CANADA

DEPARTMENT OF MINES AND RESOURCES

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BULLETIN No. 103

GEOLOGICAL SERIES No. 54

CANADIAN DINOSAURS

BY

C. M. Sternberg
Geological Survey

OTTAWA
EDMOND CLOUTIER
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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PREFACE

Dinosaurs roamed the continents of the world many millions of years ago. They were reptiles, and among them were the largest and most terrible flesh-eating animals the world has ever known. Plant-eating forms, as large or larger than their carnivorous foes, were protected by curious developments of bony armour, or depended on other physical advantages and natural habitat to maintain existence in an age of deadly peril.

In the present account the author draws particular attention to the various forms of Canadian dinosaurs. These lived in Upper Cretaceous time, and, consequently, towards the close of the long "Age of Reptiles" symbolic of the Mesozoic era, during which dinosaurs were the dominant land animals. The information is presented in a style designed to interest the general public in the life of one of the more spectacular periods in the geological history of this Dominion. It is illustrated with many plates and figures, based largely on fossilized specimens obtained from our western collecting grounds, in the discovery and preparation of which the author has long been identified.

GEORGE HANSON,
Chief Geologist, Geological Survey

OTTAWA, January 14, 1946

CANADIAN DINOSAURS

INTRODUCTION

Dinosaurs[1] lived during the "Age of Reptiles" and became extinct about 60,000,000 years ago. To obtain some idea of their place in nature and the conditions under which they lived, we must glance at the past history of the earth and its ancient inhabitants.

Palæontology deals with the history of life on the earth, and its time is measured in geological periods, each many millions of years long, rather than in centuries as civilization is measured. Ancient life is studied in terms of species instead of individuals or dynasties. Prehistoric time is commonly thought of as that during which man inhabited the earth but before history recorded his doings, and, consequently, we are apt to think of the past only in terms of historic and prehistoric time, and not realize that life existed for millions of years before man appeared, and that the 6,000 or 8,000 years of civilization are as yesterday compared with the time during which animals have inhabited the earth. Some people believe that because the carcass of a hairy mammoth was found frozen in a glacier in Siberia, we might also find the frozen flesh of a dinosaur, but in this they fail to realize that the mammoth lived until quite recently (possibly within the last 3,000 years) and like the musk-ox was adapted for life in the Arctic regions, whereas dinosaurs were extinct for millions of years before the first mammoth trod the frozen wastes of the earth during the last great "Ice Age."

We must not think of extinct animals as merely prehistoric, and imagine that they all lived together, but rather we should realize that during past geological ages a great variety of animals have flourished during successive periods of the earth's history. Some of these have become extinct without leaving descendants; others evolved into highly specialized forms[2]; and still other primitive forms have persisted to the present time with little change. It is important to remember that a single geological period, with its special types of plants and animals, covered millions of years (*See* Figure 1), and that the plants and animals of that period were as distinct from those of an earlier or later period as they are from those of today. Most of us have some idea of the evolution of the horse, the camel, and the elephant, but many do not realize that dinosaurs and other reptiles also evolved from simple to highly specialized forms before they became extinct. It should be remembered also that the dinosaurs represented only two of the sixteen orders of reptiles that lived during the Mesozoic era, the "Age of Reptiles."

We often remark what strange animals lived in ancient times, but we do not regard such specialized animals as the bat, the giraffe, or the turtle as strange because we are familiar with them. The common turtle, for example, is one of the most peculiar of reptiles, with its box-like carapace composed of plates of dermal bone overlying and thoroughly fused with the expanded ribs. Actually turtles differ from any other order of reptiles more than other living reptiles differ from dinosaurs.

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[1] Pronounced "dine-o-sores".

[2] "Specialization" is difficult to explain, but in general it has reference to a race of animals becoming adapted to certain environments or mode of living. Specialization may be toward bulk, speed, defensive weapons such as horns or dermal armour, or special feeding habits. If a group becomes highly specialized for a certain habitat, the change of that habitat might cause the extinction of the group.

We would know nothing about ancient animals were it not for the fact that many of them have left their bones, shells, tracks, or impressions entombed in the sand, mud, lime-ooze, or other material that covered them and later became hardened to rock. By the study of these fossil remains we are able to get a bird's-eye view of past life on the earth, and trace the gradual change, through countless generations, from simple to highly specialized forms.

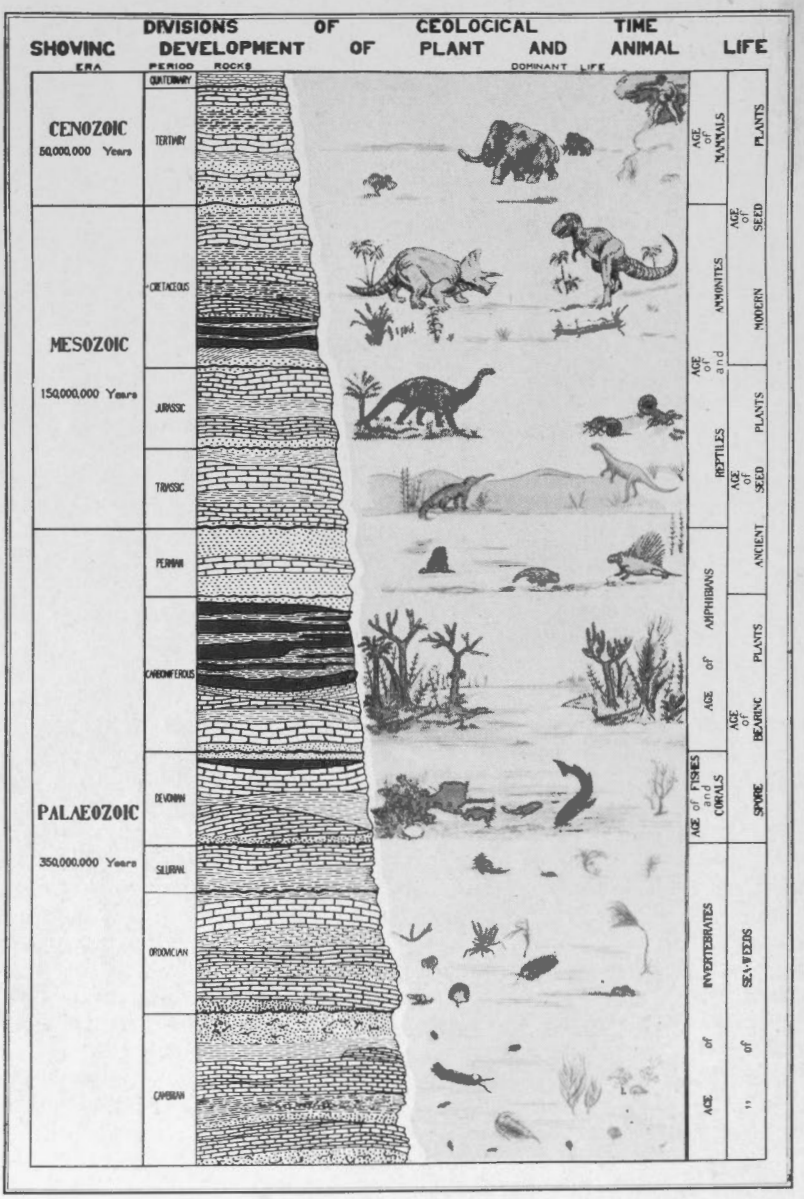


Figure 1. Geological time table; illustrating dominant life in past geological ages. By courtesy of Royal Ontario Museum of Palæontology.

