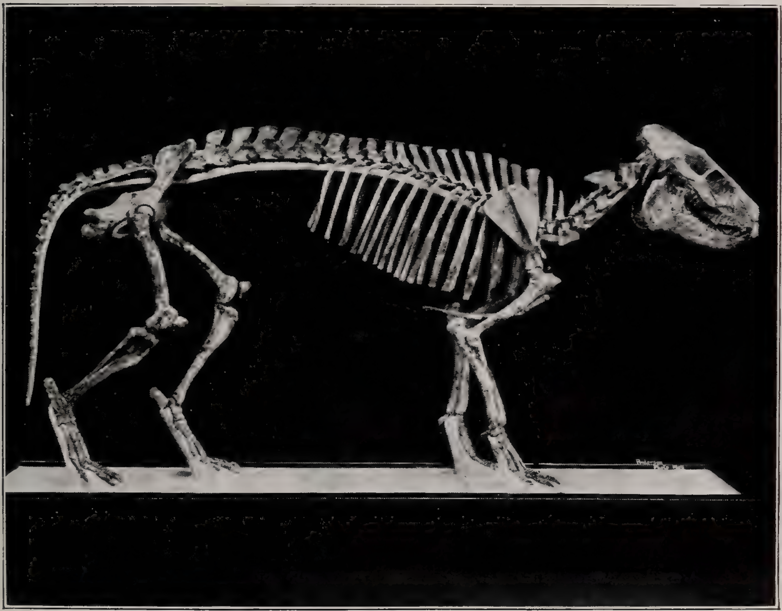
B. Skull of *Protoceras celer* as seen from above. Marsh, 1897.



C. Skull of *Protoceras celer* as seen from below. Marsh, 1897.

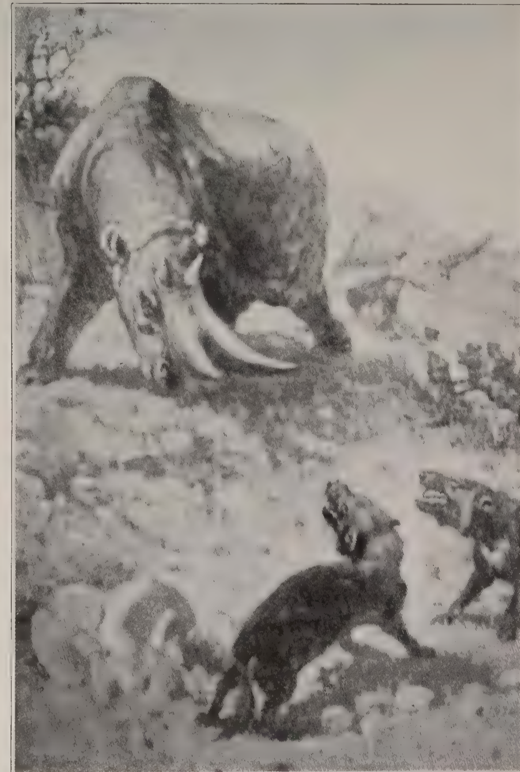


A. Skeleton of the Upper Miocene three toed horse *Neohipparion whitneyi*. Osborn. Copyrighted by the American Museum of Natural History. Reprinted by permission.

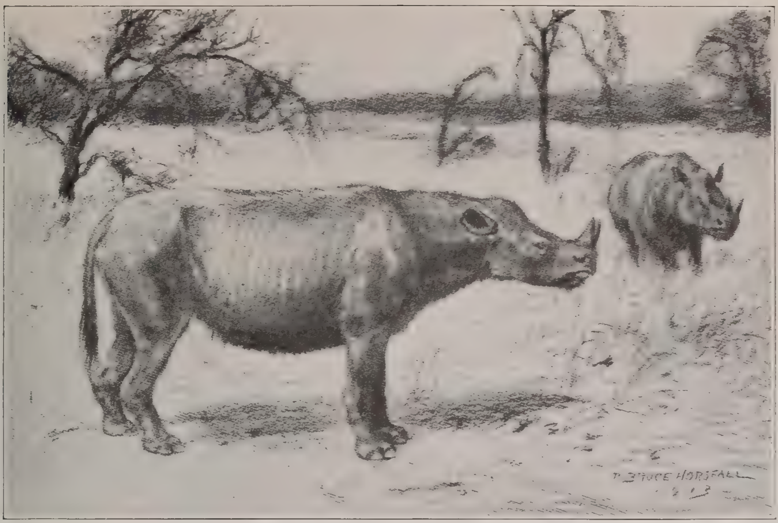


B. Skeleton of the primitive antiodactyl *Merycoidodon* (*Oreodon*) *culbertsoni* of the Oligocene. Osborn. Copyrighted by the American Museum of Natural History. Reprinted by permission.

A. Hyaenodon, a Creodont Carnivore of the Oligocene. H. R. Knipe, Nebula to Man, 1905. Published by J. M. Dent and Co., Reprinted by permission.

