I.—*On the squamoso-parietal crest of the horned dinosaurs Centrosaurus apertus and Monoclonius canadensis from the Cretaceous of Alberta.*

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Monoclonius dawsoni and *M. canadensis* were described by the writer in 1902 in part II of volume III (quarto) of Contributions to Canadian Palæontology[1] from material derived from the Belly River series of Red Deer river, Alberta. The specimens on which the former species was founded consist of an imperfect skull (Cat. No. 1173), figure 14, p. 58, op. cit., and a posterior crest with a nasal horn core (Cat. No. 971), figure 15, p. 59, op. cit. These remains were thought to belong to the same species, but it has since become evident that the separate posterior crest and horn core belong to a distinct species and probably also to a different genus. As the skull was referred to first in the original description and, although poorly preserved, supplies information regarding a number of the cranial elements, it is retained as the type of *Monoclonius dawsoni*. For the form represented by the posterior crest the writer has proposed[2] the generic name of *Centrosaurus* in allusion to the remarkable inwardly directed hook-shaped processes springing from the posterior border of the frill. The species has been designated by the name *apertus* in reference to the very large openings or fontanelles lying wholly within the parietal expansion.

In *Monoclonius canadensis* the openings in the posterior crest are bounded on the outer side by the squamosals as well as by the parietals and are probably even proportionally larger than those of *Centrosaurus*.

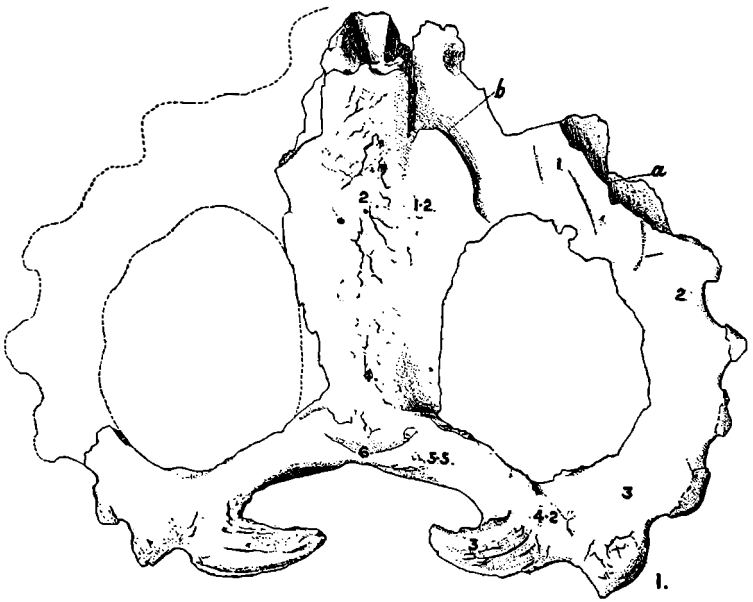
The crests of these two Ceratopsids are so remarkable in their structural characteristics that it is thought desirable to refer to them at the present time at greater length than was possible when originally described, and to provide figures for the better illustration of the specimens.

The crest or frill of Centrosaurus is composed mainly of the coalesced parietals which form an expansion broader than long and decidedly saddle-shaped, with a large opening on either side of the longitudinal axis. The parietal expansion, for the purpose of description, may be said to consist of a longitudinal central or axial part, a transverse portion forming the posterior border, and lateral or alar extensions that complete the sides and front margin. The central portion is comparatively broad, is high in front, concave in a longitudinal direc-

[1] On Vertebrata of the Mid-Cretaceous of the Northwest Territory.

