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ON EOCERATOPS CANADENSIS, GEN. NOV., WITH REMARKS ON OTHER GENERA OF CRETACEOUS HORNED DINOSAURS

by

Lawrence M. Lambe

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On Eoceratops canadensis, gen. nov., with Remarks on Other Genera of Cretaceous Horned Dinosaurs.

By Lawrence M. Lambe.

The above species was established in 1902[1] on parts of the skull of one individual collected by the writer in the Belly River formation on the east side of Red Deer river, Alberta, a short distance below the mouth of Berry creek, during the summer of 1901. In the original description the species was referred to the genus Monoclonius, Cope.

The type material consists of the right squamosal (Cat. No. 1254a), the right posterior lateral extension of the parietal (Cat. No. 1254b), the right postfrontal and prefrontal with the supraorbital horn-core rising from the former bone (Cat. No. 1254d), the right nasal including the right half of the nasal horn-core (Cat. No. 1254c), the left dentary without teeth (Cat. No. 1254e), and an anterior dorsal vertebra (Cat. No. 1254).

More detailed descriptions, with figures, of the squamosal and the posterior parietal bar were published in 1904[2].

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[1] Geological Survey, Canada; Contr. to Can. Palæont., Vol. III (quarto), Plate II, pp. 63-66, figures 18 and 19, Plate XVII, figures 3 and 4, and Plate XVIII, figures 1-7.

[2] Trans. Royal Soc. of Canada, Vol. X, second series, pp. 7-9, Plate II, figures 4-7c; and Ottawa Naturalist, Vol. XVIII, p. 83, Plate II, figures 4-7.

The above type material is regarded as representing an undescribed generic form of Ceratopsia to which the name Eoceratops is now given.

Eoceratops appears to be a generalized type with an occipital crest or neck-frill resembling that of Triceratops in the broad triangular squamosal but differing very decidedly therefrom in the presence of long fontanelles. An approach to Triceratops is also found in the enlarged supraorbital horn-core and in the formation and position of the small, forwardly directed nasal horn-core.

It is thought, as the name for the genus suggests, that Eoceratops was a form ancestral to Triceratops, representing an evolutionary stage of the Ceratopsia leading to the later and culminating types (Triceratops and Diceratops) with immense brow-horns.

The characters of Eoceratops may be summarized as follows: skull small, short, compact; supraorbital horn-core moderately large, slender, overhanging the orbit, circular in cross section, tapering to a point and directed upward, and slightly inward and backward above; nasal abbreviated and deep; nasal horn-core short, contributed to by the nasals and two separate, anterior ossifications; crest or neck-frill slightly longer than half the total length of the head; squamosal broadly triangular, longer than broad, with a smooth, undulating outer border, without epoccipitals, forming the greater part of the crest laterally; fenestræ of the crest long, enclosed without by the squamosal, and behind by a slender parietal bar which passes forward beneath the inner posterior border of the squamosal; dentary robust, with about twenty-five vertical series of teeth.

In the restoration outline of the skull given in Plate I, the parts of the one individual constituting the type material are shown by continuous lines; the parts restored are in broken outline. A right maxilla (Cat. No. 285) thought to belong to Eoceratops has been used in the restoration of the skull. It was found separately about 3 miles below the mouth of Berry creek and cannot be positively referred to this species. From the elements represented the length of the skull is approximately obtainable, the unrepresented parts necessary for the determination of its exact length being the premaxilla, the rostral bone, and the median portion of the neck-frill. The restored outline indicates a short, heavily built head, in which the total depth from the upper surface between the supraorbital horn-cores to the lower margin of the dentary, is slightly over one-third of the length from the front edge of the rostral bone to the back border of the frill.

Eoceratops thus appears to have had a short skull, compact and deep in front, and tapering behind as seen in side view. The lower jaw is robust, the nasal bones are remarkably deep, and the supraorbital horn-cores are large in comparison with the inconspicuous nasal horn-core (Plate I). This compactness of the anterior half of the skull with great depth is also found in Brachyceratops, a form in which the nasal horn was the principal weapon of defence. In comparison with Eoceratops the later Triceratops has lengthened the face and added greatly to the size of the supraorbital horn-cores to the neglect of the nasal horn. In Diceratops with the enlargement of the brow-horns there is the concomitant non-development of the nasal one.

The supraorbital horn-core rises from above the orbit, so as to overhang the latter's anterior half, its front convexity at mid-height being almost directly above the anterior surface of the rim of the orbital opening. The horn-core tapers to a point and throughout its length is circular in cross section, except near the base where there is a very slight flattening above the orbit and a feeble lateral compression on the antero-exterior face causing the fore and aft diameter to somewhat exceed the transverse one. In shape, without considering its direction of growth from the head, it very much resembles that of a modern bison, but it is shorter, tapers more rapidly, and is less curved than the average horn-core in the adult mammal.

The postfrontal (Plate IX, figure 1) is of irregular shape, broad behind and narrow in front with the base of the supraorbital horn-core rising from it slightly in advance of its mid-length. The surface slopes gently backward and inward from the base of the horn-core in continuation of the concave curve of the same. Postero-externally it is bent downward with a decided angulation to form a nearly vertical plate of some extent, the foremost part of which constitutes the hinder border of the orbital opening. In advance of its midlength, in line with the centre of the horn-base the bone is much reduced in breadth by the upper curve of the orbital opening externally, and by an emargination of its border (postfrontal fontanelle) internally. The breadth of the bone is here occupied almost entirely by the base of the horn-core which externally curved down into the orbit. From its inner side the edge of the bone runs obliquely forward and outward close under the steep inner anterior face of the horn-base. Anteriorly the bone curves concavely forward as a narrow spur to meet the nasal. Antero-externally it extends outward conspicuously as the upper front part of the orbital rim acting as a buttress to the horn-base, and no doubt in life serving as a protection to the eye. Elsewhere, above and behind, the rim of the orbital opening rounds into the surrounding bone without any protrusion.

The postfrontal ends postero-laterally beneath in a rather straight suture which underlaps the jugal. This suture reaches the orbital rim low down in the orbit. Behind, the suture for the squamosal passes upward onto the upper surface in the form of a deep groove into which the edge of the squamosal fits. At its upper end this groove enlarges into a pit or socket for the reception of a forwardly directed peg from the squamosal. Posteriorly the bone apparently reached the edge of the supra-temporal fossa between the squamosal and the median portion of the neck-frill as in Styracosaurus, Centrosaurus, and Chasmosaurus. Its inner edge forms a concave curve cutting into the slope descending from the horn-base. This edge is the lateral boundary of the postfrontal fontanelle in advance of the suture between the postfrontal and the anterior end of the median frill element (coössified parietals) so clearly preserved in the type of Styracosaurus. In front the line of contact with the prefrontal runs outward and forward and then obliquely inward to the nasal with which latter element the postfrontal was in sutural contact for a short distance at right angles to the longitudinal axis of the skull.

The prefrontal (Plate IX, figure 1) is irregularly five sided. Its upper surface is somewhat concave sloping slightly downward to the front and toward the outer side. This bone met its fellow toward the front for a short distance in the midline of the skull. Outwardly on two of its sides it was bounded by the postfrontal. The suture for the nasal is shown in the specimen as a transverse groove in its front border.