The discovery of fossils may enable the geologist to determine the age of the rocks in which they are found, and thereby assist him in his search for oil, coal, or other valuable mineral products. The study of fossils also helps to

settle many problems of the present distribution of animal life, and to determine at what geological periods land areas now separated by the sea were once united, or vice versa.

CONDITIONS IN ANCIENT TIMES

The earth's crust is unstable, and changes are continually taking place, but these changes are usually so slow that they are not noticed. Frost, rain, wind, and waves are continually wearing down the highlands, and sand, silt, and mud are carried by wind and streams into the seas, lakes, or lowlands. During periods of volcanic activity large areas may be deeply buried beneath erupted ash or lava. Unequal pressure on the earth's crust may cause certain land areas to sink below sea-level and others to rise from beneath the sea.

75771

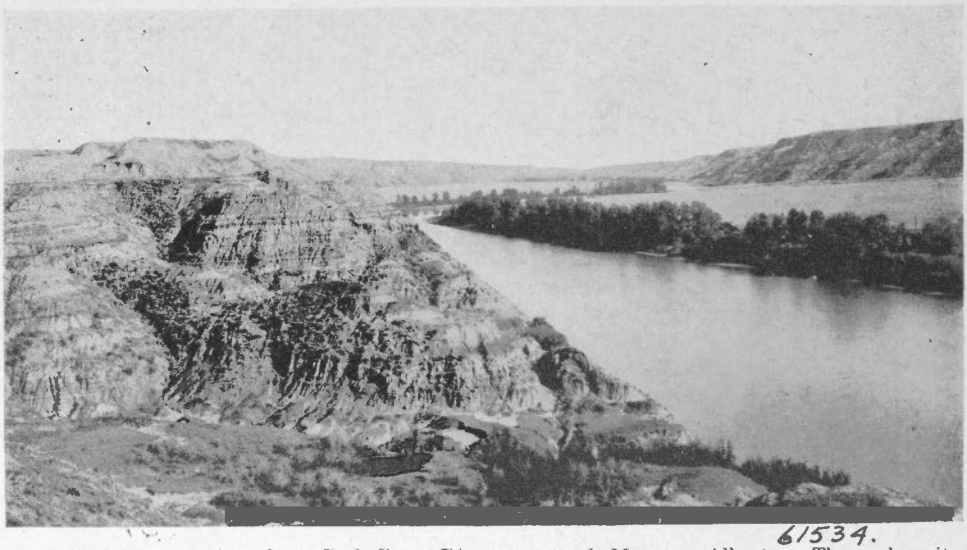
Figure 2. North America in late Cretaceous time. After Matthew. Dinosaurs inhabited the deltas that were being built up along the western edge of the inland sea. Courtesy of American Museum of Natural History.

Such movements may result in the gradual depression or elevation of great continental areas, or they may develop relatively rapidly to the accompaniment of sharp folding of the earth's crust and the uplift of high mountain ranges. Many parts of North America have been depressed and re-elevated several times during past geological ages.

If we could be transported to late Cretaceous time by some mysterious time machine, North America would seem very strange to us. A great depression then extended through the central part of the continent and was occupied by a shallow sea that reached from the Gulf of Mexico to the Arctic Ocean, and completely separated the eastern and western parts of North America (*See* Figure 2). The Rocky Mountains had not yet been formed, but the end of the Cretaceous period marked an uplift of western Canada and the draining of the inland sea. During this time a land bridge must have connected the western part of North America with Asia, permitting animals to migrate freely between these continents, as similar dinosaurs have been found on both.

Rivers flowing from the higher lands to the west carried vast quantities of sand and clay into the western edge of the Cretaceous Sea, building up great delta deposits hundreds of feet thick and thousands of square miles in area (*See* Plate I). On these deltas, in the swamps, on the flood-plains of the rivers, and on the uplands farther west lived a great variety of dinosaurs and other reptiles. Fossil wood and the remains of both land and water plants point to a dense vegetable growth, and the presence of palms, figs, and other plants of similar habitat indicates that the climate was warm temperate to sub-tropical.

PLATE I



Ancient delta deposits along Red Deer River, west of Munson, Alberta. These deposits are now elevated to more than 2,500 feet above sea-level.

Not all the different kinds of animals found buried in these deltaic deposits lived together. Some lived in swamps; others inhabited the highlands a hundred or more miles from the seashore, and their remains were carried by streams onto the deltas and buried there. The building up of these deltas must have taken many, many thousands of years, and the fact that the big, swamp-dwelling animals are more numerous in our collections does not prove that in actual life they were more numerous than the upland types, but merely that a greater proportion of them were buried in the deltas before the flesh was devoured or the bones destroyed by exposure to the air. Of the animals that lived on the uplands only the more durable skeletal parts would normally withstand transportation to the deltas; the occasional carcass, however, might be brought down by a flood.

Usually an upland habitat is not favourable for the preservation of fossils, for even if a skeleton were covered by wind-blown sand or other deposits these would be the first swept away by erosion during periods of uplift. A notable instance of where desert deposits have escaped erosion is found in the Gobi Desert of Mongolia where dinosaurian remains, including fossilized eggs and skeletons of young individuals, are found in strata that were deposited under arid conditions somewhat similar to those existing there today. The apparent absence of eggs and skeletons of very young dinosaurs from swamp and delta deposits may mean that eggs were laid and the young reared away from the deltas, and that only more or less mature dinosaurs inhabited the swamps and bayous. Many modern animals are known to travel hundreds of miles to deposit their eggs or rear their young in some favoured locality; among living reptiles the sea turtle affords a good example of this habit.

PLATE II

C 93381

Skelton of hooded, duck-billed dinosaur, *Lambeosaurus*, in the rock east of Manyberries, Alberta. Note the strongly arched neck, typical of articulated skeletons. Much of the back part of the skeleton was eroded away before discovery.