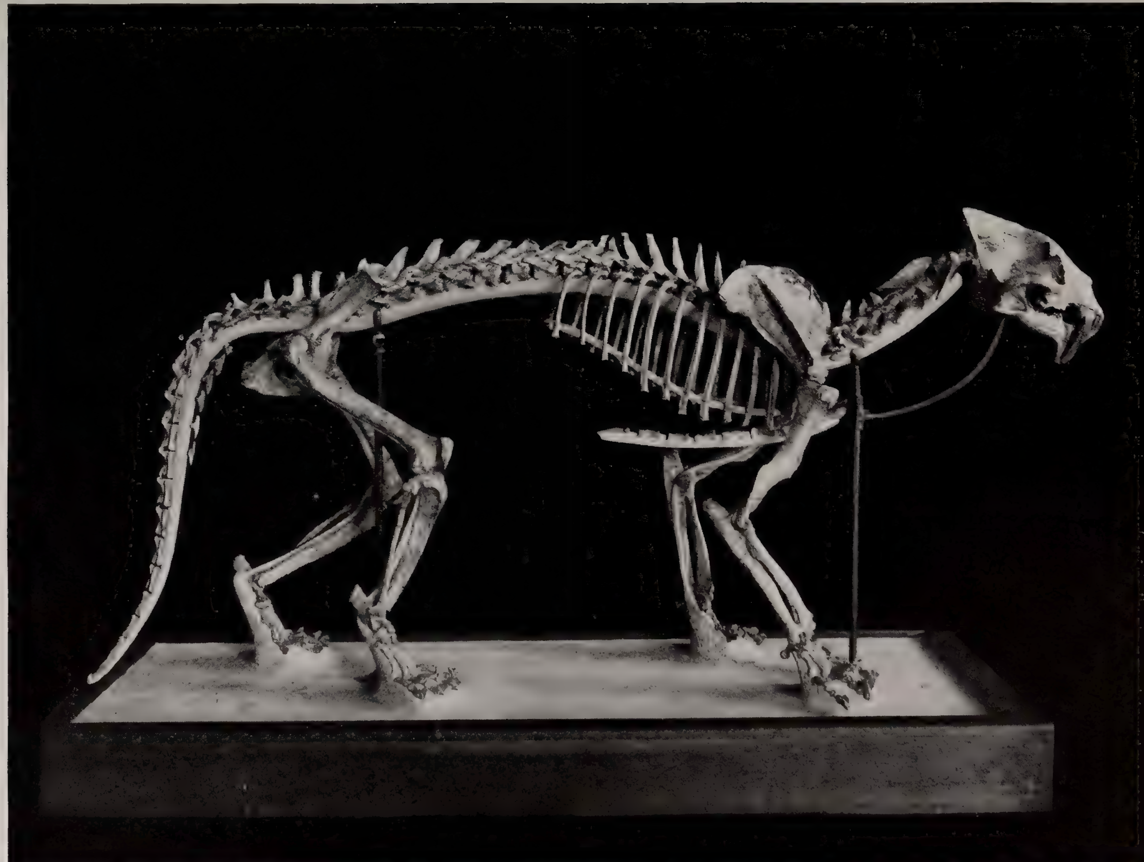


B. Restoration of animals of the Fayum, Egypt, approximately contemporaneous with those of the White River Badlands. Arsinoitherium attacked by the Creodont Pterodon. H. F. Osborn, The Age of Mammals in Europe, Asia and North America, 1910. Published by the Macmillan Company, Reprinted by permission.



A. The small paired-horned rhinoceros, *Diceratherium cooki* of the Lower Miocene. Restored from a skeleton in the Carnegie Museum, Pittsburgh, W. B. Scott. A History of Land Mammals in the Western Hemisphere, 1913. Published by The Macmillan Company. Reprinted by permission.

B. The Lower Miocene bear dog *Daphoenodon superbus*. Restored from a skeleton in the Carnegie Museum. Pittsburgh. W. B. Scott. A History of the Land Mammals in the Western Hemisphere, 1913. Published by The Macmillan Company. Reprinted by permission.



Skeleton of the early saber-tooth tiger *Hoplophoneus primaevus* of the Oligocene. Osborn. Copyrighted by the American Museum of Natural History. Reprinted by permission.

Restoration of the Oligocene saber-tooth tiger. *Hoplophoneus primaevus*. Osborn. Copyrighted by the American Museum of Natural History. Reprinted by permission.

The Oligocene aquatic rhinoceros. *Metamynodon planifrons.* Osborn.
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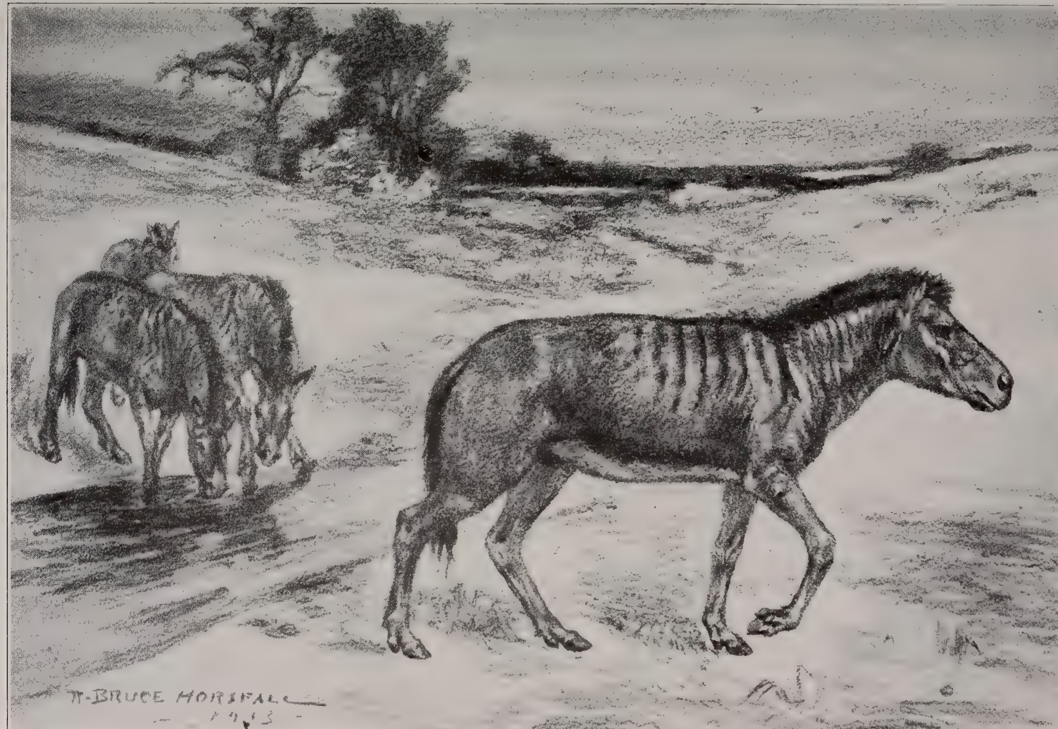
The aquatic rhinoceros, *Metamynodon* the smaller running rhinoceros, *Hyracodon* and the saber-tooth tiger *Dinictis*, all from the Oligocene. H. R. Knipe, Nebula to Man, 1905. Published by J. M. Dent and Co. Reprinted by permission.

