On the Dinosaurian Fauna of the Iren Dabasu Formation

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Article II.—ON THE DINOSAURIAN FAUNA OF THE IREN DABASU FORMATION[1]

By Charles W. Gilmore[2]

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INTRODUCTION

The present contribution gives the results obtained from a study of all dinosaurian material collected from the Iren Dabasu formation in Mongolia by the Asiatic Expeditions of The American Museum of Natural History. While this collection is deficient in articulated skeletons, there is considerable material which is, for the most part, in a splendid state of preservation. The bulk of the collection came from two bone deposits, respectively seven and eight miles east of the Iren Dabasu telegraph station. In these two quarries were the remains of many individuals intermingled in much confusion. An occasional foot, limb, or series of vertebrae was found either articulated or in such close asso-

[1]Publications of the Asiatic Expeditions of The American Museum of Natural History. Contribution No. 117.
[2]Curator of Vertebrate Palæontology, U. S. National Museum.

ciation as to indicate individual ownership, but for the most part it is quite impossible to reassemble these disarticulated skeletons. Fortunately some of the animals so closely resemble their North American relatives, known from nearly perfect skeletons, that it has been possible to segregate the skeletal parts of certain genera. One rather unusual feature of this assemblage is the presence in one quarry of many young animals—a rare occurrence in similar North American bone deposits.

Four families (Ornithomimidae, Deinodontidae, Hadrosauridae and Nodosauridae) have been recognized in the dinosaur collection from the Iren Dabasu formation. These comprise four genera and four species, of which two genera and the four species are described as new. That several undescribed forms exist in this fauna is indicated by fragmentary remains.

I wish here to express to Professor Henry Fairfield Osborn and to Dr. Walter Granger my great appreciation for the privilege afforded me of studying this interesting collection; also to Mr. Barnum Brown for reading the manuscript.

Geological Age of the Iren Dabasu Formation

The Iren Dabasu formation was named and defined by Granger and Berkey in American Museum Novitates No. 42. It was regarded by them in the original and subsequent publications as belonging to the Lower Cretaceous.

Matthew[1] held the opinion that the Iren Dabasu fauna was "rather primitive" and for that reason should be tentatively placed in the Lower Cretaceous. After a critical study of all the known specimens, I fail to find any skeletal characteristics pointing to such a conclusion. In my judgment they represent the same stage of development as found in the Upper Cretaceous Dinosauria of North America, and this evidence is in accord with the faunal assemblage as indicating the Upper Cretaceous age of the Iren Dabasu formation, to which it should be assigned.

The recognized fauna of the Iren Dabasu formation as known at this time is as follows:

- Dinosauria
  - Theropoda
    - *Ornithomimus asiaticus*, new species
    - *Alectrosaurus olseni*, new genus and species
    - Dromaeosaurinae, gen. and sp. indet.

[1]Berkey, C. P., and Morris, F. K. 1927, 'The Geology of Mongolia,' The Natural History of Central Asia, II, p. 355.

Ornithischia
Mandschurosaurus mongoliensis, new species
Bactrosaurus johnsoni, new genus and species
Nodosauridae, gen. and sp. indet.
Crocodilia
Chelonia
Trionychid, gen. and sp. indet.
Pisces

In its main features the above assemblage differs from the Upper Cretaceous faunas of America only in the absence of the Ceratopsidae. The presence of crested and noncrested hadrosaurians associated with a theropodous dinosaur that cannot be generically distinguished from *Ornithomimus*, together with a representative of the Nodosauridae, is a combination found in both the Belly River and Edmonton formations in Canada and their equivalents in the United States. The stage of development as represented in the ornithomimids points to a closer relationship with the Belly River forms than with those of the geologically younger Edmonton. Further evidence corroborative of this conclusion is furnished by *Protoceratops* from the overlying Djadochta formation, from the fact that a restudy of this form will undoubtedly show it to have its closest affinities, if it does not prove to be congeneric, with *Leptoceratops* from the Edmonton.

In a short paper[1] describing some fragmentary dinosaurian remains from the Chinese side of the Amur River in Manchuria, Riabinin reaches the conclusion that these beds are equivalent in age to the Edmonton. This decision was apparently based upon the supposed recognition of two Edmonton genera, *Saurolophus* and *Albertosaurus*, from the Amur locality. That he was dealing with an Upper Cretaceous assemblage is quite probable, but an analysis of the specimens upon which these deductions were based shows that they were very fragmentary and offer little evidence concerning their geological age. *Mandschurosaurus amurensis* is adequately founded, but *Saurolophus krischtofovici*, established on a fragmentary ischium, and *Albertosaurus periculosus*, founded on a single tooth, are valueless, as neither specimen is diagnostic and either might with equal propriety be referred to any one of several known genera. The presence in the Iren Dabasu of a specimen that I am unable to distinguish from *Mandschurosaurus* leads to the suggestion that the Amur locality may be of close if not equivalent geological age.

The Iren Dabasu formation is composed of sandstone and clay with a few lenses of limy nature, its greatest estimated thickness being 100

[1]Riabinin, A. N. 1930. 'On the age and fauna of the dinosaur beds on the Amur River.' Mem. Russian Mineralogical Society, LIX, No. 1, pp. 46–51, Pl. I.

feet. According to Berkey and Morris,[1] the vertebrate fossils occur only in the upper 30 feet of the formation. They also state (p. 204) that one bed of red sandy clay contained numberless fragments of egg-shells. These are said to "vary in size, and doubtless belong to several different types of dinosaur. The large eggs are much bigger than those found at Djadokhta," but none was as perfectly preserved.

DESCRIPTION OF GENERA AND SPECIES

THEROPODA

ORNITHOMIMIDAE

The family Ornithomimidae is represented in the American Museum's Mongolian collections by two genera, *Oviraptor philoceratops* described by Osborn[2] from the Djadochta beds, and **Ornithomimus asiaticus**, new species, here described from the Iren Dabasu formation.

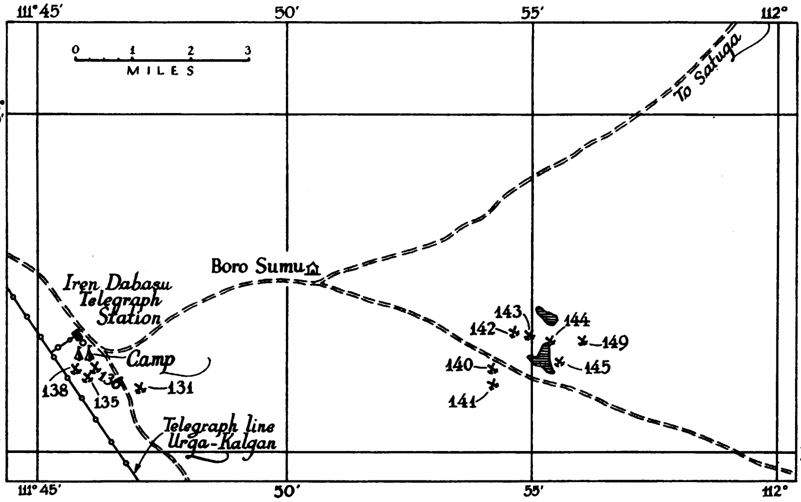

Fig. 1. Map showing the location of the more important fossil occurrences in the Iren Dabasu Basin. These are designated by the original field numbers.

Another Asiatic occurrence of this family has recently been reported by Matley[3] from the Upper Cretaceous of the Jubbulpore district of India. These three discoveries constitute, so far as I am aware, all of the reported occurrences of this family outside of North America.

[1]1927. 'The Geology of Mongolia,' The Natural History of Central Asia, II, p. 203.
[2]Osborn, H. F. 1924. Amer. Mus. Novitates, No. 144, pp. 7–12, figs. 6–8.
[3]Matley, C. A. 1931. Geol. Mag., LXVIII, No. 804, p. 279.

The ornithomimid materials consist of articulated parts of individual skeletons and single bones only, but these are from several localities in the Iren Dabasu basin (see Fig. 1) and usually in an excellent state of preservation. Practically all bones of the skeleton are represented except the skull. There are a considerable number of individuals which, as indicated by the various sizes, range from young to adult.

Critical comparison of these specimens bone by bone with the American *Ornithomimus* (*Struthiomimus*), shows the closest resemblances —in fact, such differences as are found are of minor importance, and were one dealing with American materials alone, would not be regarded as more than variations well within a single species. These differences, however, when coupled with the distant geographical occurrence, appear to justify the establishment of a new species, for which I propose the name **Ornithomimus asiaticus.**

Ornithomimus asiaticus, new species

COTYPES.—Nos. 6565, 6569. A. M. N. H. Consist of a nearly complete fore foot and much of an associated hind foot. Collected by Mr. Peter Kaisen, 1923. Field Nos. 140, 141.

LOCALITY.—Eight miles east of Iren Dabasu telegraph station, Mongolia.

HORIZON.—Iren Dabasu formation, Upper Cretaceous.

SPECIFIC CHARACTERS.—Smaller than *Ornithomimus altus;* cervical ribs free from vertebrae; pelvic bones not coössified; two bones in distal row of tarsus; Mtc. I relatively shorter than in American species.

In the pages to follow, the different skeletal parts are briefly reviewed in comparison with described species, but since they so closely resemble American members of the genus, a detailed description appears unnecessary. The skull, one of the most characteristic parts of the whole skeletal structure, is unknown at this time but it is anticipated that it will show features which will definitely characterize this species.

VERTEBRAE.—Practically all parts of the vertebral column are present, the dorsal, sacral, and caudal regions being represented by a series of articulated sections with from three to eight vertebrae in each section. These pertain to two if not more individuals. These articulated vertebrae are supplemented by a considerable number of scattered vertebrae, most of which have lost some if not all of their neural arches and attendant processes. Most of the vertebrae are from the "Kaisen Quarry" (Field No. 140). See Fig. 1.

The articulated vertebrae have as yet been only partially prepared and thus are not fully available for detailed study. However, so far as they can be contrasted with the homologous parts of the *Ornithomimus* *altus* skeleton, they are in full accord except for their somewhat smaller size.

The few cervical vertebrae present are elongate, strongly amphicoelous, and all have the ribs detached. In *O. altus* Lambe and *O. samueli* Parks they are fully coalesced. No special significance is placed on this fact, as it may represent a difference in age rather than any structural modification.

The thoracic or dorsal vertebrae, so far as can be observed from present materials, are all amphicoelous. In describing *O. (Struthiomimus) altus*, Osborn[1] says they are "gently opisthocoelous." The spinous

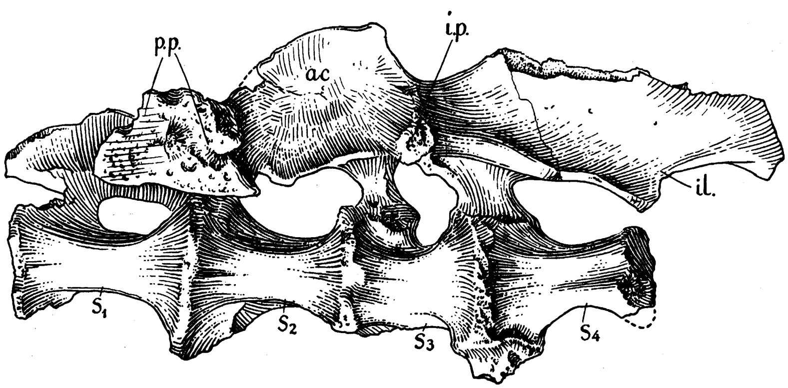

Fig. 2. Sacrum of *Ornithomimus asiaticus*, No. 6576, A.M.N.H. Ventral view. *Ac.*, acetabulum; *Il.*, ilium; *I.p.*, ischiac peduncle; *P.p.*, pubic peduncle; s_1, s_2, s_3, and s_4, sacrals one to four. One-third natural size.

processes are relatively low and moderately wide fore and aft throughout the series. There is indication that the spines gradually increase in height from front to back.

The one sacrum (No. 6576) present has four coössified sacral vertebrae as shown in Fig. 2. In this respect the present specimen is in accord with both *O. altus* and *O. sedens*. While it now seems that in the genus *Ornithomimus* only four vertebrae functioned as sacrals, this number in some individuals will be found to be augmented by an additional vertebra, a sacro-dorsal. Such an addition is indicated by a flattened, slightly rugose articular end on the most anterior sacral centrum, not only in this specimen but also in the sacrum of the type of *O. sedens* from the Lance formation.[2]

[1]Osborn, H. F. 1916. Bull. Amer. Mus. Nat. Hist., XXXV, p. 747.
[2]Gilmore, C. W. 1920. Bull. 110, U. S. Nat. Mus., pp. 132–133, fig. 67.

Sacral 1 extends half its length forward of the pubic peduncle, while sacral 3 is directly opposite the ischiac peduncle of the articulated ilium. In *O. sedens*, s_1 is opposite the pubic peduncle and s_3 is largely posterior to the ischiac peduncle. All four vertebrae have flattened ventral surfaces, and deep pneumatic cavities along their sides. The centra are joined to the ilia by short but stout sacral ribs. These ribs do not unite with the centra intervertebrally but with strong buttresses developed on the sides close to their anterior ends. The buttress on the second sacral extends backward to the mid-length of the centrum much as in *O. sedens*. The neural spines were apparently fused with one another, and anteriorly their upper extremities are on a level with the upper borders of the ilia. The length of the four sacral centra is 245 mm. divided as follows: S_1, 69 mm., s_2, 63 mm., s_3, 53 mm., and s_4, 60 mm.

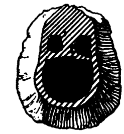

Fig. 3. Cross-section of median caudal vertebra of *Ornithomimus asiaticus*, No. 6570, A. M. N. H. One-half natural size.

The caudal vertebrae display typical theropod characters. They are moderately elongate throughout the series with biconcave ends, the anterior usually being most deeply cupped. The articular ends of the caudal centra are peculiarly characteristic of the Ornithomimidae. Scattered vertebrae of this family may at once be recognized from the fact that the cupping is uniform from the center outward to the extreme border of the bone, thus forming a sharp edge, whereas in all other theropod caudals these edges are slightly thickened and rounded. Vertebrae from the distal half of the tail exhibit the same rod-like elongation of the prezygapophyses as found in the American species of the genus. The postzygapophyses are much reduced in size.

A bird-like adaptation of the vertebrae is shown in the extreme pneumasticity of the vertebral centra which, as shown in Fig. 3, have very thin walls and large internal chambers separated by thin transverse and vertical laminae.

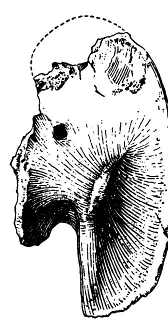

Fig. 4. Right coracoid of *Ornithomimus asiaticus*, No. 6567, A.M.N.H. Lateral view. One-third natural size.

Pectoral Girdle and Fore Limb.—Three coracoids and the proximal half of two scapulae are all that is preserved of the pectoral girdle. The scapula is like that of *O. altus*, but I am unable to contrast the coracoid, since no description or illustration of it has been published. For that reason the more important features of this bone are briefly described below. Coracoid much shortened antero-posteriorly (64 mm.) but deep dorso-ventrally (about 115 mm.) There is a decided notch on the inferior border anterior to which the bone turns abruptly downward, terminating in a truncated end, instead of being pointed as in many theropods. The coracoidal foramen is small, and on the external surface well in front of the sutural contact with the scapula. The main features of this bone are well shown in Fig. 4.

In the present collection there are six humeri, three ulnae and three radii that may be attributed to *Ornithomimus asiaticus*. These vary much in size, ranging from young to adult. None attains the size of the adult specimen of *O. altus* described by Osborn, but otherwise I fail to find a single character that would distinguish them. The segments of the fore limb (see measurements below) have practically the same ratio of length, the same relative slenderness and are identical in the development of processes and articular ends.

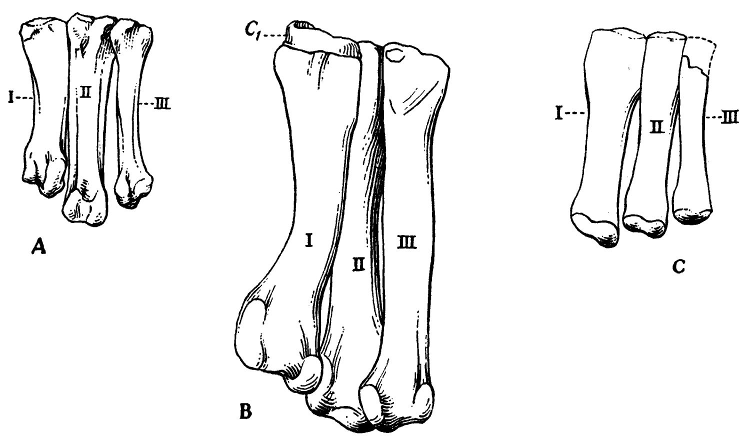

Fig. 5. Metacarpals of *Ornithomimus asiaticus*, *O. altus*, and *O. velox* compared. A, right manus *Ornithomimus asiaticus*, Palmar aspect, American Museum No. 6569. B, left manus *Ornithomimus altus*, Palmar aspect, American Museum No. 5339, reversed. After Osborn. C, right manus of *Ornithomimus velox*, front view, Yale Museum No. 548. After Osborn. All figures one-half natural size.