The frontal is not preserved, but its size and position are indicated by the inner posterior edge of the prefrontal (Plate IX, figure 1). It was, therefore, triangular in outline, and with its fellow, ran forward for some distance between the prefrontals. It appears to have been relatively smaller than the same bone in Centrosaurus (Plate IX, figure 2) and Styracosaurus and, as in these two genera, the posterior edge of the pair no doubt formed the anterior margin of the postfrontal fontanelle.

The lachrymal is not preserved in the type material but it evidently formed the lower anterior part of the orbital rim, as a small roughened sutural surface (Plate I) at the lower limit of the postfrontal part of the rim, in line with the centre of the orbital opening, marks its entry into the formation of the rim. The lachrymal carries downward the prominence given to the rim by the postfrontal. Anterior to this small roughened surface the remainder of the lachrymo-postfrontal suture is not clearly indicated. From our knowledge, however, of the exact shape and position of the lachrymal in Centrosaurus it is probable that this bone in Eoceratops would have somewhat similar proportions and lie along the lower edge of the postfrontal reaching the nasal in front.

The nasal (Plate I) is short, very deep, and thin through from the exterior to the interior surface. Inferiorly in front a narrow, stout process descends to articulate with the premaxilla, and posteriorly there is a broad thin extension passing downward to meet the posterior ascending process of the premaxilla. Between these processes the lower border is deeply emarginate and forms the upper half of the nasal opening. The outer surface is flatly convex from above downward. The bone thins near the hinder border and flares outward to form a suture overlapping the lachrymal and postfrontal, and fitting into the grooved anterior edge of the prefontal.

The nasal meets its fellow in a flat, vertical, triangular surface of contact which extends, with increasing depth, from the prefrontal suture to nearly the full depth of the bone in front. This large sutural surface occupies more than one-half of the inner surface of the bone and must have given great strength to the anterior nasal region. Behind this extent of contact the inner surface of the bone is excavated and the bone is reduced in thickness. The anterior descending process displays a well defined flat, oval surface on its inner front face for its sutural union with the upper limb of the premaxilla. The posterior descending extension is divided into two unequal parts by a deep groove at its lower end to receive the ascending posterior limb of the premaxilla. Anteriorly and facing obliquely outward and forward, there is a shallowly concave sutural surface of crescentic outline for the reception of a separate bone which, with its mate and the anterior end of the nasals, formed the nasal horn-core. This separate ossification is transversely compressed, higher than long, pointed above, thickest at the centre and thin toward the hinder and lower margin. Its outer surface is convex, flush behind with that of the nasal, and rounds forward and inward to the median line. Its inner surface shows that it met its fellow in a vertical surface in the median line. Its outline is convexly curved behind and below, and almost vertical in front. The nasal rises upward and extends over the ossification nearly as far forward as the front face of the latter which at its lower end is considerably in advance of the proximal end of the anterior descending nasal process.

The nasal horn-core of Eoceratops is thus seen to be formed by the nasals with the assistance of two separate bones, which may be called the epinasals, anterior to the nasals, the median vertical plane of contact between the two pairs of bones dividing the horn-core into two equal parts. This vertical, longitudinal division of the nasal horn-core is seen in the type specimen of *Brachyceratops dawsoni* (Plate VI, figure 3), and has had special attention drawn to it by Gilmore in his description of *B. montanensis*. In the type specimens of *E. canadensis* and *B. montanensis* the vertical division of the horn-core is continuous due no doubt to juvenility; with greater age coössification would be expected.

In the type specimen of *B. dawsoni* the large backwardly curved nasal horn-core exhibits this division in the median line at its base and for a short distance upward into the horn-core, but above this all trace of it is lost. Also in this particular horn-core (*B. dawsoni*) there is a very definite demarcation traceable between the anterior ossifications (epinasals) and the nasals (Plate X, figure 4). In the growth of the ceratopsian nasal horn-core an early union took place between the epinasal bones and between them and the nasals.

In Mr. Gilmore's paper on *B. montanensis*, in figure 1A on page 4, a definite curved groove is shown, in the anterior part of the nasal horn-core at its mid-height, which is strongly suggestive of the upper boundary of the epinasal ossification. If this groove represents what remains of the upper part of the suture between the ossification and the nasal the union of the lower portion of the former bone with the nasal had, judging from the figure, already taken place without leaving a trace of the lower portion of the suture (Plate X, figure 3).

Attention has already been drawn to the extension of the nasal forward over the epinasal in the type of Eoceratops which evidently represents an individual not fully adult. It is probable that in the growth of the ceratopsian nasal horn-core the nasals, with increasing age in the individual, contributed an increasing share to the formation of the horn-core, the epinasals remaining of relatively small size and acting apparently as an anterior basal support to the nasal contribution. In comparing the relative proportions of the nasal and epinasal bones in the horn-core of *E. canadensis* and of *B. montanensis* (Plate X), keeping in mind differences that may be due to individual age in distinct genera, it is seen that in the type of the latter species the nasal contribution to the horn-core is much larger than in the former. Also in the nasal horn-core of *B. dawsoni* (Plate X) the proportion supplied by the nasals is preponderant, the epinasals entering into the formation of the horn-core only as small anterior buttresses.

The squamosal (Plate I) has been already described in some detail in two papers published in 1904.[1] It is irregularly tri-

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

angular and longer than broad, its greatest length being about one and a half times the maximum breadth. In lateral outline the outer free border forms a sinuous convex curve to the posterior pointed end, and the inner border a concave one to the same termination. The front edge, constituting the base of the triangle, displays, in succession from below upward, the posterior margin of a deep quadrato-jugal notch, the hinder half of a rather large lateral temporal fossa, a short suture for contact with the jugal which overlapped it, and a long one for the postfrontal.

Both the outer and inner surfaces of the bone are remarkably smooth. A few inconspicuous vascular grooves occur on the outer surface back of the suture for the jugal. Superiorly in front the bone is bent inward about at right angles to the general plane of its outer surface, forming a strong angulation which descends backward from the postfrontal suture in continuation of the postfrontal angulation behind the horn-core. The bone is here thin and comes to a sharp inner edge, which constitutes the outer boundary above of the supratemporal fossa. The lower free border flares outward somewhat causing the general surface of the bone to be concave in a longitudinal direction, but it is difficult to say whether this is normal or accentuated by pressure.

The coalesced parietal portion of the neck-frill is known only from the slender postero-lateral bar by means of which a union was effected with the squamosal. This parietal bar (Plate I) passed forward beneath the inner border of the squamosal, which was grooved to receive it, to a point slightly in advance of the latter's length. It is of nearly the same breadth for the greater part of its length, tapering slightly in front for a short distance before it apparently terminates. That part of the bar which underlies the squamosal is triangular in cross section. Its upper surface is flat where it comes in contact with the squamosal, but beneath there is a ridge which passes with decreasing prominence from the middle of the lower anterior surface obliquely backward to the inner edge. Behind the squamosal, in its free part, the bar is lenticular in cross section, curves slightly inward, and gives evidence, where it is broken off, of having expanded horizontally but to what extent is not known. On its outer free border there is a convexity which is a backward continuation of the series of undulations of the free border of the squamosal. Also, behind the squamosal, the bar has a slight axial twist which would bring its upper surface into greater conformity with the general plane of the median portion of the neck frill.

The form of the back and median portions of the frill and the size and shape of the fontanelles must for the present remain conjectural. That the openings in the frill were long in a fore and aft direction is indicated by the squamosal and the portion of the parietal bar remaining.