[2] The Ottawa Naturalist, Vol. XVIII, pp. 81-84, plates I and II, July, 1904.

tion, and transversely convex on the upper surface, a rounded ridge being thus formed that extends backward to near the posterior border. From here an abrupt lateral extension of the bone to either side as a robust transverse bar, concave in outline behind when seen from above, constitutes the hinder margin from which are thrown off, at some distance on either side of the median line, the robust hook-shaped inwardly directed processes that form so prominent a feature in the general appearance of the crest. The posterior bar continues outward and forward on either side as relatively thin, narrow extensions, which, finally curving in to join the axial part anteriorly, completely enclose the large fontanelles. These alar extensions slope downward at a considerable angle, about 25°, on each side, and in an antero-posterior direction



partake, though in a less degree, of the longitudinal concavity of the median ridge. Along the median line the bone gradually thickens backward until a maximum thickness of six centimetres is attained at the centre of the posterior border. In the following figure, which represents the crest, as seen from above, one-eighth the natural size, the thickness of the bone in different parts is indicated in centimetres. From this it will be seen that the crest is decidedly robust behind, and that the bone gradually thins toward the front. The posterior bar near the median line presents a backwardly directed vertical face, which becomes rounded and less robust in the neighbourhood of the hooked processes; it is not, however, quite bilaterally symmetrical, its transverse section near the left hooked process being nearly

circular, whilst in the corresponding position on the other side it is decidedly thickened next to the fontanelle. Elsewhere the bone forming the margins of the fontanelles is thin, and comes gradually to a sharp edge. The right outer side of the crest is regularly scalloped from near the hooked process forward to a point almost in line with the front end of the fontanelle, from which point the squamosal suture extends forward and inward for some distance, as indicated in figures 1 and 2, and in the text figure, at *a*. The five protruding portions of the outer undulating margin bear sharp-edged epoccipital bones, with the exception, apparently, of the anterior one, which was partially in contact with the squamosal. The epoccipitals decrease in size forward and appear to have been firmly coössified with the underlying bone, the foremost one of the four, however, still showing the line of junction clearly. They lie in the general plane of the alar extensions, with their greatest diameter in an antero-posterior direction. Between them the bone is regularly emarginated and is evenly rounded at the edge. The coössification of the epoccipitals with the bone beneath would indicate an animal of mature age. The hooked processes appear to be a special development of the epoccipital bones and are of so extraordinary a nature as to demand special attention. Anteriorly the postfrontal suture, *b*, figures 1 and 2, and text figure, extends forward from the inner side of the front end of the fontanelle, in a general direction parallel to that of the squamosal, round the front end of the elevated axial ridge to meet the suture from the other side in the median line. The coalesced parietals extended beneath the postfrontals and squamosals as is indicated by the smoothness of the upper surface of the bone and its increased thinness in front of the groove or step marking the back limit of the sutural contact. At the extreme anterior end of the crest two vertical flanges of bone, one on each side of the median line, separate a deep central depression from lateral ones of about equal depth and size. Behind these latter occur smaller but deep pits that run beneath the edges of the elevated median ridge; these two pits are cut off from the more anterior pair by stout buttresses of bone. These five depressions evidently provided an increased surface of contact between the parietals and the postfrontals, where the principal strain in the support of the crest probably came and where great strength with lightness was no doubt requisite. On the lower surface the axial portion for a short distance in advance of the transverse posterior bar is flat, but in front of this the bone, on account of its increasing thinness as the front of the crest is approached, conforms more nearly with the general form of the upper surface so as to be deeply hollowed out in a longitudinal direction below. The lower surface of the crest is smoother

than the upper surface, where numerous vascular impressions are conspicuous as indicated in the accompanying figures. The markings are accentuated and most numerous on and in the vicinity of the hooked processes and epoccipitals both above and below, and on the upper surface they extend along the axial part forward. A shallow groove, *g*, figure 2, more clearly shown on the right side of the specimen, extends on the anterior side of the posterior bar from the upper surface near the median line downward and then upward in a regular curve, ending at a point in advance of the base of the hooked process. Above this groove the face of the bar presents a broken surface. On the left side the corresponding groove is only faintly indicated, and the bone above it is intact.