The measurements given below are made from an associated fore limb.

Comparative Measurements

	Ornithomimus asiaticus No. 6566 A.M.N.H.	*O. altus* No. 5339 A.M.N.H.
Greatest length of humerus	275 mm.	310 mm.
Greatest length of ulna	221 mm.	230 mm.
Greatest length of radius	202 mm.	......

MANUS.—The manus is represented by associated bones, No. 6569, A.M.N.H., found by Mr. Peter Kaisen in a quarry at Iren Dabasu in 1923 (Field No. 140). It consists of the radius, ulna, metacarpals I, II, and III, first phalangeal of digit I, first and second of digit II, and second and third of digit III. In addition there are many disassociated manus bones of varying sizes, especially unguals from this and other deposits. The manus displays the same peculiar foot specialization as is found in *Ornithomimus altus* in that the elongation of the phalanges is very unequal and metacarpal I is divergent at the distal end but strongly appressed to metacarpal II on the proximal half. Metacarpal III, the slenderest element of this portion of the foot, is subequal in length to metacarpal I with which it lies nearly parallel in the articulated foot. Metacarpal I is slightly shorter than either II or III, whereas in *O. velox* it is the longest bone of the metacarpus (see Fig. 5c).

It will be seen in the posterior view (Fig. 5A) that the proximal end of metacarpal II of *O. asiaticus* is not so fully encompassed by the lateral metacarpals as in *O. altus*, but otherwise the proportions of the individual bones, the relative length of digits, and the elongate, slightly curved nature of the unguals are all strikingly similar to those of the American species.

As shown in the table of comparative measurements, specimen No. 6569, A.M.N.H., is little more than half the size of *O. altus* described by Osborn. This difference indicates the immaturity of the individual, as other bones in the collection show that the Mongolian species attained a larger size, although from evidence in hand it apparently never reached the stature of *O. altus*.

COMPARATIVE MEASUREMENTS OF MANUS AND FORE ARM

	O. asiaticus No. 6569 A.M.N.H.	*O. altus* No. 5339 A.M.N.H
Total length ulna-radius	150 mm.	230 mm.
Digit I, metacarpal I, length	46	85
Phalanx 1, length	58[e]	110
Digit II, metacarpal II, length	54	100
Phalanx 1, length	27	40
Phalanx 2, length	57	90
Digit III, metacarpal III, length	50	95
Phalanx 2, length	17	35
Phalanx 3, length	43	75

e = estimated.

Pelvic Arch.—All of the pelvic bones present were found disarticulated and none shows evidence of coössification as in the American species. The two preserved ilia, so far as they can be compared, since both are slightly incomplete, agree in all important particulars with those of *O. altus* except for their smaller size. The pubes, of which there are three individuals represented, may be distinguished by the extremely slender shaft and the relatively longer and more pointed posterior extension of the foot-like distal end. In all other respects these bones are in perfect agreement with the American forms. A single pair of ischia cannot be distinguished from those of *O. altus*.

Hind Limbs.—Although there are three femora, eight tibiae, and one fibula in the collection, none was so definitely associated as to in-

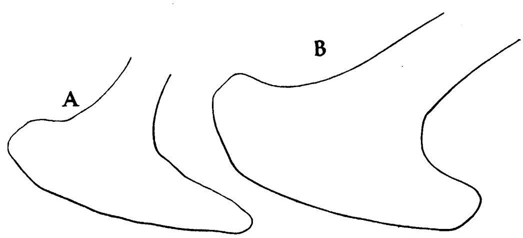

Fig. 6. Distal end of pubes of *Ornithomimus altus* and *O. asiaticus* compared. Lateral view. A, pubis of *O. asiaticus*, No. 6570, A.M.N.H.; B, pubis of *O. altus*. After Osborn. Both figures one-fourth natural size.

dicate the limb of one individual. On that account the ratio of length of femur to tibia cannot be determined. The femora vary in length from 300 mm. to 400 mm. and the tibiae from 305 mm. to 440 mm. The femora are only slightly bowed from end to end, and the fourth trochanter is reduced in size, but the general form and areas for muscular insertion are very similar to the larger theropods. The tibia is elongate and probably a little longer than the femur. Some of the tibiae have the astragalus coössified with the distal end, as so often occurs in the members of the Deinodontidae.

Pes.—The incomplete pes is represented by associated bones (No. 6565 A.M.N.H.), consisting of metatarsals II, III, and IV, first phalanx of digit IV, and two tarsi of the distal row. In addition there are a great number of separate bones representing all elements except the reduced metatarsal V. That it was present is clearly indicated by the facet found on metatarsal IV. I find no evidence of the presence of vestigial metatarsal I, as mentioned by Matthew.[1]

Careful comparison, bone by bone, of the present foot bones with original and other described material of *Ornithomimus* (*Struthiomimus*) *altus* fails to disclose a single fundamental difference in structure between the Mongolian and American forms. In size, the American species exceeds any of the bones found in the Mongolian collection. For example, mt. III, of No. 6565, A.M.N.H., measures 282 mm. over all, whereas the same bone in *O.* (*Struthiomimus*) *altus*, described by Osborn,[2] is 370 mm. long.

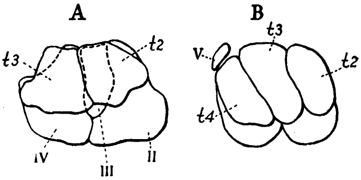

Fig. 7. Proximal end of metatarsus with distal tarsals in position. A, *Ornithomimus asiaticus*, cotype, No. 6565, A.M.N.H. B, *O. altus*, after Lambe. Both figures one-fourth natural size.

Two flattened bones (see Fig. 7A) that fit snugly over the ends of the metatarsals, constitute the distal row of the tarsus, whereas in *Ornithomimus altus* described by Lambe[3] there are three elements in a larger and presumably older individual. The outermost rests entirely on the end of mt. IV, whereas the inner caps the ends of mts. II and III, having a longitudinal ridge on the lower side that fits into the line of division between these two ends. These bones articulate with the posterior half of the articular ends of the metatarsals, leaving the remainder clear as is shown in figure 7A. In *O. altus* the ends of the metatarsals are more completely covered.

DEINODONTIDAE

The family Deinodontidae includes the large Upper Cretaceous dinosaurs, and in the Iren Dabasu fauna one form is recognized that quite certainly belongs to this family. The presence of a second carnivore, apparently rivaling *Tyrannosaurus* in size, is indicated by a few scattered foot bones.

In 1930 Riabinin[4] described a new species, *Albertosaurus periculosus* from the Amur River locality in Manchuria. This species was established on the crown of a single tooth, but since these flattened, sharp-edged teeth with serrated margins offer no basis for either specific or generic distinction, this species may be considered a nomen nudum. Its

[1]Matthew, W. D., and Brown, B. 1922. Bull. Amer. Mus. Nat. Hist., XLVI, p. 373.
[2]Osborn, H. F. 1916. Bull. Amer. Mus. Nat. Hist., XXXV, p. 745.
[3]Lambe, L. M. 1902. Contributions to Canadian Paleontology, III, p. 50, fig. 11.
[4]Riabinin, A. N. 1930. Mem. Russian Mineralogical Society, LIX, No. 1, pp. 44–47, Pl. I, figs. 2, 2*a*, 2*b*.

only interest is that it shows the presence of theropod dinosaurs in the Amur River locality.

Another Asiatic occurrence of theropod dinosaurs is reported by Matley[1] in the Jubbulpore district of India, but since these remains have

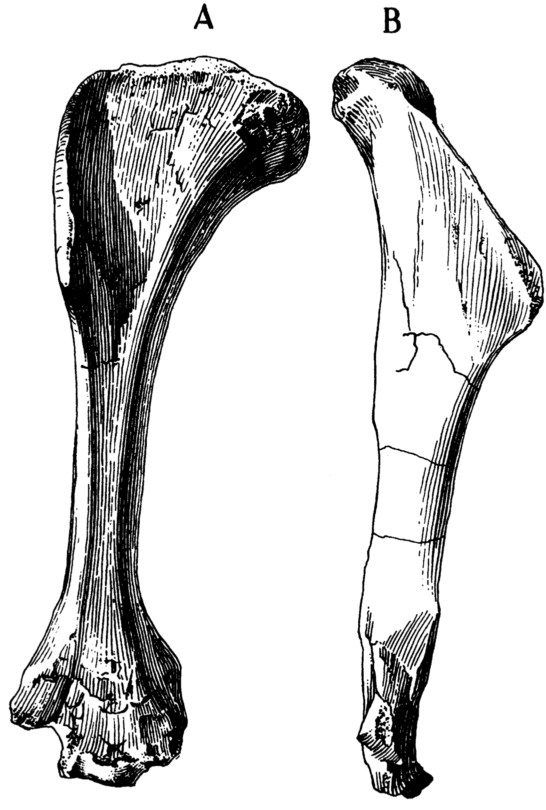

Fig. 8. Right humerus, *Alectrosaurus olseni*. No. 6368, A.M.N.H. A, front view; B, lateral view. One-fourth natural size.

not yet been described they cannot be compared with the present specimens from the Iren Dabasu formation.

Wiman[2] also recognized theropod remains among the dinosaurian materials from Shantung, China. None of the specimens, however, is well enough preserved to display their more precise relationships.

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[1]Matley, C. A. 1931. Geol. Mag., LXVIII, No. 804, June, p. 280.
[2]Wiman, Carl. 1929. Palæontologia Sinica, Ser. C, VI, pp. 40–41, Pl. VI, figs. 14, 14*a*, 16 and 16*a*.

Alectrosaurus olseni, new genus and species

Plate I, Figure 2; Plate II

COTYPES.—No. 6368, A.M.N.H., consists of right humerus, first phalanx of digit II and ungual of digit I of manus; No. 6554, A.M.N.H., consists of a right femur (lacking proximal end), tibia, fibula, astragalus, calcaneum and pes; metatarsals of left hind foot, two unguals of manus, and a portion of the expanded foot of the pubes. Both specimens were collected by George Olsen, May 4 and April 25 respectively, 1923.

LOCALITY.—Two hundred yards south of camp at Iren Dabasu telegraph station, Mongolia.

HORIZON.—Iren Dabasu formation, Upper Cretaceous.

GENERIC AND SPECIFIC CHARACTERS.—Long slender-limbed type of deinodont; humerus long and slender; ungual and phalanx of digit I robust, laterally compressed and strongly curved; femur and tibia subequal in length; length of astragalus one-fourth the combined length of astragalus and tibia.

Specimen No. 6368 was found about 100 feet distant from specimen No. 6554, and in the field they were thought to pertain to the same individual. However worthy this suggestion may be, I prefer to treat them as representing two individuals. The evidence for their reference to the same genus and species rests upon the close resemblance between the claws of the manus found with each. The two unguals belonging to No. 6554, although much smaller than the one associated with No. 6368, are in perfect agreement in being laterally compressed, strongly curved, and having sharply pointed extremities. These are the only bones in common between the two specimens. The meagerness of this evidence is fully recognized, but in view of their near association in the field and the mutual slenderness of the preserved limb bones, there is strong probability that both pertain to the same kind of animal, if not to one individual.

The unusually large size of the humerus and the enormously large claw are so unlike any known Upper Cretaceous deinodont as to at once set the animal off as a new type of theropod dinosaur. The name *Alectrosaurus olseni* is therefore proposed for its reception, the species name being in honor of Mr. George Olsen who collected the type specimens.

The great length of the humerus, 390 mm., exceeds that of the gigantic *Tyrannosaurus rex,* and among theropodous dinosaurs it is rivaled, so far as I have been able to find, only by the humeri of *Plateosaurus reingeri*[1] from the Triassic.

The proximal end of the humerus is widely expanded with the articular head situated in about the middle and having the rounded articular portion overhanging the posterior surface of the shaft. A high relatively

[1]Huene, F. von. 1907. Geol. u. Pal., Abhl., I, Pl. v.

thin radial or deltoid crest runs down the external side from the proximal end, terminating above the mid-length. The shaft is relatively slender. In *Gorgosaurus libratus* the humerus is subcylindrical in form with little-expanded distal end and with head apparently occupying the whole of the proximal end. The finely modeled form of the present humerus further distinguishes it from the more or less shapeless humerus of *Gorgosaurus*, a comparison that also applies to that of *Tyrannosaurus*. From *Antrodemus* (*Allosaurus*) the humerus may be at once distinguished from the fact that the longest axis of the two expanded ends lies in the same plane, whereas in *Antrodemus* there is a decided torque.

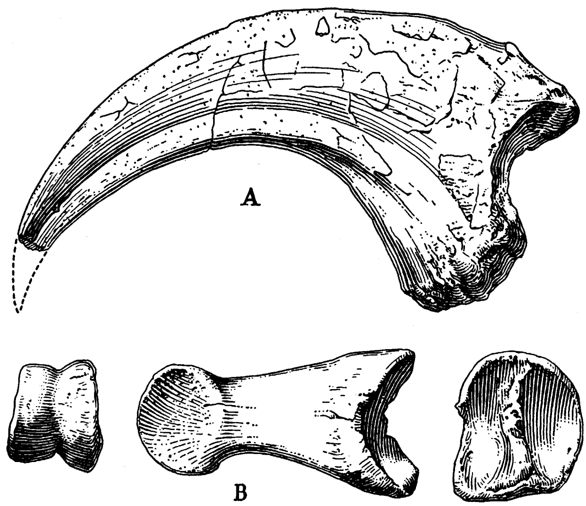

Fig. 9. Bones of the manus, *Alectrosaurus olseni*, No. 6368, A.M.N.H. A, ungual, digit I; B, proximal phalanx, digit II. Both figures one-half natural size.

The mid-section of the shaft is angularly rounded in cross-section. The condylar portions of the distal end are missing.

The single phalangeal present is tentatively regarded as being the first of digit II. This assignment seems to be indicated by its relative shortness, lack of lateral pits on the sides of the distal end, the presence of a broad central groove on the distal end, and a prominent median keel on the proximal end—all features that are in accord with the proximal phalanx of digit II in *Gorgosaurus libratus*. See Fig. 9B.

The exceptionally large, laterally compressed, strongly curved and sharply pointed ungual, shown in Fig. 9A, probably represents the terminal ungual of digit I of the hand.

MEASUREMENTS

Humerus, length	390 mm.
Transverse breadth at proximal end	112 mm.
Transverse breadth at distal end, about	89 mm.
Transverse breadth at mid-length	38 mm.
Phalanx, length	71 mm.
Width proximal end	32 mm.
Width distal end	25 mm.
Ungual, length measured over upper curve (est.)	190+ mm.
Width proximal end	20 mm.
Depth proximal end	68 mm.

The hind limb and foot, No. 6554, appear to have their nearest affinities in *Gorgosaurus sternbergi* Matthew and Brown[1] from the Belly River formation of Canada. This relationship is suggested not only by the slenderness of limb and foot but also by the close resemblance found in the individual bones in so far as they can be compared. The individuals also are coequal in size. *Alectrosaurus olseni* may be distinguished from *G. sternbergi*, however, in having the femur and tibia subequal in length, whereas the latter has the tibia considerably longer than the femur. From *G. libratus* it is distinguished by its smaller size, more slender character of limb and foot, and relatively shorter astragalus. The close similarity of structure between this specimen and the American deinodonts is quite as striking as in the case of the ornithomimids.

One of the notable features of the hind limb is its great length, which is divided about equally between femur, tibia and foot. The femur lacks the proximal end, but its total length can be closely approximated from complete deinodont femora. It has a well molded, forwardly bent shaft, well developed condyles and a relatively small fourth trochanter. This process is triangular in cross-section and projects backward as a free vertical ridge. It is placed well up on the proximal half of the shaft and appears less robust than in *G. libratus*. At mid-length the shaft is nearly round, below which the curvature is greatest.