A. Skeleton of *Hyracodon nebrascensis.* Restoration in Museum of Princeton University. Sinclair. Head of same shown enlarged in Plate 14 A.

B. *Moropus cooki*, as restored by Barbour, 1909.

Model of *Moropus Elatus*. Holland and Peterson, 1914.

The small, browsing, three toed, short-necked horse, *Mesohippus bairdi* of the Oligocene. Restored from a skeleton in the American Museum of Natural History. W. B. Scott. A History of Land Mammals in the Western Hemisphere, 1913. Published by the Macmillan Company. Reprinted by permission.



The three-toed, grazing horse, *Neohipparion whitneyi* of the Upper Miocene. Restored from skeleton in the American Museum of Natural History. W. B. Scott. A History of Land Mammals in the Western Hemisphere, 1913. Published by The Macmillan Co. Reprinted by permission.

Titanotherium (Brontops) from the Oligocene. H. R. Knipe. Nebula to Man. 1905.
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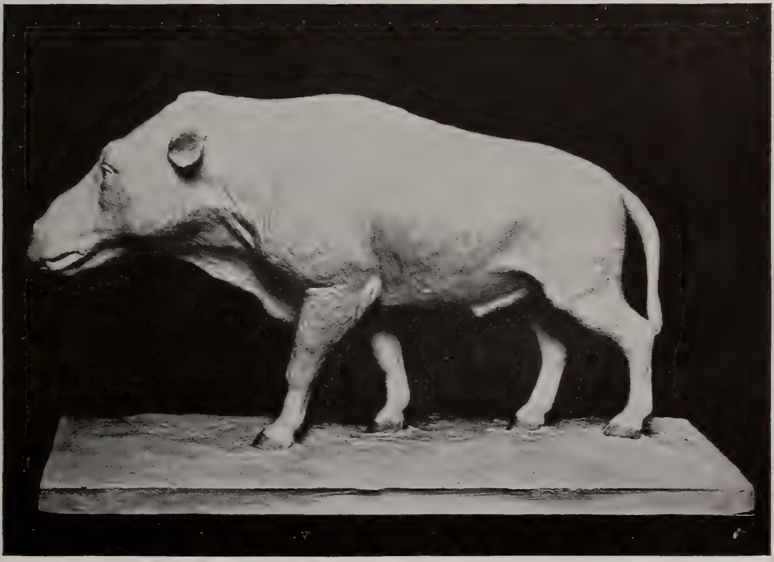
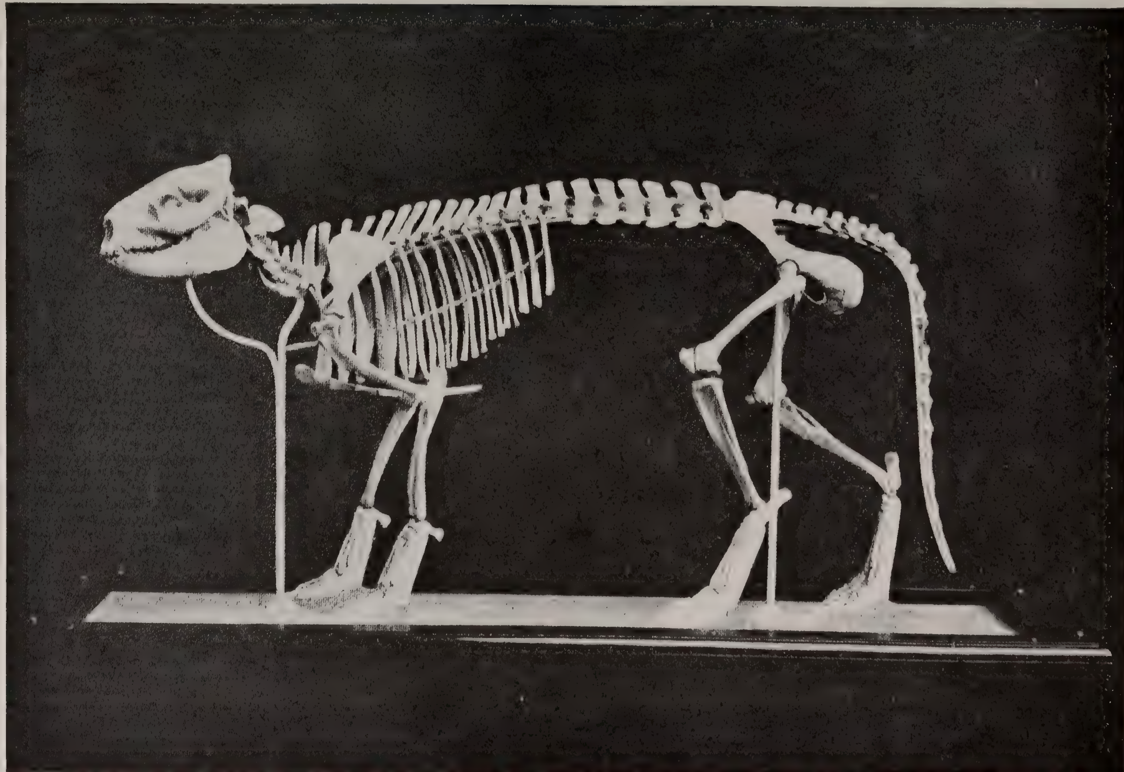
Brontotherium gigas. A flat-horned titanothere, the largest animal of the White River Badlands, Osborn. Copyrighted by the American Museum of Natural History. Reprinted by permission.