The frill opening on either side was not altogether within the parietal, as in all other known forms of the Ceratopsia in which fontanelles were present, but was bounded on the outer side, for the greater part of its length, by the squamosal and to a limited extent postero-laterally by the parietal bar. In the specimen the beginning of the inward curve of the bar, with an increased breadth, is shown immediately in advance of the break and suggests an outline to the posterior border of the frill and the median portion between the fontanelles as indicated in Plate II, figure 2. The undulations of the outer border of the squamosal continued backward by the parietal bar suggests a sinuous posterior border to the frill and it is probable that the median parietal portion between the fontanelles was of considerable breadth as an offset to any weakness in the frill occasioned by the tenuity and shortness of the lateral bar beneath the squamosal.

The lower jaw (Plate I) is represented in the type material by the dentary, a robust bone whose maximum length is slightly over three times its depth at midlength. The height of the top of the coronoid process above the lower border is nearly equal to one-half the length of the bone. In comparison with the larger dentary of Chasmosaurus (Plate VIII) it is proportionately more robust. Apart from having lost the teeth, the specimen is in a good state of preservation displaying very distinctly the surfaces for the articulation of the predentary, the splenial, the angular, and the surangular. There were about twenty-five alveoli for the teeth.

As already stated this species was originally referred by the writer in 1902 to the genus Monoclonius, Cope. In 1907 Mr. J. B. Hatcher, in his monograph on the Ceratopsia assigned it to Ceratops, Marsh. In the writer's opinion neither of these genera is at present on a sound basis and available for use.

The genus Ceratops, Marsh (type species *C. montanus*) is based on a pair of supraorbital horn-cores and an occipital condyle belonging to one individual from the Judith River beds on Cow creek, a tributary of Missouri river in Montana, U.S.A. No other parts of the skeleton are known. These horn-cores curve "strongly outward and slightly forward" (Ceratopsia monograph, page 172) the concave curve being on the outer side of the core. In Eoceratops the opposite is the case, the horn-core curving inward and backward with the concave curve on the inner side.

The validity of the genus Ceratops rests mainly on the shape of a pair of supraorbital horn-cores, and if any reliance can be placed on the position, size, and shape of horn-cores in the Ceratopsidæ as an aid to differentiation in that family then the supraorbital horn-cores of *Eoceratops canadensis* clearly indicate its distinctness from Ceratops, without reference to other parts of the skull which in the case of Ceratops are not at present available. Such a decided dissimilarity in the shape of the brow-horns suggests equally great differences, most probably of generic value, elsewhere in the skull. From our present knowledge of the horn-cores of the Ceratopsidæ their curvature, or the direction of their growth, is constant in any species. In individuals of the same species there is remarkably little variation in the curvature or direction of growth of both the supraorbital and nasal horn-cores. This is seen in Styracosaurus, Centrosaurus, Eoceratops, Chasmosaurus, and Triceratops, and is probably true of all the genera. Differences of size occur, no doubt due to age and possibly to sex, but apparently the growth of a horn-core is in a definite direction, forward, upward, or backward, and also with inward or outward curvature in the case of brow-horns, according to the genus and species to which the individual belongs.

The genus Ceratops, Marsh, is defined in Hatcher's memoir on "The Ceratopsia," page 100, as follows: "The present genus may be distinguished from *Monoclonius*, Cope, based on material from the same beds in Montana, by the greater development of the supraorbital horn-cores, the longer and narrower squamosals, the enlarged fontanelles, by which the parietals are reduced to slender median and lateral bars. The nasal horn-cores are very probably quite different also in the two genera, though we cannot as yet be certain as to their character in *Ceratops*. From our present knowledge of the skull of *Ceratops* it seems to have been a precursor of *Torosaurus*, Marsh, while *Monoclonius*, Cope, appears to have been ancestral to *Triceratops*, Marsh."

As the material on which *Ceratops montanus*, the type of the genus, is based consists of a pair of supraorbital horn-cores and an occipital condyle, no other parts of the skull (and nothing of the rest of the skeleton) being known, the above characters assigned to the squamosals, and the parietals and their openings are hypothetical. Mr. Hatcher in his monograph, page 97, expressed his conviction as to the generic identity of *Eoceratops* (*Monoclonius*) *canadensis* and *Chasmosaurus* (*Monoclonius*) *belli* with *Ceratops montanus* and no doubt it was this view which led him to assign characters to Ceratops for which there was no warrant in the generic type.

In 1897 the writer collected in the Belly River formation, Red Deer river, Alberta, a left supraorbital horn-core (Cat. No. 254) which more nearly resembles those of *Ceratops montanus* in its general shape, and forward and outward curvature, than those of any other ceratopsian of which he has any knowledge.

At present the characters of the genus Ceratops, Marsh, are not sufficiently definable and it will be necessary to await the discovery of further material before its relationship to known members of the Ceratopsia can be satisfactorily determined.

In *Eoceratops canadensis*, of which the principal diagnostic parts of the skull are known from excellently preserved material, the brow-horns are very different in shape and curvature from those of *Ceratops montanus* and it is reasonable to suppose that the skull of the latter when found will exhibit strong distinctive characters.

Also in *Chasmosaurus belli* (Plate VIII), of which the entire skull (including the lower jaw) is known, the brow-horns differ entirely from those of Ceratops.

The genus Monoclonius, Cope, with *M. crassus* as the type species, is unfortunately also in a very unsatisfactory state. According to Hatcher (Monograph on the Ceratopsia, 1907, page 73) the actual type material described by Cope from the Judith River district, Montana, U.S.A., was apparently "of a composite nature and pertained to two or more individuals."

The genus and species were originally defined by Cope as follows:—

"Char. gen.—Teeth with obliquely truncate face and distinct root, which is grooved for the successional tooth on the front. No external cementum layer, caudal vertebræ biconcave, and brim narrow. Fore limbs large and massive."

"The teeth of this genus resemble those of *Hadrosaurus*, and like them are replaced from the "front," an arrangement which precludes the possibility of more than one series of teeth being in functional use at one time. The robust fore limbs and elongate ilium distinguish[1] Monoclonius from Hadrosaurus. From Trachodon it differs in the absence of the rough cementum layer on the back of the tooth."

"*Char. specif.*—The faces of the teeth are acuminate, oval in form and are divided by an elevated keel, which is median above, but turns to one side at the base. Margin, crenate, the grooves extending more or less on the crown 'back,' which is otherwise smooth."

"Sacrum with ten vertebræ, the last centrum much compressed, the diapophyses extending horizontally from the neural arch above, and connected by a vertical lamina with the iliac supports; length 27·33 inches. The bones of the limbs are robust, the hinder the longer, but not so much so as in some other genera. Length of femur 22 inches; width proximally, 7·4 inches; distally 6 inches. Length of tibia 20 inches; greatest diameter, proximally, 8 inches; distally, 7·25 inches. The

[1] In the original description the word *Monoclonius* was by mistake printed *Diclonius*.

three anterior dorsal vertebræ are coössified, and the first exhibits a deep cup for articulation with the preceding vertebra. The episternum is a T-shaped bone, thin and keeled on the median line below. Length of transverse portion 21 inches."

As already pointed out by Hatcher a number of errors were included in the above definition. The teeth described are those of a trachodont, the supposed episternum proved to be the parietal portion of a frill as recognized by Cope in later descriptions, and the three vertebræ described as being anterior dorsals were found to be cervicals.

