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CONTRIBUTIONS TO VERTEBRATE PALÆONTOLOGY

BY

Charles W. Gilmore

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A NEW COELURID DINOSAUR FROM THE BELLY RIVER CRETACEOUS OF ALBERTA

It has long been recognized by vertebrate palæontologists that one or more undescribed members of the carnivorous dinosauria are present in the Belly River fauna, as indicated by certain fragmentary remains that have been found from time to time. It was, therefore, of great interest to find specimens in the palæontological collections of the Geological Survey, Canada, sufficiently well preserved to throw some light on the character of these unknown forms. The importance of these fossil specimens was fully recognized by the late Mr. L. M. Lambe, who, shortly before his death, had prepared brief notes descriptive of these materials and the drawings that illustrate this paper.

Before proceeding with the description, it appears in order to review briefly the status of certain described forms from the Upper Cretaceous formations of North America, so that the reader may more clearly understand why these specimens are assigned to the family Coeluridæ.

In 1903[1] Lambe founded the new species *Ornithomimus altus* upon a complete right hind limb and foot, articulated phalanges of the left foot, a pubis, and an ischium, all of one individual.

In 1917[2] Osborn, on the basis of a beautifully preserved skeleton, proposed the new "subgeneric or generic" name *Struthiomimus* to include Lambe's species *Ornithomimus altus*. Osborn failed at that time to give adequate generic differences for separating it from *Ornithomimus*, his principal argument being that *Struthiomimus* represented, geologically, a distinctly more ancient stage than the Denver-Lance *Ornithomimus*, and that since "The known carnivorous and herbivorous dinosaurs underwent profound modifications, it is not probable, therefore, that the Ornithomimidæ remained generically unchanged". Whether Osborn is correct or not in these deductions remains to be demonstrated.

In 1922[3] Matthew and Brown described the new genus and species *Dromæosaurus albertensis*, based on a considerable portion of a skull, lower jaws, and a few foot bones. *Dromæosaurus*, comparable in size with *Ornithomimus*, was placed in a distinct sub-family, the Dromæosaurinæ provisionally referred to the family Deinodontidæ.

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[1] Contr. to Can. Pal., vol. 3, pt. II, 1902, pp. 50–53, Plates XIII, XIV, XV, Figs. 1–8.
[2] Bull. Am. Mus. Nat. Hist., vol. 35, 1917, p. 733.
[3] Bull. Am. Mus. Nat. Hist., vol. 46, 1922, pp. 383–385, text Fig. 1.

This brief review shows there are at this time two adequately distinct genera of the smaller carnivorous dinosauria known from the Belly River formation of Alberta, *Struthiomimus* and *Dromæosaurus.* Whether *Ornithomimus,* the genotype of which comes from the much more recent Denver formation, is also represented in this fauna remains to be determined.

That the Geological Survey specimens about to be described are distinct from *Struthiomimus* and *Ornithomimus* can, it seems clear, be well demonstrated. Their distinctness from the contemporary *Struthiomimus* is at once shown by the great irregularity in length of the digits of the manus; the deeply grooved ginglymoid distal facets of mc. I and II; the much longer and more slender proximal phalanx of digit II; the much shorter mc. I; the less divergent pollex, and the more strongly curved raptorial type of unguals. Typically it is also a form of smaller size. From the Denver-Lance *Ornithomimus* this manus is distinguished by its larger size, and its Coelurid-like structure, as shown by the unequal lengths of the known metacarpals that have deeply grooved ginglymoid distal facets; as contrasted with the metacarpals of subequal length that have convex condylar facets, as in the genotype *Ornithomimus velox* Marsh. This distinction rests upon the metacarpus figured by Marsh[1], a referred specimen and not a part of the type individual, but this association is probably correct, since the same features are to be observed in the manus of *Struthiomimus,* which has a pes that, except for its larger size, is almost indistinguishable from the hind foot of the type of *Ornithomimus velox.*

The distinctness of the Geological Survey specimen No. 2367 from the contemporary *Dromæosaurus albertensis* cannot be established with the same degree of assurance because of the very incomplete nature of the known foot materials of *Dromæosaurus,* and the uncertainty as to whether these pertain to the manus or to the pes. Through the kindness of Dr. W. D. Matthew the foot materials of *Dromæosaurus* have been loaned me for study. After a careful comparison with the specimen here under consideration I share to some extent his doubt as to whether they pertain to the fore or the hind foot. From analogy it would appear that one of the metapodials of *Dromæosaurus* certainly belongs to the manus. Reference is made to "the distal half of a metapodial slightly larger than the mc. II of *Struthiomimus*[2]", which has a deeply grooved ginglymoid distal facet and a very distinct lateral appression surface. If this bone does not pertain to the manus, it represents a style of distal articulation the like of which has never before been known, so far as I can discover, in the metatarsals of a carnivorous dinosaur. Matthew has called attention (page 385) to the probability of three of the phalanges fitting so closely that they appear to belong with this metapodial, and from this concludes that "it must be the fourth digit, not the second, and may belong to the pes instead of the manus." I see no reason why it may not be the third digit of the manus lacking only the ungual. The relative shortness of the phalangials certainly suggests hind-foot structure, but equally short elements are found in the fore foot of *Ceratosaurus nasicornis*[3] Marsh.

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[1] "Dinosaurs of North America," U.S. Geol. Surv., 16th Ann. Rept., pt. I, 1896, Pl. 58, Fig. 4.
[2] Matthew and Brown, Bull. Am. Mus. Nat. Hist., vol. 46, art. VI, 1922, p. 384.
[3] Bull. 110, U.S. Nat. Mus., 1920, pp. 104, 105, text Figs. 60 and 62.

If correct in these deductions a comparison of the digits of *Dromæosaurus* and Geological Survey specimen No. 2367, so far as they are comparable, appears at once sufficient to show that they pertain to feet that are structurally very unlike. This conclusion appears to be substantiated by the Coelurid aspect of the foot of specimen No. 2367 and also by the presence in the Belly River formation of dentaries totally distinct from those of *Dromæosaurus*, and which in the slenderness of their proportions appear to have affinity with the slender elongated feet of the present specimen, with which they are, therefore, provisionally associated.

In view of the above evidence the name *Chirostenotes pergracilis* is proposed for this specimen. The species name is from Mr. Lambe's notes and I take great pleasure in using it.

The remote possibility of this species falling within the genus *Coelosaurus*, of Leidy, from the Cretaceous greensands of New Jersey, is, of course, recognized, but unfortunately at this time the lack of homologous skeletal parts prevents direct comparison from being made. The close resemblance, except in the much smaller size, of the type ungual of *Coelurus gracilis* Marsh, from the Arundel formation of Maryland, to unguals from the Belly River formation that may now be correlated with *Chirostenotes pergracilis*, has been fully pointed out[1]. Matthew[2] has referred *Coelurus gracilis* with doubt to the genus *Dromæosaurus*. In view of the very great similarity of the type to the unguals of *Chirostenotes pergracilis* it should now be removed to this genus. The possibility of the present specimens being cospecific with some of the named forms from the Judith River formation of Montana, as *Deinodon cristatus* (Cope), or *Deinodon lævifrons* (Cope), is also recognized, but the totally inadequate nature of the type materials, consisting of single teeth, on which these names were based, makes it very improbable that other specimens can ever be certainly identified with them.

Description of a New Carnivorous Dinosaur Chirostenotes Pergracilis, New Species

PLATE I

Type: No. 2367, Geol. Surv., Can., consists of the nearly complete articulated digits of both fore feet. Collected by G. F. Sternberg, 1914.

Locality: Sec. 17, tp. 21, range 11, W. 4th mer., 2 miles due northeast of the mouth of Little Sandhill creek, Red Deer river, Alberta.

Horizon: Belly River formation, Upper Cretaceous.

The specimen selected as the type of the present species consists of the greater part of the articulated bones of both hands, shown as found in situ in Plate I. Unfortunately neither manus is complete, but from both it has been possible to reconstruct most of the digital structure, as may be seen in Figure 1.

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[1] Gilmore, C. W., Proc. U.S. Nat. Mus., vol. 59, 1921, pp. 585–586, Pl. 110, Figs. 4, 5.
[2] Op. cit., p. 376.

The relative lengths of the digits may be considered correctly determined, since the terminal unguals of the two feet were found in the matrix occupying precisely similar positions in relation to one another. For the same reason it would also appear that digits II and III were closely appressed and that digit I was divergent, though perhaps not so strongly as in *Ornitholestes* and *Struthiomimus*. In this respect Figure 1 B has been incorrectly represented.

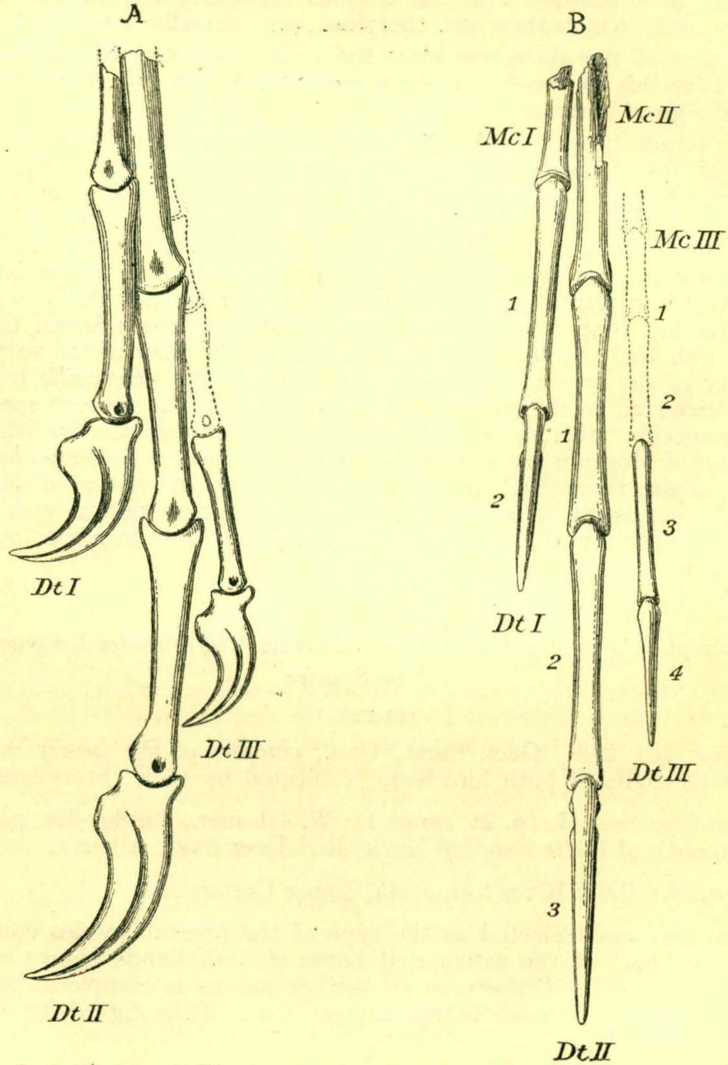

Figure 1. Left manus of *Chirostenotes pergracilis*. Type, No. 2367, Geol. Surv., Can. A, internal view; B, dorsal view. Partly reconstructed from the right manus. Dt. I, II, and III, respective digits; mc. I, II, and III, respective metacarpals. Numerals refer to position of phalangials in the digits. One-half natural size.

The manus may be described as anisotridactyl, and in the inequality of the digits it is intermediate between the fore foot of *Ornitholestes* and that of *Struthiomimus* (compare Figures 1 and 2), though closer to the former than to the latter.

The deeply grooved and keeled interphalangial joints are evidently for the purpose of confining the digits to an exclusive opening and closing movement, and this same articulation persists in the joints between the metacarpals and proximal phalanges, with the possible exception of this joint in digit III, which is still unknown.

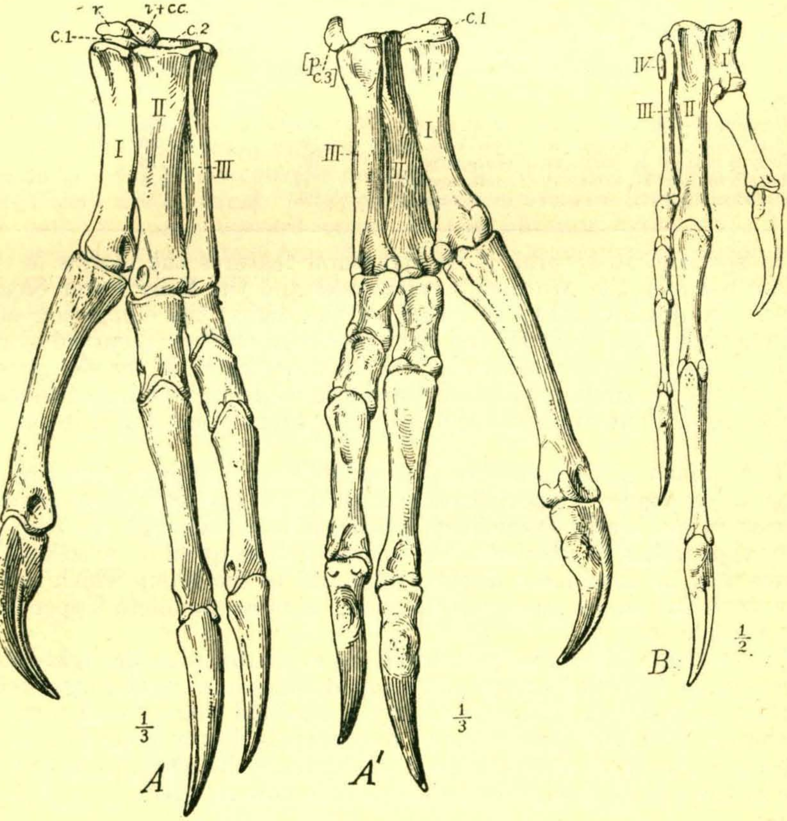

Figure 2. Left fore foot of *Struthiomimus altus* (Lambe). No. 5339, Am. Mus. Nat. Hist. A, Dorsal aspect; A^1, palmar aspect; *r*, radiale; *i*, intermedium (?) coalesced with *ce*, centrale; C_1, C_2, carpalia. One-third natural size. B, left fore foot of *Ornitholestes hermanni* Osborn. No. 587, partly restored digit I from No. 619. Am. Mus. Nat. Hist. One-half natural size. Both figures after Osborn.

The known phalanges are compressed, extremely long and slender, and highly pneumatic, as is so clearly indicated by their flattening due to post-mortem crushing. The walls of the bone are especially thin and bird-like, as in the known members of the Coeluridæ.

Comparative Measurements of Phalanges of Manus

—	*Chirostenotes pergracilis*, No. 2367, Geol. Surv., Can.	*Struthiomimus altus*, No. 5339, Am. Mus. Nat. Hist.	*Ornitholestes hermanni*[2], Nos. 587-619, Am. Mus. Nat. Hist.
	Mm.	Mm.	Mm.
Digit I			
Length of phalanx 1	63	110	30
" " 2	44	65	30
Digit II			
Length of phalanx 1	65	40	41
" " 2	72	90	44
" " 3	62	85	39
Digit III			
Length of phalanx 3	44	75	26
" " 4	36	80	30
Total length of digit I, exclusive of metacarpal	107	175	60
Total length of digit II, exclusive of metacarpal	199	215	124
Total length of digit III, exclusive of metacarpal	128[1]	215	70

In size and in several of its structural features the manus is intermediate between the Morrison *Ornitholestes* and the Belly River *Struthiomimus.* In the inequality in length of the digits, the elongation of the proximal phalanx of digit II, and the presence of strongly recurved unguals, this foot resembles *Ornitholestes.* On the other hand, in the elongation of mc. I and the proximal phalanx of the pollex, which results in a considerable lengthening of that digit, it approaches the proportions found in *Struthiomimus.*

The manus of *Chirostenotes pergracilis* is essentially a raptorial foot, though in its degree of specialization it does not appear to have advanced as far as in the highly specialized *Struthiomimus.* Though the foot, as a whole, approaches *Ornitholestes,* the answer to the question whether *Ornitholestes* may be considered directly ancestral to the group which includes the present form must await the discovery of more complete Upper Cretaceous specimens.

The relationships of *C. pergracilis* are evidently with the light-limbed, slender-jawed Coelurid group of theropod dinosaurs as characterized by Matthew and Brown. The peculiarly specialized manus with long, slim phalangials, with the distal ends of metacarpals deeply grooved and with compressed strongly curved unguals, all indicate the affinities of this form to be in the family Coeluridæ to which it is now referred.

Description of Referred Specimen

No. 343, Geol. Surv., Can., consists of considerable portions of both dentaries, containing roots of functional, and a few complete germ, teeth. Collected by C. M. Sternberg, 1917.

Locality: Sec. 30, tp. 20, range 11, W. 4th mer., 2½ miles south of the mouth of Little Sandhill creek, Red Deer river, Alberta.

[1] Estimated.
[2] Measurements taken from Osborn's figure of manus.

Horizon: About 200 feet above level of the river, Belly River formation, Upper Cretaceous.

The specimen here provisionally associated with the manus of *Chirostenotes pergracilis* consists of the greater part of the left dentary and the median part of the right of one individual. The association of these specimens is purely arbitrary, as No. 343 was discovered three years after the type and a few miles distant from the type locality. The extremely long and slender dentary suggests Ornithomimid affinities when contrasted with the toothless jaw of *Struthiomimus,* but the known Coelurid jaws are also narrow and slender, though relatively short, and even though the present association should prove incorrect it is at least of great interest in showing the presence in the Belly River fauna of another moderate-sized carnivore that is clearly distinct from either *Struthiomimus* or *Dromæosaurus.*

The left dentary, although having parts missing from both ends, has a greatest length of 193 mm., showing that in this dimension it considerably exceeds the known *Struthiomimus* dentary, but in height forward of the midlength they are co-equal. Viewed from the side the lower border is sinuous, with a strong upward curve at the anterior extremity. The external surface of the dentary near the anterior end is everywhere perforated by numerous foramina, which continue posteriorly in two nearly parallel rows. The upper row evidently ends with the posterior tooth, whereas the lower is continued farther back as a long, shallow groove, as shown in Figure 3 A. On the internal side the dentary is traversed by the horizontal Meckelian groove, which rapidly fades out posterior to the last tooth.

In the left dentary alveoli for thirteen teeth can be clearly distinguished, and comparison with the better-preserved portion of the right dentary shows that there were at least three more at the posterior end of the series. Allowing two as the number present in the missing anterior end, there were at least eighteen teeth in the complete series, a greater number than known in any other carnivorous dinosaur from North America above the Triassic, as is shown in the following table.

Dentary Teeth of Theropodous Dinosaurs

Chirostenotes pergracilis	18+	Belly River	formation
Ceratosaurus nasicornis Marsh	15	Morrison	"
Antrodemus valens Leidy	15	"	"
Gorgosaurus libratus Lambe	14	Belly River	"
Tyrannosaurus rex Osborn	13 to 14	Lance	"
Ornitholestes hermanni Osborn	12	Morrison	"
Dromæosaurus albertensis Matthew and Brown	10	Belly River	"

In the median part of the dental series ten teeth occupy a longitudinal space of 76 mm. Between the alveoli are thin alveolar septa. That interdental "rugosæ" were developed is indicated by the presence of a complete one between the third and fourth tooth of the left dentary, but all others are missing. The longitudinal groove for the dental artery is plainly shown in the right dentary.

The forward extent of the missing splenial may be tentatively determined as ending at the centre of the thirteenth alveolus, as indicated by a narrow longitudinally striated surface on the lower border of Meckel's

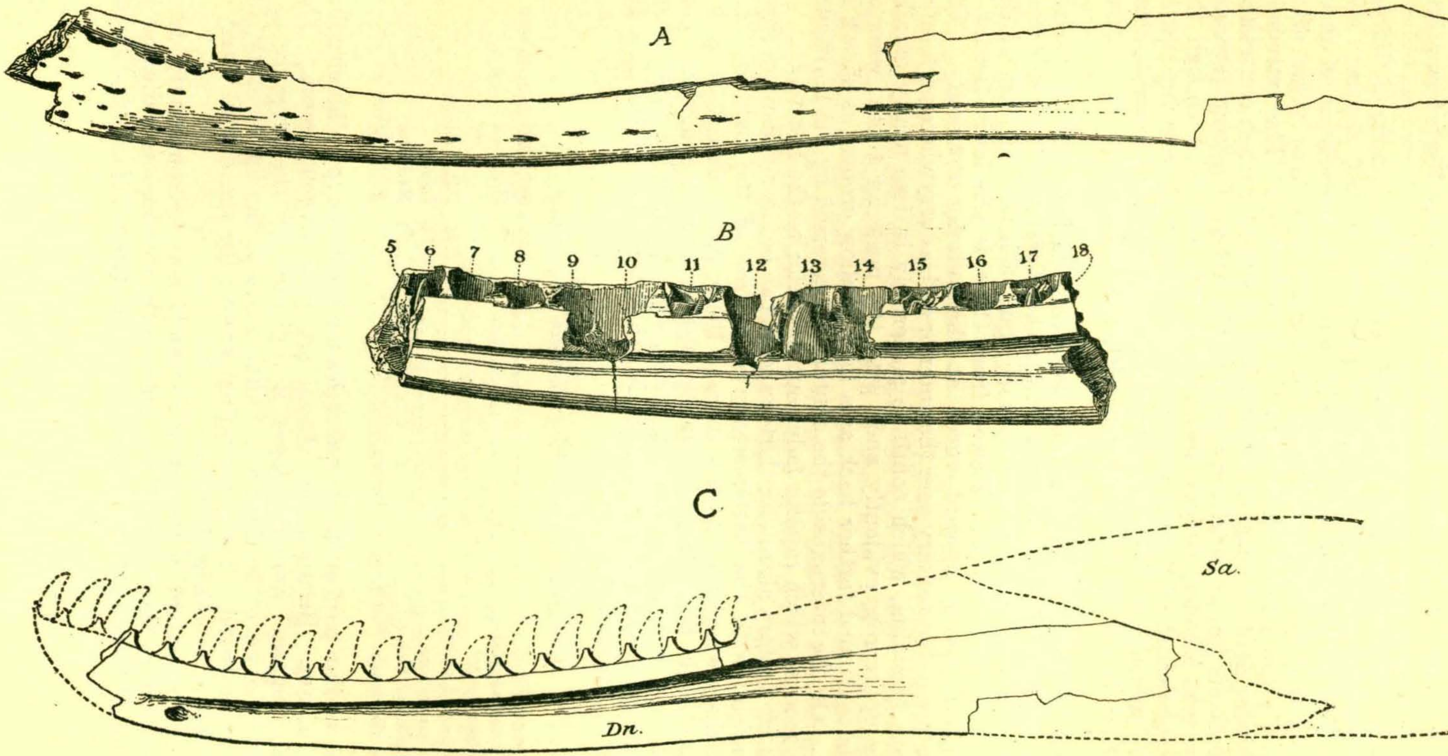

Figure 3. Dentaries of *Chirostenotes pergracilis*. No. 343, Geol. Surv., Can. A, left dentary, lateral view; B, median portion of right dentary, internal view. Numerals 5 to 18 refer to number of alveoli enumerated from the front. About natural size. C, restored dentary, internal view. *Dn*, dentary; *sa*, surangular. Drawn under the direction of L. M. Lambe. About three-fourths natural size.

groove. If a "supradentary" plate is present it has become so thoroughly coössified with the dentary that it can no longer be recognized as a separate element.

At the upper posterior end of the left dentary (Figure 3 A) a short portion of the true border is preserved, which probably was in contact with the surangular. At first I was inclined to regard this border as a part of the dentary contribution to the boundary of a large mandibular foramen, but the high position in the ramus of such an opening seems to render such an hypothesis untenable.

Measurements of Dentaries

	Mm.
Greatest length of left dentary as preserved	193
Complete length of dentary, estimated	230
Depth of right dentary at 17th alveolus	19
Depth of right dentary between 6th and 7th alveoli	15
Depth of left dentary between 4th and 5th alveoli	16·5
Greatest width at anterior end of left dentary	8
Greatest width at posterior end of left dentary	1

Teeth. None of the fully functional teeth are preserved, although the basal portions of several are present in both dentaries. Fortunately the crowns of several germ teeth, not yet protrudent above the parapet of the jaws, and a single young tooth lacking the tip but which was about to come into use, are present. A study of these gives some clue to the character of the dentition and the method of tooth replacement.