A. The giant pig *Archaeotherium ingens.* Restored from a skeleton in the museum of Princeton University. W. B. Scott. A. History of Land Mammals in the Western Hemisphere. 1913. Published by The Macmillan Company. Reprinted by permission.



B. Model of the giant entelodont, *Dinohyus hollandi* of the Oligocene. From a skeleton in the Carnegie Museum. Peterson, 1909.

Restoration of the giant pig, *Elotherium* (*Entelodon*) *imperator* of the Upper Oligocene. Osborn. American Museum of Natural History. Reprinted by permission.

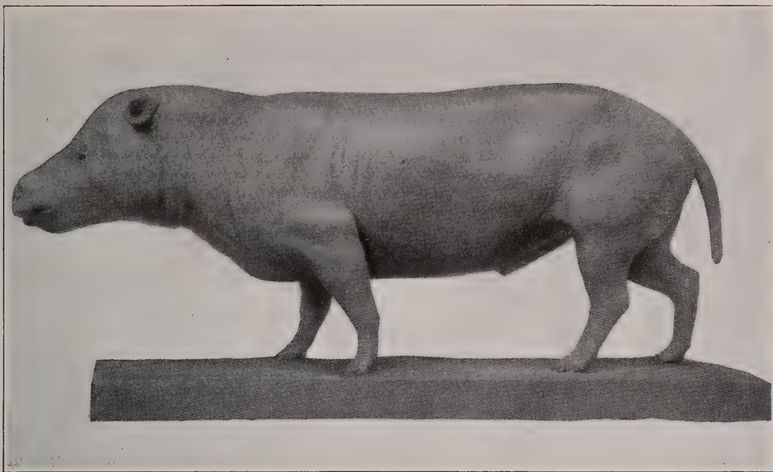


Skeleton of the Oligocene Oreodont, *Merycoidodon* (*Oreodon*) *gracilis*. Gilmore. 1906.

Restoration of the abundant Oreodont, *Merycoidodon* (*Oreodon*) *culbertsoni*. From a skeleton in the American Museum of Natural History. W. B. Scott. A History of Land Mammals in the Western Hemisphere. 1913. Published by The Macmillan Company. Reprinted by permission.

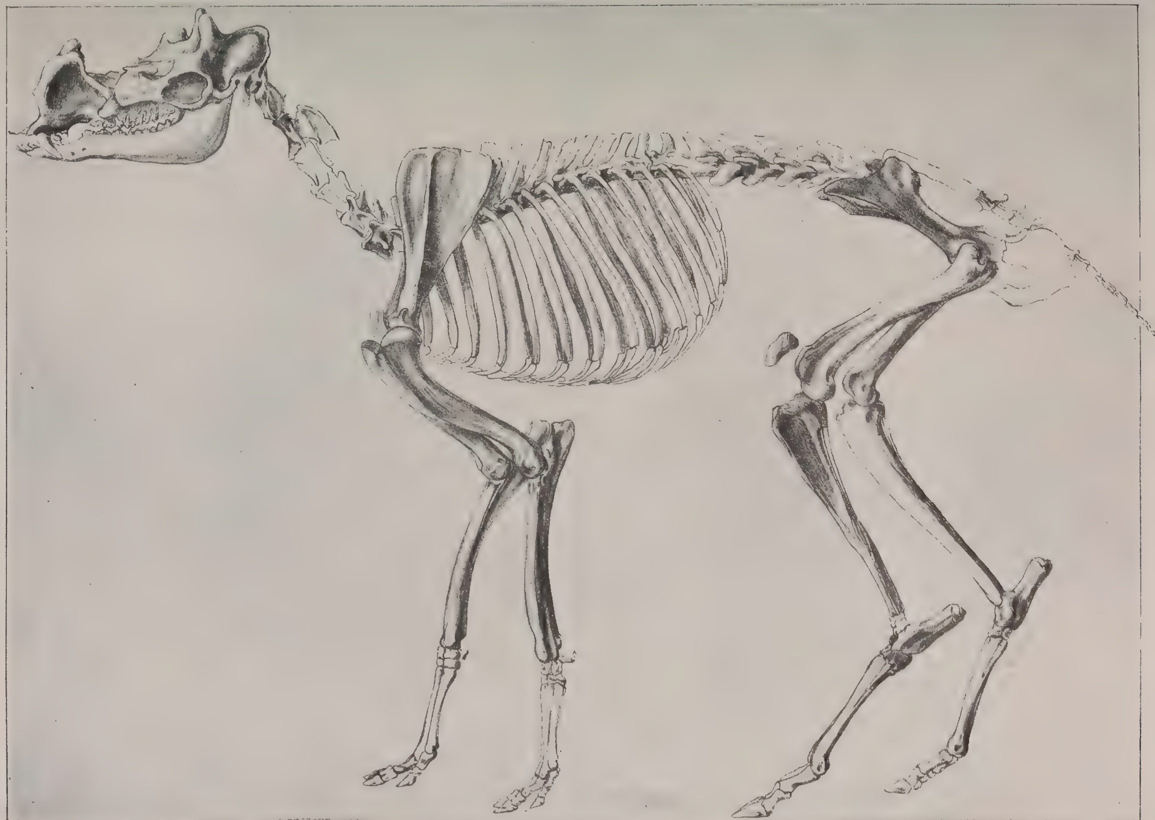
A. *Agriochoerus antiquus.* Restored from a skeleton in the American Museum of Natural History. W. B. Scott. A History of Land Mammals in the Western Hemisphere, 1913. Published by The Macmillan Company. Reprinted by permission.