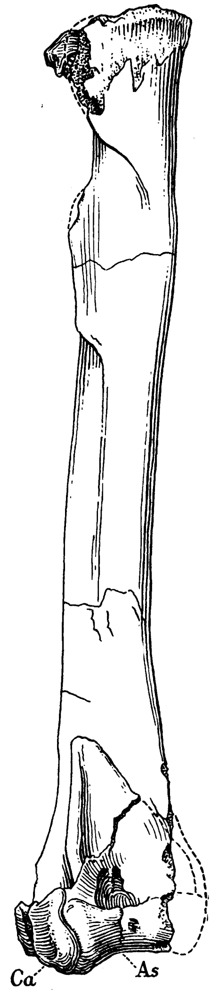

Fig. 10. Right tibia, astragalus and calcaneum. *Alectrosaurus olseni*. No. 6554, A.M.N.H. Front view; *As*, astragalus; *Ca*, calcaneum. One-sixth natural size.

[1]1923. American Museum Novitates, No. 89, p. 7, fig. 4

The tibia has a more slender shaft than *G. libratus* but otherwise I find no distinguishing characteristics. Likewise, the fibula seems to be identical in all particulars except its smaller size.

The astragalus and calcaneum are all that is preserved of the tarsus, and these bones remain firmly attached to the distal end of the tibia as shown in Fig. 10.

The proportions of the ascending process of the astragalus differ so from *G. libratus* as to be worthy of special mention. In that species the length of the astragalus, that is, from the distal articular end to the tip of the ascending process, is about one-third the length of the combined astragalus and tibia. In *Alectrosaurus olseni* it is one-fourth the combined length of these two bones. Furthermore, as Lambe[1] has pointed out, this process is about subequal in length and breadth. In the present species the length exceeds the greatest breadth. The foot, Pl. II, consists of metatarsals I, II, III, IV and V, having the usual digital formula 2, 3, 4 and 5. The first or hallux is very much reduced, the weight of the animal being carried by digits II, III and IV. The reduced metatarsal V is present, but it lacks the distal end. The pes has the peculiar and specialized character of the ornithomimids very exactly reproduced, save for the greater massiveness of the elements.

MEASUREMENTS

Femur length (estimated)	
Greatest transverse diameter, distal end	140 mm.
Transverse diameter of shaft, mid-length	65 mm.
Tibia + astragalus, length	742 mm.
Antero-posterior diameter at proximal end about	180 mm.
Astragalus, maximum height	180 mm.
Breadth, below	77 mm.
Calcaneum	
Maximum height (dorso-ventrally)	61 mm.
Maximum length (antero-posteriorly)	64 mm.
Metatarsal I, length about	72 mm.
Breadth, distal end	16 mm.
Metatarsal II, length	470 mm.
Breadth, proximal end	86 mm.
Breadth, distal end	46 mm.
Metatarsal III, length	486 mm.[e]
Breadth, proximal end	22 mm.
Breadth, distal end	58 mm.
Metatarsal IV	475 mm.
Breadth, proximal end	90 mm.
Breadth, distal end	36 mm.

[1]Lambe, L. M. 1917. Memoir 100, Canada Geological Survey, p. 69.
e = estimated.

Digit I, length about	112 mm.
Phalanx 1, length	88 mm.
Phalanx 2, length about	55 mm.
Digit II, length	232 mm.
Phalanx 1	105 mm.
Phalanx 2	82 mm.
Phalanx 3	82 mm.
Digit III, length about	300 mm.
Phalanx 1	108 mm.
Phalanx 2	82 mm.
Phalanx 3	65 mm.
Phalanx 4	
Digit IV, length	240 mm.
Phalanx 1	77 mm.
Phalanx 2	69 mm.
Phalanx 3	52 mm.
Phalanx 4	37 mm.
Phalanx 5	61 mm.

Dromaeosaurinae

Genus and species indet.

The presence of small, delicately constructed carnivorous dinosaurs in the Iren Dabasu fauna is clearly indicated by a few foot bones and other fragmentary skeletal parts. None is sufficiently diagnostic to be worthy of description, but they are of interest as showing the further similarity of this fauna to the Upper Cretaceous dinosaurian assemblage of North America.

That we have among these scattered bones parts of animals related to *Velociraptor* or *Saurornithoides*[1] of the overlying Djadochta formation seems highly probable, but their relationships cannot be determined from the fragmentary materials now available.

The reference of these specimens to the subfamily Dromaeosaurinae has no special significance further than to denote small, agile, light-limbed carnivores; they might equally well be assigned to the Coeluridae or Compsognathidae, except that both of these families chiefly contain much older Jurassic representatives and the rest of the fauna shows a closer affinity to Upper Cretaceous forms.

[1]Osborn, H. F. 1924. American Museum Novitates, No. 144, pp. 1–7.

ORNITHISCHIA

Hadrosauridae

The presence of members of the Hadrosauridae in eastern Asia was first announced by Riabinin[1] in 1925 when he described *Mandschurosaurus* (*Trachodon*) *amurensis* on an incomplete specimen discovered by Dr. A. N. Kryshtofovitch on the Amur River in Manchuria in 1914. A second occurrence was reported by Wiman[2] in 1929 when he established the new genus and species *Tanius sinensis* on a large part of a skeleton from the province of Shantung, China.

In 1930 Riabinin[3] described a second hadrosaurian from this same Amur locality under the name *Saurolophus krischtofovici*, founded on a proximal section of an ischium. This fragmentary specimen, in so far as its generic reference is concerned, might with equal propriety be referred to any one of a number of hadrosaurian genera, and for that reason the presence of the American genus *Saurolophus* in the Upper Cretaceous of Asia is yet problematical.

The presence of the Lambeosaurinae in this region is now quite fully established by a specimen in the present collection from the Iren Dabasu formation here described under the name **Bactrosaurus johnsoni.** Although the skull is incomplete and apparently lacks a crest, the characteristic reduced dentition, footed ischium, widely expanded prepubis and highly arched ilium, all show its affinities to lie in the Lambeosaurinae, the first recognized occurrence of this subfamily in Asia. A second species from the Iren Dabasu, tentatively referred to *Mandschurosaurus*, is of interest as possibly indicating the contemporaneity of the deposits in Mongolia and Manchuria.

Riabinin[4] mentions the discovery by E. V. Ivanoff and V. D. Predanoi in Turkestan in 1921–1924, of Cretaceous dinosaurs presumed to belong to the Hadrosauridae, but I have failed to find reference to this discovery elsewhere.

This brief review indicates nearly as wide a geographical distribution of the Hadrosauridae in Asia as this family now enjoys in North America.

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[1]1925. Bull. du Comité Géologique, XLIV, No. 1, pp. 1–12, Pl. I.
[2]1929. Palæontologia Sinica, Ser. C. VI, Pt. I, Geol. Survey of China, p. 41.
[3]1930. LIX, No. 11, pp. 41–51, 1 plate.
[4]1930. Mem. Russian Mineralogical Soc., Socieété Paléontologique de Russie, Mémoires, II, p. 6.

Hadrosaurinae

MANDSCHUROSAURUS

Mandschurosaurus amurensis (Riabinin)

Trachodon amurense, RIABININ, A. N. 1925. Bull. de Comité Géologıque, XLIV, No. 1, pp. 1–12, Pl. I.

Mandschurosaurus amurensis, RIABININ, A. N. 1930. Société Paléontologie de Russie, Mémoires II, pp. 5–37, 4 plates.

The genus *Mandschurosaurus* was based on an incomplete skeleton found on the bank of the Amur River in Manchuria in 1914. Riabinin first described it under the name *Trachodon amurense*, but his later more detailed study indicated its generic distinctness, and the new genus *Mandschurosaurus* was proposed for its reception. He quite properly referred it to the subfamily Hadrosaurinae, the distinctness of the genus resting principally on the reduced number (35) of vertical tooth rows in the dentary. In view of the large size of the specimen it is probably an adult individual, so that this feature can be relied on as being more or less constant, for, in the Hadrosauridae as I shall presently show, the tooth rows increase in number with the age of the individual but probably become stabilized in the adult.

Unfortunately most of the more characteristic bones of the skeleton were incompletely preserved, and this condition makes it impossible to properly characterize the genus.

It is largely a matter of expediency that I now refer one of the Mongolian specimens to this genus since full and proper comparisons cannot be made. While in most particulars they seem to be generically similar, there are a few inconsistencies; yet, on the other hand, I fail to find characters that would definitely distinguish them generically. Therefore, for the present it seems best to tentatively refer the Mongolian specimen to the genus *Mandschurosaurus* until such time as its true affinities are disclosed. I propose the specific name **mongoliensis** for its reception.

Mandschurosaurus mongoliensis, new species

Plate III, Figure 1; Plate IV, Figures 1 and 2; Plate V, Figures 1 and 2; Plate VI, Figures 2 and 3; Plate VII, Figures 2 and 3.

COTYPES.—Nos. 6551, 6371, A.M.N.H. Practically all parts of the skeleton are represented. Collected by George Olsen, May, 1923. Field No. 149.

LOCALITY.—About 8¾ miles east of Iren Dabasu telegraph station, Mongolia.

HORIZON.—Iren Dabasu formation, Upper Cretaceous.

The type materials came from a quarry, designated by the field number 149 (see Fig. 1) in which were found the scattered skeletal remains of not less than four adult animals, all apparently pertaining to the same genus and species. Careful search, however, failed to disclose a single recognizable bone of the allied *Bactrosaurus johnsoni*, the type of which came from the same formation not more than three-fourths of a mile distant. Although most of the adult bones have been assembled under the catalogue number 6551, A.M.N.H., it is quite apparent that more than one individual is represented. Due to the scattered condition of these specimens in the quarry, it is now quite impossible to segregate the bones of individual animals.

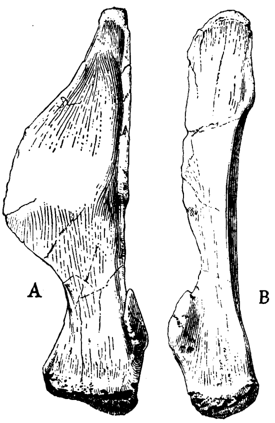

Fig. 11. Left quadrate of *Mandschurosaurus mongoliensis*. No. 6551, A.M.N.H. A, front view; B, lateral view. One-fourth natural size.

From this brief review the danger of wrongly associating some of the elements is clearly apparent, but if there has been error in this respect it can hardly be more than in combining two different species.

THE SKULL.—The skull is represented by a number of disarticulated elements pertaining to two if not more individuals, but it is assumed that all of these scattered parts can be assigned to *Mandschurosaurus mongoliensis*. The following bones are recognized: maxillary with teeth, portion of a dentary; incomplete right squamosal; two left quadrates; pair of lachrymal bones; and an incomplete right jugal. A predentary (No. 6369, A.M.N.H.) is also referred to this species. All of these bones are larger and more robust than the corresponding elements of the *Bactrosaurus* cranium.

The squamosal is nearly twice the size of that bone in *Bactrosaurus*, but it is too incomplete to offer any further basis of comparison; the jugal shows no differences of any special significance.

The quadrate is of the usual hadrosaurian type, as shown in figure 11. Viewed from the side, its posterior profile is straight as in *Tanius*, whereas the quadrates ascribed to *Bactrosaurus* have the proximal half bowed backward. Other than this and a difference in size, the quadrates of these two forms are identical. The best preserved element has a greatest length of 208 mm. The principal features of the lachrymal are well shown in Plate VI, fig. 3.

A right maxillary from quarry 149 is tentatively referred to the present genus and species. This bone has the usual triangular shape, and it will be noted from Fig. 12 that the apex of the triangle is close to the mid-length, a feature that at once distinguishes it from all known members of the Lambeosaurinae. In that subfamily the apex of the maxillary is posterior to the mid-line as in *Bactrosaurus johnsoni* (see Fig. 26). The dental magazine is filled with unworn teeth; all of the worn or functional ones have dropped out and are missing. In the complete dental series there are 29 vertical rows. This is fewer than is known in any member of either the Hadrosaurinae or the Saurolophinae, but it is quite probable that the individual is not fully adult.

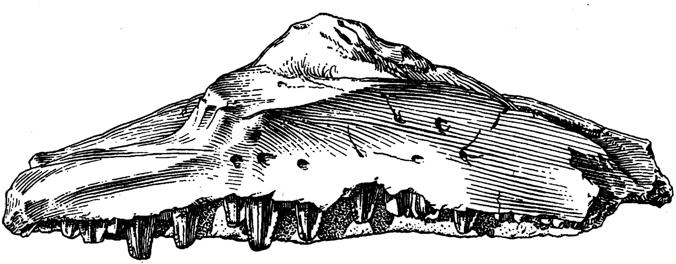

Fig. 12

Fig. 13

Fig. 12. Right maxillary of *Mandschurosaurus mongoliensis*. No. 6551, A.M.N.H. Lateral view. One-fourth natural size.

Fig. 13. Maxillary tooth of *Mandschurosaurus mongoliensis*. No. 6551, A.M.N.H. About natural size.

MEASUREMENTS

Greatest length, about	270 mm.
Length of dental series	230 mm.
Width at anterior end	45 mm.
Width at posterior end	44 mm.

TEETH.—There were ten loose teeth in the collection from locality 149 in addition to those preserved in the maxillary bone. These are sufficiently alike to indicate that all pertain to the same kind of animal and it would also appear that all belong to the upper dental series. The unworn teeth are spatulate and rather bluntly rounded at the summit, with median carina low and sharp-edged and lateral surfaces flat. From the center toward the crown both borders are papillate. This papillation is general throughout the maxillary series. The teeth as a whole are relatively broader than those of *Bactrosaurus* and can further be distinguished by the less robust carina, with sharper edge, and the presence of papillae on all of the maxillary teeth. There are twenty-nine vertical rows of teeth in the maxillary. The implantation and method of replacement are similar to other members of the group.

PREDENTARY.—A predentary bone, No. 6369, A.M.N.H., field No. 145, was found in association with the following skeletal parts: 2 scapulae, humerus, ulna, portion of ilium, 2 metatarsals II, 4 caudal and one dorsal vertebrae, phalangeal and ungual bones. All of these bones are in accord with those of the cotypes of *Mandschurosaurus mongoliensis*, and, although two or more individuals are represented, it is the presumption that the predentary also pertains to the same genus and species. The shape of this bone is well shown in Fig. 14. It is more decidedly U-shaped than the juvenile predentary of *Bactrosaurus johnsoni* (Fig. 28) and much heavier throughout. There is a decided transverse depression traversing the ventral surface on the anterior end. There is no pos-

Fig. 14

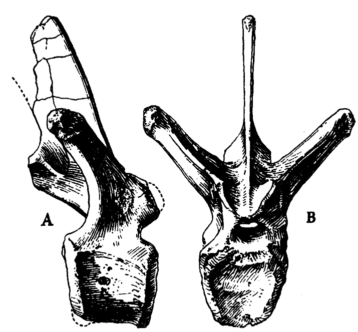

Fig. 15

Fig. 14. Predentary of *Mandschurosaurus mongoliensis*. No. 6369, A.M.N.H. Ventral view. One-half natural size.

Fig. 15. Anterior dorsal vertebra of *Mandschurosaurus mongoliensis*. No. 6551, A.M.N.H. A, viewed from the side; B, viewed from the front. One-sixth natural size.

teriorly directed process developed on the median line as found in many of the American hadrosaurians.

The superior surface is ornamented with the usual bony tooth-like projections, most of which are broken off in this specimen. At the posterior end the predentary has a greatest transverse width of 91 mm.; a greatest length of 82 mm.

VERTEBRAE.—The vertebral column is represented by four cervical, ten dorsal, seven sacral and thirty-three caudal vertebrae of several individuals. The cervicals are of the usual opisthocoelian hadrosaurian type and show no distinguishing characteristics.

There are eight adult dorsal vertebrae in the collection from locality 149 and three from 145 that may be attributed to *Mandschurosaurus*. Six of these pertain to the anterior half of the column and four to the posterior half. One of the former lacks its centrum, and the spines are missing in three, as well as from one of the posterior dorsals; otherwise the preservation is good. Differences in size indicate at least two individuals.

The outstanding features of these vertebrae as contrasted with those of *Bactrosaurus* are the much shorter spinous processes without transverse thickening except at the upper extremity, and the relatively shorter centra. The longest spines are about two and one-quarter times the height of the centrum, whereas in *Bactrosaurus* they are slightly less than four times this measurement, in this respect more nearly approaching *Thespesius* (*Trachodon*) where they are three times this measurement. The angulation of the spines is as in *Bactrosaurus*.

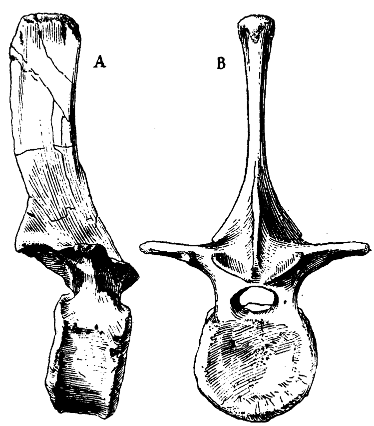

Fig. 16. Posterior dorsal vertebra of *Mandschurosaurus mongoliensis*. No. 6551, A.M.N.H. A, viewed from the side; B, viewed from the front. One-sixth natural size.