THE AGE OF REPTILES

Certain geological periods and epochs have been grouped and named for the dominant animals of the time (*See* Figure 1). The last and shortest of these periods, the Quaternary, is also known as the "Age of Man", during which man sprang from an already highly developed ancestor, evolved to his present high state, and has since ruled the earth. This age includes, roughly, the Pleistocene, or Glacial, and Recent epochs, and commenced not more than 1,000,000 years ago. The "Age of Man" was preceded by the "Age of Mammals", which lasted nearly 60,000,000 years[1], during which time modern mammals and birds

[1] Shown as 50,000,000 years on Figure 1.

developed from more primitive ancestors. Preceding the "Age of Mammals" was the much longer "Age of Reptiles", corresponding in geological time to the entire Mesozoic era, which comprises the Triassic, Jurassic, and Cretaceous periods, and which has been calculated to have lasted 140,000,000 years[1]. The modern estimate of 60,000,000 years since the close of the Cretaceous period is probably more accurate than the much shorter estimate accepted 30 years ago.

During the "Age of Reptiles", fishes and amphibians were still abundant, and primitive mammals and birds were developing, but reptiles ruled supreme (*See* Figure 1). They were prolific, and evolved into many highly specialized forms. In the seas lived several orders of reptiles such as ichthyosaurs (fish lizard), plesiosaurs (near lizard), marine crocodiles, etc. A great variety of flying reptiles known as pterodactyles (wing-finger) glided through the air. Though swamp turtles and crocodiles of the modern type were common during late Cretaceous time, the dinosaurs definitely dominated the land from the swamps to the desert highlands.

During the Cretaceous period the ancient flora of giant rushes and club-mosses, trees with fern-like foliage, cycads, and ancestral relatives of the Norfolk Island pine, gave way to modern types, and by the close of the period flowering plants and deciduous trees were well established. Members of the four orders of reptiles living today do not differ greatly from representatives of the same orders that lived during late Cretaceous time, but mammals and birds have made their greatest advance since then. We do not know what stimulated evolution of the reptiles during one age and birds and mammals during another, but probably modern flora with its more concentrated and nourishing food, the insect population, and atmospheric conditions have all had considerable influence.

PLATE III

95406

Habitat restoration model of carnivorous and horned dinosaurs in late Cretaceous time. Dinosaurs modelled by L. S. Russell, background by C. E. Johnson.

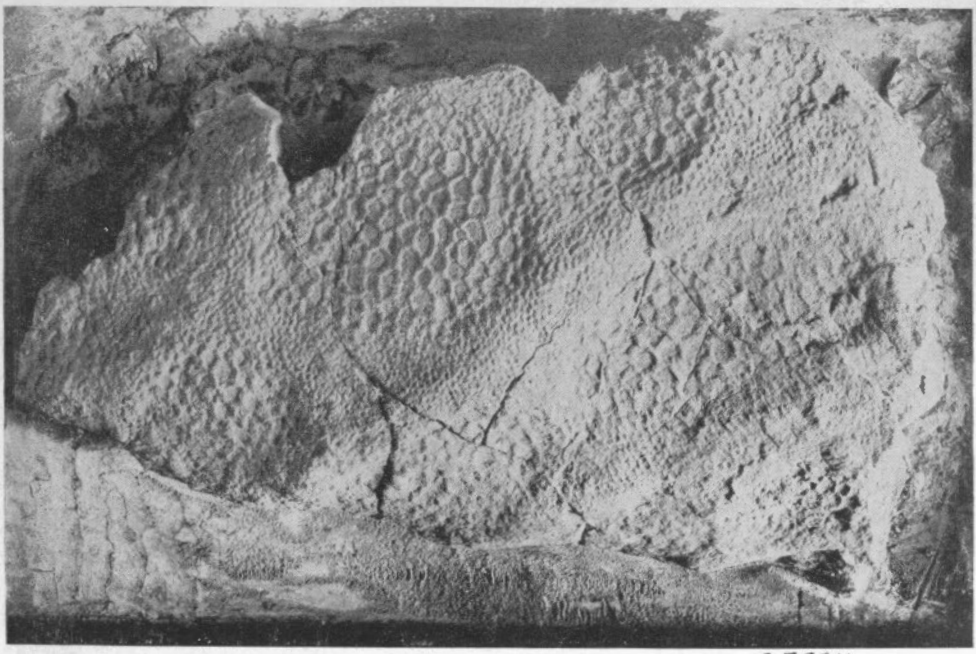
GENERAL DISCUSSION

The name dinosaur is the anglicized form of Dinosauria, which was derived from Greek words meaning "terrible lizard." It was proposed in 1842 by Professor Owen, the eminent English palæontologist. In today's accepted classification dinosaurs are regarded as representing two distinct orders of the class Reptilia.

[1] Shown as 150,000,000 years on Figure 1.

In the year 1800 Pliny Moody of South Hadley, Massachusetts, plowed up a piece of flagstone on which was impressed a dinosaur track. Young Moody referred to this as the track of Noah's raven. The first scientific description of a dinosaur was published in England in 1824. In 1836 Professor E. Hitchcock figured and described a number of fine dinosaur tracks that had been collected from Connecticut Valley. The tracks were mostly three-toed, and had been made by small to moderate sized dinosaurs. Professor Hitchcock described these as bird tracks, for at that time little was known about the structure of dinosaurs, and it was not until several years later that it was realized that the tracks had been made not by birds but by dinosaurs. The first discovery of dinosaurs in Canada was made in 1874 by G. M. Dawson of the Geological Survey, who found remains in Upper Cretaceous rocks of southern Saskatchewan. From this small beginning the study of dinosaurs has gone steadily forward until now we can recognize more than four hundred distinct species, many of which are known from almost complete skeletons, and in some even the impression of the skin is preserved (*See* Plate IV). Though dinosaurian remains have been found in many parts of the world, North America has yielded the greatest number of good specimens.

PLATE IV



25994

Skin impression of a duck-billed dinosaur.