The type material described and figured by Hatcher in his monograph includes besides the coössified parietals, a sacrum, and cervical, dorsal, and caudal vertebræ. Limb bones, a scapula and coracoid, an ilium, and an ischium are also figured and described as pertaining to *M. crassus*, and a left postfrontal bone bearing a horn-core, mentioned by Cope, is referred with a query to the same species. Hatcher was of the opinion (Monograph, page 76) that the parietals, the postfrontal, and the sacrum pertained to three different individuals.

That the parietals and the remainder of the above-mentioned material, belong to the same species or even the same genus is doubtful.

In comparing the parietals of Monoclonius with those of the wonderfully preserved skulls of the horned dinosaurs from Alberta a general resemblance to both Centrosaurus and Styracosaurus is apparent.

The parietal portion of the frill of *M. crassus* appears to be a much worn or weathered specimen, judging from the original figure in the American Naturalist, Vol. XXIII, 1889, and from the seemingly more exact one in Hatcher's monograph. In general proportions it bears some resemblance to the same part of the frill in Centrosaurus if the fontanelles are as large as they are suggested to be in the above figures. If, on the other hand, the fontanelles of *crassus* were of less ample proportions than indicated in these figures, parietals of Styracosaurus, which had been subjected to severe weathering after the large posterior bony outgrowths had been broken off close to their base, would have much the appearance of the frill specimen of *M. crassus*.

As regards the supraorbital horn-core doubtfully assigned to *M. crassus* its similarity in form to that of *Brachyceratops montanensis*,[1] Gilmore is noteworthy. This "striking similarity" has been remarked on by Gilmore (page 10) who suggests a possible identity with his genus.

Owing to the imperfections of the parietals of *M. crassus* and the doubt regarding the proper association of the short brow-horn and the rest of the described material with this part of the frill, it is clear that the genus Monoclonius rests on an uncertain basis and is in need of further elucidation.

If the main characters of the skull of *Ceratops montanus* and *Monoclonius crassus* are to be made known more comprehensive material must be forthcoming, preferably from the Judith River district in Montana. The above two genera are, in the writer's opinion, not sufficiently defined for use at the present time. In the case of Ceratops there is a paucity of material inadequate in full diagnostic characters. With Monoclonius its non-employment as a generic term is considered advisable on account of the composite nature of the material described which lacks data both as regards localities and the association of the skeletal elements in the field.

Relying on the characters of the skull, the horned-dinosaurs appear to fall into three natural groups or subfamilies which are derived through separate lines of descent from one or more ancestral forms still undiscovered. These three groups are as follows: (a) Eoceratops of the Belly River formation leading to the later Triceratops and Diceratops; (b) Centrosaurus, Styracosaurus, and Brachyceratops, an apparently natural group of which the members are all from the Belly River formation and have no known descendants; and (c) Chasmosaurus of the Belly River formation ancestral to Torosaurus.

The main characteristics of the horn-cores and neck frill in these groups appear to be as follows:—

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[1] Smithsonian Miscellaneous Collections, 1914, Vol. 63, No. 3; A new Ceratopsian Dinosaur from the Upper Cretaceous of Montana with note on Hypacrosaurus, pp. 1-10, Plates 1 and 2, and text figures.

Eoceratops to Triceratops. (Plates II and V.)

Large brow-horn increasing in size.
Nasal horn persistently small.
Squamosal broadly triangular.
Parietal fontanelle disappearing (closing).

Centrosaurus, *Styracosaurus*, and *Brachyceratops*. (Plates III and VI.)

Brow-horn persistently small.
Nasal horn persistently large.
Squamosal continuing small.
Parietal fontanelle diminishing.

Chasmosaurus to *Torosaurus*. (Plates IV and VII.)

Brow-horn increasing.
Nasal horn decreasing.
Squamosal lengthening.
Parietal fontanelle diminishing.

The more salient characters of the skull in the best known genera of horned dinosaurs may be briefly tabulated as follows:—

	Supraorbital horn-core	Nasal horn-core	Squamosal	Parietals	Fenestræ of neck-frill
Eoceratops	Of moderate size directed upward, slender, circular in cross-section, curving inward and slightly backward in its upper part.	Very short, pointing upward and forward, laterally compressed, arising from the anterior end of the nasals, and formed by the nasals and two separate, epinasal ossifications.	Triangular, longer than broad, outer border scalloped, without epoccipitals.	Central portion unknown. Postero-laterally consisting of a forwardly directed slender prolongation beneath the squamosal. Without epoccipitals.	Apparently long: width unknown. Enclosed behind by the parietal, and without by the squamosal principally.
Triceratops	Large, directed upward, forward, and generally outward, circular in cross-section.	Small, rising anteriorly from the nasals, pointing forward and upward.	Triangular, longer than broad, outer border scalloped, with epoccipitals.	Completely filling the space between the squamosals. With epoccipitals.	No opening.
Diceratops	As in Triceratops but more upright.	No horn-core.	Of the general type of Triceratops.	As in Triceratops.	No opening.
Centrosaurus	Varying from a roughened boss to short, stout, curving slightly backward.	Of moderate length, stout, curving forward, broadly oval in cross-section with the greater diameter fore and aft, placed well back on nasals.	Short, longer than broad, with a scalloped outer free border, with epoccipitals.	Broadly expanding behind the squamosals. Largest outgrowths from the hinder portion directed forward over the fenestræ. With epoccipitals.	Large, widely oval, surrounded by the parietal.

Incipient: its position | Very large, uprightly | Short, irregularly | Broadly expanding be- | Of moderate size.

Styracosaurus	Incipient: its position indicated by a small concave surface.	Very large, uprightly tapering, oval in cross-section with the greater diameter fore and aft. Set well back on the nasals.	Short, irregularly four-sided, nearly as broad as long, outer margin scalloped: no epoccipitals.	Broadly expanding behind the squamosals. Outgrowths directed backward from the posterior bar. Without epoccipitals.	Of moderate size, oval, within the parietal.
Brachyceratops	Varying from incipient to small.	Enlarged, curving backward, laterally compressed.	Short, with undulating free border, without epoccipitals.	Expanding behind the squamosals; becoming platelike. Margin scalloped without epoccipitals.	If present, small and oval, within the parietal.
Chasmosaurus	Stout, short, upright, flattened on the outer surface.	Rather short, stout, curving backward, oval in cross-section.	Very long, roughly, triangular, more than three times as long as broad, outer margin scalloped and bearing epoccipitals.	Between the squamosals in the form of a slender triangular frame with a longitudinal median bar. With epoccipitals postero-laterally.	Very large, subtriangular, within the parietal.
Torosaurus	Large, directed well forward and outward, laterally compressed, ovate in cross section.	Short, broad at the base, sharp above, pointing forward and upward.	Very long and narrow, outer anterior border slightly undulating; no epoccipitals.	Between the squamosals; less slender and more plate-like than in Chasmosaurus. Without epoccipitals.	Large, circular, within the parietal.

It is considered that the species described by Cope under the name *Monoclonius sphenocerus* is allied to *Styracosaurus albertensis* and should probably be placed in the latter genus of which the Red Deer River species is the type.

As regards the lately established genus Brachyceratops of Gilmore, based on the skull of a young individual from the "Upper Cretaceous" of Montana, the writer is of the opinion that it includes the species from the Belly River formation, Alberta, originally described by him in 1902 under the name *Monoclonius dawsoni*.