The teeth so far as they can be observed are compressed, subovate in cross-section, sharp pointed, recurved, serrate on posterior margins only. The method of tooth replacement is clearly shown in this specimen (Figure 4). Several of the broken roots of functional teeth show the tips of the successional teeth protruding from their centres, and likewise smaller germ teeth are to be observed flattened against the inner anterior sides of the alveoli, ready to assume their proper positions when the roots of the preceding teeth have been sufficiently absorbed.

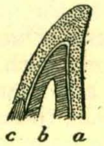

Figure 4. Diagrammatic view showing method of tooth replacement in *Chirostenotes pergracilis*. No. 343, Geol. Surv., Can. *a*, functional tooth; *b*, successional tooth; *c*, germ tooth. Twice natural size.

NOTES ON SOME UNIDENTIFIED VERTEBRÆ

In the palæontological collection of the Geological Survey, Canada, are a number of vertebral centra which possibly indicate the presence of an undescribed dinosaur in the Upper Cretaceous of western Canada. Reference is made to a dorsal and three caudal centra, No. 8504, probably of one individual, found by C. M. Sternberg in 1921, in the Lance formation on Rocky creek, southern Saskatchewan (sec. 7, tp. 1, range 4, W. 3rd mer.), and a single dorsal centrum, No. 8505, found by C. H. Sternberg in 1913, in the Belly River formation, 3 miles below Steveville, Red Deer river, Alberta.

Specimen No. 8504 was not found, Mr. Sternberg informs me, in situ, but in the float, though all the bones were close together and it, therefore, seems quite probable, because of the apparent rarity of such vertebræ, that they pertain to a single individual. These are the only vertebræ of this particular kind that have been found by Geological Survey parties during their twenty-five years of exploration in the Upper Cretaceous deposits, and it should be added that in none of the many collections which have passed through my hands for identification for the United States Geological Survey during the past twenty years, do I recall having observed any of a similar nature.

The smooth, dense, exterior surface of the bones, with coarsely cancellated internal structure, and centra with deep, clearly-defined pleurocentral cavities and with gentle concave articular faces, appear to show the theropod affinities of these bones.

The two dorsal vertebræ, though from widely separated geological formations, are almost identical in shape and structure, differing only in size. The smaller one, No. 8505, is from the Belly River formation, and the larger one, No. 8504, is from the Lance formation.

The sides and ventral surfaces of these vertebræ are moderately concave longitudinally; articular ends gently concave; no trace of neurocentral suture, though the basal portions of the neuropophyses are present in both specimens. The most conspicuous and distinctive feature of these vertebræ is the deep lenticular pleurocentral fossæ on the upper lateral surfaces of the centra. These extend inward and slightly downward nearly to the centre of the bone, though rapidly contracting in both dorso-ventral and longitudinal diameters. The neural canal is of good size and subcircular in outline. The larger dorsal, No. 8504, has a greatest length of 44 mm. and a greatest transverse diameter of 36 mm.

In Figure 5 are shown lateral, ventral, and end views of the caudal vertebræ found associated with the dorsal, No. 8504, described above. These are regarded as belonging to the anterior half of the tail because of the presence of transverse processes which have their origin on the arch. These vertebræ are relatively short, with lateral cavities high up beneath the transverse processes. The articular ends of the centra are more decidely concave than in the dorsals, though they exhibit the same coarsely vesicular internal structure of the bone. The sides of the centra are very shallowly concave from end to end, and the narrowed ventral surface is traversed by a pronounced longitudinal groove, with a foramen-like pit toward the anterior end, which leads upward into the interior of the centrum. The neuropophyses, as in the dorsals, are all firmly coössified with the centra, all trace of their union being obliterated. Chevron facets are very indistinctly indicated, if present at all. These vertebræ vary in length from 22 to 25 mm. The neural canal is circular in outline.

The relatively small size of all of these vertebræ shows them to belong to one of the smaller carnivorous dinosaurs, but whether to any of the families now known appears very uncertain. The lack of pleurocentral cavities in either dorsal or caudal regions, and the presence of more elongate caudal vertebræ in the Ornithomimidæ would appear to exclude them from that family. Likewise their affinities do not appear to lie in the Coeluridæ,

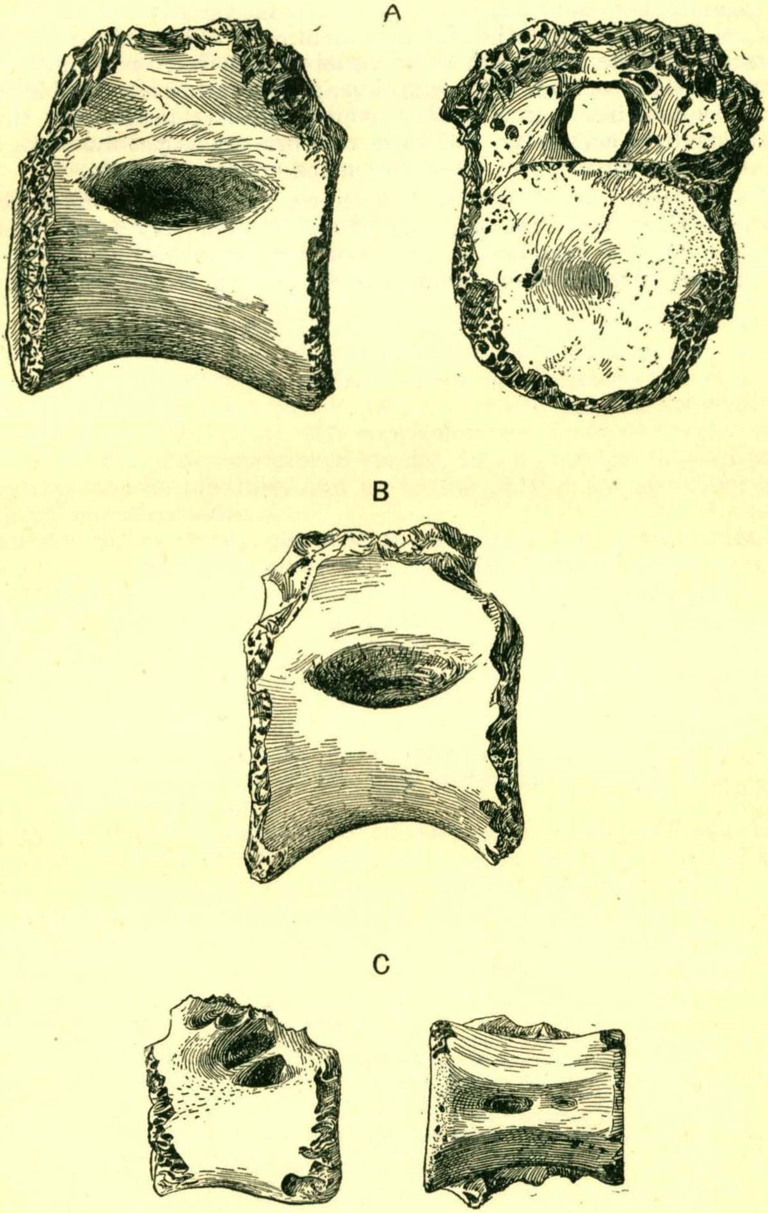

Figure 5. Dorsal and caudal vertebræ of an unidentified theropod dinosaur. No. 8504, Geol. Surv., Can. A, dorsal, lateral and end views; B, dorsal, No. 8505, Geol. Surv., Can., lateral view; C, caudal vertebræ No. 8504, lateral and ventral views. All figures natural size.

if we take the Morrison *Ornitholestes* as a typical example of that group. The gigantic Dinodontidæ, it is true, have lateral cavities in the dorsal vertebræ, but as in the other families mentioned above, there are none in the caudal region. Although these vertebræ may have relationships with a form like *Chirostenotes*, this suggestion appears rather improbable because of the Coelurid-like manus in that genus. There remains only the Dromæsaurinæ to be considered, but since vertebræ are as yet unknown of this sub-family a correlation of these specimens cannot be made.

The fragmentary nature of the known materials precludes the idea of naming these vertebræ, but they are at least of very great interest as showing a type of vertebral construction not before recognized, so far as I am aware, in the Upper Cretaceous deposits of North America.

A NEW SPECIES OF HADROSAURIAN DINOSAUR FROM THE EDMONTON FORMATION (CRETACEOUS) OF ALBERTA

A well-preserved skeleton of a large, non-crested hadrosaurian dinosaur in the vertebrate palæontological collection of the Geological Survey, Canada, is not only of great scientific interest, but noteworthy as being the first dinosaurian specimen to be mounted for exhibition in a Canadian museum. This specimen was discovered in the summer of 1912, by the Geological Survey party under Charles H. Sternberg, and was prepared and mounted the following winter by him and his son, Charles M., under the direction of L. M. Lambe.

In 1913, while this specimen was undergoing preparation for mounting, Mr. Lambe published[1] a brief account of the skeleton as a whole, but more especially dwelt on the structure of the fore feet and arrangement of the ossified tendons. At that time it was identified by him as pertaining to *Trachodon marginatus* Lambe because of certain resemblances found in the teeth. In a later communication[2], however, in which the character of the skin impressions was described, the conclusion was reached that it was not referable to the above-mentioned species, but no further attempt was made to determine its affinities, and up to the present the specimen has remained without designation.

The object of the present paper is to determine the relationships of this splendid specimen, and to give a more extended account of the skeletal anatomy, so that the information furnished by it will be available to future students of the Hadrosauridæ. Unfortunately, at this time the family Hadrosauridæ is in a somewhat chaotic state and sadly in need of revision. Many of the earlier described genera and species were founded on fragmentary specimens, and several, if not many of these, will probably have to be abandoned as indeterminate. Doubtless some of the later described species will prove to be synonyms, but these questions can be determined only by a careful comparison of the type materials and that is beyond the scope of the present paper.

Identification of the specimen under consideration is rendered still more difficult by the fact that it has no outstanding peculiarities of structure, such as distinguish many of the more recently described members of this family. In general form and structure of both skull and body it closely approaches *Thespesius*[3] *annectens* (Marsh) from the Lance formation of Wyoming, with which it agrees in most of its more detailed skeletal features.

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[1] Ottawa Naturalist, vol. 27, 1913, pp. 21–25, Pls. II, III.

[2] Ottawa Naturalist, vol. 27, 1914, p. 135, Pl. 17.

[3] In using the generic name *Thespesius* of Leidy (1856), I am fully aware of the inadequate nature of the type material on which that genus was founded, but as a temporary expedient while awaiting a revision of the family Hadrosauridæ, it appears to be a far more logical term to apply to the Lance species than such makeshift appellations as *Trachodon* (*Claosaurus*) or *Claosaurus* (*Trachodon*), which have come into vogue during the past few years. No one questions the fact of *Thespesius* being the first and only generic name ever established on specimens from the Lance formation (*See* appended chronological list, page 26), whereas *Trachodon*, founded on equally indeterminate materials, is from the much earlier Judith River formation, with every probability that this dinosaurian genus did not pass through from one formation to the other. *Claosaurus*, founded on an adequate specimen from the still earlier Niobrara formation of Kansas, is for the same reason unavailable.

The status of these names and of other members of the Hadrosauridæ have been fully discussed (Hatcher, J. B., Annals Carnegie Museum, vol. I, 1902, pp. 377–386; Gilmore, C. W., Science, vol. 41, 1910, p. 658; Lambe, L. M., Ottawa Naturalist, Feb., 1918, pp. 135–139) and it seems unnecessary to enter further into the matter at this time.

Fortunately there are no less than three nearly complete articulated skeletons known of *Thespesius annectens* (Marsh): the type, No. 2414, in the United States National Museum, Washington, D.C.; the paratype, No. 2182, in the Yale Peabody Museum, New Haven, Conn.; and a referred specimen, No. 5060, in the American Museum of Natural History, New York. None of these has been fully described, though they are sufficiently well known to afford a basis of comparison for the specimen now under consideration.

After careful study and comparison, I find that except for the presence of thirty-two presacral vertebræ in the Edmonton specimen, as contrasted with thirty in the Lance *Thespesius annectens* as originally determined by Marsh[1], there appears no reason why all these specimens should not be regarded as belonging to the same genus. This important difference in these otherwise closely allied forms is not to be accounted for by a reduced number of sacral vertebræ, for there are nine in each of the typical specimens. In all probability, as I shall attempt to show later, it is due to the mistaken idea of Professor Marsh that he was dealing with complete, articulated specimens in which none of the presacral vertebræ was missing. If such an important structural modification cannot be thus explained, it affords a most unusual difference in animals that are otherwise strikingly alike. Awaiting further evidence to clear up this uncertainty, this specimen from the Edmonton formation is provisionally regarded as belonging to the same genus as the Lance specimens first described by Marsh under the name of *Claosaurus annectens*.[2] Differences in the proportions of the fore limbs, and structural peculiarities in the manus indicate it to be a distinct species, for which the name *Thespesius edmontoni* is proposed.

Family, HADROSAURIDÆ Cope

Sub-family, *Hadrosaurinæ* Lambe

Thespesius edmontoni new species

PLATES II, III, IV, AND V

Trachodon marginatus, Lambe, L. M., Ottawa Naturalist, vol. 27, 1913, pp. 21–25, Plates II, III.

No Name, Lambe, L. M., Ottawa Naturalist, vol. 27, 1914, p. 135, Plate 17.

Type: No. 8399, Geol. Surv., Can., consists of an articulated skeleton, complete back to the sixth caudal vertebra. Ossified tendons and skin impressions. Collected by C. H. Sternberg, 1912.

Locality: Sec. 30, tp. 29, range 19, W. 4th mer., on Michichi creek, 5 miles from Drumheller, Red Deer river, Alberta.

Horizon: Edmonton formation, Upper Cretaceous.

Generic and Specific Characters: Skull long, moderately high, narrow posteriorly, concave in frontal region. Beak moderately expanded, recurved. Anterior nares confluent. Narial orifice strongly defined. Numerous rows of teeth, usually without papillate borders; enamel faces short. Pocket-like recess in postorbital, small. Mandibular ramus not

[1] U.S. Geol. Surv., 16th Ann. Rept., pt. I, 1896, p. 222.
[2] Am. Jour. Sc., 1892, p. 453, Fig. 4.

decurved, edentulous portion long. Thirty-two presacral vertebræ; 9 coossified sacrals. Radius longer than humerus. Ilium elongate, not markedly curved. Pubis with long expanded blade. Ischium long, bluntly pointed. Femur longer than tibia. Three layers of ossified tendons along spines of posterior dorsals. Integument over the sacral region composed of non-imbricating tuberculate scales arranged in clusters of the larger scales between which are minute tubercular scales. Vertebral formulæ C. 12, D. 20, S. 9, C. 5+. Fore limb lengthened, digital formulæ 3, 3, 2, 2, all terminated by flattened hoof-like unguals.

CONDITION OF THE SKELETON AS NOW MOUNTED

The specimen was found in a sandy clay that was easily removed, but many of the bones were covered with a tenacious layer of clay ironstone, and in removing it much of the detailed structure was lost or obscured. The flattening of many of the bones indicates that it has been subjected to tremendous pressure.

When the skeleton was found, the tail posterior to the fifth caudal vertebra, the distal ends of the ischia, and phalanges of the hind feet had been eroded away. The remainder of the animal, as now prepared and mounted in the Victoria Memorial Museum, is precisely as it was when found in the ground, except that the head and neck, which were originally bent downward and backward more toward the fore limbs, have been raised as shown in Plate II. The skeleton lay on its right side, with the knees drawn up and the fore limbs stretched out. The scapulæ were closely appressed to the sides of the ribs and probably lie in normal position. Both sternal bones are present and retained nearly in their proper relations with the remainder of the pectoral arch. The coracoids are badly damaged and little can be determined from them.

The complete articulated vertebral column back to the sixth caudal is present and except for lateral crushing is in a good state of preservation. The thoracic ribs of both sides are present, and although straightened by crushing and lacking small parts of their distal ends, are in a good state of preservation, and in most instances remain articulated with their respective vertebræ. The short ribs of the right side of the series are, however, buried in the matrix. Parts of all the cervical ribs of the left side, excepting the first, third, fourth, and twelfth, are present.

The humeri are much distorted and the left appears to be longer than the right, probably due to an undue lengthening of a restored section above the distal end. The other bones of the fore limbs and feet are well preserved and all are present except a few phalanges.

The sacrum and pelvic arch are complete except the distal ends of the ischia. The hind limbs have been much flattened by crushing, and the right astragulus and calcaneum are missing. The metatarsals are so much restored as to be of little value scientifically and it appears that most if not all of the phalanges are missing. These and the missing caudal vetrebræ in the mount have been supplied by the substitution of miscellaneous bones representing many individuals.

Of particular interest is the preservation of the ossified tendons on each side of the neural spines along the back, and of a considerable area of epidermal impressions above the hips. From the foregoing, somewhat detailed statement of the actual and missing parts of this skeleton it will be seen that it is a most important specimen. The mounted skeleton has a greatest length from the front of the beak to the tip of the tail of 32 feet 8 inches, of which the restored tail constitutes 14 feet 9 inches.

OSTEOLOGY OF THE SKULL AND LOWER JAWS

The skull of *Thespesius edmontoni* closely resembles *T. annectens* in all particulars so far as they can be compared, but is slightly smaller. It is long and narrow, with the facial portion elongated, and with a moderately expanded beak. This muzzle appears to have been rugose, and in life, with the predentary of the lower jaw, was probably covered by a horny integument or sheath, as in birds and turtles.

The orbit is large, subtriangular in outline. It is bounded above by the prefrontal, frontal, and postorbital bones; posteriorly by the postorbital bar formed by the slender processes of the postorbital and jugal; below by the jugal; and anteriorly by the jugal, lachrymal, and prefrontal. The infratemporal fossa is also large, but relatively narrow fore and aft. It is bounded above by the postorbital and squamosal, below by the jugal, and posteriorly by the jugal, quadrate, and squamosal.

The narial orifice, as Marsh has pointed out[1], in *T. annectens* "is an enormous lateral cavity which includes the narial orifice, but was evidently occupied in life mainly by a nasal gland, somewhat like that in the existing monitor and seen also in some birds". The outlines of this cavity in the present skull are even more strongly marked out than in the specimens studied by Marsh, and the posterior bony septum separating the two orifices extends somewhat farther forward than in the Lance skulls. This orifice lies largely within the premaxillaries, though bounded posteriorly and above also by the nasals. The bar above the orifice appears to be relatively heavier than in *T. annectens.*

The jugal, quadratojugal, quadrate, postorbital, and squamosal, are as in *T. annectens,* except that the descending branch of the postorbital has a decidedly cupped depression at midlength on its lateral surface. This, however, may be a malformation from an injury received in life.

The quadrate has a length in relation to the total length of the skull of 1 to 2·75, whereas in the Lance skulls this proportion is 1 to 2·90. In the large *Edmontosaurus* from this same formation it is 1 to 2·50. This would not appear to bear out Lambe's[2] contention "that as time progressed the skull in the Hadrosaurinæ, as a general rule, became lower", for *T. edmontoni* from the generally regarded earlier formation is certainly very closely allied to *T. annectens* from the Lance.

The parietal bones viewed from above are very much reduced, appearing on the superior surface as a very narrow ridge separating the supratemporal fossæ, and terminating behind in a point and separating the squamosals on the median line.

The frontals are relatively short and wide and contribute to the formation of the median upper border of the orbit. The frontal region is deeply concave in transverse section, but this feature may have been exaggerated by the pressure to which this skull was subjected.

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[1] U.S. Geol. Surv., 16th Ann. Rept., pt. I, 1896, p. 219.
[2] Geol. Surv., Can., Mem. 120, 1920, p. 76.

The nasal bones are long and slender, their attenuated extremities embracing the slender posteriorly directed premaxillary processes. The premaxillaries form the whole of the anterior portion of the skull and are united at the centre by suture. They are deeply excavated for the nasal openings. The front borders of the anterior expansion of the premaxillaries is recurved for some distance so as to roof over the cavity, which opens backward. This bone appears to be somewhat thickened as contrasted with the thin bone of this region of *Edmontosaurus.* On the left side the expanded beak has been distorted and flattened by crushing, but the right side appears to show the full normal width.

The lower mandible is long, with a massive predentary, and is closely articulated with the skull from which it has apparently never been separated. For this reason the character of the tooth structure cannot be observed, and I am also at a loss to understand how Lambe was able to compare it with *Trachodon marginatus* in making his first identification of this specimen.

A careful study and comparison of the skull of No. 8399 have revealed no differences in structure which might be considered of specific importance to separate it from *T. annectens* (Marsh) and were only the skull present, I should unhesitatingly refer it to that species.

Measurements of Skull and Lower Jaws

	Mm.
Greatest length, tip of beak to back of paraoccipital process	938
Greatest length paraoccipital process to posterior (centre) border of orbit	246
Greatest length anterior border of orbit to tip of premaxillary	554
Greatest vertical diameter of skull and lower jaws	410
Greatest vertical diameter of skull at muzzle	250
Greatest length of skull in front of teeth	310
Greatest width of skull between centre of orbits	139
Greatest width of skull across tops of quadrates	131
Greatest width nasal and premaxillaries above centre of narial orifice	42
Greatest width across expanded beak about	200
Greatest length of quadrate	340
Greatest height of orbit, taken obliquely	210
Greatest length of orbit, taken at midheight	145
Greatest height of infratemporal fossa, taken obliquely	227
Greatest length of supratemporal fossa	154
Greatest width of supratemporal fossa	40
Greatest length of nasal orifice	280
Greatest length of nasal opening	221
Greatest length of ramus to front of articulated quadrate	695
Greatest vertical diameter of ramus through centre of dentition	126
Greatest length from tip of predentary to front border of coronoid process	530

Vertebræ

The complete articulated presacral series is present and consists of thirty-two vertebræ. The twelve anterior ones are regarded as cervical, the remaining twenty as dorsal. The sacrum is composed of nine coössified sacral vertebræ, as in all known members of the Hadrosaurinæ. Only five anterior caudal vertebræ remain articulated with the sacrum, the others having been eroded away and destroyed before the specimen was discovered. The vertebral formula, so far as known, is C. 12, D. 20, S. 9, C. 5+.

An examination of the compiled table, giving the vertebral formulæ of various members of the Hadrosauridæ, shows there is a considerable variation not only in the number of cervical and dorsal vertebræ, but also in the total number of presacrals. The information already available is sufficient to indicate that regardless of distinctive features to be found in the vertebræ themselves, the vertebral formulæ as a whole will furnish important diagnostic characters in the Hadrosauridæ. The present specimen in this respect is, therefore, of the greatest scientific interest, as being one of the very few skeletons known in which the presacral series is completely preserved.

Known Vertebral Formulæ of the Hadrosauridæ

Name	Museum and catalogue number	Cervicals	Dorsals	Sacrals	Caudals	Total number of pre-sacrals
Thespesius edmontoni n. sp....	G. S. C. 8799	12	20	9	5+	32
Thespesius annectens (Marsh)	U.S.N.M. 2414	11?	19?	9	62+	30?
" "	Y.M. 2182	11?	19?	9	23+	30?
Diclonius mirabilis Cope......	A.M.N.H. 5730	16	18?	9	....	34?
" "	A.M.N.H. 5894	16?	18	9	....	34?
Kritosaurus incurvimanus.... Parks	Univ. of Toronto	13	16	9	17+	29
Edmontosaurus regalis Lambe	G.S.C. 2289	....	....	9[1]	....	....
Corythosaurus casuarius Brown	A.M.N.H. 5240	15	19	8	61+	34
Saurolophus osborni Brown..	A.M.N.H. 5220	12?	20?	8	50+	32?
Hypacrosaurus altispinus..... Brown	A.M.N.H. 5204	....	....	8	....	....
Parasaurolophus walkeri Parks	Univ. of Toronto	13	17	7	6+	30

In order to render the vertebral formulæ of these animals of the greatest diagnostic utility a uniform method of determining the point of division between the cervical and dorsal regions should be adopted. At present, it is necessary to select a division point arbitrarily, for in the transitional vertebræ one cannot certainly determine whether they properly belong to the cervical or to the dorsal series. It is, therefore, proposed to regard as cervical all those vertebræ bearing short slender ribs. In other words, none of the cervical ribs with the scapula in position are of sufficient length to pass well down behind it or to protrude below its ventral border. This procedure would render the formulæ in some forms somewhat different than originally determined, but it would bring about a greater uniformity.

In *Thespesius annectens* (Marsh), "There are thirty[2] vertebræ between the skull and sacrum, nine in the sacrum, and about sixty in the tail. The whole vertebral column was found in position except the terminal caudals".