The centra are opisthocoelous, the cupping being most pronounced on the posterior end; the anterior end is nearly flat. Below they are pinched together to form a longitudinal keel as in *Mandschurosaurus amurensis*. The posterior centra are much wider than long, whereas in the anterior vertebrae these two measurements are subequal (compare Figs. 15 and 16).

The neural arch, elevation of the transverse processes, position of the capitular facets and placing of the zygapophyses are all typically hadrosaurian and deserve no especial mention.

Measurements of Dorsal Vertebrae, No. 6551

	1	2	3	4	5	6
	mm.	mm.	mm.	mm.	mm.	mm.
Greatest height	....	....	230	230+	....	312
Greatest length of spine	....	....	130	137	....	170
Greatest length of centrum	56	58	62	62	61	60
Greatest width posterior end	52	54	54	66	83	92
Greatest thickness of spine	....	....	21	....	....	25

Numbers indicate only anterior to posterior, not a continuous series.

Sacrum.—The sacrum is represented by parts of two if not three individuals, three coössified centra representing a sacro-dorsal, and sacrals one and two with portions of neural arches and sacral ribs; four coalesced posterior sacral centra with fragmental processes and sacral ribs, and four articulated neural arches with incomplete spines. It is barely possible that the two first mentioned may pertain to the same individual, but the fact that the sutures (see Pl. IV, fig. 2) between the centra remain distinct on the anterior sacrals and are fully coalesced on the posterior ones, apparently indicates two individuals of different ages. Since one or more median vertebrae are obviously missing between the two series, these specimens give no clue to the total number of sacrals. Viewed from below, the sacrum is essentially like that of *Bactrosaurus,* except that the three posterior centra are traversed by a median longitudinal channel instead of being evenly rounded or keeled. The anterior vertebrae are broadly rounded on the ventral surface with a faint rounded keel. The sacro-dorsal is more pinched in thus producing a decided keel on the median ventral line.

The spinous processes all lack their upper extremities (see Pl. III, fig. 1). The basal halves are of uniform thickness and show no indication of thickening upward so characteristic of the *Bactrosaurus* spines. The edges of the spines closely abut but do not seem to be coössified. The two median spines are exceptionally wide fore and aft, the widest measuring 82 millimeters. The unusual width of these spines would at once distinguish them from those of *Bactrosaurus johnsoni.*

Measurements

Width of first sacral centrum about	88 mm.
Length of first sacral centrum	63 mm.
Width of last sacral centrum	103 mm.
Length of last sacral centrum	53 mm.

Caudal Vertebrae.—From quarry No. 149 there are thirty-three caudal vertebrae that may be attributed to *Mandschurosaurus mongoliensis.* None of these was apparently found in sequence, but vertebrae from all parts of the tail are present. Complete spinous processes are present on only a few of the vertebrae. Those present all have a decided backward slant. Comparison with the caudals of *Bactrosaurus* fails to disclose any essential differences, though an articulated series might display characters of importance.

Pectoral Girdle and Fore Limb.—The pectoral girdle is represented by two right scapulae and three disarticulated coracoids, all of the left side. No sternal elements were found. The scapulae are almost precisely alike and subequal in length. They are gently curved from end to end horizontally with a nearly straight upper border, differing markedly in this respect from the scapula of *M. amurensis* which has this border strongly bowed, as it is also in *Tanius sinensis*. The blade is only moderately expanded and in that respect bears a closer resemblance to *Procheneosaurus* than to any of the larger hadrosaurs. This reduced width of blade at once distinguishes these scapulae from the two adult

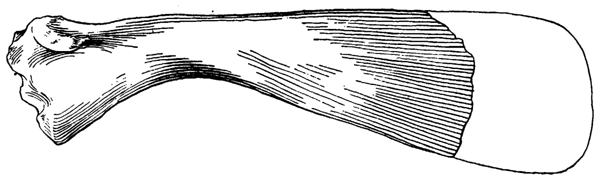

Fig. 17. Scapula of *Mandschurosaurus mongoliensis*. No. 6551, A.M.N.H. Lateral view. One-sixth natural size.

scapulae found in locality 141 and which I have attributed to *Bactrosaurus* (compare Figs. 17 and 34). Juvenile scapulae in the collection from the same locality, however, cannot be distinguished from the present bone, although I am of the opinion that they are probably the young of *Bactrosaurus johnsoni*. Certainly no bones of adult *Mandschurosaurus* were found in that deposit. The coracoids show no distinguishing characteristics.

The limb bones are of the typical hadrosaurian development and deserve no special mention, except that the humerus is short and stout and subequal in length with the radius as in *Saurolophus*. In *Tanius sinensis* the radius is decidedly longer than the humerus. The principal features of these bones are well shown in Plate V and Plate VI, fig. 2.

MEASUREMENTS

	M. mongoliensis Cotypes	*M. amurensis* Type
Scapula length	430 mm.	800 mm.
Greatest width of blade	106 mm.	200 mm.
Humerus length	315 mm.	535 mm.
Width across radial crest	120 mm.	....
Length of radial crest	145 mm.	....
Least circumference of shaft	142 mm.	....
Ulna length	358 mm.	604 mm.
Least circumference of shaft	112 mm.	
Radius length	307 mm.	
Least circumference of shaft	87 mm.	

Pelvic Arch.—The pelvic arch is represented by three ilia and an incomplete pubis. The ilium in the regular longitudinal curved contour of its upper border resembles that of *Claosaurus agilis* and those of *Thespesius annectens.* It differs, however, in the much shorter and narrower postacetabular extension. In the latter respect its nearest resemblances are found in the ilium of *Bactrosaurus* (see Fig. 35). In vertical diameter it is intermediate between *Thespesius* on the one hand

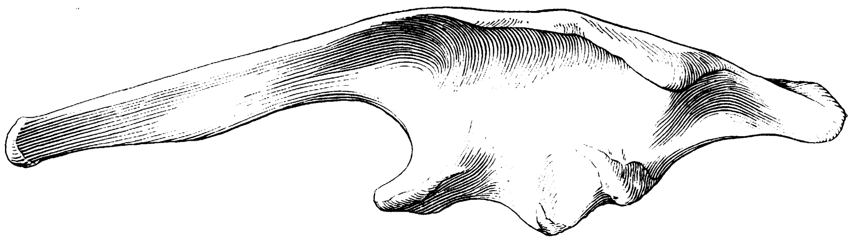

Fig. 18

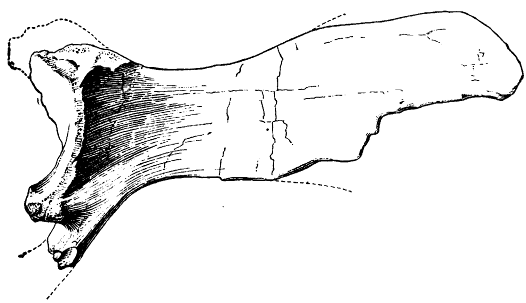

Fig. 19

Fig. 18. Left ilium of *Mandschurosaurus mongoliensis.* No. 6551, A.M.N.H. Lateral view. About one-sixth natural size.

Fig. 19. Right pubis of *Mandschurosaurus mongoliensis.* No. 6551, A.M.N.H. Lateral view. One-sixth natural size.

and *Hypacrosaurus* on the other. In *M. amurensis* only the anterior half of the ilium is preserved, but except for its larger size it is in perfect agreement with the bone before me.

The pubis lacks most of the postpubic process as well as the borders of the prepubic blade, for which reason its full outline is unknown (see Fig. 19). It is of the attenuated type with a moderately long neck and apparently a gradual expansion of the blade. These features at once distinguish it from the short-necked, broadly expanded *Bactrosaurus* pubis from this same formation. Except for its smaller size it cannot be distinguished from the fragmentary pubis of the type specimen of *Mandschurosaurus amurensis.*

MEASUREMENTS

Ilium, greatest length	650 mm.
Ilium, preacetabular border to anterior end	295 mm.
Ilium, width at pubic peduncle	175 mm.
Ilium, postacetabular border to posterior end	215 mm.
Pubis, greatest length, estimated	430 mm.
Pubis, width of neck	84 mm.

HIND LIMB.—A tibia and femur (No. 6551, A.M.N.H., field No. 149) show the usual hadrosaurian development. These bones apparently pertain to the same individual and thus display the ratio of length between these two segments of the hind limb, showing the femur to be only

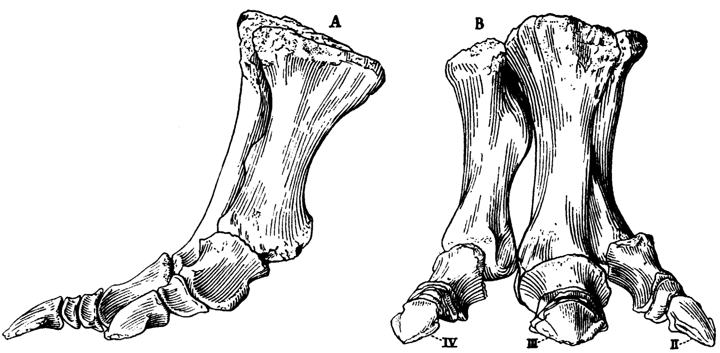

Fig. 20. Right pes of *Mandschurosaurus mongoliensis.* No. 6551, A.M.N.H. Composite. A, internal view; B, front view. Both one-sixth natural size.

slightly longer than the tibia. The femur is shorter and more slender than in *Bactrosaurus* and has the foramen at the distal end partially enclosed by bone. Otherwise these two femora are indistinguishable, as shown in Plate VII. The abraded character of the bone surfaces suggests that the distal foramen in life was probably fully bridged across by bone, a conclusion that is substantiated by juvenile femora in the collection showing such a condition, but to a much less degree than in *Tanius sinensis.*

The tibia is only about two and one half inches shorter than the femur, whereas in *Thespesius annectens* there is a difference of eight inches.

MEASUREMENTS

Femur, greatest length	720 mm.
Femur, greatest width proximal end	185 mm.
Femur, greatest width distal end	165 mm.
Tibia, greatest length	660 mm.
Tibia, greatest width proximal end	230 mm.
Tibia, greatest width distal end	222 mm.

PES.—From the scattered foot bones found in quarry 149, practically all of the elements of the pes can be recognized except Mt. IV. These represent three if not more individuals. Compared with the articulated feet of *Bactrosaurus*, some few slight differences of proportion are found but in all essential features they are indistinguishable and of approximately the same size. The unguals, however, as shown in Fig. 20, have moderately sharp edges with obtusely pointed ends, as contrasted with the thickened, truncated terminations found in the *Bactrosaurus* pes.

Lambeosaurinae

Bactrosaurus johnsoni, new genus and species

Plate III, Figure 2; Plate IV, Figure 3; Plate VI, Figures 1 and 4; Plate VII, Figure 1

TYPE.—No. 6553, A.M.N.H., consists of dentary, maxillary and other skull parts; ten dorsal vertebrae, seven sacrals, thirty-six caudals, most of which were found in series; left scapula, left sternal, both pubes, both ischia, left femur, fibula and complete left hind foot and part of right. Collected by Albert F. Johnson, 1923.

LOCALITY.—Johnson's Quarry, eight miles east of Iren Dabasu telegraph station, Mongolia.

HORIZON.—Iren Dabasu formation, Upper Cretaceous.

GENERIC AND SPECIFIC CHARACTERS.—Dentition reduced, twenty-three vertical rows of teeth in dentary, twenty-eight in maxillary. Posterior dorsal vertebra with tall spines, club-shaped. Sacrum with seven coössified vertebrae. Ilium strongly arched, preacetabular process decurved; ischium stout with expanded foot-like end. Pubis short with greatly expanded blade. Terminal phalanges of pes with thickened truncate anterior borders.

The type materials came from a deposit known to the collectors as "Johnson's Quarry" said in the field notes to be "mostly trachodont types, also portions of a crocodile specimen." Specimen No. 6553 was the largest skeleton found in the quarry, and although somewhat disassociated its large size made it possible to reassemble the scattered parts with some assurance that they pertain to the same animal. That more than one individual of large size occurred in this deposit of fossil bones is indicated by the presence of two complete left hind feet. These, however, are identical in size and are in agreement in all other respects, so that, should some of the skeletal elements listed above prove to be wrongly referred as to individual, it would not necessarily alter any of the conclusions drawn from them. Other than the feet mentioned above, there is no duplication of parts.

The occipital portions of two skulls of the flat non-crested type of hadrosaurian dinosaur and the right frontal of a third specimen found among the materials from this quarry (No. 141) have given me much concern. In all of the considerable quantity of hadrosaurian material from this one deposit, not a single bone, aside from parts of skulls, was found which could not be quite certainly attributed to the genus *Bactrosaurus*. This genus in all of its other skeletal characteristics clearly pertains to the subfamily Lambeosaurinae, and in the light of our present knowledge all of the members of this group have crested skulls. This fact alone would seem to bar the assignment of these skull parts to that genus.

On the other hand it appears highly improbable that these skulls could have become embedded here of themselves. At first I was inclined to the idea that they might pertain to *Mandschurosaurus mongoliensis*, but since no recognizable bones of that animal were found here, this viewpoint was abandoned. A more reasonable supposition, it seems to me, is to regard these skull parts as belonging to *Bactrosaurus*, whose skeletal remains form the bulk of the materials from this quarry. In doing this our present conception of the Lambeosaurinae must be revised to the extent of including this non-crested form, for in all other respects *Bactrosaurus* is in accord with our understanding of that subfamily. The lack of a crest in these individuals may after all, as first suggested by Nopcsa,[1] be a sexual characteristic, although the other parts of the skeleton do not conform with his ideas on this question.

In view of the association of materials briefly discussed above, I shall for the present regard these skull parts as belonging to *Bactrosaurus johnsoni*.

The skulls have their closest resemblances in the cranium of *Tanius sinensis*, described by Wiman[2] from the Cretaceous of Shantung, China. Both have the upper posterior border of the cranium deeply indented at the center, much as in *Camptosaurus*, a feature that at once distinguishes them from American hadrosaurian skulls which are more or less straight in posterior outline. This indenture has been brought about by a shortening of the parietal at the center and thus the inner processes of the

[1]Nopcsa, Baron Fr. 1929. 'Sexual Differences in Ornithopodous Dinosaurs,' Palæobiologica, II, pp. 187–201.

[2]Wiman, Carl. 1929. 'Die Kreide-Dinosaurier aus Shantung.' Palæontologia Sinica, Ser. C, VI, Peking, pp. 41–60, Pls. v–ix.

squamosals turn forward to meet it. In the American forms the median part of the parietal extends nearly as far posteriorly as the lateral angles of the skull and is intercalated between the squamosals on the median posterior border.

The close resemblance between the *Bactrosaurus* skull and that of *Tanius* might suggest their being congeneric, but a comparison of the known skeletal parts shows sufficient differences to apparently indicate their generic distinctness. These differences are contrasted in the two columns below.

Bactrosaurus	*Tanius*
1. Ilium strongly curved upward at the center; preacetabular process depressed; postacetabular shortened.	1. Ilium with regular curved outline from end to end; preacetabular process not especially depressed; postacetabular process long.
2. Posterior dorsal spines tall (nearly 4 times height of centrum), club-shaped, spine nearly as wide fore and aft as length of centrum.	2. Posterior dorsal spines tall (little over 3 times height of centrum), widened at top only. Spine much narrower than length of centrum.
3. Scapula widening toward distal end.	3. Scapula with two borders parallel.
4. Humerus short, not especially widened.	4. Humerus short with broad upper extremity.
5. Femur with open grooves fore and aft at distal end.	5. Femur with grooves closed in by bone.
6. Pes unguals with thickened, truncanted ends in the adult.	6. Pes unguals of usual pointed or rounded ends in the adult.
7. Moderate size.	7. Large size.

Further distinctions will doubtless appear as the skeletons of these animals become better known. It might be added that the footed ischiac ends are quite unlike in form in these two genera, although I am of the opinion that Wiman may have erred in associating this end with *Tanius*, as it has more the form and characteristics of the theropod pubis. Of that, however, one cannot be sure from the published illustrations and description.

SKULL.—Among the materials from the "Johnson Quarry" (No. 141) are the rear portions of two hadrosaurian skulls and a right frontal bone of a third individual. All of these are of the non-crested type of cranium.

These skull portions are of the same size and similar in all important details. The description to follow is based on the better preserved specimen No. 6365, with some details supplied from the second specimen, No. 6366, A.M.N.H.