In the three lines of descent through the Eoceratops, Centrosaurus, and Chasmosaurus groups, salient characters are seen in the brow-horns, the nose-horns, and the neck frill. As regards the frill, a persistent attempt is seen in all three groups to enlarge and strengthen it and to render it a more efficient means of defence by covering more of the neck and shoulders.

In the Eoceratops group greater strength was attained by the enlargement of the squamosals and the closing of the fenestræ (Plate II), resulting in Triceratops and Diceratops in a larger, more compact, and heavier covering to the neck and shoulders.

In the Centrosaurus group a larger frill surface is attained by an increase in the size of the parietal portion which expands *behind* the squamosals, these latter remaining small (Plate III). In Centrosaurus and Styracosaurus, particularly in the latter, an increased surface is gained by the addition of bony outgrowths which, while not adding to the compactness of the frill, may have served a good purpose as defensive weapons or at least as an aid to the assumption of a more alarming aspect. The fenestræ are smallest, if they have not altogether disappeared, in Brachyceratops.

In the third group, Chasmosaurus leading to Torosaurus (Plate IV), the parietal part of the frill lies not so much behind as *between* the greatly lengthened squamosals. The open framework of the older form (Chasmosaurus) is succeeded by a stronger median expansion with comparatively small openings (Torosaurus.)

A final result is reached in the Eoceratops and Chasmosaurus groups in a neck-frill of increased compactness, strength, and resisting power.

The genera included in the Centrosaurus group are all from the Belly River formation so that this group does not furnish a representative from the higher horizon in the Cretaceous in which Triceratops and Torosaurus occur as culminating types of their respective groups. This later form, if such an one existed, would probably furnish additional evidence of the attainment of somewhat similar results through different evolutionary stages.

The ancestral type of ceratopsian, presumably belonging to early Cretaceous or Jurassic times, from which the Belly River Cretaceous horned-dinosaurs descended, had, in all likelihood, a poorly developed neck-frill contributed to by small squamosals and a slender parietal framework which together enclosed fenestræ of comparatively large size (Plate II). This frill may have resembled in a general way the somewhat similarly placed, but differently constructed backward prolongation of the skull of the living *Chamaeleon vulgaris*.

It is thus seen that distinctive characters are found in the neck-frill in these three groups of horned dinosaurs. With these are linked other definite characters pertaining to the brow and nose-horns as already tabulated.

In the Eoceratops group there is an increase in the size of the brow-horns, with a continuance of a small nasal horn, and broadly triangular squamosals (Plate V).

The new genus[1] Anchiceratops of Brown founded on the posterior half of a skull from the Edmonton formation on Red Deer river, Alberta, belongs apparently to the Eoceratops group. In this genus the brow-horns are large, the squamosals are broadly triangular and of moderate length, and the frill-openings are reduced in size. In the Ceratopsia a well developed nasal horn-core accompanies small supraorbital horn-cores, and when these latter are large the former is reduced, accordingly the nasal horn-core of *Anchiceratops ornatus*, the type and only

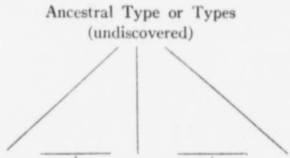
[1] Bull. Amer. Mus. Nat. Hist., Vol. XXXIII, art. XXXIII, pp. 539-548.

known species of the genus, when discovered will most probably prove to be of small size. The characters of Anchiceratops, as at present known, seem to assign it to a position between Eoceratops and Triceratops, an evolutionary stage in accord with the position of the Edmonton formation intermediate to the earlier Belly River beds and the later Lance formation.

The members of the second group (Centrosaurus, etc.) have small brow-horns, a large nose-horn, and parietals expanded behind small squamosals (Plate VI). While in this group the nasal horn is large, its shape is distinctive in the three known genera composing the group. Thus, in Centrosaurus the nasal horn curves forward, in Styracosaurus it is straight and points upward, in Brachyceratops it curves backward.

In the two genera forming the third group there is a striking increase in the size of the brow-horns, a decrease in size in the nasal horn, and a development of very long, narrow squamosals (Plate VII).

The above three groups or subfamilies of the horned dinosaurs, which may be named the Centrosaurinæ, the Eoceratopsinæ and the Chasmosaurinæ from the most primitive member of each group respectively, occur in the Belly River formation and later Cretaceous as follows:—



Horizon	Centrosaurus group	Eoceratops group	Chasmosaurus group
Belly River (Judith River)	Centrosaurus Styracosaurus Brachyceratops	Eoceratops	Chasmosaurus
Laramie (Lance Creek beds)		Triceratops	Torosaurus

Reference may here be made to the opinion expressed by Mr. Brown in a recent paper that *Centrosaurus apertus* is a synonym of *Brachyceratops*[1] *dawsoni*.

The known characters of *B. dawsoni*—large backwardly curved nasal horn-core, incipient supraorbital horn-cores (as in Styracosaurus), small squamosals, a smooth undulating free border to the frill without epoccipitals, and greatly reduced openings in the frill, if indeed they were present at all—are in marked contrast to and greatly at variance with the fully known ones of Centrosaurus a genus established by the writer eleven years ago[2] for the reception of a well preserved neck-frill discovered by him in 1901 in the Belly River beds of Red Deer river about one mile below the mouth of Berry creek. Additional Centrosaurus material in the possession of the Geological Survey, from the same locality and horizon, including skulls of which one has the lower jaw in place (Plate VI, figure 1, and Plate XI) fully confirms the early descriptions, reveals the full osteology of the skull, and further demonstrates the distinctness of the genus and species among the horned dinosaurs of the Belly River Cretaceous. Mr. Brown in the paper here referred to has proposed the specific name *flexus* for a skull of *Centrosaurus apertus* from the same beds on Red Deer from which the original neck-frill (type) and the supplementary specimens come. The skull described by Mr. Brown was found by the American Museum party in 1912 one mile below the mouth of Berry creek and presumably not far distant from where the type specimen of Centrosaurus was discovered.

There seems to have been a tendency in the horned dinosaurs to produce a separate bony growth on each prominence of the upper part of the skull. Thus the epoccipitals occur in a series along the free border of the frill, one to each convexity, and the epijugal is so named from its situation at the lower extremity of the jugal. Recently Dr. C. W. Gilmore has found in the type of Brachyceratops (Plate VI, figure 3, and Plate X) an ossicle

[1] Bull. Amer. Mus. Nat. Hist., Vol. XXXIII, art. XXXIV, pp. 549-558, 1904.

[2] Ottawa Naturalist, Vol. XVIII, pp. 81-84, 1904; and Trans. Royal Soc. of Canada, second series, Vol. X, pp. 3-9, 1904.

on the top of the nasal horn-core, and in the skull of Centrosaurus figured in Plate XI (Geological Survey collection of 1914) a separate ossification occurs at the upper termination of the rostral bone. Further, at the greatest elevation of the postfrontal above each orbit in the type specimen of Styracosaurus and also in that of *Brachyceratops dawsoni* there is a shallow concavity of somewhat irregular oval outline which has the appearance of being a sutural surface for the attachment of a separate bony growth which became detached before or during fossilization, as was often the case with the epoccipitals and especially with the epijugal. This separate ossification above the postfrontal was evidently an incipient supraorbital horn-core and furnishes the clue to the origin of this horn-core in the horned dinosaurs generally from a centre of ossification distinct from the postfrontal. The supraorbital horn-core is to be regarded, therefore, not as a simple outgrowth from the postfrontal but as a separate element, in the same category with the epijugal and the epoccipitals and like them to become firmly attached to the underlying element with generally a more or less perfect obliteration of the sutural contact. The large posterior projections of the frill in Styracosaurus (Plate III, figure 2, and Plate VI, figure 2) may be regarded as a striking example of extreme enlargement in separate bony growths with loss of any trace of a basal suture. In the supraorbital horn-core a more or less distinct basal engirdling groove or constriction is sometimes present as an indication of where coössification has taken place. Also foramina or deep pits not infrequently occur at the horn base and may be regarded as marking the position of a closed suture.