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[1]As shown by the paratype there are nine sacral vertebræ instead of eight as originally given by Lambe, Geol. Surv., Can., Mem. 120, 1920, p. 66.

[2]Dinosaurs of North America", U.S. Geol. Surv., 16th Ann. Rept., 1896, p. 222.

The presence of thirty-two presacrals in the Edmonton specimen appears at once to indicate its generic distinctness. Unfortunately the skeletons upon which Marsh based his original determinations no longer exhibit a verification of thirty as being the correct number. From other specimens now known from the Lance formation it would seem that perhaps Marsh was mistaken in his original count. The type of *T. annectens* (Marsh) now exhibited as a panel mount in the United States National Museum, No. 2414, has thirty presacral vertebræ, but four of these, the sixth and seventh cervicals and the seventh and fourteenth dorsals, are entirely restored, and this fact raises grave doubt of the column being complete. The companion specimen, No. 2182, belonging to the Yale Peabody Museum, is packed away and unavailable at this time. A study of the illustrations of the mounted skeleton published[1] by Beecher clearly shows nineteen dorsals, and certainly more than eleven cervicals. The neck bones are somewhat disarranged in this mount and it is, therefore, difficult to determine the precise number, though there appear to be twelve if not thirteen. Both of these specimens have nine vertebræ in the complete sacrum.

The two mounted skeletons in the American Museum of Natural History, New York, identified as *Diclonius mirabilis* Cope and also from the Lance formation, are likewise deficient in positive information as to the complete presacral formula. Under date of March 15, 1923, Matthew replied to my inquiry as follows: "The cervical-dorsolumbar formula on our two mounted skeletons is 16–18 in each; but the number of dorsals appears to be uncertain in the Cope skeleton (No. 5730) and the number of cervicals in the Sensiba skeleton (No. 5894), as two or three are restored in each case. There is a third skeleton, No. 5058, which has either 34 or 35 presacrals, as far as I can make out in its present condition."

From the above review of the known Hadrosaurian specimens from the Lance formation, with which the Edmonton specimen appears to have its nearest affinities, we have on the one hand one species with two less presacral vertebræ, and on the other hand a second species which has two more. If these formulæ are found to be correct they represent differences of more than specific importance.

The cervical vertebræ in *Thespesius edmontoni* are strongly opisthocoelous, and all bear small ribs. An incipient neural spine is present on the third, and though the processes increase in size posteriorly, none may be said to be especially prominent in size. The centra of the cervical as well as those of all the dorsal vertebræ have suffered much from lateral compression, though they appear to have essentially the same shape and proportions as those of *T. annectens*, and these resemblances are carried out in the development of the transverse and neural processes.

The sacrum is composed of nine coössified sacral vertebræ, with distinct spines. All known specimens of the family Hadrosauridæ from the Lance agree in this respect.

In the mounted specimen the fifth caudal is shown as bearing the first chevron, but from the contour of the lower posterior border of the centrum of the fourth vertebra it would seem that perhaps it also may have carried a reduced chevron.

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[1] Trans. Conn. Acad. of Sc., vol. XI, Jan., 1902, Pl. 45.

Measurements of Vertebræ

		Mm
Axis,	length of centrum	80
"	greatest height over all	165
Third cervical,	length of centrum	60
" "	greatest height over all	130
Seventh "	length of centrum	95
" "	greatest height over all	154
Twelfth "	length of centrum	100
" "	greatest height over all	187
Second dorsal,	" " "	260
Seventh "	" " "	305
" "	length of centrum	105
Twelfth "	length of centrum	100
" "	greatest height over all	375
Fifteenth "	length of centrum	80
" "	greatest height over all	410
Nineteenth "	length of centrum	70
" "	greatest height over all	420
Ninth sacral,	length of centrum	95
" "	greatest height over all	445
Fourth caudal,	" "	455
" "	length of centrum	70
Length of twelve cervical vertebræ		920
" twenty dorsal vertebræ, about		2050
Length of nine sacral vertebræ		760
" fifth dorsal rib (left side)		1108

Fore Limb and Feet

The fore limb of *Thespesius edmontoni* is relatively longer than in any known specimen of *T. annectens* (Marsh), as may be seen in the table of comparative measurements. Though the skull is smaller in all dimensions, a proportion that largely prevails throughout the skeleton, the fore limb is longer. This feature, combined with structural differences found in the manus, is regarded as indicating the specific distinctness of this specimen from the Lance *T. annectens,* with which it has the closest affinities.

The scapulæ are large, with a straighter blade in relation to the proximal end and having a more squarely truncated upper extremity than found in *T. annectens.* The humeri are much crushed and there is a considerable difference in the length of the two bones. The right element has a length over all of 560 mm., whereas the left measures 615 mm. It is thought that some of the distal extremity is missing in the former, whereas the latter has been unduly lengthened either by crushing or unwarranted restoration. An average of the two extreme measurements would probably be closer to the correct dimensions of these bones. The humeri have the usual prominent radial crest.

The radius and ulna are especially elongated, exceeding in length any known specimen of *T. annectens.* In their exaggerated breadths both show the effect of crushing.

The fore feet have been described[1] in detail by Lambe, from whose description the following extracts have been made: "In removing the rock particular care has been taken to keep each bone in the exact position in which it was found, so that any observer of the mounted skeleton, or any reader of this paper, with the aid of the illustrations provided, would be in a position to interpret for himself the phalangial formula presented. This policy of non-disturbance of the bones has been carried out in the preparation of the entire skeleton."

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[1] Ottawa Naturalist, vol. 27, May, 1913, pp. 22–25.

"Of the four digits in the manus all the phalanges are represented with the exception of the terminal one of digit II. As digits III, IV, and V ended distally in a hoof (or nail) carrying bone it is probable that digit II, the inner finger, bore a terminal hoof-phalanx also."

In Figure 6 the bones of the fore feet are shown in the position in which they were found, and as they are now in the mounted skeleton. They have been so little disturbed from their natural relationships that there appears to be no doubt of their proper arrangement in the manus which, it is believed, has been correctly interpreted by Lambe as shown in Figure 7, though his interpretation of the digits being uniformly spread is questioned.

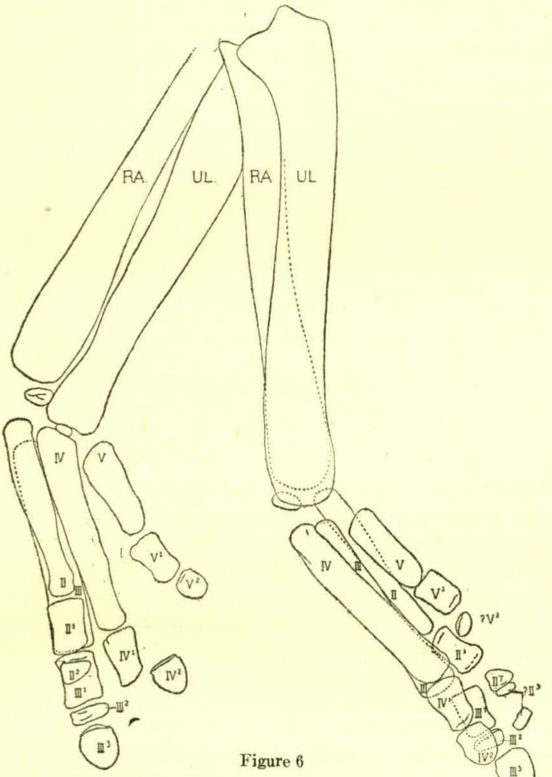

Figure 6

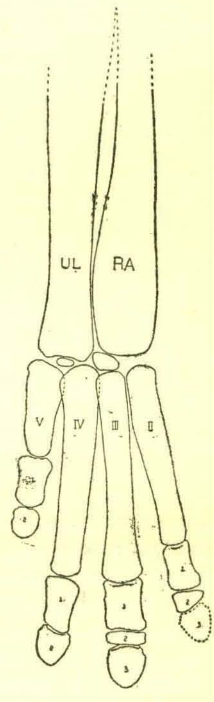

Figure 7

Figure 6. Fore feet of *Thespesius edmontoni*. Type, No. 8399, Geol. Surv., Can. Showing the position of the bones as found. *Ra*, radius; *Ul*, ulna; II, III, IV, and V, respective digits. One-tenth natural size. After Lambe.

Figure 7. Reconstructed right foot of *Thespesius edmontoni*. Type, No. 8399, Geol. Surv., Can. *Ra*, radius; *Ul*, ulna; II, III, IV, and V, respective digits. One-tenth natural size. After Lambe.

It appears to me from the evidence available that the articulated upper extremities, when viewed from above, would form an arc of a circle, and that digit V is probably more divergent than shown in Figure 7. This is demonstrated in the present specimen by the appressed arrangement of mtcs. II, III, and IV, whereas mtc. V is massive and less than half the length of mtc. IV.

The phalangial formula differs from all hadrosaurian reptiles in which the manus is known by having only two phalanges in digits IV and V, with the terminal ones flattened hoof-like bones, instead of the usual rounded bony nodules. These differences are clearly indicated in the following table:

Digital Formulæ of the Hadrosauridæ

	Thespesius edmontoni, No. 8399, Geol. Surv., Can.	*Thespesius annectens* (Marsh), No. 5060, A.M.N.H.	*Kritosaurus incurvimanus* Parks, Univ. of Toronto Museum	*Parasaurolophus walkeri* Parks, Univ. of Toronto Museum
Number of phalanges in digit II	3 H	3 H	3 H	3 H
Number of phalanges in digit III	3 H	3 H	3 H	3 H
Number of phalanges in digit IV	2 H	3	3 H?	3
Number of phalanges in digit V	2 H	3	4	3

H signifies terminated by a hoof-like ungual.

Brown[1] has called attention to the incorrectness of the manus in *Thespesius annectens* as originally assembled by Marsh, so that the evidence for the phalangial formula of that species rests entirely upon specimen No. 5060, A.M.N.H., described by Brown, and fortunately in such preservation as to furnish indisputable evidence.

In the left manus of the Edmonton specimen the phalanx V^2? (*See* Figure 6), is very likely the distal articular end of V^1, which is much shorter than the right element and which appears to lack the distal end.

"A carpal bone is preserved in each hand, in the same position, viz., at the ulnar side of the end of the radius. In addition, a smaller carpal bone was found in the right hand, at the middle of the end of the ulna, but a corresponding second carpal was not found in the left hand". The carpals in *Kritosaurus incurvimanus* Parks[2] have similar ossifications, but in *Thespesius annectens*, as shown by Brown[3] there are two, rounded, ossicle-like ossifications one above the other at the junction of the radius and ulna.

Although the elongation of the metacarpals, the rather loose articulation of the phalanges, and the imperfectly ossified carpus would indicate a manus little used as a means of locomotion, the functional hoofs on all the digits seem to show that they may have been of much use as sustaining organs when assuming a quadrupedal pose in feeding from or near the ground.

Pelvic Arch and Hind Limb

The pelvic arch and hind limbs conform closely to those of *Thespesius annectens* (Marsh). All the bones of the arch are present and perfectly preserved, except the distal halves of both ischia, which were eroded away before the specimen was discovered. The shafts of these bones appear

[1] Bull. Am. Mus. Nat. Hist., vol. 31, 1912, p. 106.
[2] University of Toronto Studies, No. 11, 1920, p. 37.
[3] Op. cit., p. 106, Fig. 1.

heavier than in *T. annectens*, though this apparent robustness may be due to crushing. The form of the obturator processes is obscured by restoration and their form can no longer be determined.

The femur is longer than the tibia, the fourth trochanter is strongly developed and extends well downward on to the distal half of the shaft. The lesser trochanter is separated from the greater trochanter by the usual narrow cleft. The greater trochanter rises well above the level of the head. Both femora are much flattened by the great pressure to which they have been subjected. The tibiæ and fibulæ are of the usual hadrosaurian type and display no distinctive features. The astragulus and calcaneum are articulated with the tibia of the right side, but both these bones of the left tarsus are missing.

Parts of the metatarsal bones of both feet are present, but all have been so much restored as to be of little value either in showing their relative proportions or other characteristics. None of the phalanges can be said to pertain to the present specimen, and it is thought all have been either restored or supplied from other individuals.

The principal dimensions of the pelvic and limb bones are given in the table of measurements.

Ossified Tendons

The preservation of a considerable number of ossified tendons in this specimen is of particular interest. Although they are present along both sides of the neural spines of the back, sacrum, and tail, only those of the left side are now visible, and many of these are covered by the overlying skin impressions. Their greatest development apparently is over the posterior dorsal, sacral, and anterior caudal regions. Anteriorly they extend forward as far as the thirteenth dorsal in front of the sacrum, but gradually diminish in number from the sacrum forward. Their diagonal lattice-like arrangement is well displayed, and is made up of three layers or series, an inner and outer and a deep-seated inner series. The outer series is best displayed in Plate IV. Each tendon originates at the base of a spine, passes backward and upward across four spines, and is attached to the anterior face of the fifth. This was the longest one observed above the dorsal region, though there is reason to believe that they become longer above the anterior caudal region. The origin of the inner series of tendons could not be clearly determined, though they clearly attach on the posterior upper face of the spines and pass backward and downward. The deep-seated series is only to be observed above the posterior dorsals.

Each of these tendons is a long, flattened rod with flattened, fibricated terminal points which are uppermost; the end of insertion is usually flattened but comes to a point. Brown[1] has observed a similar three-layer arrangement of the tendons in a specimen of *Thespesius* (No. 5058) in the American Museum of Natural History. A skeleton in the Victoria Memorial Museum, without head, but evidently pertaining to one of the crested forms, shows only two series over the dorsals and sacrals as in *Corythosaurus*. It would appear from this that there was probably a different arrangement of the musculature in the two groups: the Hadrosaurinæ having three layers of tendons over the posterior dorsals and sacrals; the Corythosaurinæ having only two.

[1] Bull. Am. Mus. Nat. Hist., vol. 38, 1916, p. 713.

A series of longitudinal tendons are also to be observed extending across the transverse processes of the posterior dorsals for a short distance, but they have not been sufficiently prepared to show their more intimate details.

Integument

On the left side of the mid-line of the back above the sacrum for a length of nearly 4 feet, a clear and sharp impression of the tuberculated skin of this specimen is well preserved. Lambe has described a patch of these skin impressions (Plate V), as follows:

"The epidermal markings found with the Edmonton specimen and already briefly described in a paper by the writer (Ottawa Naturalist, May, 1913, pp. 21, 22) are natural moulds and casts of non-imbricating scales of which some are larger than others. The larger ones are flat or slightly convex, polygonal in outline, and average about a quarter of an inch in diameter, they are aggregated in irregular oval clusters from 2 to 3 inches in greater diameter, and about three-quarters of an inch apart. Between the clusters are minute, tubercle-like scales averaging about one-tenth of an inch in diameter and forming the general ground-work of the pattern.

"This scale pattern is of the same general character as that of *Trachodon annectens* (Marsh), as described and figured by Osborn in a specimen from Upper Cretaceous beds in Converse county, Wyoming, U.S.A., but is more pronounced; the oval clusters of plate-like scales are larger, and the scales composing them have a greater average diameter. The small-sized tubercle-like scales are much the same as in the Wyoming specimen."

The scale pattern in *Thespesius annectens* is not known in this same region of the back at the present time, but the pattern closely resembles that from above the ilium and also the pectoral and abdominal region as described by Osborn[1], and such differences as noted by Lambe are just those that might be expected on the upper exposed dorsal surfaces.

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[1] Mem. Am. Mus. Nat. Hist., vol. L, pt. LL, 1912, p. 48.

Comparative Measurements

Skull	*Thespesius edmontoni*, No. 8399, G.S.C.	*Thespesius annectens* (Marsh), No. 2183, Yale Museum	*Thespesius annectens* (Marsh), No. 2414, U.S.N.M.	*Diclonius mirabilis* Cope, No. 5730, A.M.N.H.
Total length premaxillary to paraoccipital process	938	1,020	1,100	1,180
Length in front of teeth	310	380	420	
" of quadrate	340	350[1]	380	
" of dentition	320	....	350[1]	....
Lower Jaw				
Total length, ...about	715	780	980	....
" of dentary	570[1]	....	820	
" of dentition	300[1]	....	350[1]	....
Greatest depth through middle of jaw including teeth	126	160	190	....
Pectoral Girdle and Fore Limbs				
Scapula, length	927	860	970	810
" width, widest part of blade	215	....	230	200
" narrowest part of blade	130	190	130	130
Humerus, length	587[1]	590	500	501
" length of deltoid ridge	340	....	310	280
Ulna, length	655	600	630	500
Radius, length	610	550	600	440
Metacarpal II, length	215	....	245	200
" III, length	272	250·5	....	220
" IV, length	270	270	....	215
" V, length	118	110	120	75
Sternal bone, length	428	420	....	420
Pelvic Girdle and Hind Limbs				
Ilium, length	1,020	1,150	1,150	1,030[1]
Pubis, length	....	....	....	630
" width of preacetabular expansion	210	....	220	200
" length of preacetabular portion	610	600	450	360
Ischium, length	....	1,150	....	1,090
Femur, length	1,118	1,060	1,170	1,040
Tibia, length	930	950	1,000	870
" width of proximal end, antero-posteriorly	325	290	....	310
" width of distal end transversely	225	260	320	230
Fibula, length	890	920	920	820
" width of proximal end	180	140	130	160
" " distal end	....	120	....	65
Metatarsal II, length	270	260	280	280
" III, length	345	360	370	340
" IV, length	275	280	300	275

[1] Estimated.

Chronological List of North American Hadrosauridæ

Name as originally proposed, author, and date	Formation and locality	Nature of type or cotypes
Trachodon mirabilis Leidy, 1856.....	Judith River, Montana........	Teeth.
Thespesius occidentalis Leidy, 1856..	Lance, South Dakota..........	Two caudal vertebræ and a first phalanx.
Hadrosaurus foulkii Leidy, 1858.....	Greensand, New Jersey.......	Part of a skeleton.
Ornithotarsus immanus Cope, 1869...	" "	End of tibia, astragulus and fistula.
Pneumatoarthrus peloreus Cope, 1870	" "	Four sacral vertebræ.
Hadrosaurus minor Marsh, 1870.....	" "	Dorsal and caudal vertebræ.
Hadrosaurus tripos Cope, 1870.......	Black Creek, North Carolina.	Metatarsal, caudal vertebræ, humerus, and fragments.
Hadrosaurus cavatus Cope, 1871......	Greensand, New Jersey.......	Caudal vertebræ.
Hadrosaurus agilis Marsh, 1872......	Niobrara, Kansas.............	Part of skeleton.
Cionodon arctatus Cope, 1874.........	Denver, Colorado.............	Right maxillary (part) with several teeth.
Polygonax mortuarius Cope, 1874....	Denver, Colorado.............	Three dorsal vertebræ, fragments of limb bones.
Cionodon stenopsis Cope, 1875.......	Two Medicine, Montana.......	Maxillary with teeth.
Diclonius perangulatus Cope, 1876...	Judith River, Montana........	Detached teeth.
Diclonius pentagonus Cope, 1876.....	" "	"
Diclonius calamarius Cope, 1876.....	" "	"
Dysganus encaustus Cope, 1876......	" "	"
Dysganus bicarinatus Cope, 1876.....	" "	"
Dysganus haydenianus Cope, 1876....	" "	"
Dysganus peiganus Cope, 1876.......	" "	"
Hadrosaurus breviceps Marsh, 1889..	" "	Part of right maxillary with teeth.
Hadrosaurus paucidens Marsh, 1889..	" "	Left maxillary and other parts of skull.
Pteropelyx grallipes Cope, 1889......	" "	Part of a skeleton.
Trachodon longiceps Marsh, 1890....	Lance, Wyoming..............	Right dentary with teeth.
Claosaurus agilis Marsh, 1890.......	Niobrara, Kansas.............	Part of skeleton.
Claorhynchus trihedrus Cope, 1892....	?Judith River, Montana.......	Premaxillary and predentary.
Claosaurus annectens Marsh, 1892....	Lance, Wyoming..............	Nearly complete skeleton.
Trachodon marginatus Lambe, 1902..	Belly River, Alberta..........	Fore limb, etc.
Trachodon selwyna Lambe, 1902.....	" "	Fragment of dentary containing teeth.
Trachodon altidens Lambe, 1902.....	" "	Left maxilla with teeth.
Kritosaurus navajovius Brown, 1910 .	Kirtland, New Mexico........	Skull.
Saurolophus osborni Brown, 1912....	Edmonton, Alberta............	Skeleton.
Hypacrosaurus altispinus Brown, 1913.........................	" "	Part of skeleton.
Gryposaurus notabilis Lambe, 1914..	Belly River, Alberta..........	Skull and partial skeleton, fore limb, etc.
Stephanosaurus marginatus Lambe, 1914.........................	" "	Skull (referred).
Corythosaurus casuarius Brown, 1914	" "	Skeleton.
Prosaurolophus maximus Brown, 1914.........................	" "	Skull.
Edmontosaurus regalis Lambe, 1917.	Edmonton, Alberta............	Partial skeleton.
Cheneosaurus tolmanensis Lambe, 1917.........................	" "	Skull and skeleton.
Kritosaurus incurvimanus Parks, 1920.........................	Belly River, Alberta..........	Skeleton.
Parasaurolophus walkeri Parks, 1922.	" "	Skeleton.
Corythosaurus excavatus Gilmore, 1923.........................	" "	Skull.
Corythosaurus intermedius Parks, 1923.........................	" "	Skull.
Lambeosaurus lambei Parks, 1923....	" "	Skull.

REPORT ON A COLLECTION OF VERTEBRATES FROM WOOD MOUNTAIN, SOUTHERN SASKATCHEWAN

Collected by C. M. Sternberg, 1921

Pisces
- *Lepisosteus occidentalis* (Leidy)
- *Myledaphus bipartitus* (Leidy)
- *Pappicthys* sp.
- *Platæodon* sp.

Batrachia
- *Scapherpeton tectum* Cope

Reptilia
- *Testudinata*
  - *Baëna* sp.
  - *Baëna* sp.
  - *Basilemys* sp.
  - *Adocus* sp.
  - ?*Thescelus* sp.
  - *Aspiderites* sp.
  - " sp.
  - " sp.
- *Rhynchocephalia*
  - *Champsosaurus* sp.
- *Sauria*
  - *Iguanavus* sp.
  - Unnamed lizard
- *Dinosauria*
  - *Thespesius* new species
  - *Thescelosaurus neglectus* Gilmore
  - *Triceratops ? prorsus* Marsh
  - *Triceratops* sp.
  - *Ornithomimus* sp.
  - Carnivorous dinosaur (undescribed)
- *Crocodylia*
  - *Crocodylus* sp.

The fish remains as represented in the above faunal list, with one exception, have a wide geologic range and are valueless as horizon indicators. *Platæodon* has only been reported from the Lance formation of Wyoming.

Likewise the batrachia, represented by the single genus *Scahpherpeton*, is of little use because of the fragmentary nature of the known materials and also since it occurs in the Judith River formation of Montana.

None of the turtle specimens are sufficiently well preserved to be identified specifically, and with one exception all of the genera recognized have a wide geological range and none is distinctive of the Lance fauna. *Thescelus* if present has not been recognized below the Lance, though a second species occurs in the Puerco.

The single rhynchocephalian reptile, *Champsosaurus*, has a wider geologic range than any other of the extinct reptiles listed, with the exception of some of chelonian genera. *Champsosaurus* remains have been found in the Judith River, Belly River, Two Medicine, Edmonton, Lance, Puerco, and Fort Union formations.

The *Sauria* (lizards) are represented by two specimens: one pertaining to the genus *Iguanavus* the genotype of which is from the Bridger, Eocene, but which has also been reported from the Lance of Wyoming; the second specimen belongs to a new genus and species (in manuscript) first recognized from the Lance formation of Wyoming.

The dinosaur remains furnish the most conclusive evidence of the age of the beds in which they were found as being equivalent to the Lance, as that formation is known in Wyoming, Montana, and the Dakotas.

This is shown by the presence of *Thescelosaurus neglectus* Gilmore and *Triceratops? prorsus* Marsh, both typical Lance forms and unknown elsewhere.

A hadrosaurian reptile, probably a new species, which clearly has its closest affinities with the Lance, *Thespesius annectens* (Marsh), and the presence of the genus *Ornithomimus*, furnish corroborative evidence of the Lance facies of this fauna.