Viewed from above, specimen No. 6365 consists of the articulated parietal, frontals, postfrontals, and squamosal bones. The parietal is exceedingly short on the dorsal surface, measuring only 34 mm. in length on the median line. This abbreviation is brought about by the deep median indenture on the posterior border, a feature that from the superior view discloses much of the underlying supraoccipital. In this

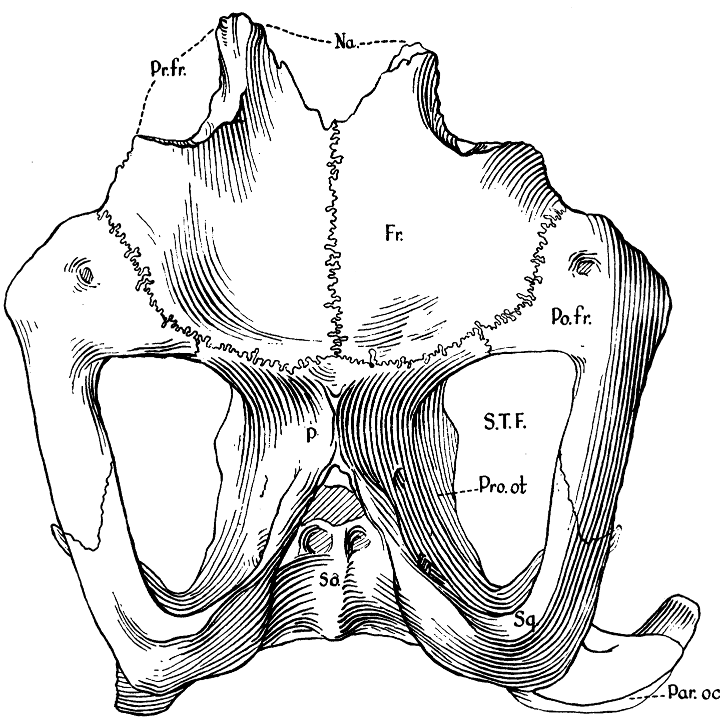

Fig. 21. Posterior portion of skull, *Bactrosaurus johnsoni*. No. 6365, A.M.N.H. Viewed from above, *Fr.*, frontal; *Na.*, sutural contact of nasal bones; *P.*, parietal; *Par. oc.*, paraoccipital process; *Po. fr.*, postfrontal; *Pr. fr.*, sutural contact of prefrontal; *S.T.F.*, supratemporal fossa; *Pro. ot.*, proötic; *So.*, supraoccipital; *Sq.*, squamosal. One-half natural size.

respect this skull is quite unlike American members of the Hadrosauridae, which have a more or less straight posterior outline that in most forms entirely hides the supraoccipital in dorsal view. There are suggested resemblances to the skull of *Limnosaurus transylvanicus* Nopcsa which apparently shows a similar indenture, though the skull described by Nopcsa[1] is somewhat broken in this region. The median lateral surfaces

[1]Nopcsa, Baron Fr. 1899. Denkschr. K. Akad., Wien, Pl. II.

of the parietal which form the upper walls of the braincase are smooth, concave antero-posteriorly, being pinched together at the top to form a low but sharp median sagittal ridge. Anteriorly the expanded end of the parietal unites with the plate-like frontals by an angular suture, the outer extremities being in sutural contact with the postfrontal as shown in figure 21. Posteriorly the sutures between parietal and squamosals cannot be traced with certainty, though it is quite evident that the squamosal forms the entire posterior boundary of the supratemporal fossa. Ventrally the parietal is in sutural contact with the proötic and alisphenoid bones, and posteriorly it enclosed the upper half of the supraoccipital.

The frontals are irregularly pentagonal in outline, longer than wide, with a smooth but slightly concave dorsal surface. The frontal is entirely excluded from the boundary of the supratemporal fossa by the intervention of the parietal and post-orbital. The antero-external angle is deeply excavated for contact with the prefrontal. Between the pre- and post-frontal articulating borders, the sharpened edge contributes to the upper boundary of the orbit for a space of 20 mm. The median border of the articulated frontals is moderately excavated for the nasals. The under or orbital surface of the frontal is large and slightly concave antero-posteriorly.

The postfrontal is a three-rayed bone. One short, heavy process unites with the posterior external angle of the frontal; a second extends backward and joins by squamous union with the forward branch of the squamosal to form the upper temporal bar; and the third extends downward to join the jugal and forms the posterior boundary of the orbit. On the under side it is in contact with the alisphenoid, which abuts against it.

The squamosal forms the whole of the posterior-external angle of the skull. A thin, internal process joins the parietal; the precise manner of their union cannot be determined from available material, but the process appears to extend well forward, in striking contrast to the usual heavy sutural end that in many hadrosaurians abuts against the interposed parietal on the posterior median border. The postfrontal process is thin, flattened, and but slightly arched outward. A slender, pointed process runs downward along the front of the quadrate. Posterior to it on the under side is an elongated pit for the reception of the quadrate head. Posterior to this pit a thin process of the squamosal extends downward, backward, and outward, being interposed between the back of the quadrate and para-occipital process with which it is in close apposition.

One is immediately impressed with the low aspect of the skull when viewed posteriorly. This is especially evident when contrasted with such forms as *Thespesius* and *Kritosaurus*, which are notably high as compared with their breadth. In this view, if it were not for the long pendant tapering para-occipital processes, the similarity to the *Camptosaurus*, occiput is striking.

The heavy *occipital condyle* is reniform in outline, having a greatest width of 36 mm. and a depth of 21 mm. The smooth articular surface is continued well forward on the under side of the condyle. There is quite

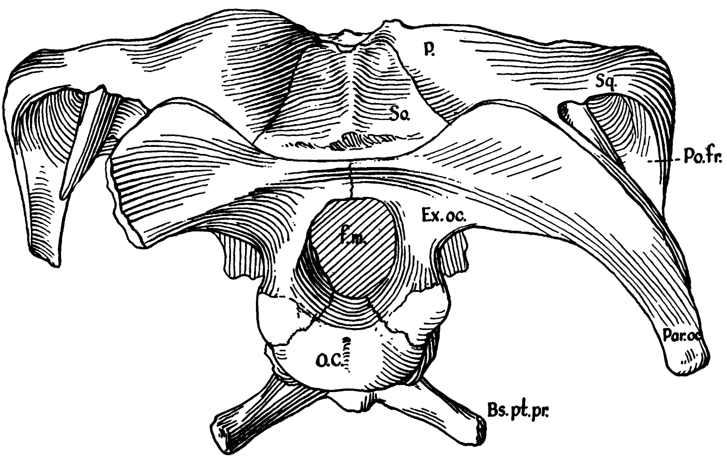

Fig. 22. Occipital view of skull of *Bactrosaurus johnsoni*. No. 6365, A.M.N.H. *Bs. pt. pr.*, basipterygoid process; *F. m.*, foramen magnum; *Exoc.*, exoccipital; *P.*, parietal; *Par. oc.*, paraoccipital process; *Po. fr.*, postfrontal; *O. c.*, occipital condyle; *So.*, supraoccipital; *Sq.*, squamosal. One-half natural size.

a pronounced median depression on the under side between the basi-occipital processes, which are stout and heavy and underlapped by the basisphenoid. The exoccipitals contribute somewhat to the formation of the condyle as in the Dinosauria generally.

The *exoccipital* rises from the basioccipital, articulating dorsally with the supraoccipital, and continuing latero-posteriorly as a vertical plate whose tapering extremity curves strongly downward. The greater portion of this paraoccipital process is closely applied to the posterior surface of the squamosal. The inferior lateral surface of the exoccipital is pierced by two foramina, one in front of the other. The more posterior one enters the foramen magnum just within the external opening, and doubtless transmitted the hypoglossal or twelfth nerve; the anterior foramen was probably the exit of the pneumogastric nerve.

The *supraoccipital* is a heavy, block-like element. It extends forward and upward as a stout pyramidal median bone that is enclosed dorsally and laterally by the parietal. Ventrally it articulates with oblique faces with the exoccipitals. A low, rounded median longitudinal ridge traverses the upper two-thirds of the posterior surface. Its external form and relationships to adjacent bones are well shown in figure 22.

A complete right exoccipital of a juvenile specimen, No. 6370, A.M.N.H., from this same quarry shows clearly that the exoccipitals have sutural contact with one another on the median line and thus exclude the supraoccipital from participation in the boundary of the foramen magnum. Although the adult skulls have these bones all coössified, with this specimen as a guide, the course of the coalesced sutures can be clearly traced, and they agree with the juvenile specimen in all particulars. The exclusion of the supra-occipital from the boundary of the foramen magnum is of much interest, for these occipital elements in the hadrosaurian skull are usually so fully coalesced that the extent of the separate bones can rarely be traced.

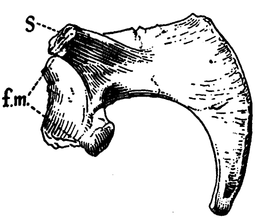

Fig. 23. Right exoccipital of *Bactrosaurus johnsoni*. No. 6370, A.M.N.H. Juvenile. Posterior view, *F. m.*, foramen magnum border; *S.*, sutural contact for opposite exoccipital. One-half natural size.

Beneath the posterior half of the parietal is the proötic. It is bounded posteriorly by the opisthotic, dorsally by the parietal, anteriorly by the alisphenoid, and ventrally by the basisphenoid. It is fully fused with the opisthotic, and the epiotic can no longer be recognized as a separate element. On the lower median surface a small foramen probably represents the point of exit of the seventh or facial nerve. Immediately forward, the proötic is notched by the large foramen ovale (V), and posterior to the seventh the bone is perforated by the large internal auditory meatus (VIII). The other foramina are either rendered more or less obscure by slight crushing or damaged beyond recognition.

The alisphenoids have the usual triangular form and arise from the anterior dorsal surface of the basisphenoid, uniting dorsally as in other Predentata with the parietal and frontals. The outer end is received in a shallow cup on the inner side of the postorbital-postfrontal complex. Their inner surfaces form much of the wall of the case which lodges the cerebral hemispheres of the brain. The anterior border of the foramen ovale (see Fig. 24) seems to be formed by the lower posterior border of the proötic as in *Camptosaurus*, though the preservation of the specimens renders this point a little uncertain.

Ossified orbitosphenoid bones are present as indicated by the fragmentary parts that form the walls inclosing the olfactory lobes. Their damaged condition gives little idea of their true form or extent.

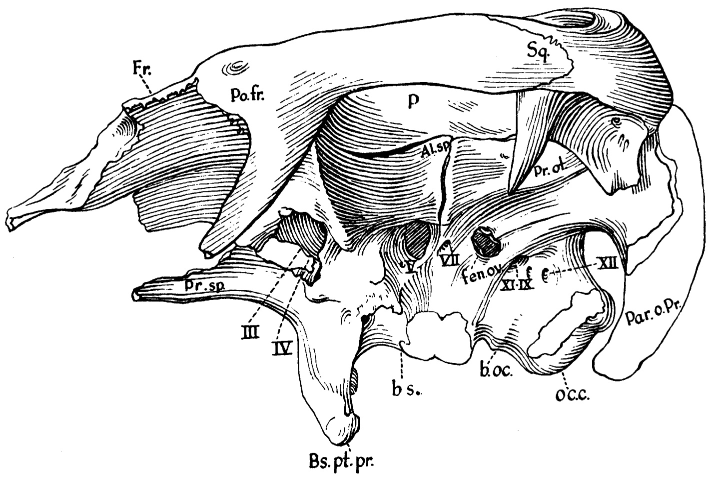

Fig. 24. Lateral view of skull of *Bactrosaurus johnsoni*. No. 6365; A.M.N.H. *Al. sp.*, alisphenoid; *B. oc.*, basioccipital; *Bs.*, basisphenoid; *Bs. pt. pr.*, basisphenoid process; *Fen. ov.*, fenestra ovalis; *Fr.*, frontal; *Oc. c.*, occipital condyle; *P.*, parietal; *Par. o. pr.*, paraoccipital process; *Pr. sp.*, presphenoid process; *Po. fr.*, postfrontal; *Pr. ot.*, proötic; *Sq.*, squamosal. III, IV, V, VII, IX, XI, XII, exits of cranial nerves. One-half natural size.

Brain Case.—The brain case of No. 6366, A.M.N.H., shows the brain to have been somewhat depressed and not so high and narrow as in the American *Thespesius*. The nerve openings, however, are very similar in size and position. Their relative size and placement are well shown in Fig. 24 and are in entire accord with Brown's determinations of cranial nerves in a hadrosaurian specimen from the Edmonton formation.[1]

A complete left adult maxillary and six maxillaries of young individuals are referred to the present genus and species. All of these

[1]Brown, Barnum. 1914. Bull. Amer. Mus. Nat. Hist., XXXIII, pp. 545–547.

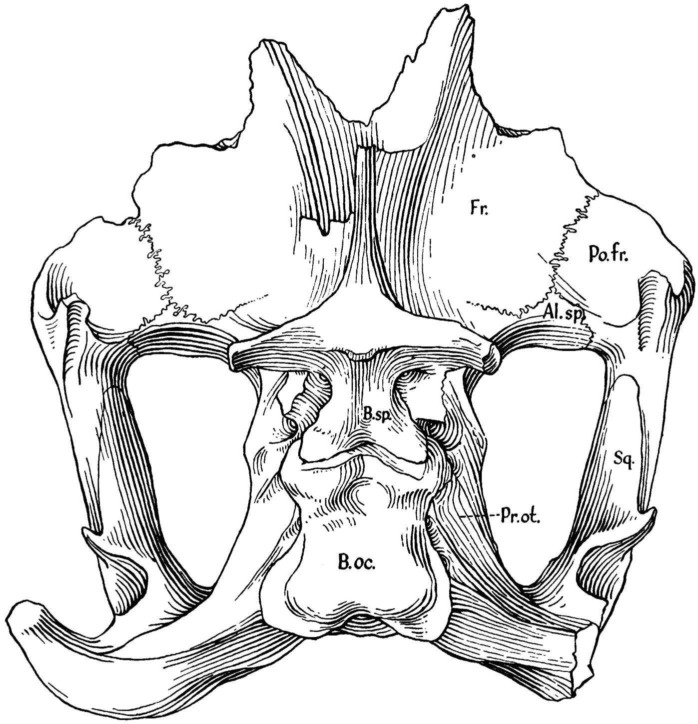

Fig. 25. Ventral view of skull of *Bactrosaurus johnsoni.* No. 6365, A.M.N.H. *Al. sp.*, alisphenoid; *B. oc.*, basioccipital; *B. sp.*, basisphenoid; *Fr.*, frontal; *Po. fr.*, postfrontal; *Pr. ot.*, proötic; *Sq.*, squamosal. One-half natural size.

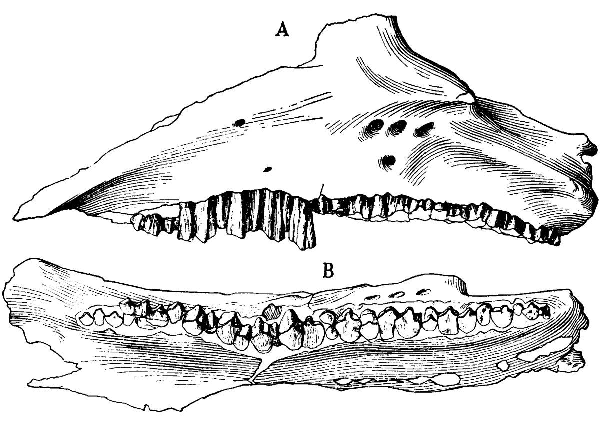

Fig. 26. Left maxillary of *Bactrosaurus johnsoni.* No. 6553, A.M.N.H. A, lateral view. B, ventral view. One-fourth natural size.

specimens are from the "Johnson Quarry." There are 28 vertical rows of teeth, more than half of which have the crowns broken off a little above the level of the alveolar borders as shown in Fig. 26A.

The maxilla is high at the center, sloping downward toward either end, the dental chamber occupying nearly the antire length of the bone. Seen from above, the posterior surface slopes downward and outward,

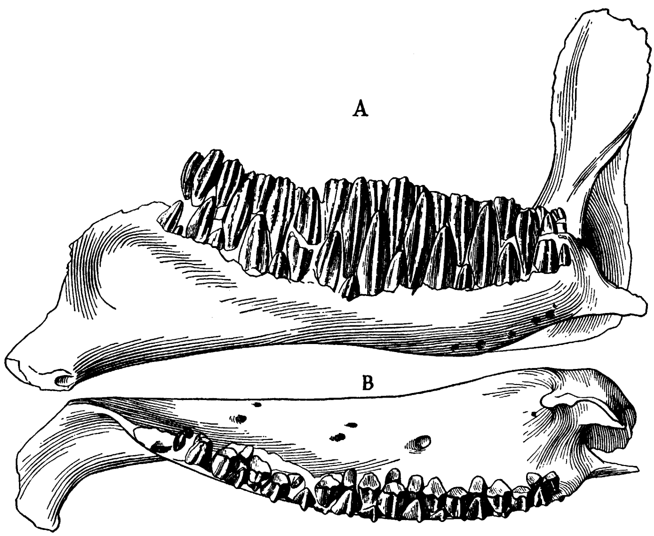

Fig. 27. Right dentary of *Bactrosaurus johnsoni*. No. 6353, A.M.N.H. A, internal view; B, superior view. Coronoid process and anterior end restored from the dentary of the opposite side. One-fourth natural size.

while in front the surface slopes both inward and outward. Also viewed from above, the posterior slope is shorter and narrower than the anterior. Inner surface flat, and its upper margin perforated by a curved row of dental foramina. Apparently not more than two teeth of a vertical series participate in the grinding surface at the same time as shown in Fig. 26B. Several large foramina occur on the anterior half of the outer side.