The presence of epoccipitals on the margin of the neck-frill is distinctive of certain genera. They were developed in all three groups of horned dinosaurs apparently as accessories during specialization, to be abandoned when found useless as appendages to the armature. The primitive Eoceratops was without them, later they appear in Triceratops. In the wholly Belly River Centrosaurus group the specialized Centrosaurus has these separate ossifications in a well-developed state, Styracosaurus has a profusion of them of unusual length, while in

Brachyceratops there is a simple undulation of the frill border. In the Belly River Chasmosaurus epoccipitals form a prominent feature of the frill armature, but in its supposed descendant Torosaurus they have altogether disappeared.

The supraorbital horn-cores have hitherto been regarded as simple outgrowths, and the nasal one as a separate ossification from a single median centre.

As regards the horn-cores Mr. Hatcher, in his monograph, pages 32 and 33, has given his views of their origin. This author stated that "While these horn cores (nasal)are supported by the nasals, and in old animals become firmly co-ossified with them, they nevertheless have their origin in separate and distinct centres of ossification. Moreover, since in young individuals every nasal horn core is seen to have had its origin in a single median centre of ossification rather than in two distinct lateral centres placed one beside the other, it is evident that this horn core is in reality morphologically quite distinct from the nasals. In this respect the nasal horn cores differ greatly from the supra-orbital horn cores, which are simple outgrowths from the post-frontals, and therefore are morphologically a part of their supporting elements" . . . . "Morphologically the nasal horn cores may be considered as dermal or epidermal ossifications similar to the epijugals, epoccipitals, the rostral, and the predentary, and as quite distinct from the frontal horn cores."

As just stated the present writer regards the horn-core over the orbit as an ossification separate from the postfrontal. With increased age in an individual a union of the base of this separate ossification (epipostfrontal) with the postfrontal took place with usually a loss later of all trace of the suture.

The type of Eoceratops throws light on the origin of the nasal horn-core. In this specimen this small horn-core is seen to be made up of the anterior end of the nasals and a separate ossification (epinasal) in front of each nasal, as explained in the description of the skull of Eoceratops and shown in the figure of that specimen, proving the quadruple origin of the nasal horn-core, that is, that there were two separate ossifications one in front of each nasal instead of one medium ossification anterior to these bones as believed by Hatcher.

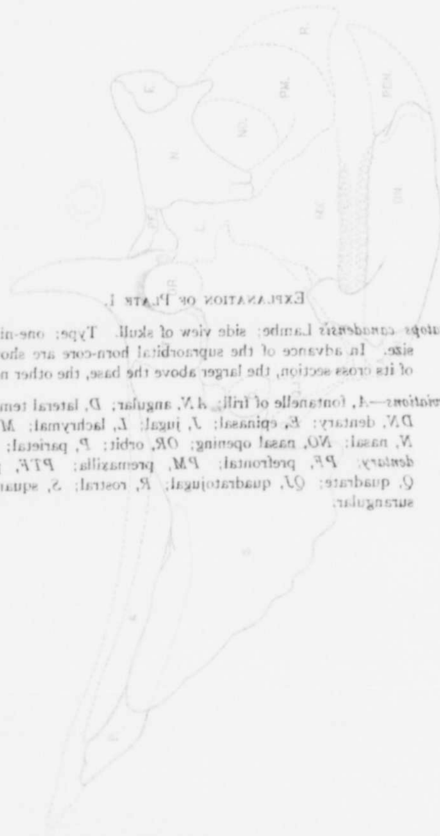
The suture between the left epinasal bone and the left nasal is well shown in the figure of the skull of *Triceratops elatus* Marsh, forming Plate XLIII of Hatcher's monograph. In *T. elatus* the form and position of the epinasal (Plate X, figure 1), as seen in side view, is very similar to that of Eoceratops (Plate X, figure 2), with this difference that in Eoceratops it is more under the upper anterior end of the nasal which extends over it.

Apparently the epinasals are to be classed with the epipostfrontal (supraorbital horn-core) the epijugal, the epoccipitals (episquamosals and epiparietals) the rostral and the predentary as having a dermal or epidermal origin. But whereas the epiparietals were subject to great enlargement (Styracosaurus) as were also the epipostfrontals, the epinasals always remained small taking a subsidiary part only in the formation of the nasal horn-core. Increase in size in the nasal horn-core was dependent on the nasals which extended over and were prolonged above the epinasals, the latter acting as basal supports and becoming ankylosed to the nasals and to each other.

In Plate X the nasal horn-core is shown in four species of horned dinosaurs (*Triceratops elatus, Eoceratops canadensis, Brachyceratops montanensis*, and *B. dawsoni*) illustrating as many phases of nasal horn-core development from the incipient horn-core made up almost entirely of the epinasals, through progressive stages of nasal enlargement until the horn-core consists mainly of the prolonged nasals with the complete subservience of the epinasals. In *T. elatus* the nasals are slightly elevated behind the epinasals, in *E. canadensis* they are sufficiently prolonged to cover the epinasals above, in *B. montanensis* (Plate X, figure 3) they are further enlarged by an upward extension, while in *B. dawsoni* (Plate X, figure 4) a full development of the horn-core is reached with their still further increase in size to form a weapon of imposing proportions.

In Plate XI is figured one of two remarkably fine skulls of *Centrosaurus apertus* from the Belly River beds of the type locality. This skull in which the nasal horn-core is abnormally bent downward in its upper half, belongs to the collection of 1914. In the other, discovered in 1913, the natural forward curve of this horn-core is preserved.

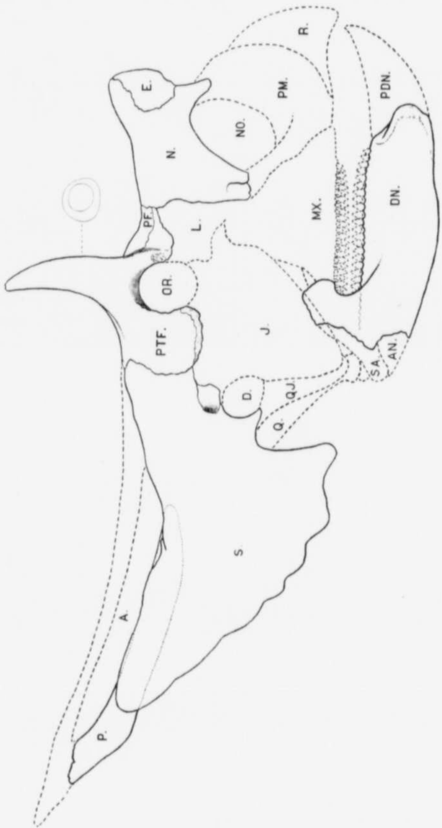
The skull of *Chasmosaurus belli* reproduced in Plate VIII also forms part of the collection of 1914 from Red Deer river. This specimen and the 1914 skull of Centrosaurus are remarkable in that they have the lower jaw in place and allow of figures being given for the first time of the complete skull in both species.