This brief review of the above faunal list of the vertebrate remains found in southern Saskatchewan, shows that though only a few of its recognized members are confined exclusively to the Lance formation, the faunal list as a whole may be considered typically representative of that formation.

ON THE GENUS STEPHANOSAURUS, WITH A DESCRIPTION OF THE TYPE SPECIMEN OF LAMBEOSAURUS LAMBEI, PARKS

DISCUSSION OF THE GENUS STEPHANOSAURUS

In 1914, the late Lawrence M. Lambe proposed[1] the new genus *Stephanosaurus* for reception of the species originally described[2] by him under the name of *Trachodon marginatus*. At the same time he described and figured the skull and jaws of a helmet-crested Hadrosaur which he referred to this species. In October of the same year Barnum Brown[3], in a paper describing the genus *Corythosaurus casuarius*, remarks that "It appears probable that this skull [Lambe's *Stephanosaurus*] is congeneric with *Corythosaurus casuarius*, though clearly distinct as to species. That either is congeneric with the type of *T. marginatus* is improbable". Subsequent discoveries showed that Brown was mistaken in the matter of the *Stephanosaurus* skull pertaining to the genus *Corythosaurus*, for in 1920 Lambe described[4] and figured a second and more complete skull that clearly showed, so far as the referred skulls were concerned, that the genus *Stephanosaurus* was distinct generically from *Corythosaurus*.

That Lambe was correct in referring the skulls to *Stephanosaurus marginatus*, however, has never been satisfactorilly established, and the present paper is an attempt to straighten out this uncertainty.

Brown[5] has given a concise review and discussion of the status of the type materials with which, after an examination of the original type materials and a full and careful review of the original and subsequent descriptions by Lambe, I fully concur.

Brown says: "Lambe states (1914) that *T. marginatus* was based upon 'a ramus of the lower jaw and a maxilla and the remains of one individual.' But reference to his original description (1902) shows clearly that the last-named specimen (consisting of humerus, radius, ulna, and some other parts named but not figured) was regarded as type at the time of description. It is first mentioned, and the describer goes on to say that '*the species is represented further by* dissociated femora, tibiæ, metacarpals, and phalanges of the manus, *rami of the lower jaw and maxillæ,* dorsal and caudal vertebræ, a pubic bone, ischia, ilia, chevron bones, and numerous teeth, as well as other remains *probably* referable to the same species.' Whether the upper and lower jaws described by Mr. Lambe belonged to one individual has never been stated. The remains of the associated individual are then described and measured, and the descriptions of the femur, tibia, jaws, and other referred specimens follow.

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[1]Ottawa Naturalist, vol. 28, April, 1914, p. 17, Pl. I.
[2]Contr. to Can. Pal., vol. 3, pt. II, 1902, p. 71.
[3]Bull. Am. Mus. of Nat. Hist., vol. 33, October, 1914, p. 559.
[4]Geol. Surv., Can., Mem. 120, 1920, p. 74, Fig. 39 H.
[5]Bull. Am. Mus. of Nat. Hist., vol. 3, pt. II, 1902, pp. 559-560.

"While the upper and lower jaws referred to *T. marginatus* may rank as paratypes, if they are associated, the species obviously rests primarily upon the 'remains of one individual'. The other specimens referred to are not cotypes, and the author is not at liberty to select any of them as a lectotype to the exclusion of his primary type. If the latter be indeterminate, valid generic characters may be drawn from the paratypes, and if they also be indeterminate, then from other specimens subsequently referred."

In 1916 Brown[1] calls attention to the fore limb of *Corythosaurus* as having the radius much longer than the humerus, and infers that Lamb was correct in his first reference of the front leg to the genus *Trachodon* in which the humerus is longer than the radius. In the table below I have compiled from several authorities the comparative lengths of the fore limb bones of various members of the Hadrosauridæ, and I find that all the crested forms in which the fore limb bones are known, except *Parasaurolophus,* have the radius longer than the humerus, whereas it is always shorter in the non-crested types. It would appear more than probable from this evidence that the fore limbs pertaining to the skulls referred to *Stephanosaurus,* when known, will have the limb proportions of the other crested hadrosaurs. Brown may have erred in considering Lambe's original reference of the limb to the genus *Trachodon* correct, but he certainly was right in believing it did not pertain to a helmet-crested form.

Comparative Measurements of Hadrosaurian Fore Limbs

Name	Length of humerus	Length of radius	Length of ulna
	Mm.	Mm.	Mm.
Stephanosaurus marginatus Lambe, type	683	632	708
Kritosaurus incurvimanus Parks, type	630	555	610
?*Trachodon mirabilis* (Cope)	501	440	500
Parasaurolophus walkeri Parks, type	520	496	560
Hypacrosaurus altispinus Brown, paratype	580	700	750
Saurolophus osborni Brown	610	620	680
Corythosaurus casuarius Brown, type	"Radius much longer than humerus", Brown		

The elimination of the fore limb and associated bones of the "single individual" (No. 419, Geol. Surv., Can.) from further consideration as pertaining to a helmet-crested hadrosaur, leaves the evidence for the genus *Stephanosaurus* as used by Lambe resting upon the maxilla and dentary which were subsequently selected by him as being characteristic of that genus and species. An examination of these specimens shows that they did not pertain to the same individual. Both were labelled as coming from the west side of Red Deer river, 1½ miles below the mouth of Berry creek, but the maxilla was collected August 1, 1898, whereas the dentary was not discovered until August 19 of the same year. The difference in the date of collection, coupled with the fact of their having been assigned separate catalogue numbers by Mr. Lambe, implies their distinctness as to individuals.

[1]Bull. Am. Mus. Nat. Hist., vol. 35, Nov. 2, 1916, p. 710.

A careful comparison of the maxilla with those of the two crested skulls referred by Lambe to *Stephanosaurus* discloses structural differences important enough to show that they pertain not only to distinct genera but to distinct sub-families. The maxilla in its large size, massiveness, more robust teeth, greater horizontal distance between forward end of jugal articulation and border of infraorbital foramen, and more massive and bluntly truncated anterior extremity, agrees so closely with the maxilla of the type specimen of *Kritosaurus notabilis* (Lambe) that I have little hesitation in referring it to that genus. These differences and resemblances in the compared maxillæ are graphically shown in the following table:

Comparative Measurements of Maxillæ

	Referred *Kritosaurus maxilla*, No. 362, G.S.C.	*Kritosaurus notabilis*, type, No. 2278, G.S.C.	Referred *Stephanosaurus* skull, No. 2869, G.S.C.	Referred *Stephanosaurus* skull, No. 351, G.S.C.
	Mm.	Mm.[1]	Mm.	Mm.
Greatest length of maxillary..........	360	395	286	325
Length of dental series................	316	....	252	290−
Distance between anterior end of jugal and infraorbital foramen............	65	80	20	30
Horizontal distance between border of infraorbital foramen and anterior tip of maxillary..........................	90	100	105	125

The identification of the maxillary with the genus *Kritosaurus* leaves only the left dentary of the typical specimens of the genus *Stephanosaurus* to be considered. Comparison of the dentaries of the referred skulls with this bone shows several important differences, although the damaged condition of the anterior edentulous and symphysial portions of the typical dentary renders close comparisons exceedingly difficult. Lambe has given a very complete description[2] of this bone, but failed to point out its imperfections, many of which are not indicated in the illustrations. The coronoid process is shown too erect and too long, possibly because there is no bony connexion between the spatulate top and the basal portion and the restored connexion has been unduly lengthened. The preparator has also erred in the angulation of this process in relation to the main body of the bone, in directing it outward at the top at too great an angle away from the dental series. In the original illustrations the front of the dental magazine is correctly shown as missing, but the edentulous border in front of the teeth and much of the symphysial border are lacking. Were these borders present the contours would obviously be very unlike the narrow pointed extremity shown in Lambe's figures. It is also obvious that the edentulous portion of this bone is considerably more elongate and narrowly truncate than in either of the dentaries belonging to the skulls which Lambe referred to *Stephanosaurus*. Attention should also be drawn to

[1]Estimated.
[2]Contr. to Can. Pal., vol. 3, pt. II, 1903, pp. 73, 74, Pl. III, fig. 1, and Pl. IV, fig. 1.

the diseased condition of this bone at the centre of the dental magazine. An injury in life has caused a swelling of the bone on the external side and development of a deep pit without tooth rows forward of the centre of the tooth series. That this injury altered the normal proportions of the edentulous portion is, of course, very improbable.

Comparative Measurements of Dentaries

	Paratype? of *Stephanosaurus marginatus*, No. 361, G.S.C.	Skull first referred to *S. marginatus*, No. 351, G.S.C.	Skull last referred to *S. marginatus*, No. 2869, G.S.C.
	Mm.	Mm.	Mm.
Length of dentary from posterior tooth to tip	489	432	400
Length of dental magazine	320+	315	272
Length from most anterior dental foramen to tip of dentary	172	133+	140
Length (longitudinally) of 10 tooth rows, 12 to 21 inclusive	81	85	84
Average length of nonfunctional teeth in above rows	28	35	36
Number of vertical tooth rows in dentary	45 or 46	40	41

Examination of the above comparative table demonstrates conclusively that the dentary included by Lambe in the description of *Stephanosaurus* (*Trachodon*) *marginatus* pertains to a different animal than do the dentaries belonging to the subsequently referred skulls. That the fundamental differences observed are outside the range of variation within a species appears to be shown by the close agreement of the two referred specimens that represent individuals of somewhat different age and size, but agree so closely in their important details as to leave no doubt that they belong to the same genus and species. The greater number of vertical tooth rows; the shorter and narrower proportions of the individual nonfunctional teeth; the longer, narrower, and apparently less abruptly decurved edentulous-symphysial portion of the typical dentary are features that together appear sufficient to indicate its distinctness from those specimens subsequently referred to it.

This critical examination of the type materials of *Stephanosaurus* (*Trachodon*) *marginatus* Lambe, may now be summed up as follows: The "remains of one individual" is, I believe, determinate, and, therefore, obviously remains the primary type. The proportions of the fore limb bones show that it cannot pertain to the Lambeosaurinæ. The maxilla, which could only by the most liberal interpretation be considered a paratype, is also excluded from that sub-family. Likewise, the dentary is shown to be in all probability generically and specifically distinct from the subsequently referred skulls, which clearly pertain to the Lambeosaurinæ. The question now arises, can the remains of "one individual" which consist, as originally enumerated by Lambe[1], of the "humerus, ulna, and radius of the left fore limb, a metatarsal and phalanges of the pes, the

[1]Op. cit., 1902, p. 71.

zygapophyses of cervical vertebræ, ribs, fragments of teeth, broken ossified tendons and impressions of the integument", be identified with one or another of the described hadrosaurian genera from the Belly River formation? The possibility of these remains belonging to a crested form of the Hadrosauridæ has been fully discussed, and I believe it to be most improbable. There remain only the non-crested or flat-headed members of the subfamily Hadrosaurinæ to be considered. In this group is found only one genus, *Gryposaurus,* that occurs in the Belly River formation.

This genus, described by Lambe[1] in 1914, is considered by Brown[2] to be congeneric with *Kritosaurus,* a point of view in which he has been followed by Gilmore[3] and Parks[4]. Certainly generic distinctions have not yet been pointed out, and *Kritosaurus* having priority by several years, that generic name will be used. At this time three species, *Kritosaurus navajovius* Brown, *K. notabilis* (Lambe), and *K. incurvimanus* Parks, are recognized as pertaining to this genus.

We are now concerned with the two last-named species since the type of *K. navajovius* Brown comes from the distant Ojo Alamo formation in New Mexico. The specific distinctness of *K. incurvimanus* from *K. notabilis* appears to rest upon a very insecure foundation and possibly future discoveries may show them to be cospecific. Parks in the above cited publication (1920, p. 34) has called attention to the close similarities of the humeri of the types of *Stephanosaurus* and *Kritosaurus,* regarding which he says: "The figure given by Lambe for the humerus of *Stephanosaurus marginatus* might serve to illustrate the present species except for some details of measurement". Likewise the radius and ulna of *Stephanosaurus marginatus,* except for their slightly larger size, appear indistinguishable from those of *K. incurvimanus.* In the light of our present knowledge of the Belly River fauna there appears no reason why *Stephanosaurus* and *Kritosaurus* should not be considered congeneric, and since *Kritosaurus* (1910) has priority, *Stephanosaurus* (1914) becomes a synonym.

Could it be shown that Lambe's type of *marginatus* is cospecific with either *K. notabilis* (Lambe) or *K. incurvimanus* Parks it would as a matter of course supersede either species name, over which it has clear priority. Its larger size would suggest affinities with the former species rather than with *K. incurvimanus.* At present, however, I see no way to definitely determine this point, and while awaiting preparation of the remainder of the type materials of *Kritosaurus notabilis* (Lambe), it appears best to retain the name as a distinct species to be called *Kritosaurus marginatus* (Lambe).

It having now been shown that *Stephanosaurus* is invalid, the subfamily name Stephanosaurinæ disappears, for according to nomenclatural usage a family or sub-family name must be derived from an included genus. Parks has proposed the sub-family name Lambeosaurinæ to replace it. (*See* University of Toronto Studies, No. 15, 1923, p. 8.)

If correct in the preceding deductions the two skulls referred by Lambe to *Stephanosaurus* are now without generic and specific designation. A name, however, has been given them by Prof. W. A. Parks of the University of Toronto from whom it was learned shortly before the completion

[1]Ottawa Naturalist, vol. 27, 1914, pp. 145–149, Pl. XVIII.
[2]Bull. Geol. Soc. Am., vol. 25, Sept., 1914, p. 380.
[3]Prof. Paper 98 Q, U. S. Geol. Surv., 1916, p. 283.
[4]University of Toronto Studies, No. 11, 1920, p. 8.

of the present manuscript that independently he had arrived at the same conclusion, and in an article then submitted for publication had proposed the name *Lambeosaurus lambei* for the reception of the referred skulls. The better preserved specimen, No. 2869, Geol. Surv., Can., had been selected by him as the type of this new genus and species. Since the discussion by Parks obviously rests on information largely gleaned from the literature, the present more detailed and critical study of the typical specimens, together with a complete description of the type of *Lambeosaurus*, appears worthy of publication with but little change from the form in which it was originally prepared.

In view of the several nomenclatural changes proposed in the present paper a list of the recognized genera and species of Canadian hadrosaurian dinosauria is appended in order to show their assignment in the classification of the Hadrosauridæ as here adopted.

Family, HADROSAURIDÆ[1] Cope, 1869

Sub-family, *Hadrosaurinæ* Lambe, 1918

Belly River Formation

Kritosaurus marginatus (Lambe), 1902
" *notabilis* (Lambe), 1914
" *incurvimanus* Parks, 1919

Edmonton Formation

Edmontosaurus regalis Lambe, 1917
Thespesius edmontoni Gilmore, 1923

Sub-family, *Saurolophinæ* Brown, 1914

Belly River Formation

Prosaurolophus maximus Brown, 1916

Edmonton Formation

Saurolophus osborni Brown, 1912

Sub-family, *Lambeosaurinæ* Parks, 1923

Belly River Formation

Corythosaurus casuarius Brown, 1914
" *excavatus* Gilmore, 1923
" *intermedius* Parks, 1923
Lambeosaurus lambei Parks, 1923
Parasaurolophus walkeri Parks, 1922

Edmonton Formation

Hypacrosaurus altispinus Brown, 1913
Cheneosaurus tolmanensis Lambe, 1917

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[1] The family name Hadrosauridæ was not proposed by Lambe, as Parks has inferred (Toronto Univ. Studies, No. 11, 1920, p. 8), but by Cope, and as shown by Lambe (Ottawa Naturalist, vol. 33, 1918, p. 137), clearly has priority over Trachodontidæ of Lydekker, 1888. Since at this time it is impossible to determine whether the genus *Trachodon* belongs to the crested or non-crested forms, I see no good reason for the proposed retention of the sub-family name Trachodontinæ (Brown, 1914) instead of Hadrosaurinæ (Lambe, 1918), which in all probability, as shown by the non-footed ischium, is a non-crested form.

DESCRIPTION OF THE TYPE OF LAMBEOSAURUS

Lambeosaurus lambei Parks

PLATES VI, VII, VIII, AND IX

Stephanosaurus marginatus, Lambe, L. M., Ottawa Naturalist, vol. 28, April, 1914, pp. 17–20, Pl. I (in part): Geol. Surv., Can., Mem. 120, 1920, pp. 68, 74 to 76, Fig. 39 H (in part).

Lambeosaurus lambei Parks. University of Toronto Studies, No. 15, 1923, p. 7.

Type: No. 2869, Geol. Surv., Can., consists of a fairly complete skull and right ramus. Collected by C. M. Sternberg, 1917.

Locality: 4 miles southwest of the mouth of Little Sandhill creek, Red Deer river, Alberta, 100 feet below contact with the Pierre.

Referred Specimens: 351, Geol. Surv., Can., consists of the left half of skull, both dentaries and predentary, both femora, both tibiæ, one fibula, both ischia, and 5 metatarsals. Collected by C. H. Sternberg, 1913.

Locality: Sec. 20, tp. 21, range 11, W. 4th mer., 3½ miles southwest of the mouth of Berry creek, Red Deer river, Alberta.

No. 8503: Geol. Surv., Can., consists of the nearly complete skull with much of the skeleton. Only the skull has been prepared at this time. Collected by C. M. Sternberg, 1917.

Locality: Sec. 25, tp. 20, range 11, W. 4th mer., 3½ miles west of south of Little Sandhill creek, Red Deer river, Alberta.

Horizon: All three specimens from the Belly River formation, Upper Cretaceous.

Generic and Specific Characters: Skull comparatively short, with a high, narrow crest bearing a long, narrow, posterior prolongation that overhangs the occiput, both crest and prolongation being formed by the premaxillaries and nasals. Highest point of crest falling in front of orbit. Premaxillaries extending to extreme posterior tip of crest. Beak narrow, nares in beak open. Maxillæ very short between anterior jugal articulation and entrance to infraorbital foramen, 38–39 vertical rows of teeth. Lachrymal greatly reduced. Quadrate relatively short. Mandible strongly decurved in front. Dentary with 40 to 41 vertical rows of teeth. Teeth long and relatively narrow, borders papillate.

Description

The specimen selected as the type of *Lambeosaurus lambei* has been described[1] to some extent by Lambe, but it seems desirable that these descriptions should now be somewhat elaborated and revised in order to incorporate in this one article all information concerning this highly interesting reptile. I shall, however, whenever possible, quote directly and fully from Lambe's descriptions, though reserving the right to change the order in which they were arranged in the original articles. Reference is occasionally made to other individuals when important structural details or modifications are displayed, but the description, as far as possible, is based entirely on the better preserved type specimen (No. 2869, Geol. Surv., Can.).

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[1] Ottawa Naturalist, vol. 28, April, 1914, pp. 17–20, Pl. I; Geol. Surv., Can., Mem. 120, 1920, pp. 74–75, text fig. 39 H.

"In *Stephanosaurus* [*Lambeosaurus*] the top of the skull bears a high hood or crest, narrow from front to back, and laterally compressed, from whose posterior base there is a comparatively slender backward prolongation forming a process which reaches far beyond the occiput at a considerable distance above the level of the parieto-squamosal bar. The crest with its posterior extension is made up of the premaxillary and nasal bones. The inferior portion of the premaxillaries is greatly expanded posteriorly to form the central, lower part of the crest proper on either side. [In this respect it approaches the crest of *Hypacrosaurus*]. Superiorly the premaxillaries form the whole of the crest above, rising vertically in front and descending as steeply behind, thence continuing backward to take part in the formation of the posterior process. The nasals extend obliquely upward and forward from in advance of the small frontals and appear externally in the crest between the broad hinder termination of the inferior part of the premaxillaries (which cannot properly be referred to as a *lower limb* of the premaxillary) and the posterior descending portion of the premaxillaries above. They also extend narrowly backward beyond the frontals as part of the crest prolongation constituting the lower surface of the process, embracing the premaxillaries from below, and more posteriorly enveloping them externally also. In the back part of the crest, therefore, and in the crest-prolongation, the premaxillaries are between the nasals, that is along the whole of the latter's length. A long, narrow vacuity in the crest occurs between the nasals and the lower premaxillary expansion."

This vacuity is even more pronounced in specimen No. 351, Geol. Surv., Can. (Plate VII). A somewhat similar opening is found in the skull of *Corythosaurus excavatus* Gilmore, in the University of Alberta collections (Can. Field Naturalist, vol. 37, No. 3, 1923, Fig. 1), but in that specimen it is confluent with the more anterior horizontal vacuity, developed as in *Corythosaurus casuarius* Brown.

"The depth of the skull above its midlength is equal to its total length. Viewing the skull from the side, the facial outline is sigmoid, at first concave, ascending rapidly from the front until it is vertical, whence it continues upward and reaches a point directly above by an even convex curve.

"A broad, shallow groove runs obliquely upward and slightly backward across the lower portion of the premaxillary a short distance in advance of the anterior end of the jugal. [A similar groove is also present in *Corythosaurus*, *Hypacrosaurus*, and *Cheneosaurus*.] This groove was considered to mark the back termination of the lower part of the premaxillary ("lower limb of the premaxilla") in the original description of the skull of *Stephanosaurus*. What was then named prefrontal is now clearly seen to be the greatly expanded postero-inferior part of the premaxillary as the structure of the bone is continuous across the groove."

The frontal, as Lambe has pointed out, is excluded from the orbital rim by the prefrontal and postorbital, and this is true of all members of the Lambeosaurinæ. It lies almost entirely under the anterior, lower surface of the posteriorly directed naso-premaxillary process. The frontals are very much reduced in size, being wider than long, with a deep vertical suture at their anterior ends for union with the nasals and prefrontals, as shown in a fragmentary specimen, No. 8502. This vertical sutural surface has a greatest depth that is nearly equal to one and one-half times the greatest length of the frontal bones.

This fragmentary specimen, as I have determined by comparison, pertains to the genus *Lambeosaurus,* and consists of the greater part of the parietals, complete frontals, postorbital, and part of the alisphenoid, the latter of the right side. It displays for the first time in the sub-family Lambeosaurinæ, the strong-grooved sutural surfaces (*See* Figure 8 A, *Nas*) for the anchorage of the nasals, which in these crested forms have assumed such fantastic and unusual proportions. The great vertical depth of this contact is most striking. Viewed from above it is a straight, transverse suture that is in line with the prefrontal-postorbital suture. The fronto-parietal suture, as shown in Figure 8, runs inward and slightly backward from their lateral borders and at the centre sends forward a loop that separates the frontals on the median line for one-half their total length, much as in *Troödon* (*Stegoceras*) *validus.* The forward extent of this loop on the ventral side, however, is much abbreviated.

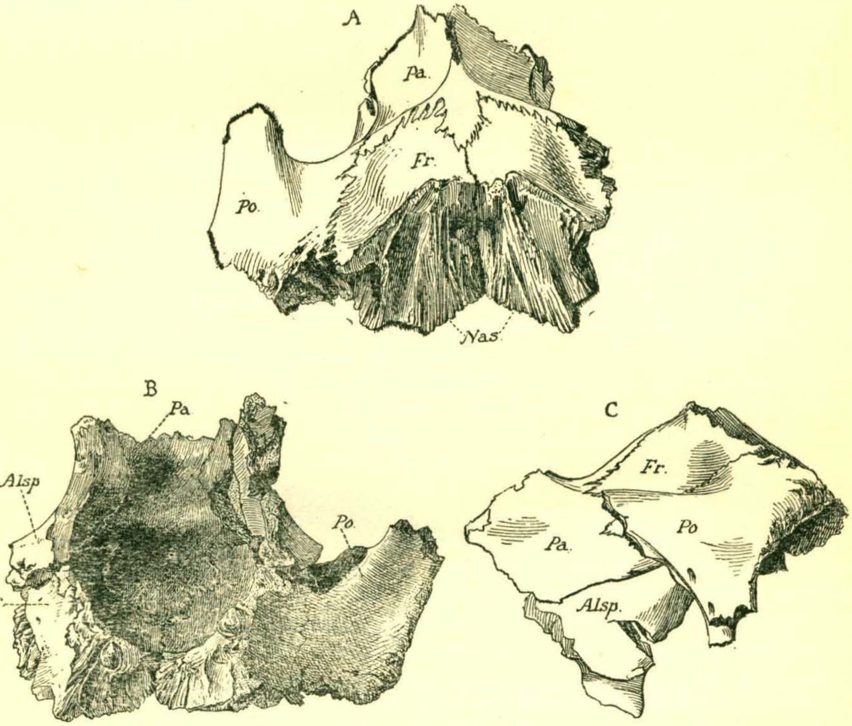

Figure 8. Brain case of *Lambeosaurus* sp. No. 8502, Geol. Surv., Can. *A*, Oblique superior view; *B*, Inferior view; *C*, lateral view. *alsp.*, alisphenoid; *fr*, frontals; *nas*, nasal suture; *pa*, parietal; *po*, postorbitals. One-half natural size.