Birds and dinosaurs have many characteristics in common, and it is now generally believed that dinosaurs and birds developed from a common ancestor, and not that birds evolved from dinosaurs as was once believed by some. Dinosaurs evolved from a small, lizard-like reptile with compact body, relatively long limbs, long tail, and five-toed feet. This dinosaurian ancestor may not have been very far removed from the ancestor of birds. From this ancestral form was developed a great variety of dinosaurs ranging from less than 2 feet to more that 80 feet in length. Though the largest of these were the longest land animals that ever existed, their bulk was not as great as that of some of

the modern whales, because much of the dinosaur's length was taken up by the very long neck and tail. The limbs of all dinosaurs were constructed so as to bear the weight of the animal and carry the body free of the ground and, therefore, instead of crawling as most reptiles do, they walked or ran like mammals or birds. All the carnivorous (flesh-eating) and some of the herbivorous (plant-eating) dinosaurs were bipedal, at least in their later development, but many of the herbivores were habitually quadrupedal. Others probably rested on their front feet while feeding, but when in a hurry assumed the bipedal pose. Some were light-limbed and swift, whereas others were heavy, broad-backed, clumsy creatures. Some were protected by bony armour, but in others the skin was thin. Some had very small heads; others had huge heads surmounted by long, sharp horns; and others had powerful jaws filled with long, sharp teeth (*See* Plate VI). The brain was of a primitive type and very small. In long-necked forms the head was small, but in forms with a very large head or powerful jaws the law of mechanics made it imperative that the neck be short and well muscled.

PLATE V

73726.

Dinosaur tracks in Lower Cretaceous rocks, about centre of Peace River Canyon, British Columbia.

None of the very large or very primitive forms of dinosaurs has yet been found in Canada. The rocks from which our dinosaurs are collected are deltaic deposits of Upper Cretaceous age, whereas the above-mentioned forms lived during earlier geological periods or in a different habitat. Many other kinds, particularly those found in Europe, have not been found in Canada. However, more than sixty distinct species have been described from Alberta and Saskatchewan. Two localities on Red Deer River, one about 120 miles east of Calgary and the other above Drumheller, have yielded most of these. Fairly complete skeletons or skulls of many species are known, but only parts of the skeletons of other species have been found. In the collections are also many fragments that are known to represent undescribed forms, but that are not

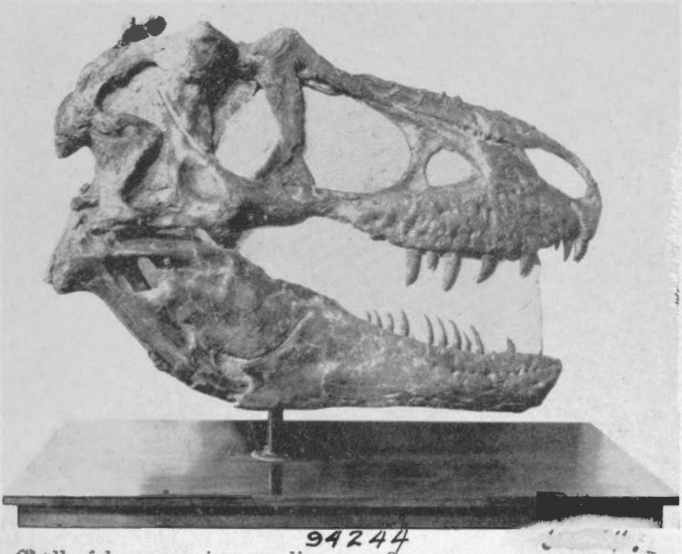
sufficiently complete to serve as the type of a new species. Most of these latter are smaller forms that probably inhabited the uplands. If and when we locate dinosaur-bearing, upland deposits in Canada, we shall probably learn much more about the small carnivores and the little-known upland herbivorous forms.

Eight species of dinosaur tracks have been described from the Lower Cretaceous rocks of Peace River Canyon, British Columbia. Some of these tracks were made by carnivorous dinosaurs not greatly different from those found in Alberta, but others must have been made by as yet unknown forms.

CARNIVOROUS DINOSAURS

All of the carnivorous dinosaurs as well as the huge sauropod (lizard-foot) forms belong to the reptilian order Saurischia. Five families of carnivorous dinosaurs are represented in collections from Alberta. Good skeletons of the large flesh-eaters, *Gorgosaurus* and *Albertosaurus*, and of the bird-mimic form *Struthiomimus*, have been found, but only parts of the skeletons of the other three families are known.

PLATE VI



Skull of large carnivorous dinosaur, *Gorgosaurus*, mounted in the National Museum, Ottawa. The lower jaws were nearly 4 feet long and were hinged far back, enabling him to open the mouth with a very wide gape, like a crocodile.

True Carnivores

The large carnivores were the culmination of a long line of large, lowland forms. They were by far the largest flesh-eaters that ever walked the earth, and were the tyrants of the everglades. Some were 40 feet long, had a huge head with 4-foot jaws armed with lance-shaped, recurved teeth as much as 6 inches long (*See* Plate VI). They walked on powerful hind limbs, and, in an upright pose, the head would reach nearly 20 feet above the ground. The hind feet were bird-like, and three powerful toes carried the weight whereas a fourth toe had shifted toward the back of the foot and could assist in grasping prey. All toes were tipped with sharp recurved claws. The front limbs were ridiculously small, with only the first and second digits functional, and could have

been of little use in either feeding or fighting. Such huge carnivores could survive only in a country with an abundance of large herbivorous animals, and the extinction of the large plant-eaters spelled the doom of the large carnivores.

The small carnivorous dinosaurs were of the same general build, but the skeleton and skull were of much lighter construction and the fore limbs relatively larger and more useful.

PLATE VII

Restoration of small, carnivorous dinosaur, *Ornitholestes*, depicted as catching a primitive, toothed bird. After Osborn. Courtesy of American Museum of Natural History.

Bird-mimic Dinosaurs

The bird-mimic dinosaurs, *Struthiomimus* and *Ornithomimus*, are so named because in general build they suggest a large, struthious (ostrich-like) bird with a long tail, but, of course, without feathers. The neck was long and slender, and the small, lightly built head was without teeth. Although these dinosaurs belonged to the same order as did the fierce flesh-eaters, they had evolved new feeding habits, as shown by the absence of teeth. We do not know on what they fed, but perhaps on shell-less invertebrates, insects, honey, fruit, or the eggs of other dinosaurs. The front limbs were very long and slender, and the three long narrow fingers could have reached into cavities to extract insects, honey, or other food. The long hind limbs and slender feet with hoof-like claws were adapted for running rather than grasping, as was the case with all true carnivores.