Measurements of Maxilla

Greatest length	200 mm.
Length of dental series	162 mm.
Width at anterior end	42 mm.
Width at posterior end	28 mm.

DENTARY.—There are twelve dentaries in the collection, more than half of which pertain to juvenile individuals. Presumably all of these, judging from the character of the preservation, came from the "Johnson Quarry," although only five are definitely marked. All contain magazines full of teeth which agree so perfectly in form, implantation and other details, that I have no hesitancy in referring them to the same species. At this time there is no evidence available for definitely connecting any of them with the type specimen of *Bactrosaurus johnsoni*, but the greatly reduced number of tooth rows implies Lambeosaurinae affinities, and since this is the only crested hadrosaur recognized among the materials from this deposit, it would seem they can be safely referred to that form.

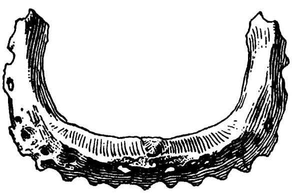

Fig. 28. Predentary bone of *Bactrosaurus johnsoni*. No. 6372, A.M.N.H. Superior view. One-half natural size.

The dentaries are of the typical hadrosaurian type but with a high and relatively slender coronoid process as shown in Fig. 27. In the adult dentaries there are from 20 to 23 vertical rows of teeth, while the juvenile jaws vary from 16 to 18 rows each. The dentaries are comparatively narrow and turn strongly inward on the anterior end. The largest one has a length over all of 222 mm., the smallest about 99.5 mm.

PREDENTARY.—A single predentary bone of a young animal found at locality 141 may be provisionally referred to the present genus and species. Its form and principal features are well shown in Fig. 28. It has the usual broad U-shape with regularly dentated anterior margin. Below each of the bony tooth-like projections, the bone is perforated by foramen-like holes arranged in a transverse row. The horny covering which in life overlaid the premaxillaries and predentary bones was no doubt nicely adjusted, forming an efficient cropping organ for obtaining food. It differs from a predentary bone from locality 145 referred to *Mandschurosaurus* in being relatively broader with shorter posterior extension of the sides and with a less pronounced transverse depression on the median ventral surface. There is no evidence of a posteriorly directed process on the median posterior border as found in *Lambeosaurus*.

TEETH.—In composition, implantation and manner of succession, the teeth of *Bactrosaurus* conform fully to the usual arrangement in the Hadrosauridae. The inner enameled tooth surfaces are lozenge-shaped and relatively large for the size of the jaws. Largest in the central part of the dental magazines, they decrease in size toward the ends. The lower unworn teeth have their upper ends bluntly rounded.

The edges of the teeth are usually smooth, although low rounded papillae, sparsely placed, are observed on the marginal areas of a few of the lower teeth, especially toward the front of the magazine. All of the teeth are traversed by rounded longitudinal median keels, with shallow longitudinal depressions along either side, being usually more pronounced on the anterior side. The tooth borders are depressed and rounded. There were probably never more than three teeth in any one vertical series in the dentary and not more than two in juvenile specimens. Never more than two teeth appear on the triturating surface of any one row. The enamel surfaces of the median unworn teeth have a vertical diameter 3.3 times their greatest width. Adult dentaries have as many as 23 rows of teeth, while there are as few as 16 in the young. A complete lower median tooth measures 33 mm. in length and 10 mm. in breadth. The complete dentary series of the largest specimen occupies a longitudinal space of 152 mm. The outer enameled surface of the maxillary teeth do not combine to form a continuous fluted surface as in the dentary, but present a rather irregular row of crowns in which the less protuberant teeth are very narrow and the fully functional ones are wide. The longitudinal keels of the upper teeth are more robustly developed.

Study of the present series of maxillae and dentaries, most of which have full dental complements, showed clearly that in the Hadrosauridae the number of vertical tooth rows increases with the age of the individual from young to adult. In the smallest dentary of the series there are 16 rows; a little larger one shows 17 rows, and in the largest, supposed to be an adult, 23 rows can be counted. The smallest maxillary has 17 rows; a slightly larger one 18 rows, and the largest 28 rows. It is also observed that the teeth increase in size from young to adult.

In the table below, compiled from all available sources of information, it is clearly indicated that members of the Lambeosaurinae have fewer vertical rows of teeth in the dental magazines than either of the other two subfamilies of the Hadrosauridae. It therefore seems reasonable to infer that all of these scattered dentaries and maxillaries with reduced dentition found in the "Johnson Quarry" at Iren Dabasu belong to some member of the Lambeosaurinae. Since only a single representative of this subfamily has been recognized as occurring here, it may be assumed that they can safely be referred to the present genus and species. It is upon this evidence that I am relying for the present association.

TABLE SHOWING THE NUMBER OF VERTICAL ROWS OF TEETH IN THE HADROSAURIDAE

Name	Dentary	Maxillary
Subfamily Hadrosaurinae		
Thespesius annectens (Marsh)	52 to 57	
Edmontosaurus regalis Lambe	48 to 69	51 to 53
Thespesius saskatchewanensis Sternberg	44	52
Kritosaurus notabilis (Lambe)	42	47
Mandschurosaurus amurensis Riabinin	35	..
Mandschurosaurus mongoliensis Gilmore	..	29+?
Subfamily Saurolophinae		
Prosaurolophus maximus Brown		45+
Saurolophus osborni Brown	50+	60
Subfamily Lambeosaurinae		
Lambeosaurus lambei Parks	40 to 41	38 to 39
Corythosaurus casuarius Brown	34?	36?
Corythosaurus intermedius Parks	37?	43?
Parasaurolophus walkeri Parks	34+	..
Hypacrosaurus altispinus Brown	34+?	
Cheneosaurus tolmanensis Lambe	33	35
Procheneosaurus sp.	28 to 30	
Bactrosaurus johnsoni Gilmore	18 to 23	16 to 26?

CERVICAL VERTEBRAE.—Three cervical vertebrae from the mid-portion of the neck are of the typical hadrosaurian form with anterior ends of centra strongly convex and posterior ends deeply concave. All three vertebrae are without neural spines, thus indicating their mid-position in the cervical series. Compared with cervicals of *Mandschurosaurus mongoliensis* from the same part of the neck and of about the same size, the various processes are relatively lighter in their construction; otherwise the vertebrae are indistinguishable.

MEASUREMENTS

	1	2	3
Length of centrum	63 mm.	65 mm.	66 mm.
Width of centrum posterior	56 mm.	54 mm.	55 mm.

DORSAL VERTEBRAE.—There are ten dorsal vertebrae of specimen No. 6553, eight of which have the spinous processes intact, and three anterior dorsals of No. 6577. The vertebrae of the posterior half of the series are characterized by high massive club-shaped spines, and it is to this feature that the generic name refers. Moderately wide at the base, there is a steady increase in transverse diameter from bottom to top. The most massive spine in the series transversely measures 47 mm. at the top, whereas this same diameter at the bottom is only 23 mm. This feature of the posterior dorsal vertebrae will at once distinguish them from all other known members of the Hadrosauridae. The longest spines are slightly less than four times the height of the centrum. In *Hypacrosaurus*, which has the tallest spinous processes of all hadrosau-

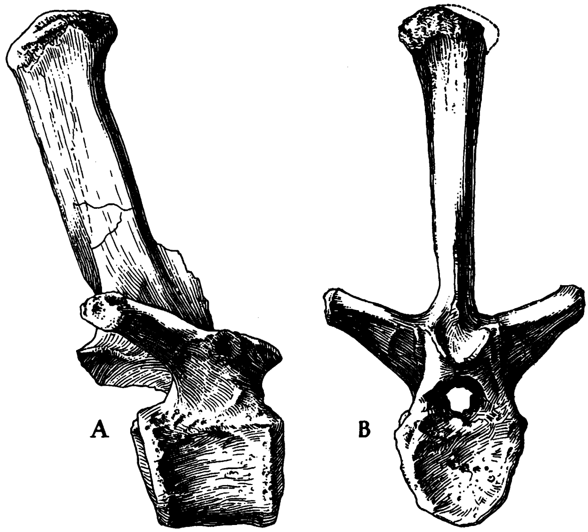

Fig. 29. Anterior dorsal vertebra of *Bactrosaurus johnsoni*. Type. No. 6553, A.M.N.H. A, lateral; B, front view. One-fourth natural size.

rians, they are five times the height of the centrum, and in *Thespesius* (*Trachodon*)[1] they are only three times.

The centra as in other hadrosaurians are opisthocoelous, the cupping being most pronounced on the posterior end. In fact in most of the vertebrae the anterior end of the centrum is nearly flat. The posterior centra are wider than long, the anterior ones being longer than wide. The neural arches are comparatively weak, considering the massive development of the spines. The transverse processes are small, those of the more anterior vertebrae being triangular in cross-section and inclined upward and decidedly backward. In the posterior dorsal region

[1]Brown, Barnum. 1913. Bull. Amer. Mus. Nat. Hist., XXXII, p. 398.

the diapophyses are subovate in section and project outward horizontally and with slight, if any, backward inclination. Five of the ten dorsals show the capitular facet on a level with the diapophyses at its junction with the arch.

The spines of the most posterior dorsals lean slightly forward; those of the mid-dorsal region stand erect, while the more anterior ones with

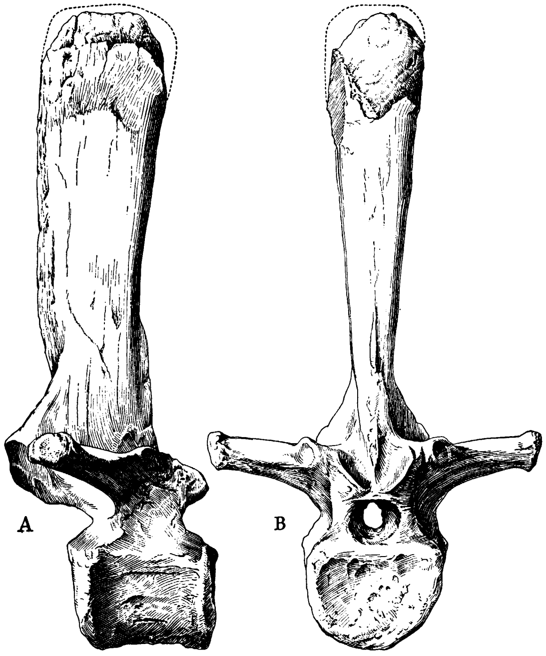

Fig. 30. Posterior dorsal vertebra of *Bactrosaurus johnsoni*. Type. No. 6553, A.M.N.H. A, lateral view; B, front view. One-fourth natural size.

shorter and less club-shaped spines have a strong backward inclination as shown in Fig. 29.

From the evidence afforded by these disarticulated vertebrae, it would appear that the complete vertebral column of this animal from a side view would closely approximate the conditions found in other long-spined, crested hadrosaurians.

MEASUREMENTS OF DORSAL VERTEBRA NO. 6553

	1	2	3	4	5	6	7	8	9	10
Greatest height over all	...	...	230	275	279	304	334	339	340	338
Greatest length of spine	...	...	163	195	190	200	236	230	225	230
Greatest length of centrum	74	74	72	75	74	73	71	68	66	67
Greatest width of centrum, posterior end	71	69	69[e]	72	73	76	73	70	68	77
Greatest thickness of spine	...	...	25	34	43	45	48	46	41	38

The numbers used above do not imply a continuous series but indicate anterior to posterior position in the series.

SACRUM.—The sacrum of No. 6553, A.M.N.H., is essentially complete, Pl. III, Fig. 2. It is composed of seven coössified vertebrae, all except the last giving support to the ilium. The parapophyses of the first six have a tendency to coössify at their outer ends, and the second, third, fourth and fifth appear to have contributed to the inner boundary of the acetabulum. The spines are tall, coössified below, but with their upper third distinct from one another except two and three which are joined at the top as shown in Fig. 31.

In old individuals it is probable the spines were completely coössified, forming one continuous plate. The tops of sacral spines two, three, four and five are transversely expanded but are more plate-like and lack much of the club-like thickening of the posterior dorsals.

Viewed from below (see Fig. 32) the first is the widest of the series. The centra are pinched in at the center to form a sharp median keel posterior to the second.

The reduced number of sacral vertebrae gives further evidence of the Lambeosaurinae affinities of this genus, for in reviewing the literature it is found that the members of this subfamily in which the complete sacrum is known have either seven or eight vertebrae, whereas the members of the Hadrosaurinae all have nine. *Saurolophus* of the Saurolophinae has eight.

e = estimated.

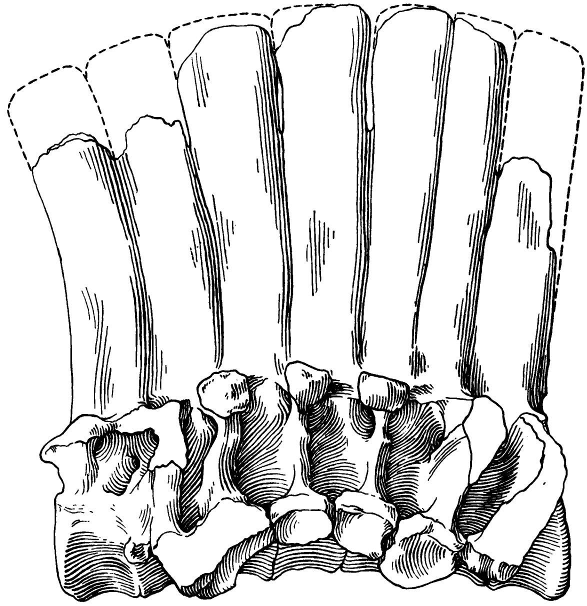

Fig. 31. Sacrum of *Bactrosaurus johnsoni*. Type. No. 6553, A.M.N.H. Viewed from the right side. One-sixth natural size.

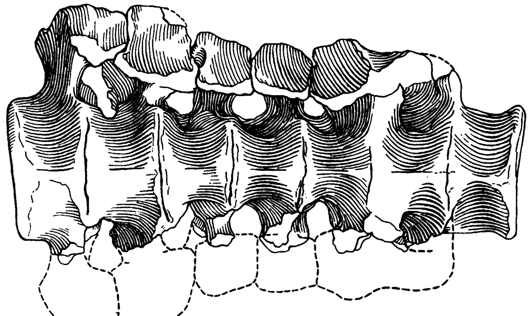

Fig. 32. Sacrum of *Bactrosaurus johnsoni*. Type. No. 6553, A.M.N.H. Viewed from below. One-sixth natural size.

MEASUREMENTS OF SACRUM

Length of seven sacral vertebrae	402 mm.
Height of fourth sacral vertebrae over all	442 mm.
Width of first sacral centrum	110 mm.
Length of first sacral centrum	58 mm.
Width of seventh sacral centrum	104 mm.
Length of seventh sacral centrum	54 mm.

CAUDAL VERTEBRAE.—Of the caudal series there are four anterior vertebrae; an articulated series of thirty-two vertebrae from the mid-part of the tail backward, and three disarticulated elements from the distal extremity. The anterior vertebrae are quite broad and short with nearly amphyplatan articular surfaces; the spines are tall and of moderate slenderness, all of those preserved having a decided backward slant. In the articulated series the first two have small transverse processes, indicating their position in the tail as being about the 19th or 20th of the caudal series. All of the caudals present appear to have carried chevron bones.

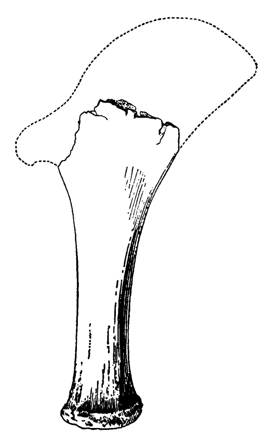

Fig. 33. Sternal bone (left), *Bactrosaurus johnsoni*. No. 6553, A.M.N.H. Type One-fourth natural size. External view.