The ventral view (Figure 8 B) of this cranial fragment shows the very short, broad cerebral expansion of the brain, a peculiarity of the crested hadrosaurs that is strikingly different from the elongated compressed cerebrum of *Edmontosaurus* or *Thespesius annectens* as figured by Marsh.

The prefrontal is a triangular bone that forms the orbital rim between the lachrymal in front and the postorbital behind. Internally it unites strongly with the frontal and the nasal as shown in Figure 8 A. The postorbital, called the postfrontal by Lambe, Brown, and others, may possibly represent a complex of the two elements, as in the theropodous dinosaurs. The alisphenoid, however, abuts against it internally, and from an examination of detached hadrosaurian postorbital bones, a cupped depression or pit is found for the articulation of this end of the alisphenoid. In those dinosaurian skulls in which prefrontal, postfrontal, and postorbital bones remain distinct this cupped depression is always on the postorbital and for that reason, and also because the supratemporal arcade in the reptilia is usually formed by the united processes of the postorbital and squamosal bones, it would appear more proper to identify this element as the postorbital. It unites anteriorly above the orbit with the prefrontal, internally

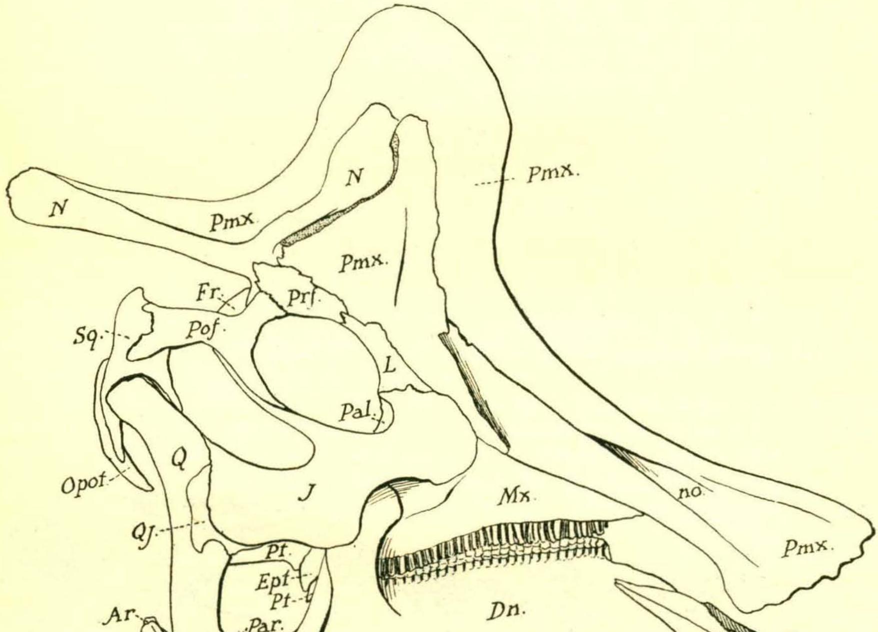

Figure 9. Skull of *Lambeosaurus lambei* Parks. Type, No. 2869, Geol. Surv., Can. Viewed from the right side. *Ar*, articular; *Dn*, dentary; *Ept*, ectopterygoid; *Fr*, frontal; *J*, jugal; *L*, lachrymal; *Mx*, maxillary; *N*, nasal; *No*, external nares; *Opot*, paraoccipital process; *Pd*, predentary; *Pal*, palatine; *Pmx*, premaxillary; *Par*, prearticular; *Pof*, postorbital; *Prf*, prefrontal; *Pt*, pterygoid; *Q*, quadrate; *Qj*, quadratojugal; *Sa*, surangular; *Sq*, squamosal. About one-seventh natural size.

with the frontal, and slightly with the parietal, but sufficiently to exclude fully the frontal from participation in the anterior boundary of the supratemporal fossa. The posteriorly directed branch meets the squamosal, forming the relatively wide supratemporal bar. The posterior widely bifurcated end strongly overlaps the ascending process of the jugal by a long squamous suture to form the relatively slender postorbital bar.

From a lateral aspect the squamosal presents a very wide surface between its upper border and the top of the excavation or cotylus for the head of the quadrate, and a comparison with other known skulls shows that this is a peculiarity of all members of the Lambeosaurinæ. In this sub-family, when the skull is viewed from the side with the tooth rows in an horizontal position, the top of the infratemporal opening extends above the proximal end of the quadrate, whereas in the Hadrosaurinæ and Saurolophinæ it is on the same level or below. The cotylus for the head of the quadrate is deep, with a pointed process of moderate length extending down in front of the quadrate, and a longer and more robust process at the rear. The latter is applied to the outer anterior surface of the paraoccipital process in the usual way. Internally, the squamosals meet narrowly on the median line behind the thickened posterior crest of the parietal, to which they are closely joined.

The parietals are much constricted between the supratemporal fossæ, and present at the centre a high, thin median crest which at the posterior end rises to the height of the superior squamosal border, where it suddenly widens out and is extensively joined with the squamosals laterally. At the centre on the anterior end the parietal sends forward a tongue of bone that separates the frontals on the median line for fully one-half their total length. Ventrally, within the supratemporal fossæ, they join the alisphenoid and presumably the proötic bones by a nearly horizontal suture (Figure 8 C).

"The orbital opening is narrowly elliptical, with its longer diameter directed obliquely downward and forward. It is more than twice as long as wide. The lateral temporal fossa is larger than the orbit, and is also longer than wide with a similar obliquity of length."

The quadrate, as in all the Lambeosaurinæ, is relatively short, but presents no other unusual features.

The quadratojugal appears distinctive in having its inferior border concavely notched. That this is not a feature of the individual is shown by the presence of a similar notch in this bone in a third specimen, No. 8502, in the collections of the Geological Survey, Canada. This border in specimen No. 351 is missing.

The jugal shows no specially distinctive features. The lachrymal is very greatly reduced as in all the members of this sub-family. It is especially long and attenuated, measuring 133 mm. in length. It barely separates the forward end of the jugal from being directly in contact with the premaxillary. Within the border of the orbit it is perforated by a large lachrymal foramen. The lachrymal forms the greater part of the anterior border of the orbital rim.

The maxilla is relatively small and slender and contains 39 vertical rows of teeth. It is slightly less than two times as long as high. On the side of the maxillary below its union with the jugal there are five foramina in a line, the three median ones being of good size. In front of the jugal articulation the maxillary has an extensive union with the under surface of the premaxillary by a long but wide, thin, oblique process that strongly overhangs the internal side of the dental magazine. Between this process and the higher external maxillary process that passes up in front and behind the jugal is a large foramen which passes longitudinally through the bone and which appears to be comparable with the so-called infraorbital foramen in the Ceratopsia.[1] The distance forward from the jugal articulation to the lower border of this foramen forms an important character for distinguishing the Lambeosaurinæ from the other members of the Hadrosauridæ, inasmuch as the distance has been greatly shortened antero-posteriorly in all members of this sub-family, whereas it is relatively long in the Saurolophinæ and Hadrosaurinæ. The high external superior maxillary process mentioned above, passes up behind the jugal and is in contact with the lachrymal above.

In the type specimen parts of the right pterygoid, and nearly complete ectopterygoid, and palatine bones remain articulated with the maxillary of that side. The ectopterygoid (Plate VII) has its greatest length in an antero-posterior direction. It is thin, except at the anterior end where it thickens outwardly to abut against the inner lower surface of the jugal. This bone is closely applied to the inner and posterior-superior surface of the maxillary, having a long contact internally with the pterygoid and a short but heavier articulation with the palatine. The fragment of the palatine present rests upon the superior-anterior end of the ectopterygoid, with the greatest diameter of this piece transverse. The outer end is strongly in contact by a roughened expanded surface with the jugal, and its inner border meets the forwardly directed process of the pterygoid.

The pterygoid is seen to have the usual irregular form of this bone. It closely envelops the supero-internal and postero-internal surfaces of the ectopterygoid. A thin anteriorly directed process is in contact with the upper edge of the ectopterygoid and anteriorly with the fragmentary palatine. Posteriorly the pterygoid sends a broad, thin, nearly vertical wing-like process back to meet the quadrate. A shelf extending inward on the lower internal side makes its lower edge appear relatively wide.

The occipital region in all the skulls is so poorly preserved as to contribute but little to our knowledge of its structure. The right paraoccipital process in the type has a very broad, expanded, hatchet-shaped outer extremity, that, on its anterior face, broadly rests against the squamosal. The outer end is especially produced in a ventral direction ending in a flattened obtuse process that hangs far below the posterior process of the squamosal. This end of the paraoccipital has a greatest vertical diameter of 122 mm.

"Anteriorly the premaxilla is somewhat depressed, but laterally much expanded. Its upper surface, next to the median line of the head, is continued in a curve outward anteriorly and backward laterally as a marginal area enclosing a wide depression in advance of the long and narrow nasal opening." In the Lambeosaurinæ the external nares and nasal passages of the two sides are separated by the premaxillaries, the latter being enclosed outwardly by an upward growth of the floor of the passage and a downward bend of the roof of the same.

"In *Stephanosaurus* [*Lambeosaurus*] the nasal passages lead up into the front part of a large double chamber within the crest, the entry [apparently] being made at about the mid-height of the chamber on either side

[1] Mon. 49, U. S. Geol. Surv., 1907, *cf.* Figs. 20, 21, and 22, pp. 26, 27.

of a vertical median septum. This nasal chamber occupies the greater part of the crest within, is flanked outwardly by the premaxillary and nasal bones and is somewhat over 150 mm. in height, and narrow from side to side, with a fore-and-aft diameter about three-fifths the height. An exit from the chamber is indicated externally by the greater convexity of the crest laterally in an area surrounding the narrow central vacuity. The Stephanosaurinid form of the external nares of *Corythosaurus* and *Cheneosaurus* points to the presence of a nasal chamber in these genera also."

Beneath the above-described chamber, the palatal surface also arches upward and it appears very probable there may be openings through could the specimen be prepared sufficiently to show them.

A third specimen, No. 8503, in the Geological Survey collections, consisting of a considerable part of a skeleton of which only the skull has been prepared, is provisionally identified as belonging to this same species. The surfaces of the skull and especially of the crest are much abraded and eaten away, probably before entombment, and the posterior extension of the crest is missing. This skull is of interest in having, at the place where the elongated posterior extension would attach, a vertically elongated aperture that apparently leads into the nasal chamber described above, and it suggests the probability that this passage continued still farther backward within the posterior premaxillary extension.

I fail to detect any divisional septa, but may this air passage not be analogous to the "tube-like passages" described[1] by Parks in the posteriorly elongated crest of *Parasaurolophus?* It further suggests that the upper longitudinal half, at least, of the *Parasaurolophus* crest is composed entirely of the premaxillæ instead of being formed by the nasals as these bones were provisionally determined. After a study of the skulls of several crested hadrosaurian genera in the Canadian Geological Survey collections, it seems quite certain that the longitudinal half of the *Parasaurolophus* crest is composed of the nasals instead of the frontals, as tentatively identified by Professor Parks. Although *Parasaurolophus* has a remarkable development of the crest, in the lack of positive evidence, I see no reason for regarding it as fundamentally different in composition from those other members of the crested Hadrosauridæ in which the structure is now so fully known. In none of these forms do the frontals enter into the formation of the crest; rather, as has been shown, these bones are greatly shortened antero-posteriorly, and have their anterior ends specially modified by a deep vertical suture in order to give the necessary anchorage for the extensive premaxillary-nasal crest. Parks is certainly in error in regarding all the lateral area above and in front of the orbit as being composed of the frontal. If this were true the prefrontal has entirely disappeared and the lachrymal has assumed a position that has no parallel in the reptilia either recent or extinct. The element identified as lachrymal is surely the upper extremity of the superior maxillary process, and when other specimens are found in which the sutures can be seen, the lachrymal will undoubtedly be found occupying its proper position within the border of the orbit. The notching of the suture at the top of the jugal is exactly as it unites with the lachrymal in several other hadrosaurian crania.

[1] University of Toronto Studies, No. 13, 1922, pp. 10, 11.

So far as the skull structure is concerned, I see no reason for not regarding *Parasaurolophus* to be a true member of the Lambeosaurinæ. In fact the whole skeletal structure, except the relative proportions of the fore limb bones, is in accord with such an assignment. The short skull (exclusive of crest), strongly decurved edentulous portion of the mandible, short quadrate, and roofed narial passages are typical Lambeosaurid features, and strikingly unlike the high, long-headed, long-beaked skulls of the Saurolophinæ to which it was originally assigned. In view of these facts I now propose its removal to the sub-family Lambeosaurinæ.

Brain Case

"In the brain-case of the skull *Stephanosaurus* [*Lambeosaurus*] type the sutures can be readily traced between the presphenoid and orbitosphenoid and between the orbitosphenoid and alisphenoid. Also the suture between the alisphenoid and the basisphenoid is preserved, proving by its position that the large flange, directed outward from above and somewhat behind the basisphenoid process, belongs to and is part of the basisphenoid. It may be of interest, also, to note that in this skull the ophthalmic branch of the trigeminal nerve (V) is enclosed in bone in its forward course and does not occupy an open channel as it appears to do in *Edmontosaurus*. Further, indicating an unusually perfect preservation of structural detail, the separation of the fenestra rotunda from the fenestra ovalis by an horizontal bar of bone is excellently shown."

The proötic, which is always pierced by foramen VII for the exit of the facial nerve, may also be partly differentiated. The suture between it and the opisthotic may be traced from the fenestra ovalis as running slightly upward, outward, and backward and thence turning forward and upward to the nearly horizontal parietal contact. The foramen ovale (V) is especially large, and it is quite apparent that its boundaries lie largely within the proötic, the alisphenoid forming only the anterior boundary, as in *Saurolophus*, *Camptosaurus*, and the dinosauria generally.

Mandible

The complete lower mandible in *Lambeosaurus lambei* consists of the dentary, surangular, angular, articular, prearticular, which are all paired bones, and the single predentary. These are all present in the type, (Plate VI), and in a beautiful state of preservation. The splenial appears to be absent in all members of the Hadrosauridæ. The element which has been identified by Lambe and others as splenial is the prearticular. It borders as usual the upper inner margin of the posterior meckelian fossa, is in contact posteriorly with the articular, and continues forward as a nearly vertical plate to meet the dentary. At the anterior end it curves outwardly over the pointed supero-internal termination of the dentary behind the magazine, and continues forward as a rapidly narrowing process that ends in a point beneath the hindermost part of the dental magazine. The tip of this bone is missing in the type, but is present in other specimens in the collection. It is in contact inferiorly with the angular for practically its entire length. It will be noted from the above description that this bone fulfils all the requirements of the prearticular as to position and relationship with adjacent bones, for it is found not only in the primitive reptilian jaw, but also in numerous members of the dinosauria, notably the Camptosauridæ, Stegosauridæ, and Ceratopsidæ. So far as I am able to determine, the splenial has never been found in any reptile, recent or extinct, in contact with the articular, nor has it ever been known to occupy such a posterior position in the ramus as is necessary if the earlier identification of this bone should prevail. Since this and other rami before me show the angular and prearticular forming the covering for the greater part of Meckel's groove, with no trace forward of another element, it would seem that the splenial has disappeared in the Hadrosauridæ. However, should it later be found to be present, it can exist only as a very small elongated bone that would be invisible from a lateral aspect.

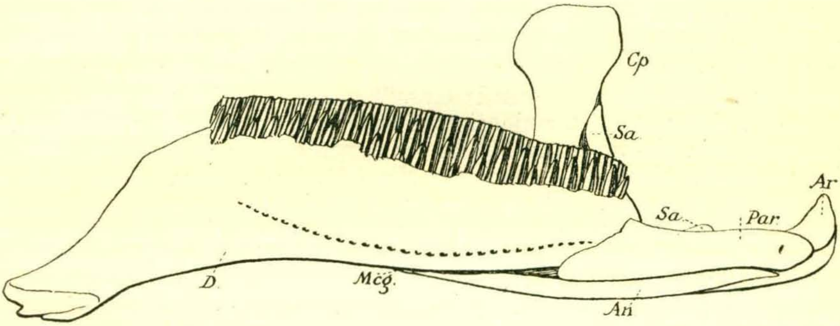

Figure 10. Right ramus of *Lambeosaurus lambei*. Type, No. 2869, Geol. Surv., Can. Internal view. *ar*, articular; *an*, angular; *cp*, coronoid process; *d*, dentary; *par*, prearticular; *sa*, surangular; *Mcg*, Meckel's groove. About one-fifth natural size.

The angular is a long, narrow, and thin bone that is closely applied internally to the surangular and dentary, and superiorly with the prearticular. Its posterior end is pointed and falls considerably short of reaching the end of the surangular. Its forward elongate extremity is missing in this specimen, but judging from the width of the broken end and the continuation of the flattened surface on the lower border of Meckel's groove, the complete anterior termination would be, as in *Edmontosaurus*, at a point below the mid-length of the dental magazine.

The articular is imperfect, but enough of this element is present to show it to be a thin flattened bone that was vertically intercalated between the prearticular and surangular, as shown in Figure 9. The upper border is thickened transversely and shallowly concave antero-posteriorly in conformity with the contiguous surface of the surangular. Its posterior border extends to the extremity of the surangular.

The surangular is relatively more slender throughout than in the more robust *Hypacrosaurus altispinus*, but otherwise there is a remarkably close similarity in shape and method of articulation with the dentary and the other bones of the inner side of the ramus. The vertical process articulates with the inner posterior side of the coronoid process and has a height over all of 136 mm. The upper surface has a shallow cotylus, the principal articulation of the quadrate, the remaining part being furnished by the much reduced articular. Behind the quadrate articulation the surangular is thinly compressed transversely, with an upwardly turned hook at the extreme posterior end. Antero-posteriorly the surangular has a greatest length over all of about 185 mm.

The dentary is comparatively narrow vertically, with a short edentulous border that is abruptly decurved in front. It is deeply excavated posteriorly by the mandibular fossa. This fossa is confluent in front with the rapidly diminishing Meckelian groove, which extends forward intero-inferiorly on the inner face of the dentary to about the middle of its length, whence it passes more to the ventral surface of the bone, but continues nearly or quite to the symphysis as a very shallow, ill-defined channel. The symphysial border is relatively short, measuring 70 mm. in a fore-and-aft direction. The coronoid is of moderate size and comparatively short. The dentary at this point has a greatest height over all of 184 mm. On the posterior end of the dentary, extending backward from the base of the dental magazine, is a transversely flattened but pointed process that laps a thin vertical process from the superior surface of the surangular. Internally this dentary process is closely overlapped by the prearticular. The broad, thin ventral termination of the dentary strongly underlaps the surangular in the usual manner. In the type dentary there are 41 vertical series of teeth, whereas in specimen No. 351, Geol. Surv., Can., only 40 rows can be detected. These occupy a longitudinal space 315 mm. in length. At the base of each row is the usual foramen, these being arranged in a curved row following the contour of the lower border of the magazine.

The predentary is present in all three skulls now before me, but in none is this bone perfectly preserved. Its form and principal characters are well shown in Figure 11. The predentary in *Lambeosaurus* is a broad U-shaped bone, truncated in front, with two pointed posteriorly directed processes that loosely articulate on the inferior side with the decurved edentulous portions of the dentaries. Viewed from above, a thin but high longitudinal ridge is developed on the inner superior surface of these processes, forming a sharp cutting edge. The horny coverings which in life enveloped the expanded premaxillaries and predentary were probably nicely adjusted to one another, forming an efficient cropping organ for procuring food. Superiorly the broad beak portion of the predentary is shallowly concave from side to side, with the front edge curving slightly upward and to an obtuse edge. This edge, in the type, is formed of scalloped bony tooth-like projections, which at their bases have the bone perforated by foramen-like holes arranged in a transverse row.

The predentary is wider than the expanded premaxillaries, but does not extend as far forward as those elements. On the median postero-inferior surface there is a broad bifurcated process which receives the symphysial ends of the dentaries. Each dentary is underlapped by a posteriorly directed branch of this process, as shown in Figure 11 A. Above, at the centre of the predentary, is a sharp longitudinal ridge that is extended backward as a pointed projecting process, which overlaps the median symphysial junction of the two dentaries. There is no bony separation of the predentary interposed between these symphysial borders of the dentary and they have a direct ligamentous union.

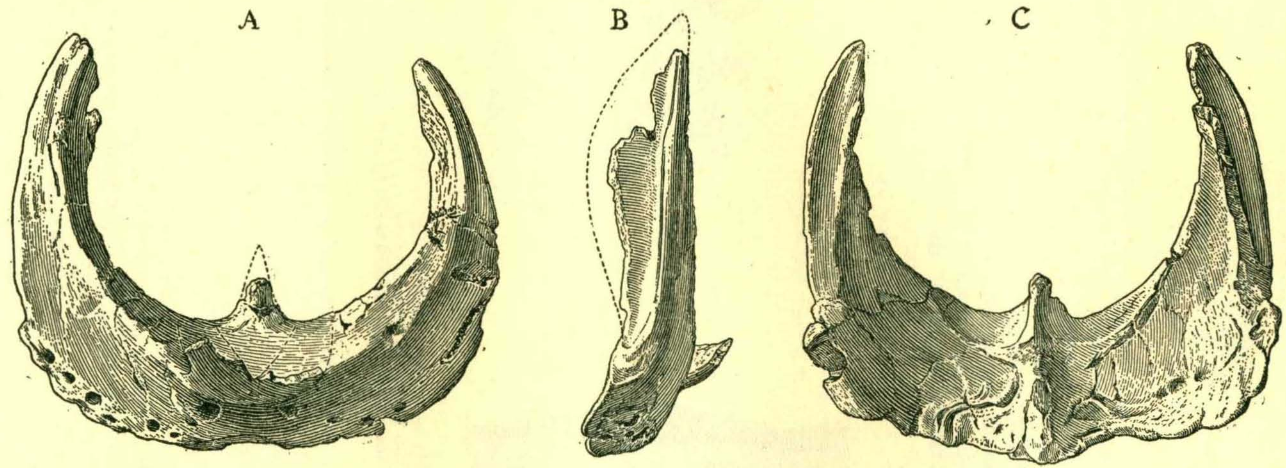

Figure 11. Predentary of *Lambeosaurus lambei* Parks. No. 351, Geol. Surv., Can. *A*, ventral view; *B*, lateral view; *C*, superior view. Restored portions based on the predentary of the type specimen. One-third natural size.