B. *Leptauchenia nitida.* Restored from a skeleton in the American Museum of Natural History. W. B. Scott. A History of Land Mammals in the Western Hemisphere. 1913. Published by The Macmillan Company. Reprinted by permission.



A. Model of *Promerycochoerus carrikeri.* From a skeleton in the Carnegie Museum. Peterson, 1914.

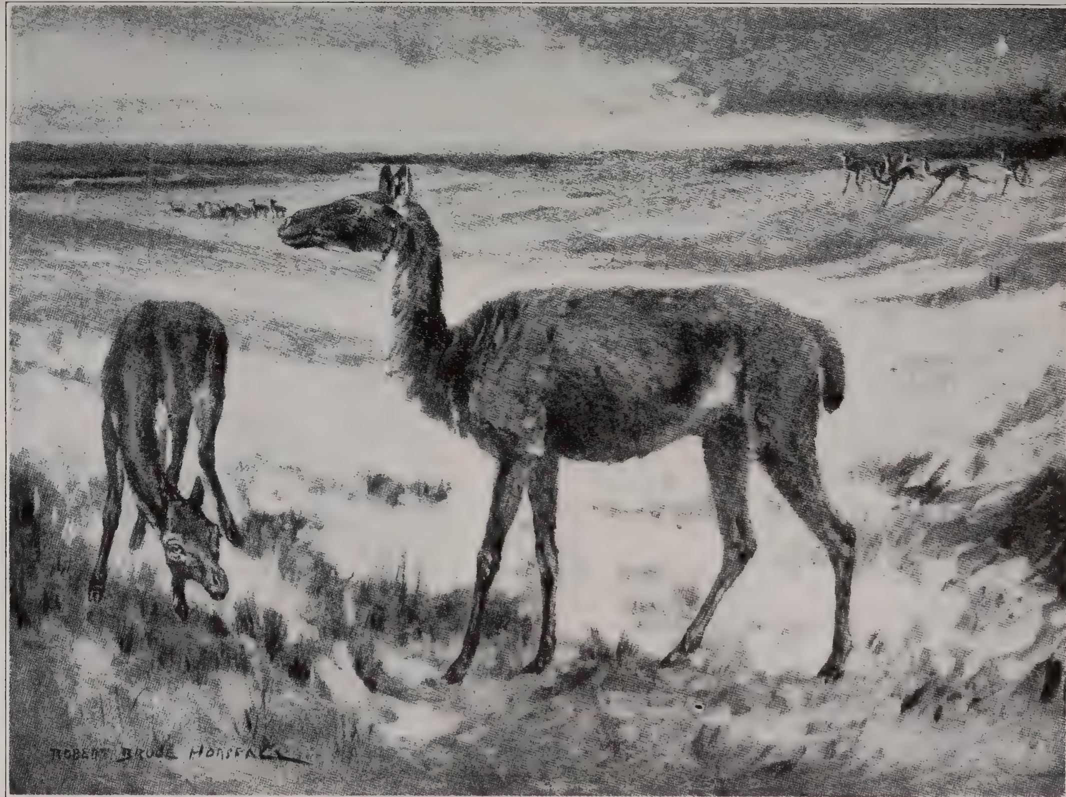
B. The Lower Miocene hornless deer, *Blastomeryx advena.* Restored from a skeleton in the American Museum of Natural History. W. B. Scott. A History of Land Mammals in the Western Hemisphere. 1913. Published by The Macmillan Company. Reprinted by permission.



Skeleton of the six horned herbivore *Protoceras celer* of the Upper Oligocene. Scott. 1895.

Restoration of the six horned herbivore *Protoceras celer* of the Upper Oligocene. Osborn. Copyrighted by the American Museum of Natural History. Reprinted by permission.

Syndyoceras cooki, a four horned ruminant of the Lower Miocene. Restored from a skeleton in the museum of the University of Nebraska. W. B. Scott. A History of Land Mammals in the Western Hemisphere, 1913. Published by The Macmillan Company.

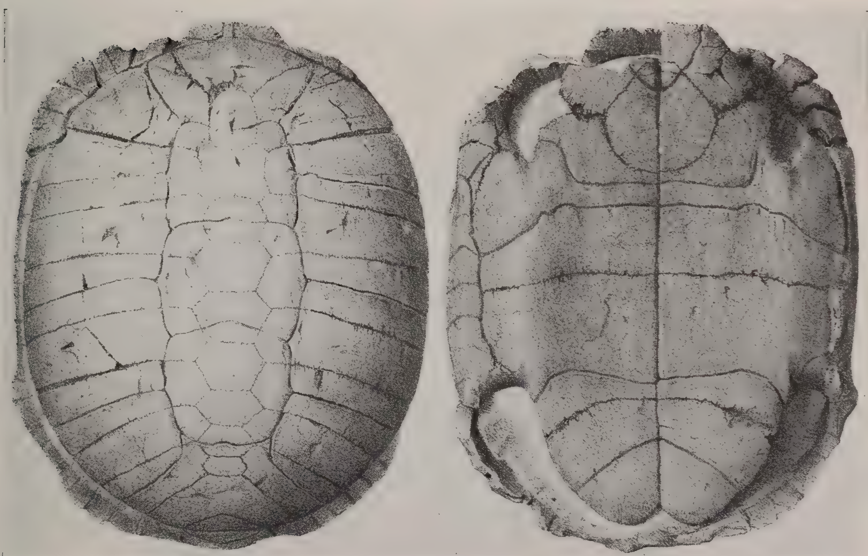


Poebrotherium labiatum, A White River camel of the Middle Oligocene, Restored from a skeleton in the museum of Princeton University. W. B. Scott, A History of Land Mammals in the Western Hemisphere, 1913. Published by The Macmillan Company. Reprinted by permission.