Explanation of Plate I.

Eoceratops canadensis Lambe; side view of skull. Type; one-ninth natural size. In advance of the supraorbital horn-core are shown outlines of its cross section, the larger above the base, the other near the top.

Abbreviations—*A*, fontanelle of frill; *AN*, angular; *D*, lateral temporal fossa; *DN*, dentary; *E*, epinasal; *J*, jugal; *L*, lachrymal; *MX*, maxilla; *N*, nasal; *NO*, nasal opening; *OR*, orbit; *P*, parietal; *PDN*, *predentary;* *PF*, prefrontal; *PM*, premaxilla; *PTF*, postfrontal; *Q*, quadrate; *QJ*, quadratojugal; *R*, rostral; *S*, squamosal; *SA*, surangular.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EXPLANATION OF PLATE II.

Figure 1. Hypothetical form of frill of ancestral ceratopsian; **superior** aspect.

Figure 2. Frill of *Eoceratops canadensis* Lambe; one-eighteenth natural size; viewed from above.

Figure 3. Frill of *Triceratops flabellatus* Marsh; one-sixteenth natural size; viewed from above. After Marsh.

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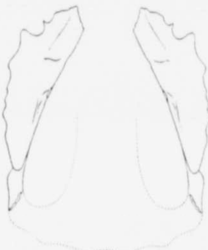

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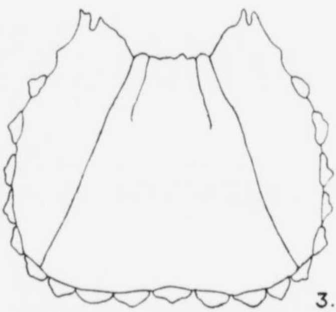

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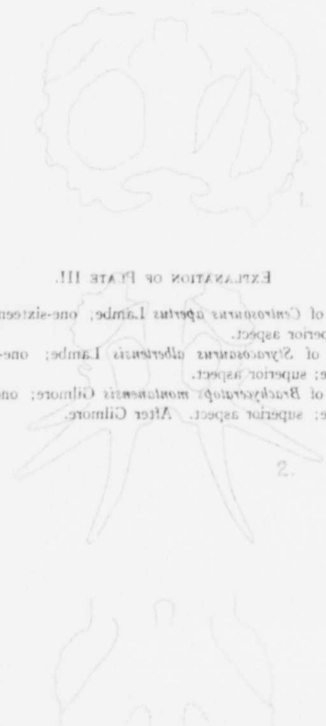
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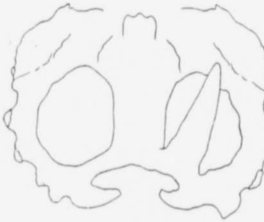
Explanation of Plate III.

Figure 1. Frill of *Centrosaurus apertus* Lambe; one-sixteenth natural size; superior aspect.

Figure 2. Frill of *Styracosaurus albertensis* Lambe; one-twelfth natural size; superior aspect.

Figure 3. Frill of *Brachyceratops montanensis* Gilmore; one-eighth natural size; superior aspect. After Gilmore.



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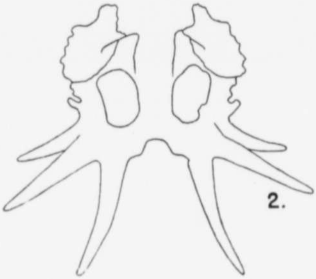

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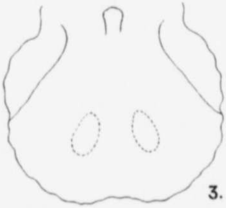

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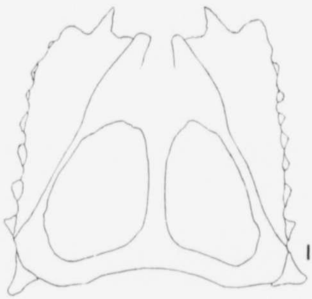
EXPLANATION OF PLATE IV.

Figure 1. Frill of *Chasmosaurus belli* Lambe; one-twentieth natural size; viewed from above.

Figure 2. Frill of *Torosaurus gladius* Marsh; one-thirty-second natural size; superior view. After Marsh.



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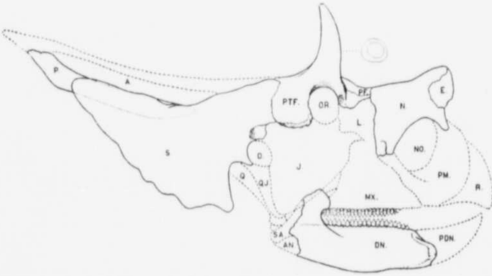
Explanation of Plate V.

Figure 1. Skull of *Eoceratops canadensis* Lambe: lateral aspect: about one-fifteenth natural size.

Figure 2. Skull of *Triceratops flabellatus* Marsh; lateral aspect; one-twelfth natural size. After Marsh.



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Explanation of Plate VI.

Figure 1. Skull of *Centrosaurus apertus* Lambe; lateral aspect; about one-eighteenth natural size.

Figure 2. Skull of *Styracosaurus albertensis* Lambe; lateral aspect; about one-twentieth natural size.

Figure 3. Skull of *Brachyceratops montanensis* Gilmore; lateral aspect; one-seventh natural size. After Gilmore.

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EXPLANATION OF PLATE VII.

Figure 1. Skull of *Chasmosaurus belli* Lambe; lateral aspect; about one-seventeenth natural size.

Figure 2. Skull of *Torosaurus gladius* Marsh; superior aspect; about one-twenty-fourth natural size. After Marsh.

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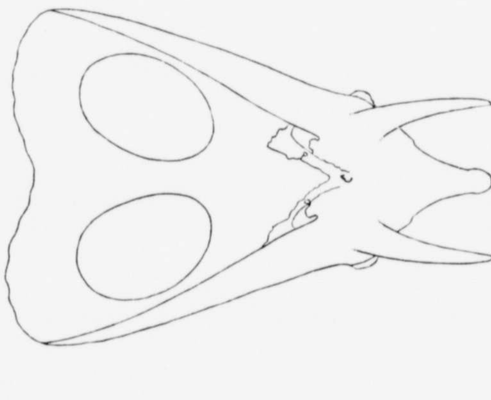

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EXPLANATION OF PLATE VIII.

Skull of *Chasmosaurus belli* Lambe; side view; one-eighth natural size. Belly River formation, Red Deer river, Alberta; collection of 1914 made by the Geological Survey vertebrate palæontological field party under Charles H. Sternberg.


R. Weber, del.


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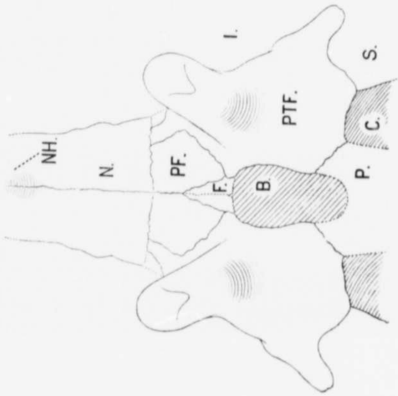
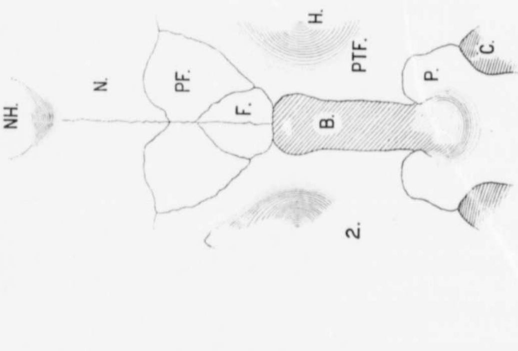
Explanation of Plate IX.