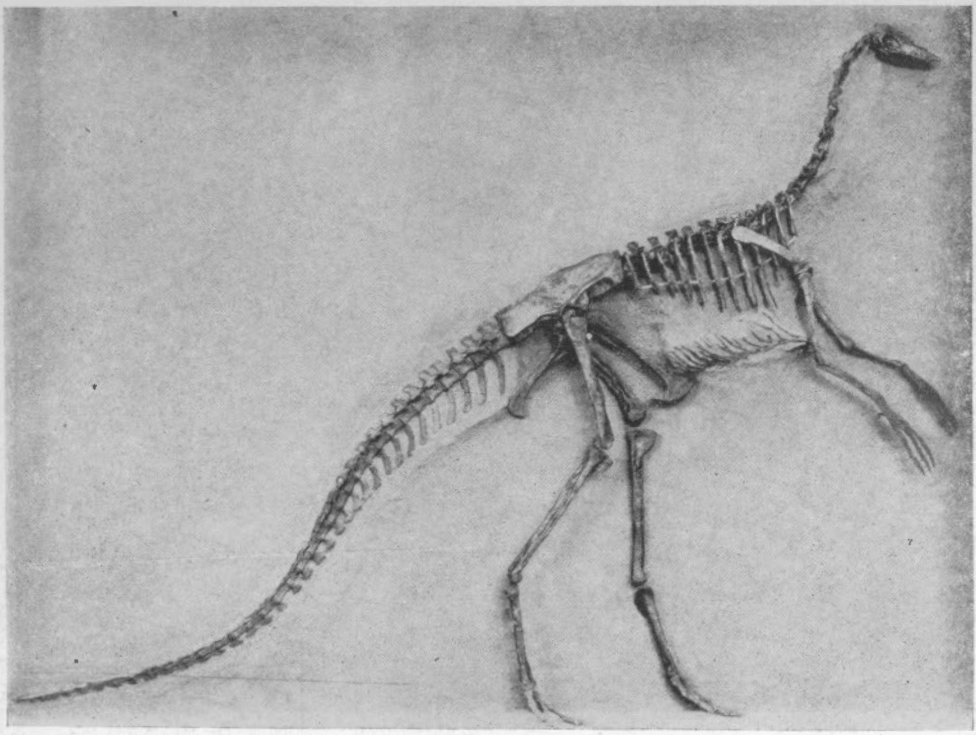
The bird-mimic forms ranged from 10 to 15 feet in length, and evidently inhabited the deltas and river flood-plains, as their skeletons are fairly common in the lowland deposits.

We have no positive evidence on the character of the skin of the carnivorous dinosaurs, for in spite of careful search no impression has ever been found. It is surmised, therefore, that the skin was smooth or composed of very small scales.

HERBIVOROUS DINOSAURS

There were at least five distinct families of plant-eating dinosaurs living in Alberta during Upper Cretaceous time. These are classified under the order Ornithischia. Members of this order had an extra bone in front of the lower jaw or dentary. This bone is known as the predentary, and is not found in any other order of reptiles. Three of these families inhabited the deltas, swamps, and river flood-plains, but it is probable that the others were upland forms.

PLATE VIII



Skeleton of bird-mimic dinosaur, *Struthiomimus*, mounted in Royal Ontario Museum. Courtesy of Royal Ontario Museum of Paleontology.

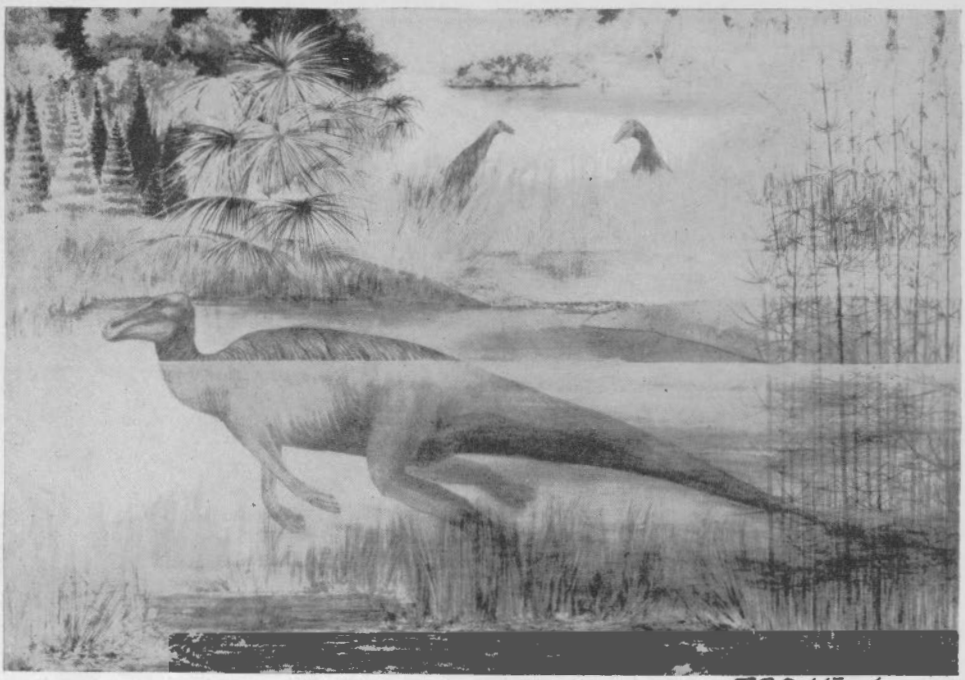
Duck-billed Dinosaurs

The duck-billed dinosaurs are so-named because of an expanded beak, like the bill of a duck. They are the best known and most abundantly represented dinosaurs in our collections, because they were very numerous and lived on the deltas and in the bayous where there were good chances of skeletons being buried and preserved. It is common to find a skeleton lying on its back, with the head under the shoulder, which seems to indicate that the animal died in water and that the carcass floated and finally came to rest in some backwash or on a mud flat out of reach of the carnivores. Rapid deposition of mud and sand covered the carcass before the flesh decayed, and the scaly hide was impressed on the

fine sediments. Though the scales themselves were not fossilized, the impression is often perfect (*See* Plate IV). In other instances, where the flesh was devoured by some carnivorous dinosaur or crocodile, the bones were torn apart but not widely separated and it is possible to find such a complete, but disarticulated, skeleton (*See* Plate XV).

In addition to the more or less complete skeletons or skulls, there are many extensive "bone beds" containing thousands of bones, teeth, turtle shells, and pieces of wood that had been thrown upon a beach by waves or carried onto a mud-flat by floods. These bones are from disarticulated skeletons, and, consequently, no two found together necessarily belong to the same individual. Many of them show signs of being tossed about by waves or rolled along the river bottoms.

PLATE IX



72215-6

Restoration of duck-billed dinosaurs in their natural habitat. Restoration by A. Miles.