A. Daemonelix or "Devils corkscrews" in the Daemonelix beds near Harrison, Sioux county, Nebraska. Photograph by Barbour.

B. Anterior portion of head of the Oligocene crocodile, *Crocodilus prenasalis* found in Indian draw, 1899.

A. Petrified egg of a supposed anatine (duck like) bird of Oligocene age. Farrington, 1899.



B. *Stylemys nebrascensis*, the commonest fossil turtle of the Big Badlands, Leidy, 1853.

Good types of Sioux Indians who controlled the White River Badlands before the coming of white settlers. From the Indian Craftsman, Carlisle, Pennsylvania.

The Hall of Fossil Mammals of the American Museum of Natural History, New York City. Shows the manner of exhibiting fossil vertebrate collections to the public. Many of the cases in this room contain highly important specimens from the White River Badlands. Am. Mus. Guide Leaflet, 1903.

The Geological Museum of the South Dakota State School of Mines. Contains illustrative fossils and models of animals of the Big Badlands, 1920.

Sand-Calcite Crystals from the Miocene of Devils Hill. Foote Mineral Co., Philadelphia.

Photograph by O'Harra, 1909.

A. White River at wagon bridge near Interior.

Photograph by O'Harra, 1899.

B. Cheyenne River near mouth of Sage Creek.

Photograph by O'Harra, 1909.

A. Sun-cracked surface of an alluvial flat showing loosening and curling of the drying mud.

Photograph by Todd.

B. Spongy surface of disintegrating Titanotherium clay. The gumbo lily, as here shown, not infrequently finds root in the porous material.

A. The old postoffice of Interior on White River in the heart of the Badlands before the coming of the railroads and the days of the automobile.

B. A cowboy home in Corral Draw in the early days of Badlands settlement.

Photograph by O'Harra, 1911.

A. A new ranch home near the Great Wall north of Interior.

Photograph by O'Harra, 1911.

B. The beginning of a farm near the Great Wall northwest of Interior. Newly plowed sod in the foreground.

Photograph by O'Harra, 1911.

A. Detail of the Great Wall north of Interior.

Photograph by O'Harra, 1912.

B. The Great Wall at Cedar Pass northeast of Interior. A roadway suitable for automobiles winds up this slope and reaches the top at the lowest skyline depression to the left of the center. See Plate 88.

A. Cattle descending from grass-covered table land to grass-covered valley below. Ricard Art Co., Quinn, S. D.

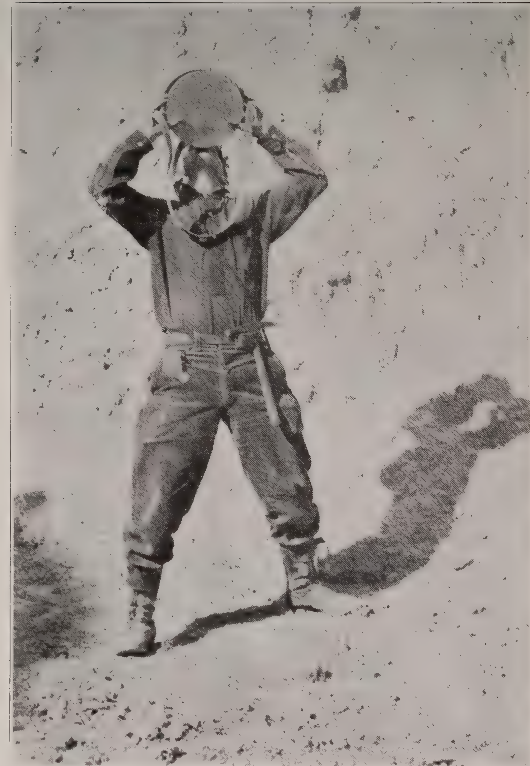
B. The 6L Ranch near Imlay showing success in soil cultivation. McNamara's Book Store, Rapid City.

A. Geology class of South Dakota State School of Mines in Indian Creek Basin, 1900.

Photograph by O'Harra.

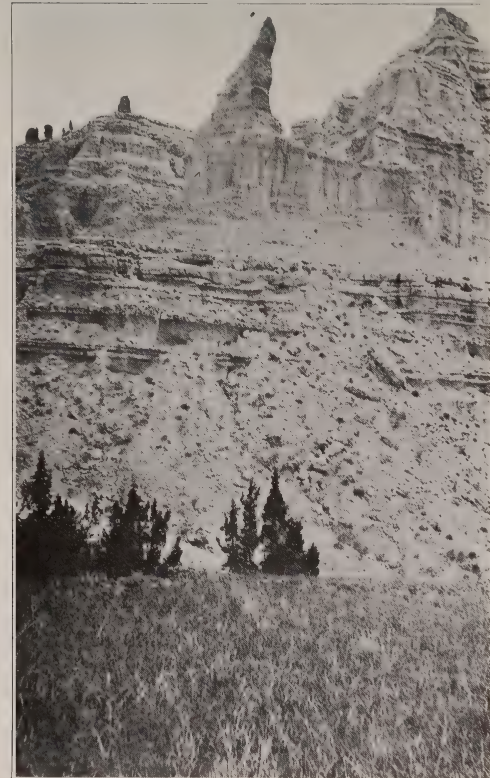
B. Geology class of South Dakota State School of Mines at top of Sheep Mountain (Cedar Point) the highest part of the Big Badlands.

Going up the northern slope of Sheep Mountain table near Hines' ranch, South of Scenic. Note the small figure of the man on the left skyline.