STERNAL BONE.—The distal half of a left sternal element found in the "Johnson Quarry" may, on account of its occurrence, be quite certainly identified as pertaining to the present genus and species. Its form is well shown in Fig. 33.

SCAPULA.—A right and a left scapula from locality 141, on account of their large size are referred to the genus *Bactrosaurus*. They are of the usual hadrosaurian form with a moderately wide blade. The wider expansion of the blade distinguishes it at once from the narrowly expanded scapula of the contemporary *Mandschurosaurus mongoliensis*. The most completely preserved bone is illustrated in Fig. 34.

MEASUREMENTS

Length	490 mm.
Greatest width of blade	145 mm.

ILIUM.—There was no ilium found in the "Johnson Quarry" of sufficient size to be attributed to the type specimen of *Bactrosaurus*. A juvenile specimen, No. 6577, A.M.N.H., however, from this deposit has a complete ischium (Pl. VI, fig. 1) that, except for its very much

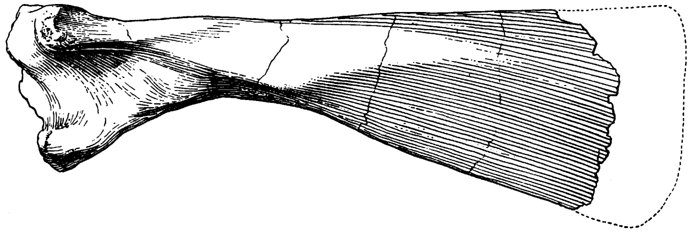

Fig. 34. Left scapula of *Bactrosaurus johnsoni*. No. 6553, A.M.N.H. Type. Lateral view. One-sixth natural size.

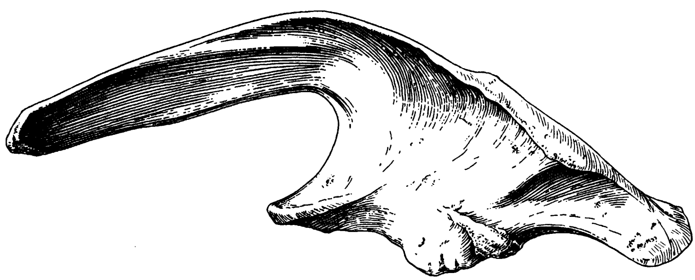

Fig. 35. Left ilium of *Bactrosaurus johnsoni*. No. 6577, A.M.N.H. Referred juvenile specimen. One-third natural size.

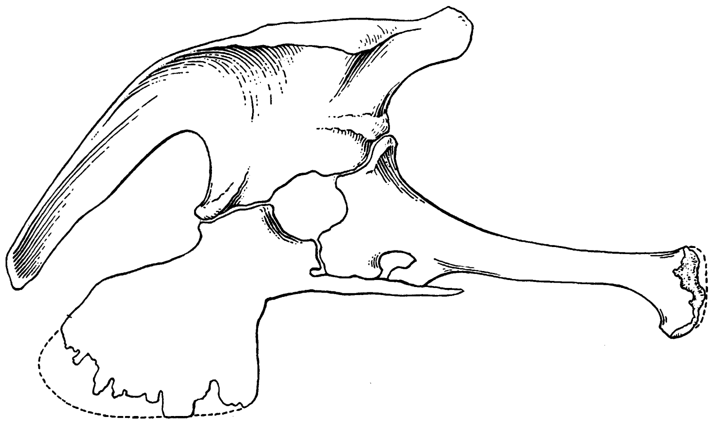

Fig. 36. Outline of pelvis, *Bactrosaurus johnsoni*, Nos. 6553 and 6577, A.M.N.H. About one-tenth natural size.

smaller size, is comparable in every way with those of the type, and with it was associated the ilium shown in Fig. 35. As in other crested forms of the Hadrosauridae, the upper outline of this bone is strongly curved upward at the center of its length, whereas in the non-crested members of this family, the upper outline of the ilia is a more or less regular curve from end to end.

The preacetabular process of the ilium is strongly decurved and tapers to a thin blade of uniform thickness. In *Thespesius* this process is triangular in cross-section and but slightly decurved. From the upper border a large process overhangs the ischiac peduncle as in other members of the family.

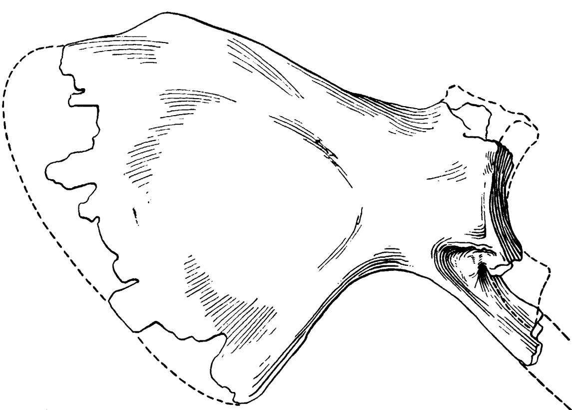

Fig. 37. Left pubis of *Bactrosaurus johnsoni*. Type. No. 6553, A.M.N.H. Lateral view. One-sixth natural size.

PUBIS.—The prepubis of *Bactrosaurus* is characterized by its short neck, great dorso-ventral expansion of the blade, and extreme shortness. Both pubes are present, but both are incompletely preserved, lacking much of their anterior borders and most of the post-pubic processes. Figure 37 is a composite illustration based on both elements. In all respects the prepubis is more specialized than in *Parasaurolophus* which it most closely resembles. The neck is relatively shorter, and the ventral border of the blade turns downward more abruptly, thus producing a relatively wide blade.

Fortunately, the left pubis has a small portion of the anterior border preserved, and this fact permits a fairly accurate estimate of its greatest length as being about 400 mm. The greatest width of the blade is about 312 mm., width of neck 124 mm. The entire posterior end contributes to the formation of the anterior border of the acetabulum. At the center this border has a width of 25 mm. The even dorso-ventral concavity of this end at once distinguishes it from the deeply notched pubes of *Saurolophus* and *Thespesius*. The post-pubis is largely missing, so that its exact extent cannot be determined from existing materials. Figure 36 shows it as restored from allied forms. The form of the pre-pubis in *Bactrosaurus* is sufficiently distinctive to be differentiated at once from those of all known hadrosaurians, and it will be most useful in recognizing future specimens of this genus.

Ischium.—Both ischia are in a good state of preservation. The ischium resembles that of *Hypacrosaurus*, although relatively shorter and having a more uniform width of shaft. This bone is heavy for its length and is united with its mate by ligamentous attachment along the

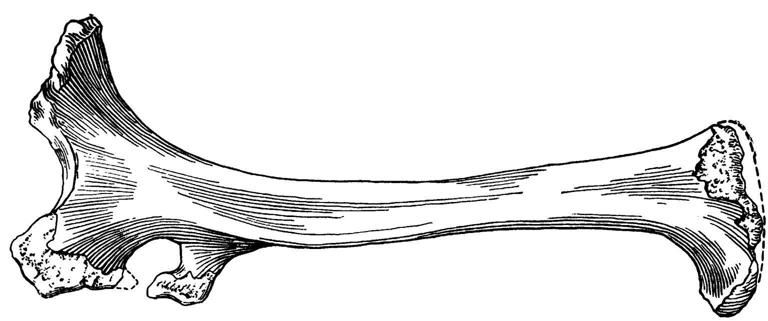

Fig. 38. Left ischium, *Bactrosaurus johnsoni*. Type. No. 6553, A.M.N.H. Lateral view. One-sixth natural size.

distal half of the shaft, which is terminated by a foot-like enlargement. It differs further from the *Hypacrosaurus* and *Saurolophus* ischia in having an open rather than a closed foramen. This feature, however, is probably not a constant one, and doubtless individuals will be found in which the outer border is entirely bridged by bone as in the above-mentioned genera. Such is the case in *Camptosaurus*; not only in the ischium but also in the coracoid the foramen may occur either open or closed.

The greatest length of the ischium over all is 590 mm., the greatest width of proximal end 270 mm., greatest expanse of distal end about 145 mm., least diameter of shaft 34 mm. The short, expanded prepubis combined with this footed ischium at once established the affinities of this hadrosaurian with the crested groups of the family Hadrosauridae. In so far as I have been able to learn, these bones record the second occurrence of a crested hadrosaur in eastern Asia, *Saurolophus krischtofovici* Riabinin[1] from the Manchurian bank of the Amur River being the first. It was founded on a fragmentary ischium, at once distinguished from the present species by its decidedly more slender iliac process as well as shaft.

FEMUR.—A left femur (Pl. VII, fig. 1), on account of its large size, can quite certainly be referred to the present genus and species. It has the usual hadrosaurian form of a long, straight shaft with strongly developed fourth trochanter that extends on to the distal half of the

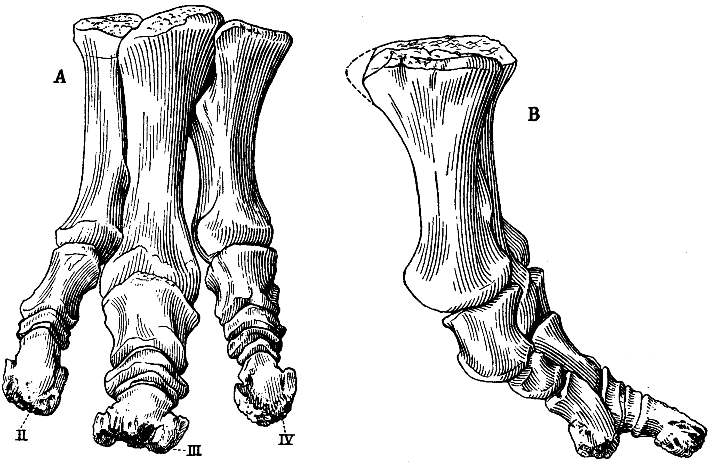

Fig. 39. Left pes of *Bactrosaurus johnsoni*. No. 6553, A.M.N.H. Type. A, viewed from the front; B, viewed from the external side. Both figures one-sixth natural size.

bone. The greater trochanter is massive and as high as the head; the lesser trochanter is broken off and largely missing. The femur measures 800 mm. in length over all. The anterior foramen is open—not bridged across as in many of the American members of this group.

A fibula, lacking a mid-section of the shaft, from this same quarry, may, on account of its size, also be attributed to this skeleton. It shows no distinguishing characteristics.

PES.—In the collection from the Johnson Quarry are two left hind feet and a part of one right foot, all of adult individuals; also a nearly complete hind foot and parts of others of young animals. The adult specimens are of the same size and proportions throughout and clearly

[1]1930. Mem. Russian Mineralogical Society, LIX, No. 1, pp. 42–44, Pl. I, fig. 1.

indicate the presence here of two individuals. Their large size is in accord with the other materials assigned to the type specimen, and I believe it is safe to assume that all pertain to *Bactrosaurus johnsoni*. Except for their smaller size, the juvenile feet are in accord with the larger ones and may also be referred to the present genus and species.

The hind foot of *Bactrosaurus* is of the usual hadrosaurian type and I fail to find any characters that would serve to distinguish it from American forms of equivalent size. The digital formula is 3, 4 and 5, each being terminated by a depressed hoof-like ungual.

The unguals differ from those of other hadrosaurs with which I have had previous acquaintance in having squarely truncated anterior margins. These thick ends have the surface rugosely roughened. This feature of the unguals gives them an unfinished appearance, as shown in Fig. 39.

Measurements of Left Pes No. 6553, A.M.N.H.

Metatarsal II length	200 mm.
Metatarsal II transverse diameter proximal end	50 mm.
Metatarsal III length	240 mm.
Metatarsal III transverse diameter proximal end	68 mm.
Metarsal IV length	195 mm.
Metatarsal IV transverse diameter proximal end	50 mm.
Digit II length, proximal phalanx, median line	55 mm.
Digit II length, median phalanx, median line	30 mm.
Digit II length, ungual phalanx, median line	58 mm.
Digit III length, proximal phalanx, median line	65 mm.
Digit III length, second phalanx, median line	26 mm.
Digit III length, third phalanx, median line	20 mm.
Digit III length, ungual phalanx, median line	45 mm.
Digit IV length, proximal phalanx, median line	63 mm.
Digit IV length, second phalanx, median line	20 mm.
Digit IV length, third phalanx, median line	13 mm.
Digit IV length, fourth phalanx, median line	10 mm.
Digit IV length, ungual phalanx, median line	65 mm.

REMARKS ON JUVENILE SPECIMENS

In the same bone deposit (No. 141) with the type specimen of *Bactrosaurus johnsoni* were mingled the scattered remains of juvenile hadrosaurians. Of these practically all parts of the skeleton are represented. That these immature bones represent young individuals of the genus *Bactrosaurus* appears to be indicated by the following: (1) Maxillae and dentaries of small size but having magazines of teeth that, except for being smaller, are identical with those of the adult; (2) the presence of an ischium similar in all particulars to the ischia of the type specimen; (3) ilia with highly arched upper outline and decurved preacetabular process, features characteristic of this bone in the crested type of hadrosaurs; (4) feet and limb bones that, aside from their smaller size, are in full agreement with the homologous adult elements.

On the other hand there are a few discordant features. For example, none of the pes unguals shows the truncated, thickened terminations of the adult specimens, but they are of the usual pointed type with rounded obtuse edges; the scapula lacks the widened blade of the adult and in outline cannot be distinguished from those attributed to *Mandschurosaurus mongoliensis*.

A single complete posterior dorsal vertebra has a spine relatively shorter than that of the type specimen, and there is little if any of the club-like transverse thickening so characteristic of the adult.

This brief review of the similarities and dissimilarities found between the juvenile and adult skeletal parts seems to show that in the most important particulars they are in accord and such inconsistencies as are found can probably be attributed to the youth of the individual.

One of the important developments in the hadrosaurian structure noted for the first time in these young specimens is that the number of vertical tooth rows in the upper and lower dental series increases with the age of the individual.

SKELETAL RESTORATION OF *BACTROSAURUS*

The skeletal restoration of *Bactrosaurus johnsoni* shown in Fig. 40 is based principally on the more or less scattered remains of what appears to be a single individual. Missing bones have been introduced from other individuals or else have been drawn in outline from related forms brought to the desired scale. The restoration was originally done under the direction of Mr. Barnum Brown but is reproduced here with some modification brought about by this more detailed study of the original specimens.

The skull of this animal as depicted in the reconstruction has been restored from a few elements pertaining to three if not more individuals. It may, therefore, be regarded as somewhat conjectural. Elsewhere in this paper (p. 51) attention has been called to the possibility of error in the association of this non-crested skull with this skeleton, so that the existing evidence of the cranium must be used with much caution.

With the discovery of better preserved specimens it is to be expected that details of skeletal structure will be found erroneous, but in the light of our present information I believe this to be a fairly accurate representation of this animal.

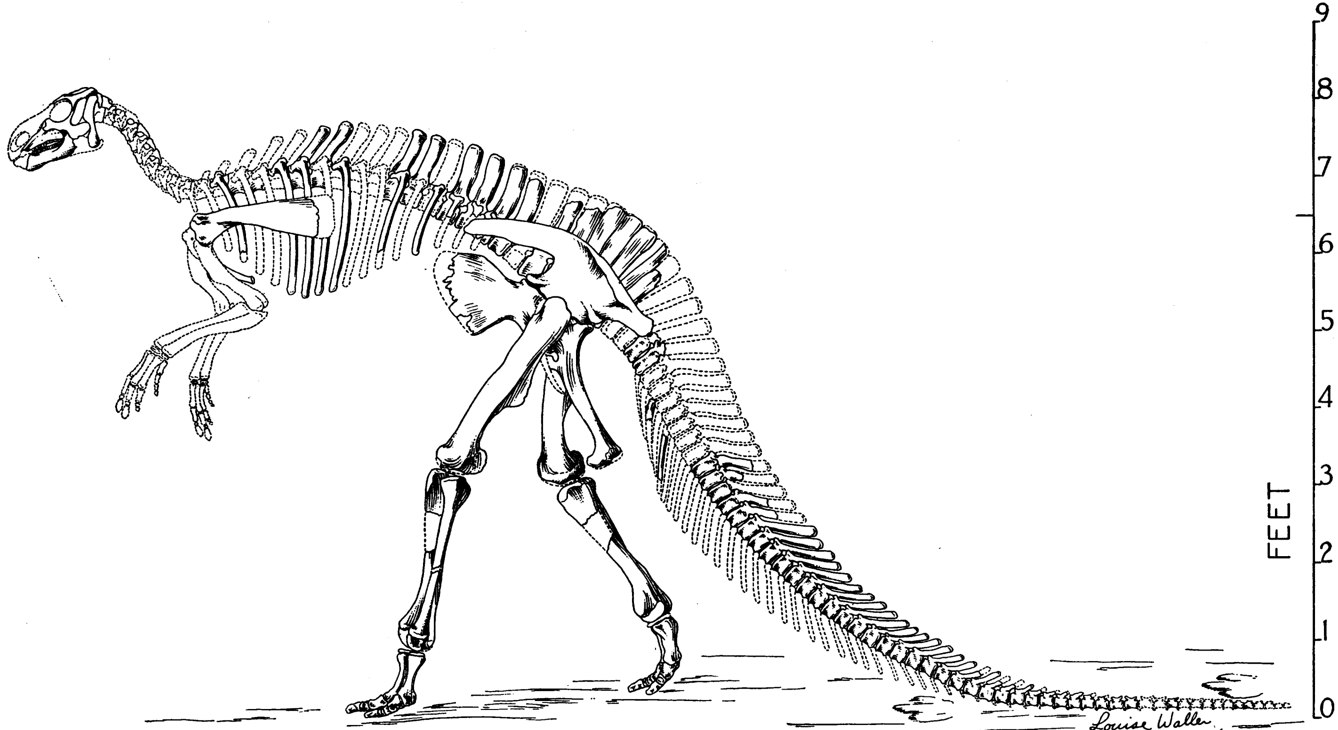

Fig. 40. Reconstruction of the skeleton of *Bactrosaurus johnsoni*. The bones actually preserved are shaded, those in dotted outline are conjectural and restored; the restoration of the skull is somewhat conjectural. One-thirtieth natural size.