More than a dozen species of duck-billed dinosaurs have been found in Western Canada. These belong to two sub-families, which are popularly known as flat-headed and hooded duck-bills. They ranged from about 12 to 40 feet in length, almost half of which was tail. They were well adapted for life in the water, though, of course, had to come to the surface to breathe. They were mainly bipedal, and the powerful hind limbs could support them whether on dry land or wading in the swamp or bayou. The toes terminated in hoofs, each of the three on the hind feet being as large as the hoof of a horse. The hoofs on the front feet were much smaller and were not developed on some of the toes. This suggests that they were disappearing from lack of use. All four feet were webbed, and the high narrow tail was well adapted for swimming. The skin was thin, and was composed of small scales that did not overlap but that

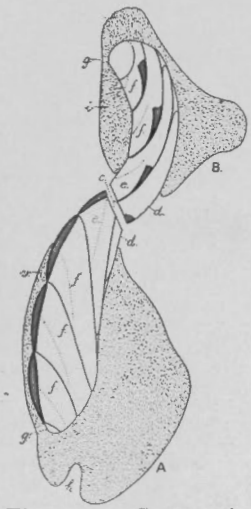


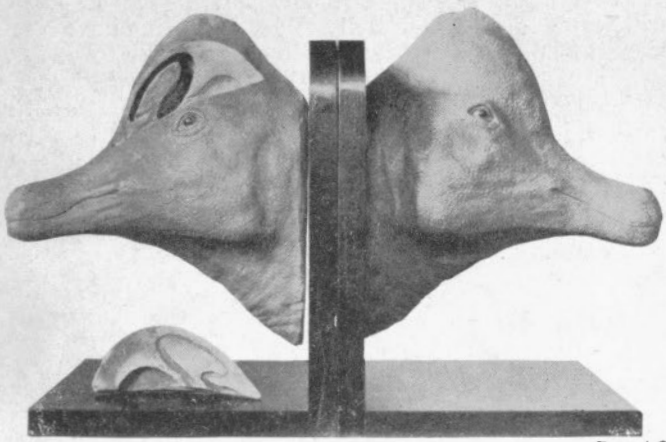
Figure 3. Cross-section through upper and lower jaws of duck-billed dinosaur, showing arrangement and replacement of teeth. After Lambe.

resembled those of the present-day desert lizard known as the Gila Monster, though relatively much smaller. The thin skin and lack of any means of defence, coupled with the webbed feet and swimming tail, indicate that these dinosaurs spent most of their time in the swamps and bayous, and that they probably took to the water for protection from the big carnivores.

Each of the four jaws of the duck-billed dinosaurs contained from two hundred to four hundred slender teeth arranged in a magazine of vertical as well as horizontal rows. Only about one-third were in use at a time, but, as these wore out, new ones grew up to take their places. Unlike mammals, reptiles do not have highly specialized teeth with true roots, nor are they confined to two sets, but throughout life new teeth develop to take the place of those that wear out. The lower jaws passed inside the upper jaws, and the teeth, which are worn to a bevelled edge, sheared the rushes or other swamp plants after they had been nipped off by the duck-like beak.

The hooded duck-bills had developed a specialized breathing arrangement as an aid to underwater feeding. The premaxillæ (the bones that surrounded the external nares) were extended and folded to surround the elongated nasal passages. These thin extended bones grew back and up to form a hood-like development on the top of the head and pushed the nasal bones back and up over the frontals. Within these expanded premaxillæ the elongated narial passages made loops, thus trapping air to prevent water entering the lungs while the reptile was feeding under water (*See* Plate X).

PLATE X



97183.

Hooded duck-billed dinosaur skull modelled by C. M. Sternberg. Part of one side of the skull is cut away to show the winding narial passages, an underwater feeding adaptation. The mouth opening is much smaller than in the carnivores.

Horned Dinosaurs

The horned dinosaur group includes forms that ranged from about 5 to 30 feet in length. Their most noticeable feature is the huge head surmounted by three horns and extending back over the neck and shoulders as a great crest or

cape. The head including the crest, which was made up of extended parietal and squamosal bones, was equal to about one-third the total length of the animal.

PLATE XI

The horned dinosaurs were habitually quadrupedal and the limbs were very heavy and sprawly for a dinosaur. The back was broad and the body massive and low-set. The tail was much shorter than in the duck-bills and there is no evidence that these dinosaurs were swimmers. Their protection lay in the great shield-like crest, the long horns, and the powerful, pointed beak. Their skin was composed of scales much like those of the duck-bills, but some of them were much larger. Certain species had rows of large scales on the side and back, surrounded by smaller scales.

64249.

Foot of horned dinosaur, in the rock.

In the early evolution of this group, bar-like extensions of the parietal and squamosal bones grew backward to give greater area for attachment of the powerful jaw muscles. These bars later developed into a shield-like crest, but with large openings between the bones. In the evolution of the horns, the first to develop was over the nose, then at a later period small horns developed over the eyes. Most forms found in the Belly River formation have a relatively large nasal horn, but all skulls obtained from succeeding Upper Cretaceous formations have large horns over the eyes and the nasal horn is much shorter. In *Triceratops* (three-horned-face), which was the last of the horned dinosaurs, the brow horns were more than 3 feet long and there were no openings in the crest. Some individuals of *Triceratops* were nearly 30 feet long, with a head measuring 9 feet from tip to tip. When the nose was lowered and the crest thus elevated, "horny face" was well shielded against attack from even the huge carnivores.

Armoured Dinosaurs

The armoured dinosaurs were low-set, broad-backed, heavy-boned, quadrupedal reptiles with short, very massive limbs and short, stubby feet. All members of this family were encased in a dermal armour of bony scutes or plates in the skin. In some species the scutes were high-keeled, thick, and more than a foot long, but in others they were more plate-like with only slightly elevated keels. The large scutes were arranged in rows on the sides and back, the spaces between them were filled with smaller scutes, and the under parts were protected by little, shapeless, bony lumps filling the thick skin. In some forms the short tail terminated in a club-like mass of fused scutes. Except for size, these dinosaurs somewhat resembled the little, present day desert lizards known as "Horned Toads", though they were less flattened and the head was relatively smaller. A 15-foot armoured dinosaur would stand about 4 feet high, but more than 5 feet broad at the hips.

The teeth were very small and weak, with pointed, compressed crowns, and were not suitable for chewing tough plants. One genus had lost the teeth completely and developed a crushing plate on each jaw. Armoured dinosaurs may have fed on tubers or soft roots of swamp plants or on soft-bodied invertebrates or even insects. Although they were very heavy, the broad body and short powerful limbs would enable them to slither through the swamps much as turtles do today. If such a dinosaur were caught on dry land he could drop flat on the ground and the bony armour would protect him from the sharp teeth or claws of the carnivores. Most skeletons of this group found in the deltaic deposits are preserved upside down, indicating that as the carcass floated it was turned over by the weight of heavy plates of bone on the upper parts of the body.

PLATE XII

77048

Restoration of armoured dinosaur, *Palaeoscincus*. After Matthew. Courtesy of American Museum of Natural History.