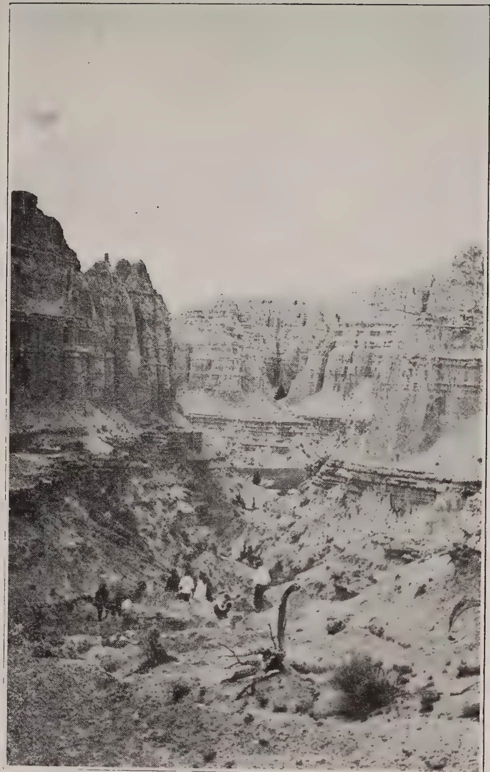


A water canteen is an essential part of the collector's equipment during the dry season.

A. A resistant clay dike in the Big Badlands.



B. An erosion pinnacle near Sheep Mountain.

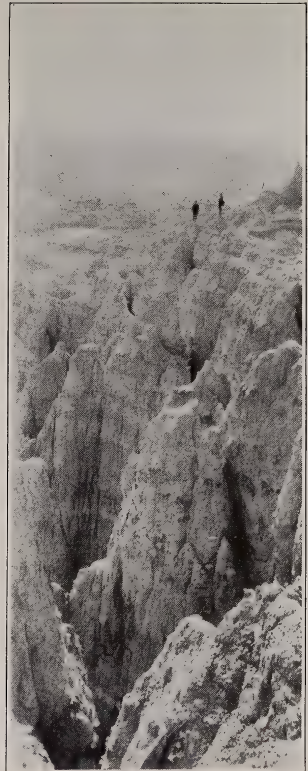


Photograph by O'Harra, 1915.

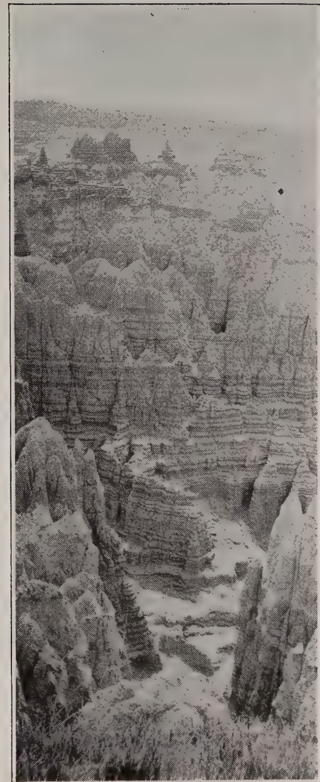
Midway down School of Mines Canyon, See Plate 91.

Photograph by O'Harra, 1915.

Geology class of the South Dakota State School of Mines in School of Mines Canyon near base of Sheep Mountain-



Steep walled canyon on eastern side of Sheep Mountain.



South side of Sheep Mountain looking toward White River.

Detail of the Great Wall near Big Foot Pass.

Photographs by O'Harra, 1915.

Photograph by O'Harra, 1899.

A. Rugged wall approximately 350 feet high separating the grassy valley of Indian Draw from the grass covered flat known as Sheep Mountain Table. Site of the School of Mines camp in the early overland trips of the Geology class to the Big Badlands. For a more general view see Plate 87.

Photograph by C. A. Best, 1920.

B. South Dakota State School of Mines students on Sheep Mountain Table. A short distance from the edge of the Wall shown in A.

A. Balanced rock on Great Wall near Big Foot Pass.

Photograph by O'Harra.

B. Balanced rock near head of Indian Draw.

Photograph by O'Harra, 1910.

A. Oreodon Beds near Big Foot Pass showing color bands.

Photograph by O'Harra, 1912.

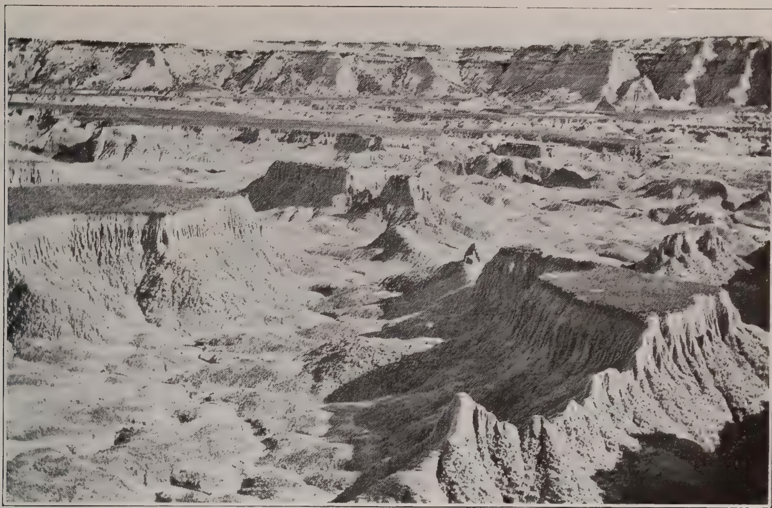
B. Erosion forms near head of Corral Draw.

Photograph by O'Harra, 1909.

A. Erosion detail of Titanotherium Beds near Big Foot Pass.

Photograph by O'Harra, 1899.

B. Erosion detail of Oreodon Beds in the valley of Indian Creek.



Photograph by O'Harra, 1910.

A. Erosion forms north of the Great Wall near Cedar Pass.

Photograph by O'Harra, 1910.