Measurements	No. 2869 Mm.	No. 351 Mm.
Greatest transverse width of predentary	158	190
" length antero-posteriorly	160	170
" length at centre, lacking median process	52	62

Teeth

The teeth in both the dentary and maxillary series are arranged in vertical and horizontal series as in all the known Hadrosauridæ. Both upper and lower teeth are largest in the middle of the dental magazines and decrease in size toward either end, but more especially at the anterior extremity. The lower anterior teeth of the dentary also have the most pronounced papillation of the entire series, and are especially reduced in width. This feature is not so pronounced apparently in the maxillary series. The nonfunctional teeth in the dentary may be described as

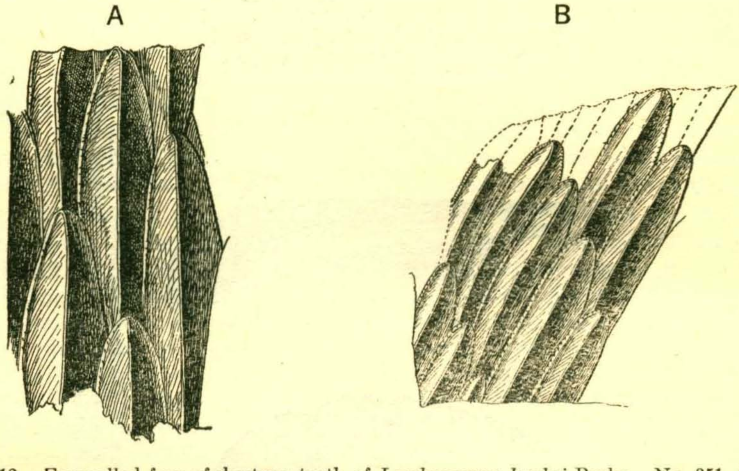

Figure 12. Enamelled face of dentary teeth of *Lambeosaurus lambei* Parks. No. 351, Geol. Surv., Can. *A*, taken from the twentieth to twenty-second vertical series from the front of the right dentary; *B*, taken from the first to fifth vertical series from the front of same. Natural size.

lozenge-shaped, rather acutely rounded above and apparently pointed below. There is no evidence of the lower ends being emarginated as Lambe has found them in *Edmontosaurus*. The upper tip of the next lower tooth in the series overlaps the base of the one above, shinglewise, and nowhere do I find evidence of a notch. All the teeth have high, broad-based, sharp-edged, median keels that traverse the greater part of their length, subsiding, however, before reaching the lower end and thus producing a smooth surface for the overlap of the succeeding tooth. There is a slight elevation of the margins, especially on the upper half of the anterior side. The enamelled surfaces of the dentary teeth do not lie flat in relation to the longer axis of the jaw, but are slightly oblique with the edge toward the front, standing out more prominently than the posterior border. A majority of the teeth, especially of the posterior half, have smooth margins, becoming progressively more and more papillate toward the front of the jaw. The first five or six rows are prominently ornamented (Figure 12 B). Although they cannot be actually counted, because of the overlying sheet of bone, it is quite apparent that there could not be more than three fully developed teeth in any one vertical series. On the cutting edge there are usually three teeth of the same vertical series present in various stages of wear, rarely four. In the maxillary, there are one and two, alternating, and rarely, if at all, there are three. Toward the ends these numbers are reduced to two and then one. The enamel faces of the nonfunctional teeth of the dentary have a vertical diameter nearly three and one-half times their greatest breadth. In this as in many other respects they are very close to the teeth of the helmet-crested *Hypacrosaurus* from the Edmonton. So far as known it appears that all members of the Lambeosaurinæ have the teeth relatively long in relation to their breadth, and that in *Cheneosaurus* they have reached their maximum specialization in this respect. They certainly furnish a striking contrast to the short, somewhat diamond-shaped, teeth of *Thespesius annectens* (Marsh).

The maxillary has 39 vertical rows of teeth in its magazine, and the median keel appears to be relatively higher at the basal portion than in the dentary series. The outer enamelled faces of the 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 protrudent teeth are seen, very narrow, and the fully functional ones very wide.

Comparative Measurements of Skulls

Skull	*Lambeosaurus lambei*, No. 2869, G.S.C.	*Lambeosaurus lambei*, No. 351, G.S.C.	*Lambeosaurus lambei*, No. 8502, G.S.C.
	Mm.	Mm.	Mm.
Greatest length between perpendiculars	693	....	....
Greatest length from tip of beak to terminal end of crest	822	....	....
Greatest length from tip of beak to posterior border of squamosal	691	777	600
Greatest depth, top of crest to lower border of dentary	610	660	478
Greatest height of crest above orbital rim	302	307	193
Greatest width of premaxillaries at beak	136	180	100[1]
" length of quadrate	251	292	225
" " maxilla	284	330[1]	....
" " dental series	253	300[1]	....
Number of vertical rows of teeth in maxillary	40	....	....
Lower Jaw			
Greatest length over all with predentary	565	654[1]	495
" " of dentary	440	470[1]	373
" " from last tooth to tip, anterior edentulous portion	165	165	140
Greatest depth of dentary at centre to alveolar border	88	91	75
Greatest length of dental series	264	300	....
Number of vertical rows of teeth	41	40	....
Average length of median nonfunctional teeth	35	35	....

[1]Estimated.

Limb Bones

With specimen No. 351, Geol. Surv., Can., there was preserved in addition to the skull, both femora, both tibiæ, one fibula, two ischia, and five metatarsals. None of these bones are available for study, as they remain in the packing cases as received from the field. Measurements taken of these bones in the field are appended, as contributing something to our knowledge of their relative proportions. These measurements will probably be subject to correction when the bones are prepared.

Field Measurements

Length of femur........	3 feet	8 inches,	about	1117 mm.
" tibia.........	3 "	6 "	"	1066 mm.
" ischium	3 "	7 "	"	1092 mm.
" metatarsal...		7½ "	"	190 mm.

Integument

Nothing is known of the character of the integumentary covering of *Lambeosaurus.* The impressions attributed to *Stephanosaurus marginatus* by Lambe and described[1] by him, pertain to other individuals than the referred skulls here described. These skin impressions, therefore, may perhaps still be regarded as illustrating the dermal covering of *Kritosaurus marginatus* (Lambe), though the evidence for so doing is meagre.

[1] Ottawa Naturalist, vol. 27, 1914, pp. 133, 134, Pls. XV and XVI.

ON THE SKULL AND SKELETON OF HYPACROSAURUS, A HELMET-CRESTED DINOSAUR FROM THE EDMONTON CRETACEOUS OF ALBERTA

In 1913 in establishing[1] the genus *Hypacrosaurus* on a fragmentary skeleton lacking the head, Brown predicted that when the skull was known it would prove to be one of the crested forms. His prediction was well founded, as is now shown by a specimen in the palæontological collections of the Geological Survey, Canada, which consists of a fairly complete skull associated with the greater part of the skeleton. This skull has a high, helmet-shaped crest, which in its enormous development closely rivals that of the Belly River *Corythosaurus*, and is the first crested skull of this particular type to be discovered in the Edmonton formation.

The preparation of the specimen has not been completed, but the bones most needed for comparison with the type of *Hypacrosaurus altispinus* Brown are available and these show such close resemblances in form and size as to leave no uncertainty as to their generic identity. The presence of a closed foramen in the ischium, coupled with proportionately shorter spinous processes on the posterior dorsal vertebræ, appeared at first to indicate specific distinctness from *Hypacrosaurus altispinus* Brown, but on my request Dr. W. D. Matthew very kindly re-examined the ischium of the type of the above species and under date of February 28, 1923, wrote me as follows: "I examined the type of *Hypacrosaurus* (No. 5204) and the ischium is clearly incomplete on the border, as you suggest, so there might be an enclosed foramen instead of a notch. The inner half of the foramen border is perfect, but proximally and distally it is a broken edge and the lines to me look quite conformable to either interpretation—a deep notch or an enclosed foramen." From this it seems quite probable that if the foramen in the ischium of the type were perfectly preserved it would be closed as in the specimen now before me. Although the spinous processes are relatively shorter than those of the paratype discussed by Brown, none are completely preserved in the type of *H. altispinus*, and since the specimen now before me closely resembles the type in nearly all other particulars, as far as they can be compared, it is identified as belonging to that species.

I wish here to express my appreciation to E. M. Kindle, chief of the Division of Palæontology, and to the other officials of the Geological Survey, for the privilege of describing this important and highly interesting dinosaurian specimen. The drawings illustrating this paper were made by Arthur Miles of the Survey staff.

[1]Bull. Am. Mus. of Nat. Hist., vol. 32, Aug. 19, 1913, pp. 395–406.

DESCRIPTION OF THE SKELETON OF HYPACROSAURUS

Hypacrosaurus altispinus Brown

PLATES XI AND XII

Brown, B., Bull. Am. Mus. Nat. Hist., vol. 32, art. 20, 1913, pp. 395-406.

Referred Specimens: No. 8501, Geol. Surv., Can., consists of the skull, right ramus, an articulated series of dorsal, sacral, and caudal vertebræ, numerous thoracic ribs, right humerus, ulna, radius, pelvic arch, and complete right hind limb and foot. Collected by G. F. Sternberg, 1915.

Locality: Sec. 6, tp. 33, range 21, W. 4th mer., 3 miles below Tolman ferry, left hand side of Red Deer river, Alberta. From 175 feet (aneroid) above the river.

No. 8500, Geol. Surv., Can., consists of a skull lacking the crest, both dentaries. Collected by P. A. Bungart, 1915.

Locality: Sec. 12, tp. 34, range 22, W. 4th mer., 5 miles north of Tolman ferry, east side of Red Deer river, Alberta. From 115 feet (aneroid) above the river.

Horizon: Both specimens from the Edmonton formation, Upper Cretaceous.

Generic and Specific Characters: Skull with high, helmet-like crest. Narial passages roofed over, external nares opening far forward. Premaxillaries entering extensively into formation of crest. Dentary deep, massive, and carrying 40 rows of vertical teeth. Cervical vertebræ strongly opisthocoelous, spines reduced or absent, ribs stout. Dorsal vertebræ with centra reduced in size, high massive spines, five to seven times the height of their respective centra. Sacrum with eight vertebræ. Scapula long and very broad. Radius much longer than humerus. Ischium long with closed foramen and large terminal foot-like expansion. Pubis with anterior blade short and broadly expanded. Ilium deep and strongly curved. Femur, tibia, and fibula of nearly equal length. Pes long and massive.

Skull

The skull has been entirely freed of the matrix and although the bone is in a good state of preservation, below the crest it has suffered considerably from lateral compression, but more especially from the loss of important elements and dislocation of the right maxillary and jugal. The latter bones, as the skull is now assembled for exhibition, could not be properly articulated, and being pushed forward out of position give the cranium an unwarranted depth when viewed from the right side. This is clearly indicated in Plate XI, reproduced here from a photograph of the specimen. The principal bones missing from the head are the quadrate, jugal, quadratojugal, and ramus of the left side; the predentary and all the palatal elements.

Viewed in lateral aspect the high, helmet-like crest forms the most characteristic and conspicuous feature of the skull of *Hypacrosaurus*. In its great extent and general contour there is a striking resemblance to the crest of *Corythosaurus* from the earlier Belly River formation. The crest in this sub-family, as Lambe has clearly and convincingly demonstrated,[1] is composed entirely of the backward prolongation of the combined premaxillary and nasal bones. The facial slope of the crest in this specimen is steep, but more receding than in either *Corythosaurus casuarius* Brown or *Lambeosaurus lambei* Parks, and resembles more nearly in this respect the skull of *Corythosaurus excavatus* Gilmore in the University of Alberta collections. With the tooth rows in an horizontal position, the crest reaches its highest elevation at a point slightly posterior to the midline of the orbit. From the apex posteriorly it presents a convex outline that curves rapidly downward. Unlike *Corythosaurus* the posterior termination does not overhang the occiput of the skull. Throughout its extent the lateral halves of the crest are distinctly separated by a median suture, and this suture is continued forward to the tip of the beak.

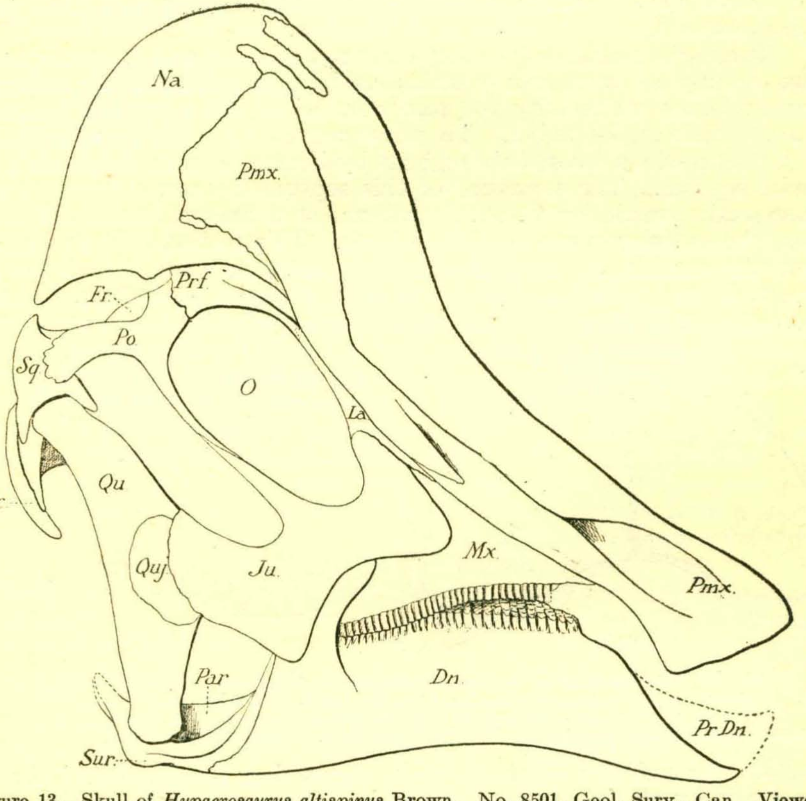

Figure 13. Skull of *Hypacrosaurus altispinus* Brown. No. 8501, Geol. Surv., Can. Viewed from the right side. Slightly restored. *Dn*, dentary; *Fr*, frontal; *Ju*, jugal; *la*, lachrymal; *mx*, maxillary; *na*, nasal; *o*, orbit; *par*, prearticular; *prf*, prefrontal; *pmx*, premaxillary; *poc*, paraoccipital; *po*, postorbital; *PrDn*, predentary; *qu*, quadrate; *quj*, quadratojugal; *sq*, squamosal; *sur*, surangular. About eleven-sixteenths natural size.

The greatly expanded posterior end of the inferior branch of the premaxillary is a conspicuous feature of this genus, and it forms the greater part of the central area of the crest. The narrower superior prolongation of the premaxillary forms the whole of the upper anterior portion, extending

[1] Geol. Surv., Can., Mem. 120, 1920, pp. 74–76.

backward to its highest point, where it is strongly united with the nasals by interlapping finger-like processes, much as in *Cheneosaurus.* A short distance in advance of the anterior end of the jugal a broad, shallow groove runs obliquely upward and slightly backward across the lower part of the premaxillary, as in *Lambeosaurus* and *Corythosaurus.*

The crest above and in front of the orbits is swollen outwardly on both sides and this swelling undoubtedly indicates the extent of the enclosed chamber, which has been so fully described[1] by Lambe in a skull of *Lambeosaurus.* This part of the crest has a greatest transverse diameter near the base of 153 mm., whereas directly above, near the apex, it is only 13 mm. in thickness. Viewed from the front the facial slope is relatively broad transversely, and strongly convex in the same diameter except for a median longitudinal depression that rapidly fades out as the beak proper is approached.

The narial passages are completely roofed over, and the anterior nares thus occupy an advanced position as in *Cheneosaurus.* Anteriorly the premaxillaries are broadly and somewhat angularly expanded to form the characteristic duck-like bill. They are excavated in front by wide V-shaped narial depressions, floored throughout by bone, and with a complete internarial septum. The structure of this septum is beautifully shown in a cross-section made by C. M. Sternberg, at a natural break 10½ inches from the anterior extremity of the beak. This section (Figure 14) shows that the median septum, though very thin, is made up of two walls separated at the centre by the median premaxillary suture. A second cross-section (Figure 15) from a second skull, at a slightly more advanced

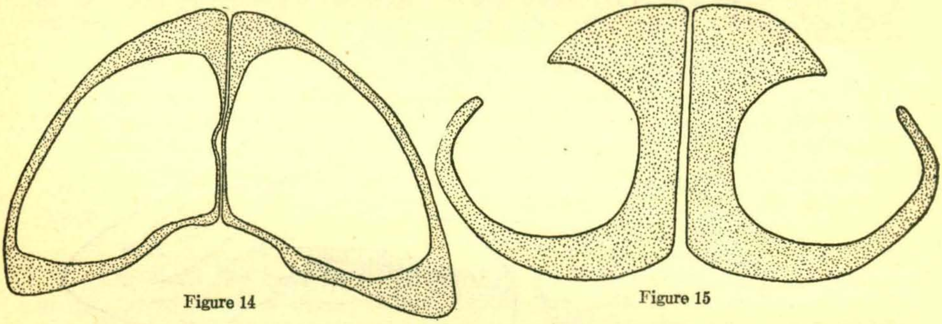

Figure 14 Figure 15

Figure 14. Cross-section of beak of *Hypacrosaurus altispinus.* No. 8501, Geol. Surv., Can. Section taken 10½ inches posterior to the tip of the beak. One-half natural size.

Figure 15. Cross-section of beak of *Hypacrosaurus altispinus.* No. 8500, Geol. Surv., Can. Section taken 8 inches posterior to the tip of the beak. One-half natural size.

position through the external nares, shows that the septa and the other walls rapidly thicken toward the front. The under side of the anterior ends of the premaxillaries have low, pseudo tooth-like projections that in life were doubtless covered by a horny skin.

The prefrontal, shown best on the left side of the skull, is roughly triangular and forms the upper boundary of the orbit. It was apparently in contact with the lachrymal, but one cannot be positive of this fact due to the damaged condition of this region in both skulls.

[1]Op. cit., pp. 74, 75.

The lachrymal, as shown on the left side of specimen, No. 8500, is especially attenuated, its length being more than three and one-half times the maximum breadth. It forms much of the median anterior rim of the orbit. The narrowed upper extremity apparently meets the prefrontal, and the slender distal extension is intercalated between the jugal and premaxillary, the extreme end passing downward between the premaxillary and maxillary. There is a moderate-sized lachrymal foramen.

The jugal is deep and, except for a more angular development of its posterior inferior extension, does not present any other unusual features. In front it is strongly in contact with the maxillary and less so with the lachrymal. Its exact posterior contact with the quadratojugal is not shown in these specimens, but it probably met the quadrate above the quadratojugal as in all other hadrosaurs except *Kritosaurus navajovius* Brown.

The quadratojugal, quadrate, and postorbital are almost exactly comparable to those bones in other crested hadrosaurian skulls of equivalent size.

The squamosals are irregularly shaped triradiate bones, whose wide, medially directed branches narrowly meet on the median line above the parietal much as in *Lambeosaurus.* In many of the duck-billed dinosaurs, however, the squamosals are separated on the midline by the interposition of the parietal. The only exceptions in this respect found outside of the Lambeosaurinæ are in the genus *Prosaurolophus* of Brown[1] and in an undescribed hadrosaur in the collection of the Survey from the Lance formation of southern Saskatchewan. The squamosals are very narrowly separated in *Cheneosaurus.*

The parietals, as in other helmet-crested dinosaurs, lie below the level of the supratemporal arcades. A thin but comparatively high median longitudinal ridge developed on the coalesced parietals divides the supratemporal fossæ, but the posterior end of this crest does not appear to rise to the level of the squamosals as in a skull of *Lambeosaurus* now before me, but passes beneath, though apparently not reaching the occipital aspect. The sutures joining the elements forming the brain case have nearly all become coalesced, but so far as determinable they closely resemble a cranial fragment (No. 8502) of a skull of *Lambeosaurus* in the Survey collections, in which these sutures are clearly and beautifully shown.

The median crest of the parietals subsides before reaching the anterior end of this bone where it widens out transversely to join the frontals at the centre and the postfrontals laterally, and as in *Lambeosaurus* effectually excludes the frontals from direct participation in the boundaries of the supratemporal fossæ. It cannot be determined whether a tongue of bone is sent forward between the frontals as in *Lambeosaurus,* nor can the suture between the parietal and the underlying proötic be observed in this specimen.

The frontals are wider than long, and strongly swollen, indicating a brain of similar shape and proportions to that of *Lambeosaurus* instead of the compressed elongated brain found in *Edmontosaurus* and *Thespesius.* The obscure condition of the fronto-nasal region makes a study of its features particularly difficult, but the nasals seem to extend forward from their union with the frontals for some little distance before turning backward and upward to enter the crest proper. On either side they extend

[1]Bull. Am. Mus. of Nat. Hist., vol. 35, 1916, Figure 3.

outward to join the prefrontals, their junction being indicated by a short, raised, flaring border of the prefrontal. On the left side above the orbit a longitudinal excavated recess runs underneath the base of the crest and terminates anteriorly at the forward border of the orbit.

The alisphenoid of the right side is missing, but on the left side it turns outward from its participation in the brain case beneath the parietal and frontal, with its outer extremity received in the usual pit on the inner side of the postorbital.

The maxillary and attached jugal have been crushed forward out of their normal positions (Plate XI), but, except for the loss of parts of the anterior and posterior ends, are in a fair state of preservation. They are relatively heavier than in *Lambeosaurus*, but, as in the other crested forms, the restricted distance between the anterior end of the jugal articulation and the entrance to the infraorbital foramen is very short.

The precise number of rows of teeth carried by the maxillary cannot be determined, but it is in excess of forty.

The occipital condyle when viewed from the back may be described as subreniform with a broad, slightly convex articular condyle that looks strongly downward in relation to the longitudinal axis of the skull. The basioccipital bounds the foramen magnum below, and on either side articulates by oblique sutural surfaces with the exoccipitals. The latter bones contribute extensively to the condyle by sending backward two high posteriorly directed processes whose posterior extremities slightly overhang the occipital condyle. These condylar processes are wide apart, slightly divergent, and form together a deep valley leading up to the entrance of the foramen magnum. The articulation of the basioccipital with the basisphenoid has become coalesced and their sutural union can no longer be observed. The condyle has a greatest transverse diameter of about 60 mm., a vertical diameter at the centre of 26 mm., and at the sides 55 mm.

The exoccipitals bound the foramen magnum laterally and above, and contribute largely to the formation of the occipital condyle. In completion of the occipital condyle they extend freely backward where their articular posterior ends overhang the condylar portion of the basioccipital. Though no median suture can be detected between the exoccipitals above the foramen magnum, a low vertical ridge appears to represent the line of their coalescence. The exoccipitals extend outward and slightly backward from the centre, developing greatly expanded, pick-shaped paraoccipital processes. Their distal expansion is especially produced as long tapering processes that terminate far below the squamosal processes against which they abut.

The suture between the exoccipitals and the supraoccipital cannot be detected, but a broad area lying between the upward expansion of the paraoccipital processes, having a vertical, median ridge with flattened surface that widens from below upwards, is regarded as the supraoccipital contribution to the occiput. The surface of this part of the occipital region is inclined slightly forward. In *Edmontosaurus* the median portion of the coalesced exoccipitals is directed strongly backward as a broad overhanging roof, in striking contrast with the slight overhang in this genus. It is certain that in *Edmontosaurus* the supraoccipital was excluded from participation in the boundary of the foramen magnum. Lambe,[1] however, believed that the supraoccipital entered into the boundary of the foramen, but in *Kritosaurus incurvimanus* Parks[2] also finds the supraoccipital excluded from the foramen boundaries.

Viewed from the rear, the squamosals are especially high, with their lower borders at the centre resting upon the supraoccipital and exoccipital, but passing from a superior to an anterior position as they continue outward toward the distal extremities of the paraoccipital processes.

The foramina of the brain case in the *Hypacrosaurus* skull, so far as they can be observed, do not appear to differ materially in arrangement from those of the other described genera.

Comparative Measurements of Skulls of Hypacrosaurus Altispinus

	No. 8501, Geol. Surv., Can.	No. 8500, Geol. Surv., Can.
	Mm.	Mm.
Greatest length of skull between perpendiculars	725[3]	....
Greatest length of skull, tip of beak to terminal end of crest	785[3]	....
Greatest length of skull, tip of beak to posterior end of squamosals	720	....
Greatest height of skull with lower jaws	695	....
Greatest height of skull, bottom of ramus to orbital rim	385	....
Greatest height of crest above orbital rim	305	....
Greatest length of quadrate	310	....
Greatest width of premaxillaries at beak	260	194
Greatest width of crest at base above centre of orbits	155	....
Greatest width across paraoccipital processes	220	....
Length from tip of beak to centre of anterior orbital rim	575	....
Length of maxillary	340	360

Mandible

The right ramus, except for the loss of the angular and minor portions of the posterior extremities of the surangular, articular, and prearticular, is practically uncrushed and in a good state of preservation. The jaw is unusually deep and massive throughout. The edentulous portion in front of the tooth magazine is short, strongly deflected ventrally, with a broad, spout-like symphysial shelf whose upper surface forms nearly a right angle with the thinner, vertically directed, nondentigerous portion. The coronoid process is robust, high, with the anterior border of the upper end expanded and strongly overhanging. In profile the forward end of the dentary, as in all other helmet-crested members of the Hadrosauridæ, is strongly decurved.