Upland Dinosaurs

At least two families of herbivorous dinosaurs found in Alberta are believed to have inhabited the uplands. One is referred to as dome-headed dinosaurs. These ranged from about 3 to 10 feet in length, were mostly bipedal, and without horns or armour, but possessed a greatly thickened skull roof. The hind limbs were long and their four toes were tipped with narrow hoofs that were adapted for running on dry ground. The head was rather small, but the bones overlying the brain were dome-shaped and very thick. In one specimen in which the head was about 8 inches long the bone over the brain was 3 inches thick, and in a form found in the United States the dome was nearly 9 inches thick. The purpose of this great thickening is not understood. As the huge carnivores lived in the swamps, these upland forms would have only the smaller carnivores to contend with.

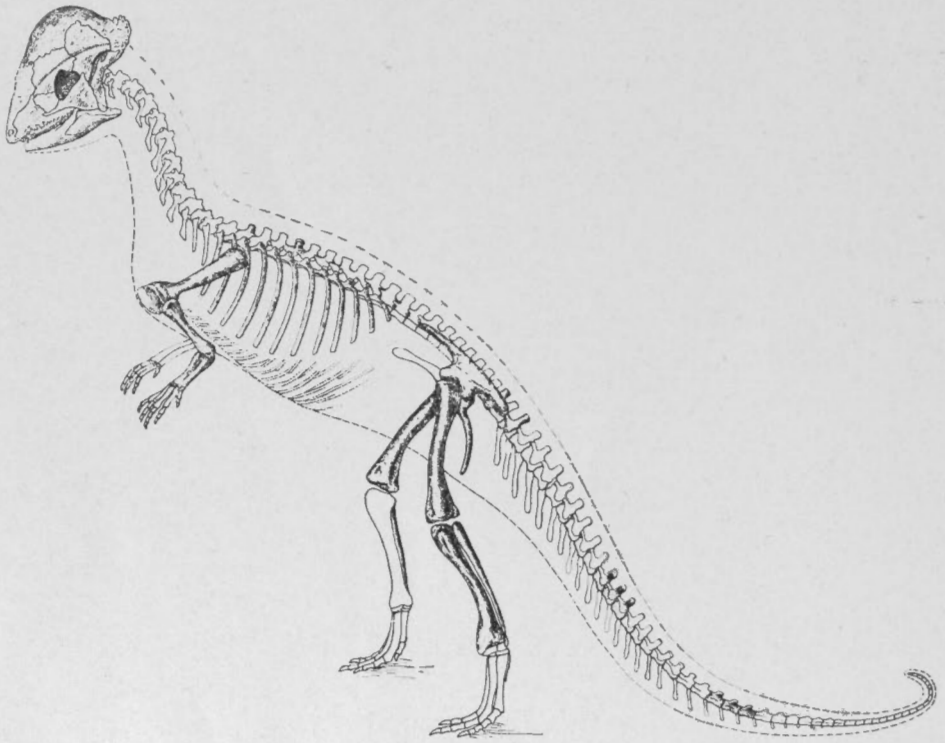


Figure 4. Skelton restoration of dome-headed dinosaur, showing the greatly thickened skull roof. After Gilmore. Courtesy University of Alberta.

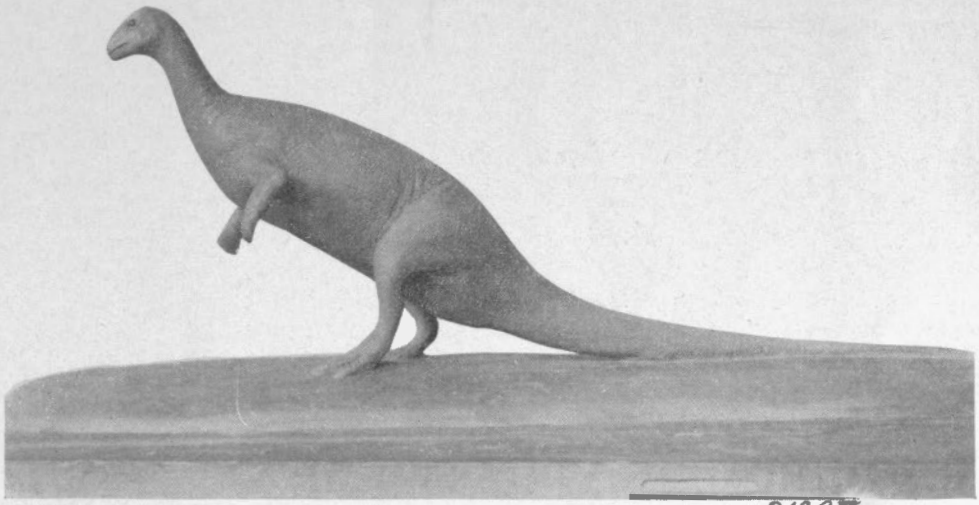
PLATE XIII

Skeleton of small-head, upland dinosaur, *Thescelosaurus*, left in original rock with all bones in position in which they were found. Missing parts restored in light-coloured plaster to distinguish them from original fossil.

Though the dome-headed forms are classified with the herbivorous dinosaurs, there are certain features about the skeleton, such as the presence of abdominal ribs (*See* Figure 3), and the tongue and groove articulation of the neural arches of the spinal column that are elsewhere found in the carnivorous dinosaurs. This suggests that the dome-headed dinosaurs may represent the end of a long line of descent from earlier, unknown forms.

Two genera of the other family are represented by fairly complete skeletons from Red Deer River, Alberta. No popular name has been applied to this family, but we might call them the small-headed, upland dinosaurs. *Thescelosaurus*, collected from the Edmonton formation northwest of Rumsey, Alberta, is best known. It was about 12 feet long, and the head was less than 8 inches in length. The bones overlying the brain were very thin; the body was fairly broad; and the moderately long, powerful hind limbs show that the reptile was mainly bipedal, though the presence of tiny hoofs on the five-toed front feet suggests that at times he may have progressed on all four feet. The tail was very long, and in older individuals was stiffened by ossification of the long tendons.

PLATE XIV



Restoration of *Thescelosaurus*, modelled by C. M. Sternberg. The body wa moderately massive, the hind limbs powerful, and the tail very long.

In this family as well as in the dome-headed forms the bones in the front of the upper jaws (the premaxillæ) possessed teeth as in the carnivorous dinosaurs. In most members of the order (Ornithischia) the premaxillæ were toothless and covered with a horny sheath. The teeth in the jaws resembled those of the armoured dinosaurs, but were relatively larger and better adapted to a vegetable diet. Little is known regarding the ancestry of these upland forms.