Figure 1. *Eoceratops canadensis* Lambe; view of the more anterior portion of the skull from above to show the relation of the elements to each other; one-sixth natural size.

Figure 2. *Centrosaurus apertus* Lambe; view of part of the skull from above for comparison with figure 1; one-sixth natural size.

Abbreviations—*B*, postfrontal fontanelle; *C*, supratemporal fossa; *F*, frontal; *H*, supraorbital horn-core; *L*, lachrymal; *N*, nasal; *NH*, nasal horn-core; *P*, parietal; *PF*, prefrontal; *PTF*, postfrontal; *S*, squamosal.





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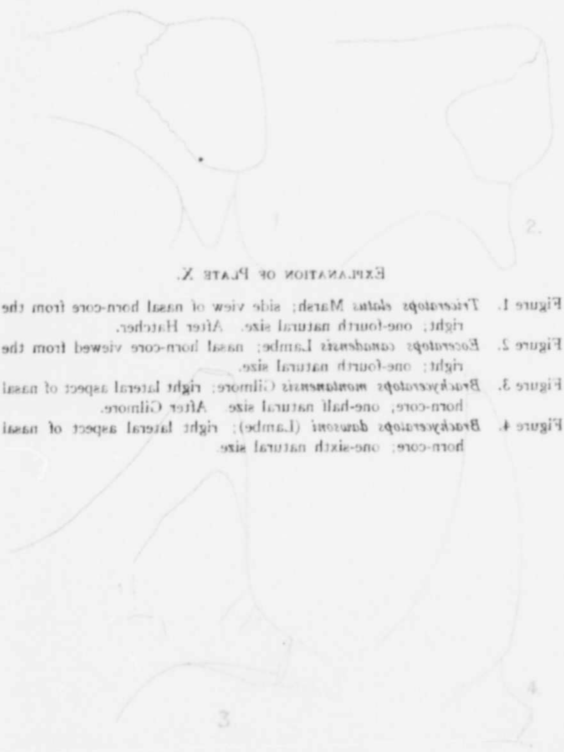
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EXPLANATION OF PLATE X.

Figure 1. *Triceratops elatus* Marsh; side view of nasal horn-core from the right; one-fourth natural size. After Hatcher.

Figure 2. *Eoceratops canadensis* Lambe; nasal horn-core viewed from the right; one-fourth natural size.

Figure 3. *Brachyceratops montanensis* Gilmore; right lateral aspect of nasal horn-core; one-half natural size. After Gilmore.

Figure 4. *Brachyceratops dawsoni* (Lambe); right lateral aspect of nasal horn-core; one-sixth natural size.

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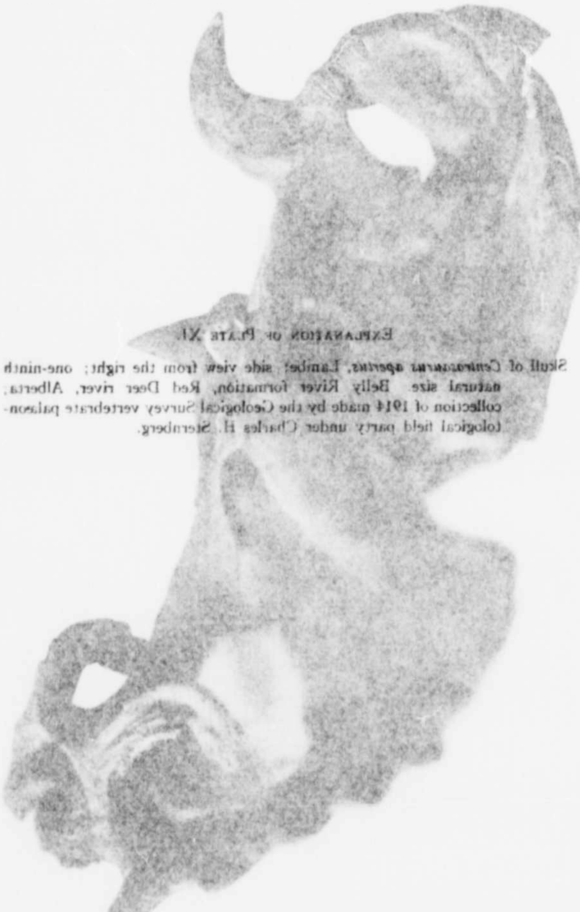

Explanation of Plate XI.

Skull of ***Centrosaurus apertus***, Lambe; side view from the right; one-ninth natural size. Belly River formation, Red Deer river, Alberta; collection of 1914 made by the Geological Survey vertebrate palæontological field party under Charles H. Sternberg.

The first number of the Museum Bulletin was entitled, *Victoria Memorial Museum Bulletin, Number 1.*

The following articles of the Geological Series of Museum Bulletins have been issued.

Geological Series.

1. The Trenton crinoid, Ottawacrinus, W. R. Billings; by F. A. Bather.
2. Note on Merocrinus, Walcott; by F. A. Bather.
3. The occurrence of Helodont teeth at Roche Miette and vicinity, Alberta; by L. M. Lambe.
4. Notes on Cyclocystoides; by P. E. Raymond.
5. Notes on some new and old Trilobites in the Victoria Memorial Museum; by P. E. Raymond.
6. Description of some new Asaphidæ; by P. E. Raymond.
7. Two new species of Tetradium; by P. E. Raymond.
8. Revision of the species which have been referred to the genus Bathyurus (preliminary paper); by P. E. Raymond.
9. A new Brachiopod from the base of the Utica; by A. E. Wilson.
10. A new genus of dicotyledonous plant from the Tertiary of Kettle river, British Columbia; by W. J. Wilson.
11. A new species of Lepidostrobus; by W. J. Wilson.
12. Prehnite from Adams sound, Admiralty inlet, Baffin island, Franklin; by R. A. A. Johnston.
13. The origin of granite (micropegmatite) in the Purcell sills; by S. J. Schofield.
14. Columnar structure in limestone; by E. M. Kindle.
15. Supposed evidences of subsidence of the coast of New Brunswick within modern time; by J. W. Goldthwait.
16. The Pre-Cambrian (Beltian) rocks of southeastern British Columbia and their correlation; by S. J. Schofield.
17. Early Cambrian stratigraphy in the North American Cordillera, with discussion of the Albertella and related faunas; by L. D. Burling.
18. A preliminary study of the variations of the plications of Parastrophia hemiplicata, Hall; by A. E. Wilson.
19. The Anticosti Island faunas; by W. H. Twenhofel.
20. The Crowsnest Volcanics; by J. D. Mackenzie.
21. A Beatricea-like organism from the middle Ordovician; by P. E. Raymond.
22. The Huronian formations of Timiskaming region, Canada; by W. H. Collins.
23. Physiography of the Beaverdell map-area and the southern part of the Interior plateaus of British Columbia; by Leopold Reinecke.