In the dental magazine 38 vertical rows of teeth can be counted, and there may be one or two more in the complete series. In the second specimen, No. 8500, there are 40 vertical rows of teeth. The dental magazine is unusually deep and thick. The dentary is deeply excavated posteriorly by the mandibular fossa, from which Meckel's groove narrowly leads forward on the infero-internal side to entirely disappear at a point

[1]Geol. Surv., Can., Mem. 120, 1920, p. 12.
[2]University of Toronto Studies, No. 11, 1920, p. 17.
[3]20 mm. added for missing tip of beak.

slightly in advance of the middle of the magazine. A narrow, flattened surface beneath the Meckelian groove marks the contact with the missing angular. It would appear from the character of this surface that the angular probably extended forward to the midlength of the dentary. The dental foramina, one for each vertical tooth series, are arranged in a row following the lower curve of the dental magazine. A few irregularly placed foramina are present on the upper external surface of the dentary. The articulated elements forming the post-dentary part of the ramus are unusually short and stout. These have an anterior-posterior length of about one-fourth the total length of the jaw. The surangular, the largest of these bones, has an irregular shape that may best be described as consisting of a narrow anterior vertical portion, and a larger transversely expanded posterior portion that at its posterior end is obliquely truncated with an inwardly directed hook, which is missing in this specimen. The surangular articulates in front with the dentary, postero-superiorly with the articular, and internally with the prearticular and angular. The vertical and horizontal anterior ends of the surangular pass within the dentary, the former lapping along the inner side of the external wall of the coronoid process, and when complete rising to fully one-half its total height. The horizontal portion is broadly underlapped by the dentary and the floor of the mandibular fossa is continued back on the upper surface of the surangular for nearly one-half its length. The bone behind the fossa is crossed by a low, rounded, diagonally developed swelling, posterior to which the bone is shallowly cupped to form the cotylus of the jaw for the articulation of the quadrate.

The articular, although present, cannot be clearly differentiated in this specimen. The prearticular (splenial of authors) is a thickened bony plate that forms the upper inner margin of the posterior mandibular fossa (Plate XII). In contact with the articular and surangular posteriorly it extends forward to, and embraces, the thin, pointed, posterior projection of the dentary behind the tooth magazine. A thin, pointed anterior projection continues forward beneath the magazine, terminating in this specimen at a point in line with the fifth vertical row of teeth, but in specimen No. 8500 it continues as far as the tenth vertical tooth row. This process, with the anterior portion of the angular, forms a covering for Meckel's groove and that fact may account for its previous designation as the splenial. Elsewhere (page 42) evidence is presented showing that this bone cannot be other than the prearticular, and that in the Hadrosauridæ the splenial is probably absent. The lower border of the prearticular rests for the greater part of its length upon the underlying surangular, and was apparently slightly in contact along its lower internal surface with the missing angular.

Teeth

The teeth of this specimen are to be observed only in the dentary, and their finer details are not well preserved. In composition, implantation, and succession they conform fully to the usual arrangement of the teeth in the Hadrosauridæ. The inner enamelled tooth surfaces are nearly lozenge-shaped, being relatively narrower and longer than in the much larger *Edmontosaurus*. They are largest in the central part of the magazine. The upper ends of the teeth are acutely rounded and slightly emarginated at the base into which the next succeeding tooth closely fits. There is a slight elevation of the margins, but most of the larger dentary teeth appear to be devoid of papillations in No. 8501, though they are more evident in the dentary of No. 8500. The smaller anterior teeth in dentary No. 8500 are more strongly papillate than those situated more posteriorly. There could hardly have been more than three complete teeth in any one vertical series. The number of teeth in wear at one time in the cutting edge cannot be determined from these specimens.

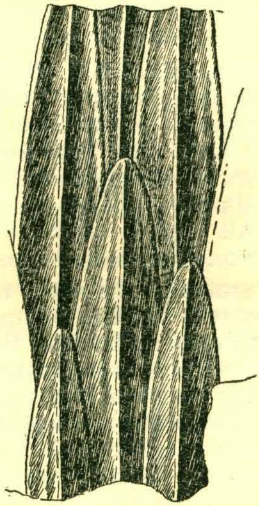

Figure 16. Teeth from dentary illustrating the type of dentition in the central part of the series. No. 8501, Geol. Surv., Can. Natural size.

Although the evidence accumulated is scarcely extensive enough to base conclusions upon, it indicates that with the shortening of the skull, as in the sub-family Lambeosaurinæ, there has been a considerable reduction in the number of tooth rows and a relative narrowing and lengthening of the individual teeth. In both these respects the teeth of *Cheneosaurus* show the most extreme specialization. From a compiled table, based on all available sources of information, it has been determined that none of the members of the Lambeosaurinæ exceed 41 vertical rows of teeth in the dentary, and all but one genus has less than that number.

All other members of the Hadrosauridæ in which the dentary series has been determined show a greater number, with the possible exception of *Parasaurolophus,* and the skull structure indicates that its affinities are within the sub-family Lambeosaurinæ rather than the Saurolophinæ, its present assignment by Parks[1]. Accumulating evidence, slight as it may be at the present time, all points to the probability that in the near future the differences to be observed in the dentition of these animals will furnish important characters to assist in the proper and more exact classification of the Hadrosauridæ.

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[1]University of Toronto Studies, No. 13, 1922, p. 5.

Measurements of Dentary and Teeth

	Mm.
Greatest length of ramus as preserved	530+
" length of dentary	465
" depth of dentary at centre to alveoli	98
" height of coronoid process	231
" depth of dental magazine at centre	102
" length of dental magazine	290
Average length of nonfunctional teeth	37 to 38
" width of nonfunctional teeth at centre	11
Total number of vertical rows of teeth	40

Vertebræ

The vertebral column of specimen No. 8501, according to notes made in the field at the time of collecting, consists of an articulated series beginning in the anterior dorsal region and continuing backward well down (11 feet) into the tail. At this time only two partly prepared sections are available. A large block showing the right side contains the preacetabular portions of the right ilium and pubis, ten or more dorsal vertebræ in sequence, and their respective ribs. All these bones have been but little disturbed, and apparently occupy their natural positions in relation to one another.

The spinous processes protruded from the rock, and although several of them are nearly complete, only one has its upper extremity fully intact. It is regarded as the fourth dorsal in front of the sacrum, reckoning from its position in relation to the ilium as compared with known articulated hadrosaurian skeletons. This vertebra has a greatest height over all of about 602 mm., a greatest diameter antero-posteriorly of the centrum of about 95 mm., an estimated vertical height of the centrum of about 110 mm. These proportions show a relatively shorter spinous process than in any of the vertebræ of this region of the type of associated specimens described by Brown, although it comes within his published proportions of the vertebræ.

In establishing the genus *Hypacrosaurus*, Brown has laid much emphasis on the great height of the spines, which are said to be from five to seven times the height of their respective centra. Though the single complete vertebra available for measurement falls within these proportions, the evidently somewhat greater length of the vertebræ immediately preceding the fourth presacral will bring them within the given proportions, although it is believed none would reach the maximum height of the typical specimens of *Hypacrosaurus altispinus*.

The spines of the dorsal series are not only high, but are massive, long antero-posteriorly, and thick. It is apparent that those from the middle of the dorsal series are largest. The eighth and ninth vertebræ in front of the sacrum show a decrease in antero-posterior width of the spines as in the genotype. The upper extremity of the fourth vertebra preceding the sacrum is expanded transversely with an obliquely truncated end that slopes toward the rear. In the posterior vertebræ the spines are inclined forward, but the eighth and ninth have a backward inclination.

The sides of the centra, so far as they can be observed, are deeply concave antero-posteriorly. The neural arches are comparatively weak and deeply excavated behind the transverse processes. The median plate descending from the posterior zygapophyses is apparently intact, and not perforated from side to side as in the type. The transverse processes are relatively small and incline decidedly upward and backward in those few vertebræ in which they can be observed.

The sacrum has not been prepared, but the field notes say it consists of eight vertebræ, as in the type of *H. altispinus*.

A block containing a series of anterior caudal vertebræ, beginning with the first or second back of the sacrum, shows these vertebræ to be very similar to those described by Brown, but slightly smaller. The centrum of the first is large, the width equalling twice the length. The anterior end is decidedly concave vertically. The sides are concave antero-posteriorly. Spines are high and strongly inclined backward. The transverse process of the first is large and connected with the spine by a high, thin plate; in the following ones, however, this plate has disappeared, and they become simple horizontal bars projecting straight outward from their respective centra. For a short distance backward of the first in this series they increase in length, and then again become successively shortened as they proceed distally.

The inability at this time, from lack of preparation, to properly study the vertebral column of this specimen renders it exceedingly difficult to make precise comparisons. However, the very great development of the spinous processes of the middle and posterior dorsal region leaves but little uncertainty that the proper reference of this specimen is to the genus *Hypacrosaurus*. None of the other known hadrosaurs from the Edmonton formation approach *Hypacrosaurus* in this respect, and if the final study should disclose differences that are not now apparent, it can safely be predicted that a new genus would need to be created rather than there being a possibility of it falling within any of those now established.

Fore Limb

The distal two-thirds of the humerus, and the radius and ulna of the right side show the fore limb to have the same relative proportions as found in the other crested hadrosaurs, the radius being much longer than the humerus, as in the paratype described by Brown. The humerus is short and heavy, whereas the limb bones of the fore arm are slenderly elongated. The field measurement for the complete humerus is 19 inches (482 mm.), though by comparison with the paratype it appears to be slightly in excess of that measurement. The radial crest is strongly developed.

Pelvis

The pelvis is represented by the right ilium, right pubis, and both ischia. All of these are about subequal in size with the pelvic bones of the type of *Hypacrosaurus altispinus*.

The ilium is sufficiently well preserved to show that the preacetabular portion was strongly decurved, as it is in all of the crested Hadrosaurs. It differs from *Corythosaurus* in being deeper, and from *Thespesius annectens* (Marsh) in having a shorter, and transversely thin preacetabular process as contrasted with the elongate, triangular, slightly decurved extension in that species. It has the usual heavy process overhanging the ischiac peduncle.

The pubis is comparatively short with broadly expanded thin blade. So far as it has been observed it appears indistinguishable from the pubis of *Saurolophus* as figured by Brown[1].

The most distinctive feature of the pelvis is found in the long, massive ischium, having a closed foramen and a heavy expanded foot. It unites with its fellow of the opposite side along the inner distal third of the shaft by a flattened longitudinally striated surface. The foot-like expanded distal ends of the united ischia closely resemble the pubic foot found in many of the theropodous dinosaurs. In the presence of a closed foramen and the extent and straightness of the anterior border of the proximal end, this bone resembles the ischium of *Saurolophus osborni* much more closely than it does the ischium pertaining to the type of *Hypacrosaurus altispinus* Brown, with a notch and much shorter ventral border. In all other respects, however, these two bones are remarkably similar.

A re-examination of the type ischium of *H. altispinus* by Matthew, as explained on page 49, shows that in all probability it also had a closed foramen and that if perfectly preserved, the differences noted above would largely disappear, as shown in Figure 17.

Hind Limb and Foot

The bones of the hind limb and foot are all present and excellently preserved. All are free from distortion except metatarsal IV, which suffered an injury in life that developed a pathologic condition which has deformed and destroyed the natural contours of its shaft and distal end.

The femur is heavy and massive, with a long straight shaft. It is 124 mm., or nearly 5 inches longer than the tibia. Brown, however, observes[2] "this genus differs somewhat from the usual form in other genera, especially in the more equal length of femur and tibia, also in the greatly lengthened metatarsals." I have gone over all available hadrosaurian specimens, and especially published measurements, and find that the proportions of these bones are remarkably similar in all. It would thus appear that this difference in length between the femur and tibia is not distinctive of the genus *Hypacrosaurus*, for although Brown does not publish the measurement of the femur he illustrates the hind limb (Figure 7) and the proportions given are almost identical with the specimen now before me.

On the distal end of the femur the condyles are strongly developed antero-posteriorly and on the anterior face completely enclose the large foramen. The lesser trochanter is separated by a narrow cleft, and ends considerably below the greater trochanter, which rises higher than the head. The fourth trochanter is strongly developed as a transversely flattened triangular process that projects almost straight backward from the posterior internal surface of the shaft. The apex at its greatest width lies almost directly in the midlength of the bone.

The tibia is also heavy in its construction, with a very strong enemial crest and well-developed condyles. The proximal end has a greatest diameter antero-posteriorly of 320 mm., and a greatest transverse diameter

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[1]Bull. Am. Mus. of Nat. Hist., vol. 32, 1913, p. 390, Figure I.
[2]Op. cit., p. 405.

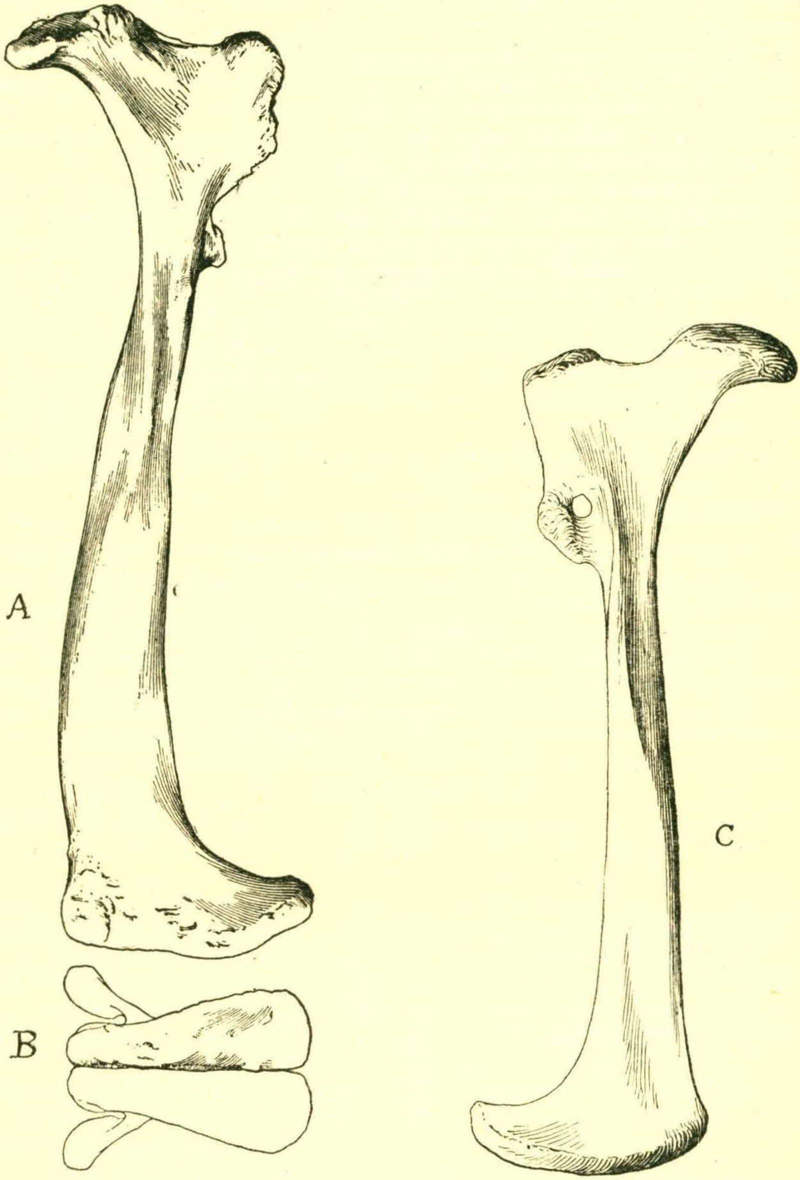

Figure 17. Ischia of *Hypacrosaurus*, side view. A, right ischium of *Hypacrosaurus altispinus* Brown. Type, No. 5204, A.M.N.H. B, expanded distal end with mate drawn in outline. After Brown. C, left ischium (reversed) of *Hypacrosaurus altispinus*. No. 8501, Geol. Surv., Can. Both figures one-ninth natural size.

of the distal end of 250 mm. Planes projected from these diameters would intersect one another at nearly right angles. The fibula shows no distinctive features.

Of the tarsal bones, the calcaneum and astragulus are present and articulated with the tibia and fibula. In the distal row the tarsale articulating with mt. IV is present and securely attached to its cupped proximal surface. It is a flattened, subovate bone that measures 60 mm. anteroposteriorly and 40 mm. in transverse diameter.

The metatarsals, although smaller than in the paratype of H. *altispinus,* bear the same relative length to the tibia as in that species. Their articulated proximal ends have a combined width of 230 mm. The articulated digit III measured along the curve on the front face has a greatest length of 617 mm. It appears that Brown was probably correct in regard to the metatarsals being "greatly lengthened," in the foot of *Hypacrosaurus,* but this applies more especially in comparison with feet of the Lance Hadrosaurs than it does to *Saurolophus* or other Belly River genera. In any event the difference is so slight that at present it is not of much aid in identification.

The phalangial formula is the same as in other hadrosaurs, and apparently the digits are of about equal length, with the possible exception of *Saurolophus osborni.*

Comparative Measurements

	Hypacrosaurus altispinus, No. 8501, Geol. Surv., Can.	*Hypacrosaurus altispinus* Brown, type, No. 5204, A.M.N.H.	*Hypacrosaurus altispinus,* paratype, No. 5272, A.M.N.H.	*Hypacrosaurus altispinus* Brown, No. 7948, U.S.N.M.
Fore Limb				
Humerus, greatest length	510[1]	....	580	....
Ulna, greatest length	665	....	750	670
Radius, greatest length	620	....	700	....
Pelvic Girdle, Hind Limb				
Ischium, extreme length	1,000	1,140	....	....
" length of foot	302	300	....	....
" across iliac and pubic heads	360	340	....	....
Greatest length of femur	1,074	....	....	1,035
" " tibia	950	....	1,060	1,000
" " tibia with astragulus	995	....	1,080	....
Pubis, narrowest width of blade	115	120	....	100
Greatest length of fibula	929	....	1,000	935
" " metatarsal II	290	....	350	....
" " " III	384	....	430	400
" " " IV	333	....	340	....
Vertebræ				
Length of first caudal centrum	....	90	....	....
Width of first caudal centrum	....	180	....	....
Length of second caudal centrum	69	....	....	60
Width of second caudal centrum	140	....	....	120

[1]Estimated.

Geographic and Geologic Occurrence

The genus *Hypacrosaurus* has only been recognized from a comparatively restricted area along Red Deer river, Alberta, with a single occurence[1] in the Two Medicine formation in northern Montana. The latter occurrence perhaps needs additional verification. However, in the light of this newly discovered skeleton, with which the remains of the Montana specimen closely agree in measurements, it appears to give credence to the correctness of the original identification.

It will be noted in the table of comparative measurements that the few bones available for comparison are remarkably close in their proportions. Attention is also called to the short, strongly-decurved, edentulous portion of the dentary, of the Montana specimen, which, with the reduced number (40) of vertical tooth rows points, quite conclusively to its being one of the Lambeosaurinæ, a group to which we now know *Hypacrosaurus* belongs.

With the above-mentioned exception all the other known specimens, six in number, have been found within 5 miles above and 16 miles below Tolman ferry. Although no special significance may be attached to the fact, yet it is of interest to know that of the four specimens collected by Brown and identified by him as belonging to *Hypacrosaurus altispinus*, none of them was found in geological levels exceeding 70 feet above the river, whereas the present specimens come from levels 175 feet and 115 feet respectively above the stream.

Whether it will ever be possible to identify horizons within the Edmonton and Belly River formations by their contained dinosaurian species is exceedingly doubtful, but the possibility of their contributing to a better understanding not only of geologic but also of palæontologic problems is sufficient reason why careful records should always be kept of the levels from which specimens are obtained.

Relationships

The discovery of the present specimen, having a nearly complete skull, with high, helmet-like crest; fronto-parietal region reduced; nasals receding; anterior nares separated by premaxillaries, which are greatly prolonged backward and enter largely into formation of the crest; reduced lachrymal; reduced number of vertical tooth rows; and an ischium greatly expanded distally; at once shows that the genus *Hypacrosaurus* is a true member of the sub-family Lambeosaurinæ as originally characterized by Lambe[2]. Long before the skull of *Hypacrosaurus* was known Brown[3] called attention to the similarity in structure of the genera *Hypacrosaurus* and *Corythosaurus* and suggested that "the two genera are closely related, and *Corythosaurus* may have been the ancestor of *Hypacrosaurus*". The skull structure, as now known, affords additional evidence of the close affinities existing between these two genera and I see nothing in the skeletal structure of the latter that could not very well have been evolved from the earlier Belly River *Corythosaurus*.

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[1] Prof. Paper 103, U. S. Geol. Surv., 1917, pp. 38–41, text Figs. 48–53.
[2] Geol. Surv., Can., Mem. 120, 1920, p. 68.
[3] Bull. Am. Mus. Nat. Hist., vol. 35, 1916, p. 710.

Attention should be drawn, however, to certain features, such as the roofing over of the narial passages; the advanced position of the external nares; the excavated narial depressions, and the general conformation of the whole beak; and the receding facial slope; which have their closest resemblance in the contemporary *Cheneosaurus.* These features probably represent a parallel development of two distinct lines of descent, for otherwise, so far as they can be contrasted, these genera show no particularly close affinities.

PLATE I

Fore feet of *Chirostenotes pergracilis*. Type, No. 2367, Geol. Surv., Can. Reproduced from a photograph of the specimens showing the foot bones undisturbed, as they were found in the field. The evidence for the relative length of the digits, the slightly divergent pollex, and the appressed digits II and III is clearly indicated. About one-half natural size. (Page 3.)

PLATE I

Plate II

Skeleton of *Thespesius edmontoni*. Type, No. 8399, Geol. Surv., Can. Shown as mounted in bold relief in the Victoria Memorial Museum, Ottawa. Viewed from the left side. The tail posterior to the fifth caudal vertebræ has been restored by the introduction of vertebræ from other individuals. Mounted by C. H. Sternberg and sons in 1913. About one-forty-fifth natural size. (Page 14.)

Plate II

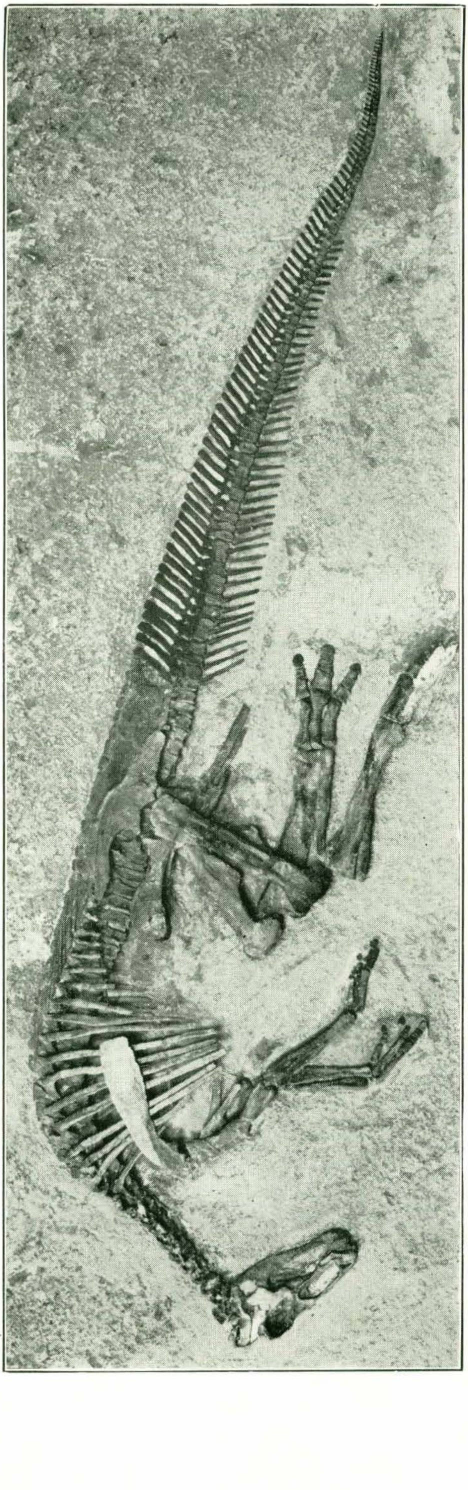

PLATE III

Skull of *Thespesius edmontoni*. Type, No. 8399, Geol. Surv., Can. Seen from the left side. About one-sixth natural size. (Page 14.)