Nodosauridae

Genus and species indet.

Plate VIII

The presence in the Iren Dabasu formation of an armored dinosaur is clearly indicated by a fragmentary specimen, No. 6367, A.M.N.H. (field No. 135), consisting of an imperfect right ilium and a caudal centrum. This specimen was found by Mr. George Olsen in April, 1923, about 200 yards south of the Iren Dabasu camp of the Asiatic expedition. It has the typical strong transverse expansion with the insignificant dorso-ventral thickness of other nodosaurs. The outer border is nearly perfect (see Pl. VIII) except for the postacetabular portion which is missing, and it shows the same more or less straight outline as in *Ankylosaurus*, *Scolosaurus* and *Dyoplosaurus*. The anterior portion of the preacetabular blade displays its full width and shows it to be relatively narrower than any of the Upper Cretaceous Nodosauridae with which it can be compared. The acetabulum has the usual shallowness. The caudal centrum is wider than long with the usual rounded form when viewed from the end. It is shallowly opisthocoelous. This vertebra, which is from the mid-caudal section of the tail, was ankylosed with the chevron. Strong transverse processes were given off from the sides of the upper half of the centrum.

Although it seems highly probable that this specimen represents an undescribed species if not genus of the Nodosauridae, the incompleteness of the materials seems to make it undesirable to name it. It is, however, of great interest in recording for the first time the presence of armored dinosaurs in eastern Asia. The only other Asiatic record is that of *Lametasaurus indicus*, described by Doctor Matley[1] from the Jubbulpore district of India. Fortunately the ilia are present with this specimen, and they are so unlike the present bone as to at once indicate their distinctness. The ilium of *Lametasaurus* with its horizontally broad preacetabular blade and long postacetabular development suggests the form of the *Triceratops* ilium, whereas the Iren Dabasu specimen is typically nodosaurian in every respect.

Under the heading "Vordere Schwanzwirbel eines Hadrosauriers," Wiman[2] has described a series of four anterior caudal vertebrae that quite certainly pertain to a representative of the Nodosauridae. Centra wider than high, amphicoelous, long transverse processes or caudal ribs ankylosed to the median upper sides of the centra, and coössified chevron

[1] 1923. Records, Geol. Survey of India, LV, pp. 105–109.
[2] 1929. Palaeontologia Sinica, Ser. C, VI, Fasc. 1, p. 60, Pl. IX, figs. 4–7*a*.

bones, are features of the armored dinosaurian caudals. The expanded outer end of the first caudal rib and the forward curvature of the second are precisely the conditions found in the anterior caudal vertebrae of *Dyoplosaurus*.[1]

Further, Wiman was of the opinion that the expanded transverse process abutted against the inner side of the ilium, and that is exactly the condition in *Dyoplosaurus*. If correct in my deductions, this specimen is of interest as apparently being the first record of the occurrence of the Nodosauridae in China proper. The specimen was found in Shantung province by Zdansky in 1923, Lai-Yank-Hsien, SW. 15 li. T'ien-Ch'iao-T'un, E. 1 li.

[1]Parks, W. A. 1924. Univ. of Toronto Studies, Geol. Series, Pl. II.

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PLATES I TO VIII

Plate I

Fig. 1. "Johnson Quarry," field No. 141, eight miles east of Iren Dabasu Telegraph Station. The type of *Bactrosaurus johnsoni* and cotypes of *Ornithomimus asiaticus* were found in this deposit.

Fig. 2. Excavating hind limb of *Alectrosaurus olseni*, field No. 136, about 200 yards south of camp at Iren Dabasu Telegraph Station, Mongolia.

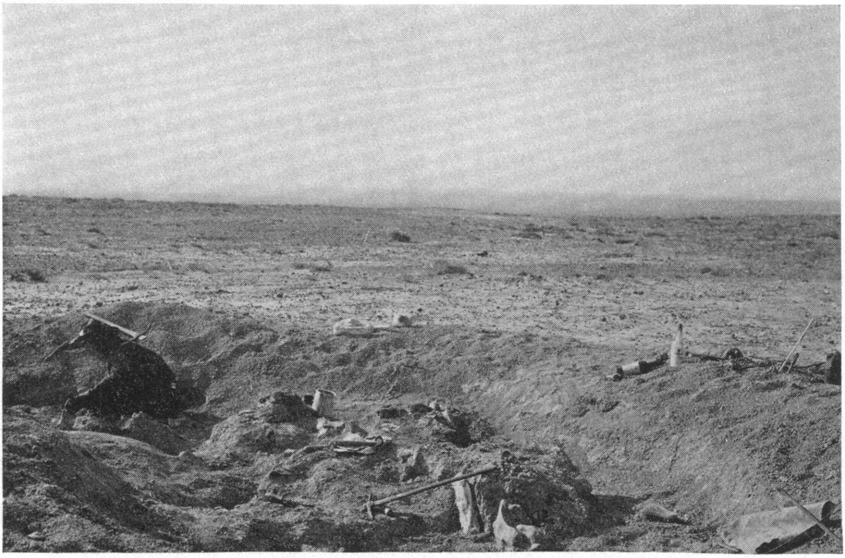

Plate II

Right hind foot of *Alectrosaurus olseni*. No. 6368, A.M.N.H. Cotype. Viewed from the front. About one-third natural size.

Plate III

Fig. 1. Neural processes of sacral vertebrae of *Mandschurosaurus mongoliensis*. No. 6551, A.M.N.H. Cotype. Viewed from the right side. About one-fourth natural size.

Fig. 2. Sacrum of *Bactrosaurus johnsoni*. Type. No. 6553, A.M.N.H. Viewed from the right side. About one-sixth natural size.

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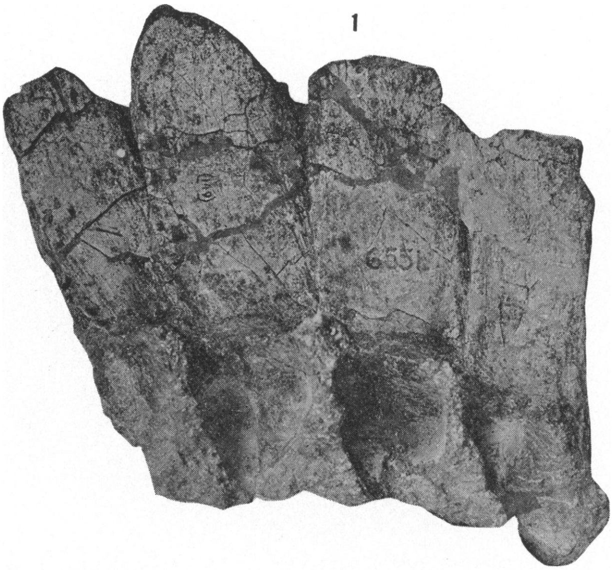

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Plate IV

Fig. 1. Four posterior sacral vertebrae of *Mandschurosaurus mongoliensis*. Cotype. No. 6551, A.M.N.H. Ventral view. About one-half natural size.

Fig. 2. Three anterior sacral vertebrae of *Mandschurosaurus mongoliensis*. Cotype. No. 6551, A.M.N.H. Ventral view. About one-half natural size.

Fig. 3. Sacral vertebrae of *Bactrosaurus johnsoni*. Cotype. No. 6553, A.M.N.H. Ventral view. About one-fourth natural size.

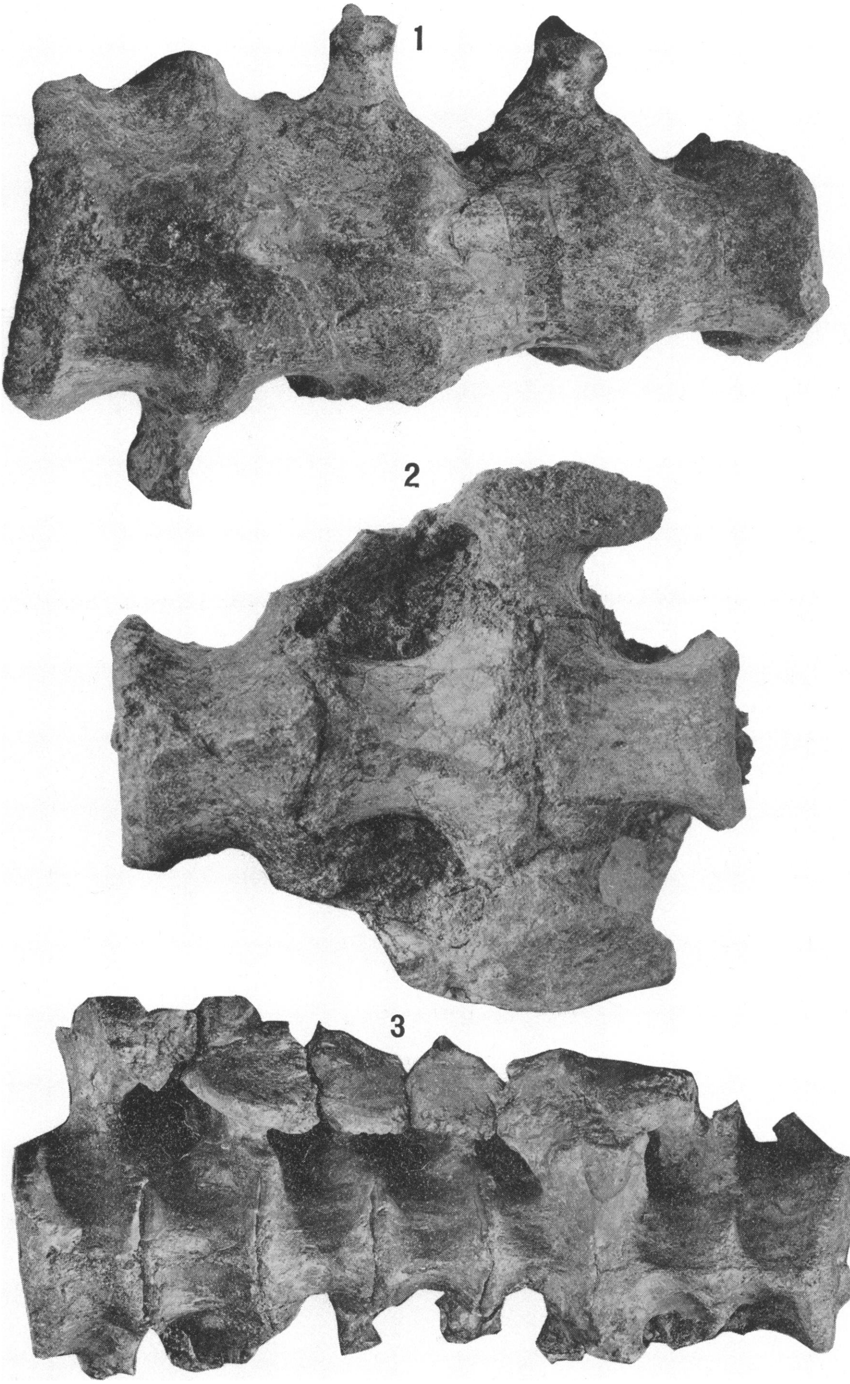
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Plate V

Fig. 1. Right humerus of *Mandschurosaurus mongoliensis*. Cotype. No. 6551, A.M.N.H. Posterior view.

Fig. 2. Right ulna of same. Anterior view.

Both figures about one-half natural size.

1

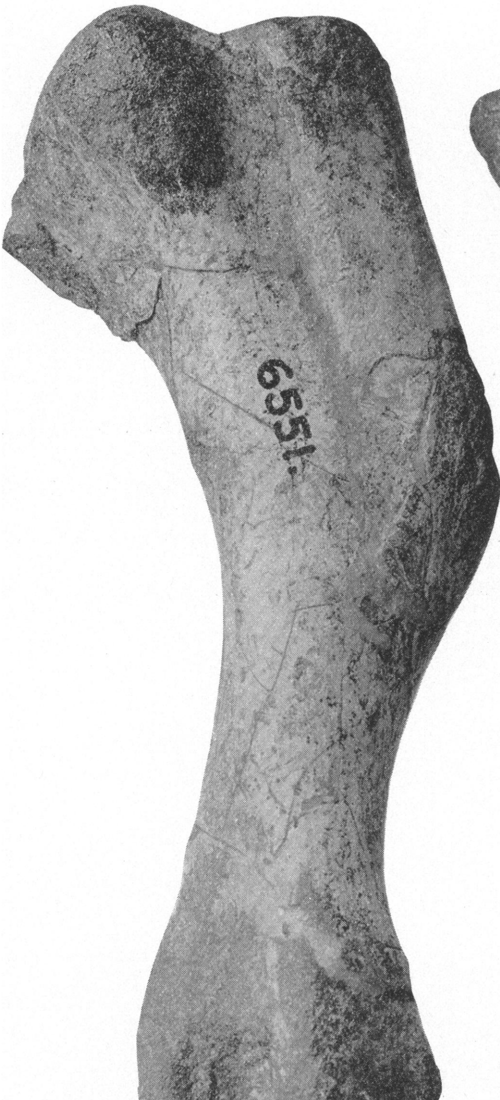

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Plate VI

Fig. 1. Left ischium of *Bactrosaurus johnsoni*. No. 6577, A.M.N.H. Juvenile. Lateral view.

Fig. 2. Right radius of *Mandschurosaurus mongoliensis*. Cotype. No. 6551, A.M.N.H.

Fig. 3. Right lachrymal of *Mandschurosaurus mongoliensis*. No. 6374, A.M.N.H. Lateral view.

Fig. 4. Left jugal of *Bactrosaurus johnsoni*. No. 6373, A.M.N.H. Lateral view.

All figures about one-half natural size.

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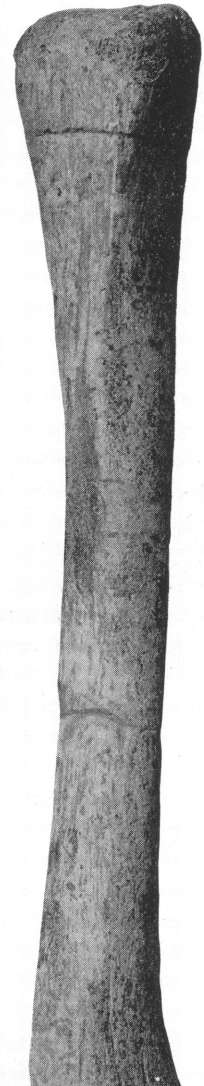

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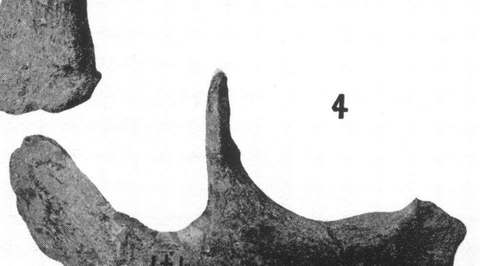

Plate VII

Fig. 1. Left femur of *Bactrosaurus johnsoni.* Type. No. 6553, A.M.N.H. Side and front views.

Fig. 2. Right tibia of *Mandschurosaurus mongoliensis.* Cotype. No. 6551, A.M.N.H. Front view.

Fig. 3. Right femur of *Mandschurosaurus mongoliensis.* Cotype. No. 6551, A.M.N.H. Front and side views.

All figures about one-eighth natural size.


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Plate VIII

Right ilium of an armored dinosaur. No. 6367, A.M.N.H. Ventral view. About one-third natural size.