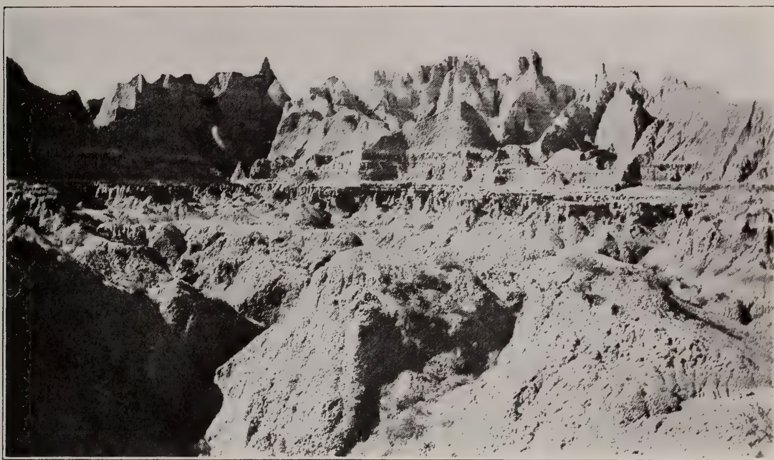
B. Erosion forms north of the Great Wall near Big Foot Pass. The flat remnants are protected by a thin covering of well-rooted grasses.

Photograph by O'Harra, 1899.

A. Looking southeast toward Sheep Mountain from Valley of Indian Creek.

Photograph by O'Harra, 1912.

B. Erosion forms in Corral Draw.



Photograph by O'Harra, 1910.

A. Detail of Great Wall north of Interior chiefly Protoceras Beds.

Photograph by O'Harra, 1910.

B. Detail of Great Wall north of Interior chiefly Protoceras Beds.

Photograph by O'Harra, 1909.

A. Clay balls in bed of little ravine near Big Foot Pass.

Photograph by O'Harra, 1899.

B. Conglomerate dike in valley of Indian Creek.

Photograph by O'Harra, 1899.

A. General view of Titanotherium Beds, Valley of Indian Creek.

Photograph by O'Harra, 1899.

B. Oreodon Beds. Valley of Indian Creek.

Photograph by O'Harra, 1899.

A. Protoceras Beds near top of Sheep Mountain.

Photograph by O'Harra, 1899.

B. Protoceras Beds near top of Sheep Mountain.

Photograph by O'Harra, 1912.

A. Oreodon Beds along the Indian Draw—Corral Draw divide.

Photograph by Best, 1920.

B. Erosion detail of the wall of School of Mines Canyon.

A. Agate Springs Fossil Quarries looking Southeast. University Hill on the left; Carnegie Hill on the right.

Photographs by Cook, 1915.

B. Stenomylus quarry of Amherst Hill, one of the Agate Springs fossil quarries.

Photograph by O'Harra, 1918.

A. General view of Slim Buttes, Perkins county, South Dakota, capped by White River Tertiary deposits.

Photograph by O'Harra, 1918.

B. Detail of the southern end of South Cave Hills, Harding county, South Dakota. Shows Fort Union sandstone of earlier Tertiary age than the White River Beds.

Photograph by E. H. Barbour.

North face of Pine Ridge, looking northeast over Hat Creek Basin. Arikaree in the left foreground. Badlands of Brule Clay in the distance.

Photograph by O'Harra, 1920.

Geological students of South Dakota State School of Mines studying concretions near head of Indian Draw.

Photograph by Johnson, 1915.

A South Dakota State School of Mines geological party near the top of Sheep Mountain.

Photograph by O'Harra, 1920.

Protoceras Beds of Sheep Mountain. The ruffled nature of the precipitous walls is due to irregularity in hardness of the bedding materials.

Photograph by O'Harra, 1920.

Characteristic steep-walled canyons in the Protoceras Beds of Sheep Mountain.

Photograph by O'Harra, 1920.

Venturesome climbing among the Protoceras Beds of Sheep Mountain.

Photograph by O'Harra, 1920.

View across the eastern slope of Sheep Mountain; Protoceras Beds above. Oreodon Beds below.

Photograph by O'Harra, 1920.

Lingering fragments of Protoceras Beds as seen from the top of Sheep Mountain looking toward White River.

Photograph by O'Harra, 1910.

Erosion forms north of the Great Wall near Interior. The grass sod protects the last lingering remnants of the once continuous level. Oreodon Beds in the foreground, Protoceras Beds in the distance.

Photograph by O'Harra, 1920.

Panoramic view of erosion forms of Protoceras Beds South of Sheep Mountain.

Photograph by O'Harra, 1910.

Panoramic view of the Great Wall, lcoking west from Saddle Pass near Interior. Protoceras Beds above, Oreodon Beds below.

Photograph by O'Harra, 1909.

Roadway through the upper portion of Cedar Pass near Interior. See Plate 57 B.

Photograph by Best, 1920.

Sheep Mountain Table as it approaches Sheep Mountain proper (Cedar Point). The cedar fringed gullies are rapidly eroding into steep-walled canyons disclosing the fluted and frilled Protoceras Beds seen in the distance.

Photograph by Johnson, 1915.

Head of Indian Draw near the heart of the Big Badlands. Cabins in the lower left hand corner mark the site of the State School of Mines camping ground in the early overland inspection trips of the Geology classes.

Photograph by O'Harra, 1920.

Midway down School of Mines Canyon. See Plate 62 B.

Photograph by O'Harra, 1920.

Near the Gateway, School of Mines Canyon.

Photograph by O'Harra, 1910.

Details of Great Wall north of Interior. Chiefly Protoceras Beds.

Photograph by O'Harra, 1915.

Protoceras Beds and Oredon Beds of School of Mines Canyon.

Photograph by O'Harra, 1915.

A Geological party descending School of Mines Canyon.

Photograph by O'Harra, 1920.

A Guardian of the Gateway, School of Mines Canyon.