Plate III

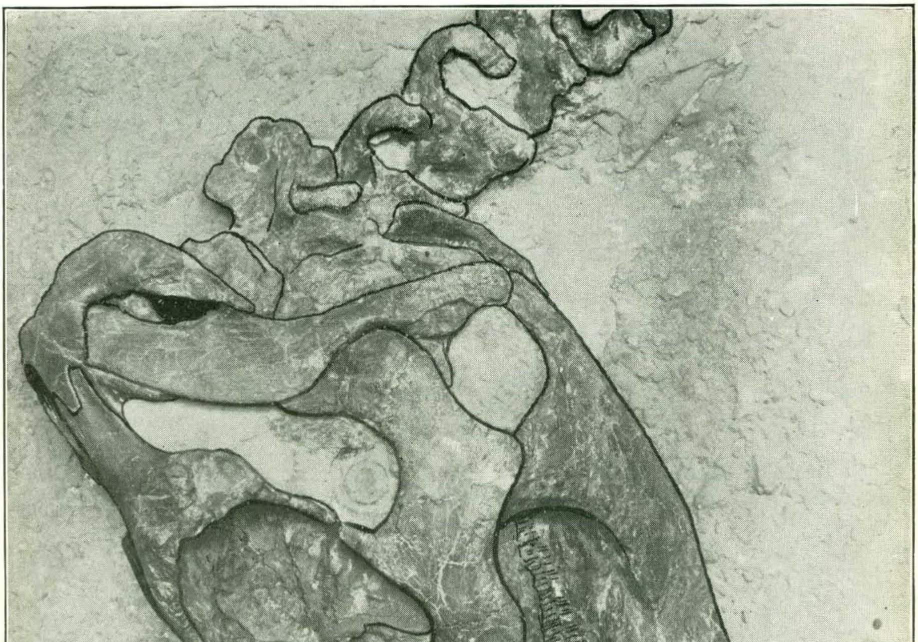

PLATE IV

Pelvis and hind limbs of *Thespesius edmontoni*. Type, No. 8399, Geol. Surv., Can. Shows the ossified tendons and skin impressions along the spines above the hips. About one-fifteenth natural size. (Page 14.)

PLATE IV

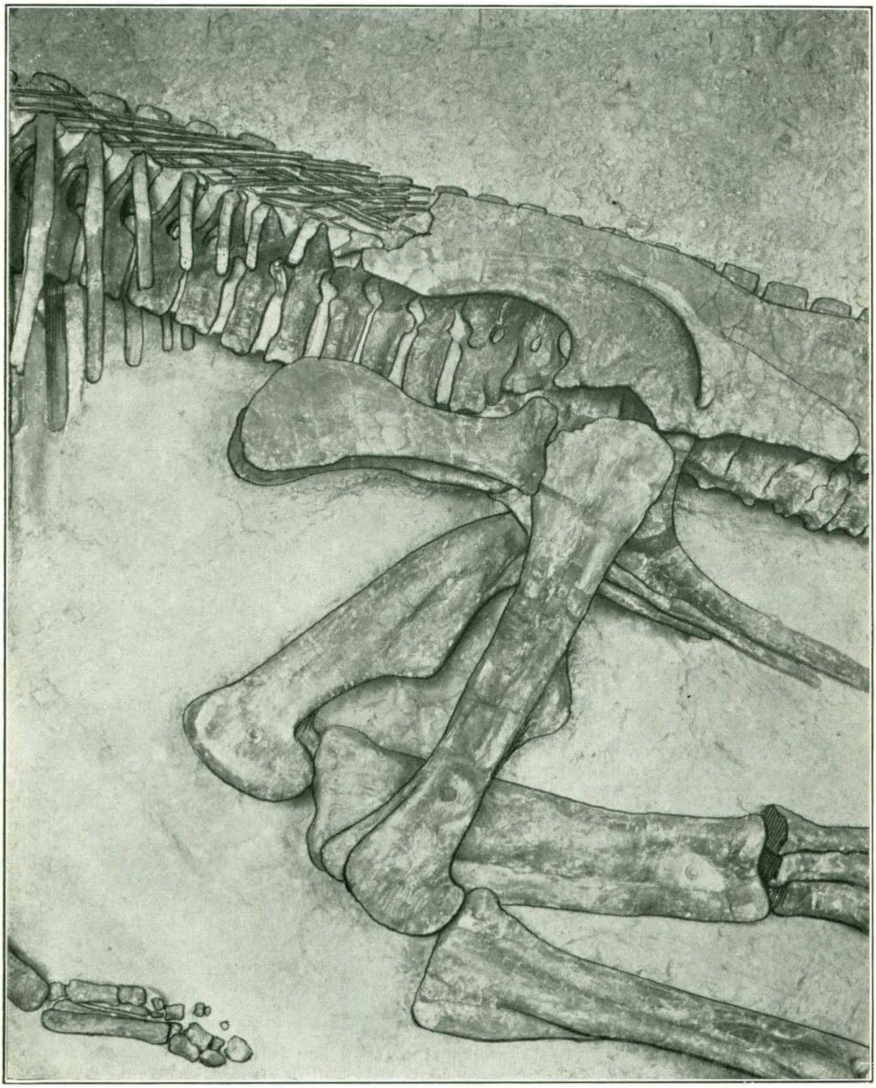

PLATE V

Skin impressions of *Thespesius edmontoni*. Type, No. 8399, Geol. Surv., Can. Section of integument from above the sacrum. Seven-elevenths natural size. After Lambe. (Page 14.)

PLATE V

PLATE VI

Skull of *Lambeosaurus lambei* Parks. Type, No. 2869, Geol. Surv., Can. Viewed from the right side. *Ar*, articular; *Dn*, dentary; *Ept*, ectopterygoid; *Fr*, frontal; *J*, jugal; *L*, lachrymal; *Mx*, maxillary; *N*, nasal; *no*, external nares; *Opot*, paraoccipital; *P*, parietal; *Pal*, palatine; *Pd*, predentary; *Pmx*, premaxillary; *Pof*, postorbital; *Prf*, prefontal; *Prs*, presphenoid; *Pt*, pterygoid; *Q*, quadrate; *Qj*, quadratojugal; *Sa*, surangular; *Par*, prearticular; *Sq*, squamosal. About one-sixth natural size. After Lambe. (Page 35.)

PLATE VI

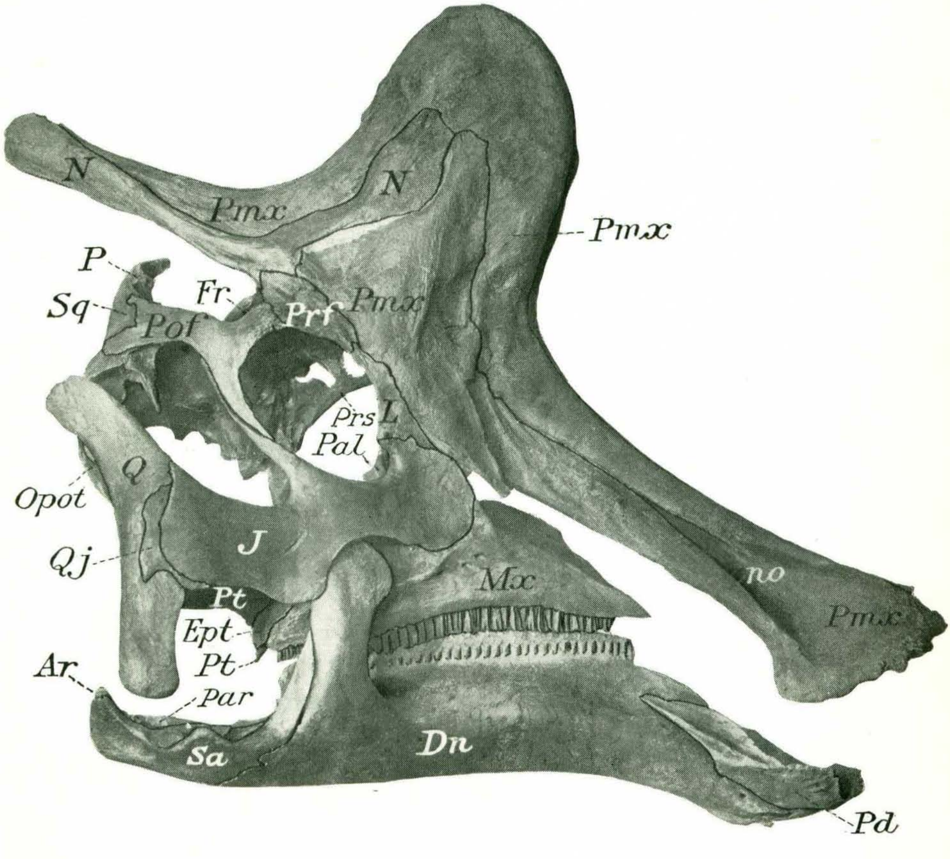
N
N
Pmx
Pmx
P
Fr
Sq
Pof
Prf
Pmx
Prs
L
Pal
Q
Opot
J
Qj
Mx
no
Pmx
Pt
Ept
Pt
Ar
Par
Sa
Dn
Pd

PLATE VII

Skull of *Lambeosaurus lambei* Parks. Type, No. 2869, Geol. Surv., Can. Viewed from the left side, showing the left nasal passage and nasal chamber in the crest; *Alsf*, alisphenoid; *Fr*, frontal; *J*, jugal; *Mx*, maxillary; *N*, nasal; *No*, left nasal passage; *P*, parietal; *Pal*, palatine; *Pmx*, premaxillary; *Poc*, paraoccipital; *Pof*, postorbital; *Pt*, Pterygoid; *Prs*, presphenoid; *Q*, quadrate *Sq*, squamosal. About one-fifth natural size. (Page 35.)

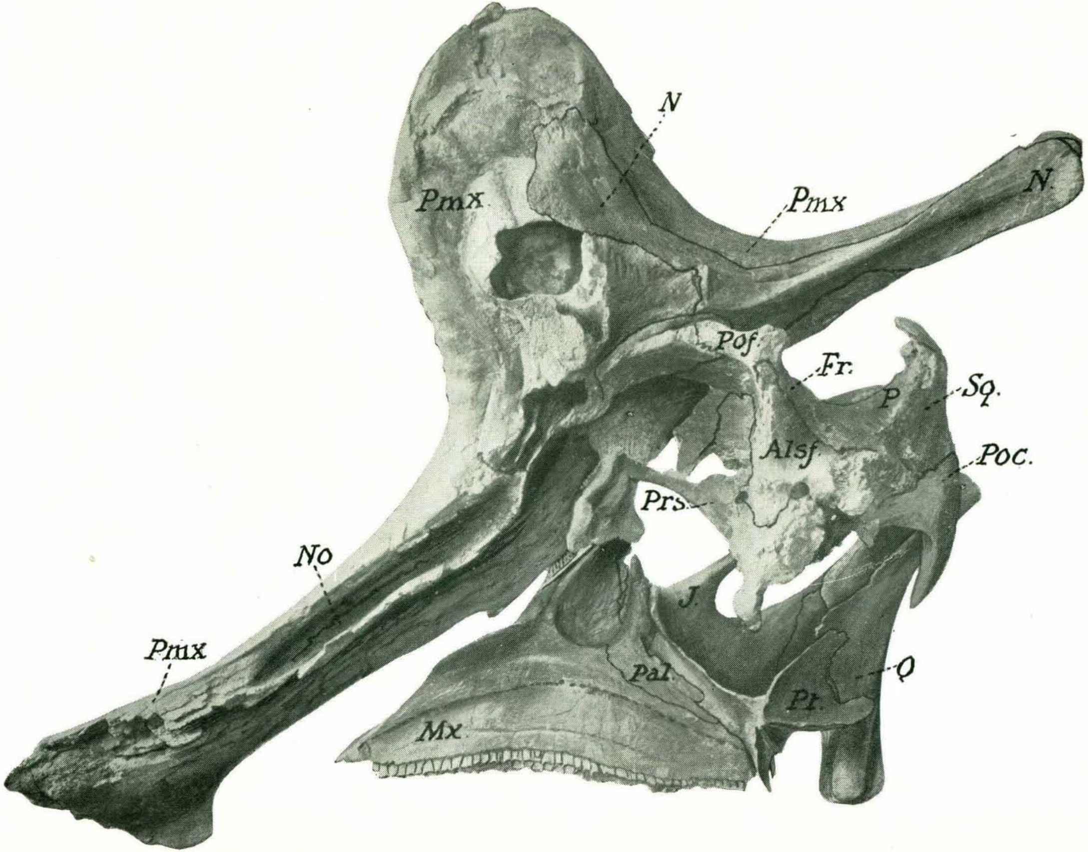
N
Pmx
N
Pmx
Pof
Fr.
P
Sq.
Alsf
Poc.
Prs
No
J.
Pmx
Pal
Q
Pt.
Mx

PLATE VIII

Skull of *Lambeosaurus lambei* Parks. No. 351, Geol. Surv., Canada. Viewed from the left side but reversed so as to make it more convenient for comparison with the type. *Dn*, dentary; *J*, jugal; *L*, lachrymal; *Mx*, maxillary; *N*, nasal; *no*, external nares; *Pd*, predentary; *Pmx*, premaxillary; *Pof*, postorbital; *Prf*, prefontal; *Q*, quadrate; *Qj*, quadratojugal; *Sa*, surangular; *Sq*, squamosal. About one-sixth natural size. (Page 35.)

PLATE VIII

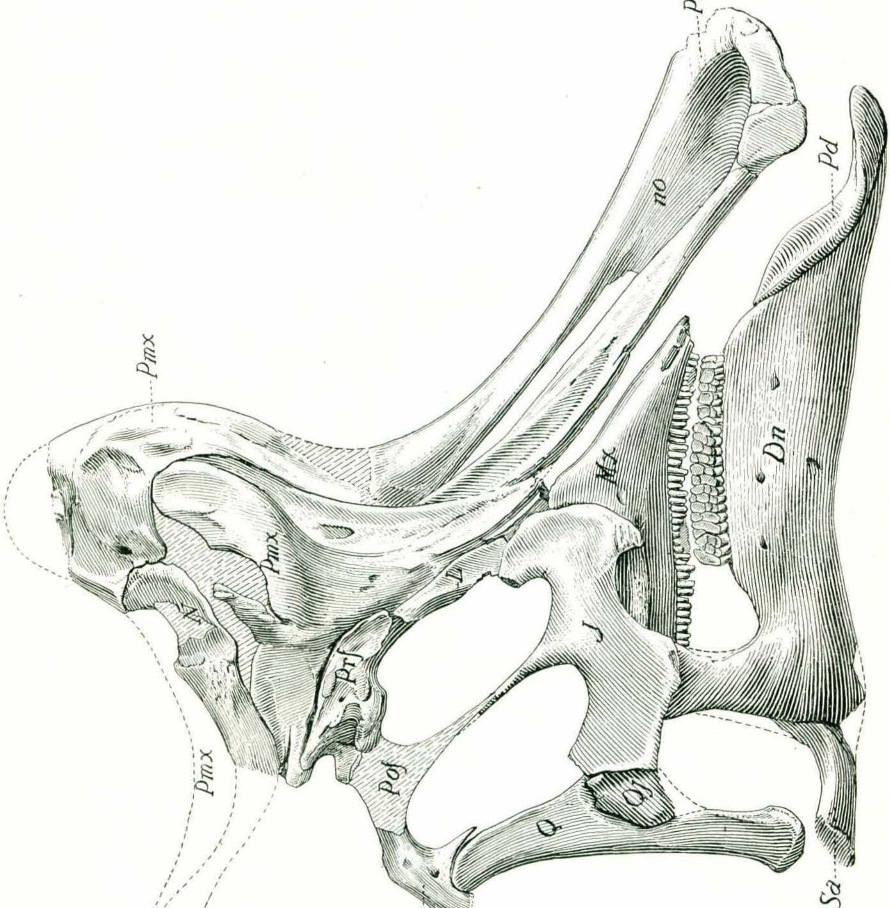

PLATE IX

Right ramus of *Lambeosaurus lambei* Parks. Type, No. 2869, Geol. Surv., Can. Internal view. *An*, angular; *Ar*, articular; *Cp*, coronoid process; *D*, dentary; *Meg*, Meckel's groove; *Par* prearticular; *Sa*, surangular. About one-third natural size. (Page 35.)

PLATE IX

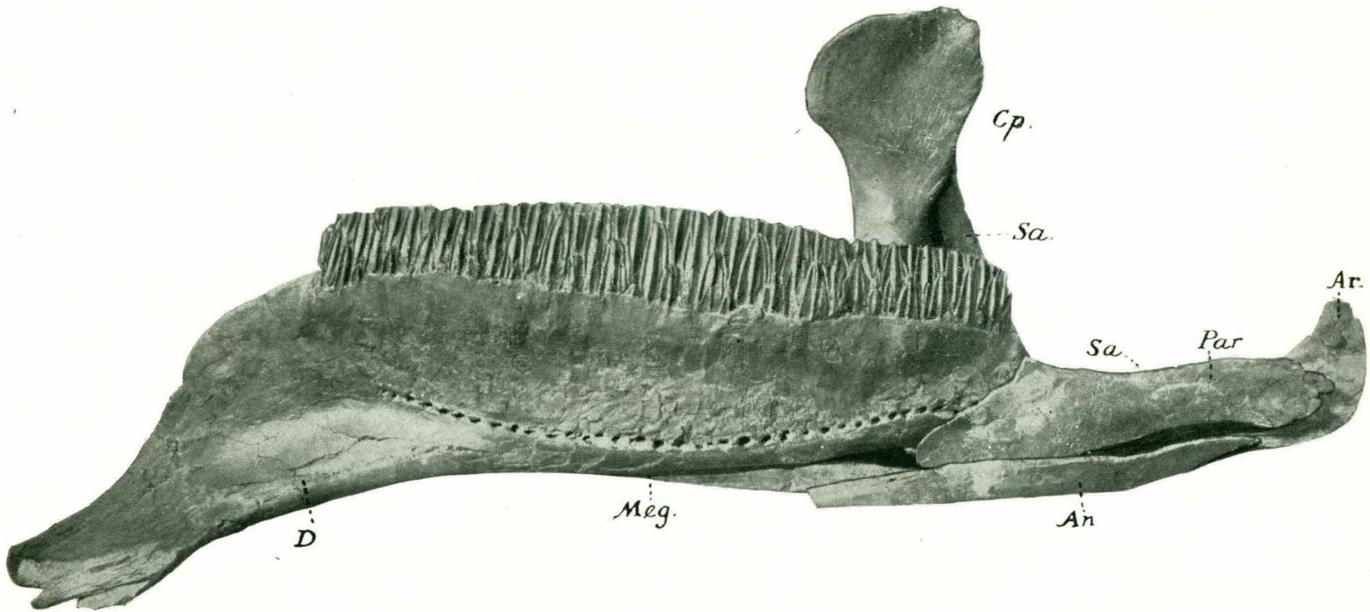

PLATE X

Right dentary of *Lambeosaurus lambei* Parks. No. 351, Geol. Surv., Can. Internal view. The symphysial end is crushed upward, which makes it appear more pointed than in the type shown above. About one-third natural size.

PLATE X

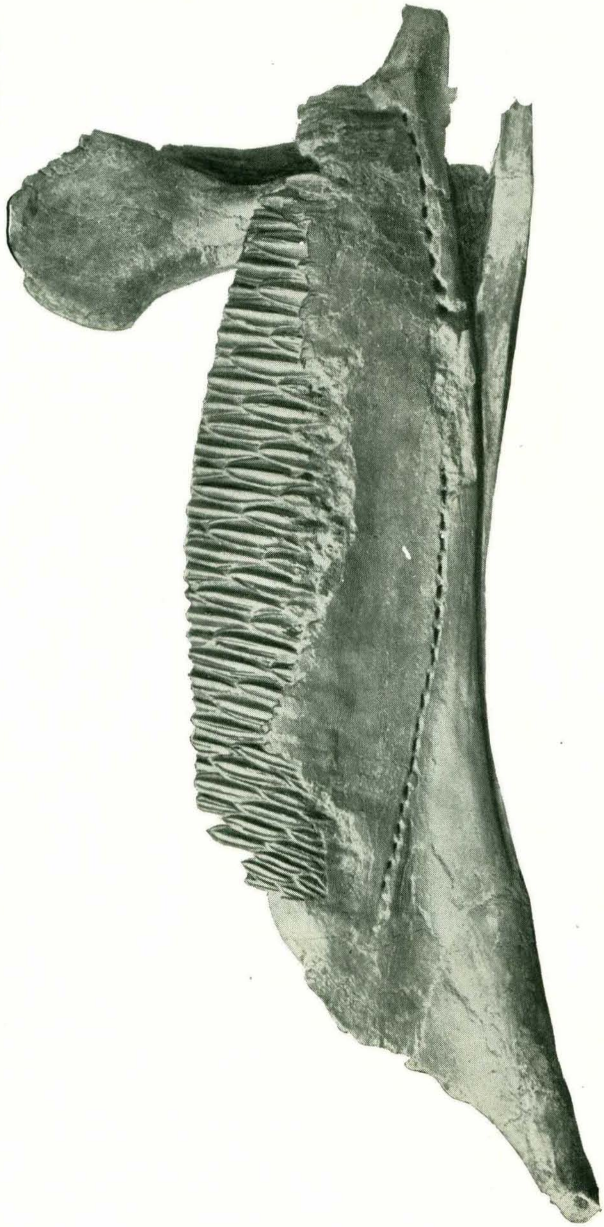

PLATE XI

Skull and lower jaw of *Hypacrosaurus altispinus* Brown. No. 8501, Geol. Surv., Can. Viewed from the right side. The right maxilla and attached jugal are pushed forward out of position and the region above the infratemporal vacuity has suffered crushing in a vertical direction. *Dn*, dentary; *Fr*, frontal; *Ju*, jugal; *Mx*, maxillary; *Na*, nasal; *oc*, occipital condyle; *Pmx*, premaxillary; *Po*, postorbital; *Poc*, paraoccipital process; *Qj*, quadratojugal; *Qu*, quadrate; *Sq*, squamosal; *Sur*, surangular. About eleven-sixteenths natural size. (Page 59.)

PLATE XI

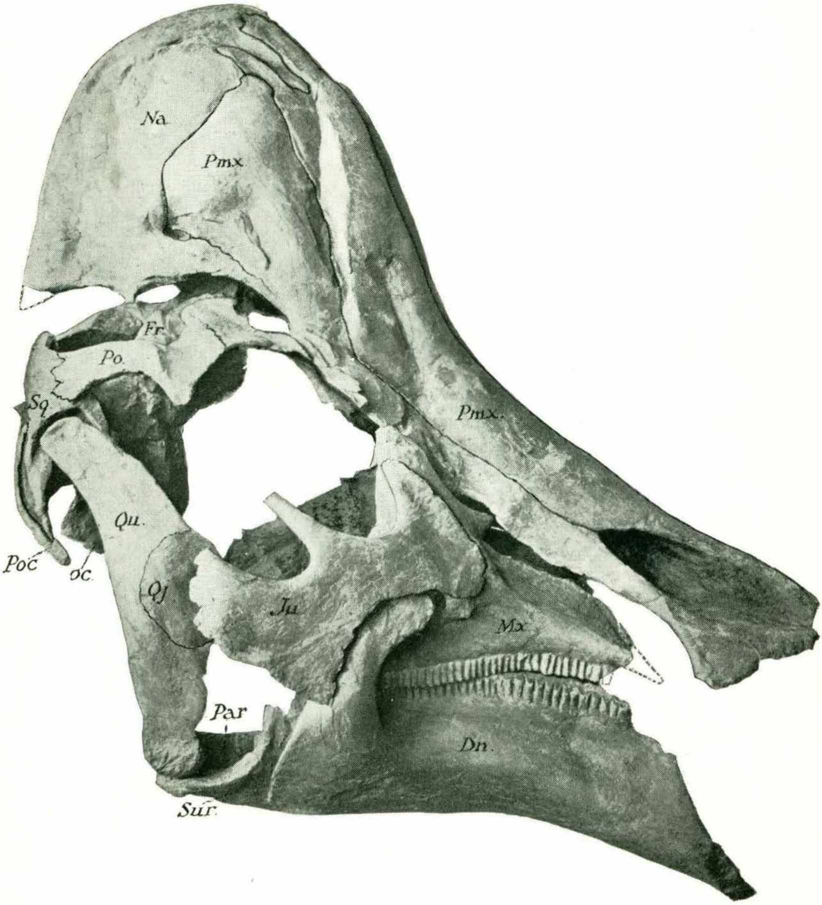

PLATE XII

Right ramus of *Hypacrosaurus altispinus* Brown. No. 8501, Geol. Surv., Can. Viewed from the internal side. *An*, angular; *Ar*, articular; *Cp*, coronoid process; *Dn*, dentary; *Par*, prearticular *S*, symphysial border. About one-third natural size. (Page 50.)

Plate XII