FOSSILIZATION AND COLLECTION

People often ask, "How do you know where to dig for dinosaurs?" The answer, of course, is that we do not dig until we have found a specimen. Throughout a period of perhaps 60,000,000 years the skeletons that were buried in the deltas have remained undisturbed, and the mud and sand by which they were covered have become hardened to shale and sandstone. Throughout these long ages the skeletons lay deeply buried beneath successive later deposits of marine, freshwater, or wind-blown origin; but these deposits have since been eroded away, and once again the ancient deltas on which the dinosaurs lived and died are

exposed. During countless ages, water percolating through the rocks in which the dinosaur bones lay buried gradually replaced the bones, cell by cell, with mineral material dissolved from the rocks. In this way the bones became fossilized or petrified, and in many instances the replacement has been so perfect that the fossil retains all the detail of a modern bone.

PLATE XV

52149

Disarticulated skeleton of carnivorous dinosaur in the rock, ready for collecting.

Quite recently, as the geologist counts time, the Red Deer and other rivers have cut gorges into the old deltas, and with the aid of smaller, tributary streams and the erosive action of rain, frost, and wind, have carved out the so-called "badlands" of Alberta. This is a region of gullies, ridges, buttes, and hillsides from which all soil and vegetation have been eroded, thus exposing the ancient strata. As the rock wears away the tip of a bone may become exposed, and this is what the "fossil hunter" calls a "prospect". If the specimen is not discovered and collected, the bone or eventually the whole skeleton will weather out and be destroyed. Many prospects lead to only a single bone, a section of the tail, or a separate jaw, but occasionally one leads to a fine skull or perhaps a complete skeleton. No doubt hundreds of skeletons have been destroyed by erosion, and thousands of others are still buried so far from the surface that they may never be seen. The experienced fossil hunter knows, when he finds a prospect, whether it is merely a scattered bone, or whether it is leading toward the head, or perhaps promises a complete skeleton. It is not uncommon to find a skeleton of a duck-billed dinosaur without the head and front limbs. The explanation probably is that as the carcass floated around the head and fore limbs dropped off, whereas the rest of the skeleton was held together by the stronger ligaments.

Horns, claws, and hoofs are composed of a chitinous substance and are not preserved as fossils, but the bony core is fossilized and in one specimen the impression of the chitinous beak was preserved.

When the prospect is located, the specimen is outlined by the use of hand pick, awl, small chisel, and whisk broom. A certain amount of rock is always left around the bones for protection while they are being removed from the field to the laboratory. If the skin impression is preserved, an extra layer of rock must be left. If the skeleton is large, it must be divided into sections, as it is difficult to handle blocks of more than 2,000 pounds. The head and neck may be included in one section, the front limbs, the hind limbs, and the tail in others. If not too large, the body part is taken up in one section. In the early days of fossil collection the bones were dug out and wrapped in paper, and then, so far as possible, they were pieced together in the laboratory; but much information was lost when specimens were collected in this way. Information about the skin, the proper articulation of the bones, and the number of joints or toes was only obtainable in the field before modern methods of collection were introduced (*See* Plate XI).

PLATE XVI

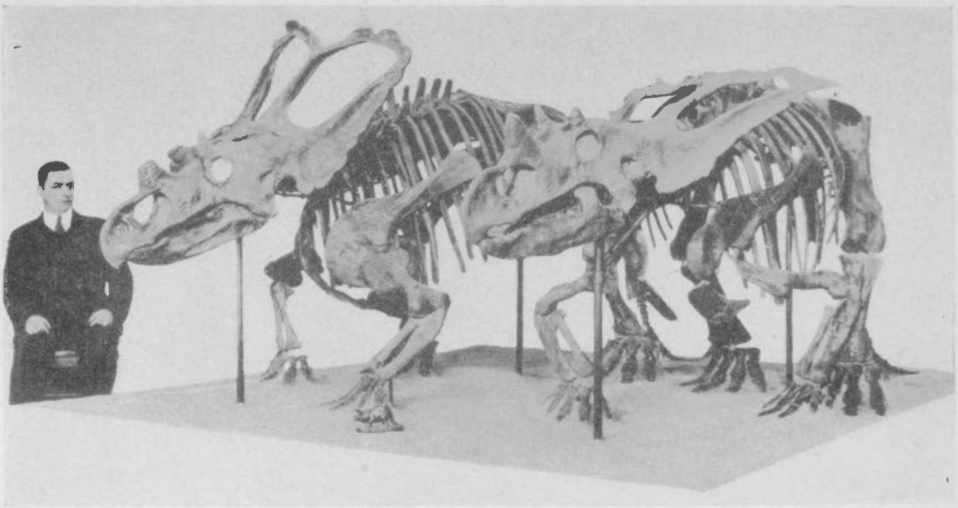
29062

Collecting ground for dinosaur remains in the "badlands" southeast of Steveville, Alberta. The sections are wrapped and ready for transportation.

When the sections are outlined and undercut, each is wrapped with strips of burlap dipped in fluid plaster. If necessary, sticks are inserted to give greater strength, much as the doctor uses splints in the cast on a broken arm. When the plaster is set, the section can be turned over and the wrapping completed, then the sections are packed in specially constructed boxes and shipped to the museum. In the museum laboratory the wrapping is removed and the slow, careful preparation is commenced. If the bones of the skeleton have not become separated, it may be decided to mount the skeleton as it lay, in the original rock. In such a "panel" mount the separate sections of the skeleton will be refitted and the whole mass supported so as to keep it together (*See* Plate XIII). Such mounts can be studied by future generations, and involve no arguments about the number of vertebræ in the back, the number of

joints in the toes, or the proper positions of each bone, because they are articulated or held together in the relative positions in which they were when the animal was alive. In some skeletons, however, the bones have become separated (*See* Plate XV), or are not suitable for a panel mount, or perhaps it may seem desirable to show the animal in a walking or standing pose (*See* Plate XVII). In such instances the bones are separated and cleaned and then posed and supported by a frame-work of iron bars or rods.

PLATE XVII



NEG. # 67938 -

Open mount of horned dinosaur skeletons in National Museum, Ottawa. In this type of mount the bones have all been separated, and later posed in a standing position supported by an iron framework.

It is not possible to state definitely what caused the extermination of the dinosaurs. Perhaps great changes in physical conditions at the close of Cretaceous time, the development of the more intelligent and active mammals, and the racial old age of the dinosaurs were the most important factors in wiping out this interesting group. It is believed that a race or order can become old and weak in the same way as an individual. Though the dinosaurs became extinct at the close of the Cretaceous period, it must not be inferred that they disappeared overnight. During the closing years of the Cretaceous the number of species and individuals gradually became fewer, although more highly specialized and gigantic. Large, specialized forms are easily exterminated if subjected to a change in habitat or food supply.