Judging from the position and extent of its suture the squamosal was evidently a comparatively small bone.

The horn core found with the posterior crest of *Centrosaurus apertus* is apparently from the nasal region; it is straight and laterally compressed so as to be lenticular in transverse section, with a sharp angular edge to the front and rear, recalling the shape of the nasal horn core described by Cope in 1889 under the name *Monoclonius sphenocerus*. The specimen is thirty centimetres in length, with the tip missing, and the lower surface imperfect. The compression may be accentuated by distortion, although the fossil does not seem to have suffered at all in that way, nor is there any evidence of injury from pressure in the posterior crest. The surface is marked by numerous vascular impressions and one side is deeply fluted longitudinally as in figure 3.

Measurements.

	M.
Extreme length from anterior end of crest (imperfect), medially, to line touching posterior edges of specimen on either side	·616
Length on median line, from anterior end to posterior border..	·486
Semi-breadth of specimen on curve of under surface	·470
Semi-breadth of specimen horizontally	·439
Vertical drop of lateral edge of specimen below median line of upper surface at mid-length	·186
Antero-posterior diameter of fontanelle	·296
Transverse diameter of fontanelle	·248
Circumference of base of left posterior spur	·172

The conclusion to be arrived at is that *Centrosaurus apertus* had a broadly expanded squamoso-parietal crest composed mainly of the

[1] Horned Dinosaurs of the Laramie. The American Naturalist, vol. xxiii., p. 715, pl. xxxiii., figs. 2, 2a.

coalesced parietals, the squamosals being confined to the antero-lateral edge of, and taking but little part in the formation of, the frill. That the large oval fontanelles were included entirely within the parietal part of the expansion and that epoccipital bones were well developed, of which the hinder pair were greatly modified so as to form large hooks or spurs of bone on the hinder border. That a closely fitting integument was present, as is indicated by the many impressions of blood-vessels on the upper surface, with the probability that the projections of the periphery, at the sides and behind, were sheathed in horn.

The frill of *Monoclonius canadensis* is made known to us through the medium of a very perfectly preserved right squamosal and the forwardly directed terminal portion of the right lateral posterior extension of the parietal which may have borne some resemblance to the parietal bone, the only known part of the crest, of *Monoclonius belli.* In the type specimen of the latter species the posterior parietal bar is broken off at some distance on either side of the median line of the head and the more lateral parts that would correspond with the known piece of the parietal of *M. canadensis* are missing. The type material on which *M. canadensis* is based includes the squamosal (Cat. No. 1254 a) and the parietal fragment (Cat. No. 1254 b) above mentioned, with a nasal[1] bone (Cat. No. 1254 c), a supraorbital horn core (Cat. No. 1254 d), a ramus of the lower jaw (Cat. No. 1254 e), and an anterior dorsal vertebra (Cat. No. 1254), all of which were found together and presumably belong to the same individual. A maxilla (Cat. No. 285), a lower tooth (Cat. No. 187), a ramus of a lower jaw (Cat. No. 284), and a supraorbital horn core (Cat. No. 212) from the type locality are also mentioned or described in the original description and referred to this species.

The squamosal, figures 4 and 6, has the form of a moderately thin plate, roughly triangular in shape, the base of the triangle being in front, the apex pointing backward. The outer border is convexly curved in outline, comparatively thick, with an evenly rounded edge, the inner one is concave and sharp-edged. Both the upper and lower surfaces are smooth and few indications of vascular impressions are present. The outer border is undulating, more decidedly so toward the front than posteriorly, there being four well defined convex projections in front with two longer but less salient ones behind; its anterior termination is pointed. The front border has two deep emarginations in its outer half, within it is thin and irregular being the edge of the sutural surface of contact with the jugal and the postfrontal.

[1] Originally referred to as the jugal. The writer wishes to express his obligations to Mr. Hatcher, of the Carnegie Museum, Pittsburgh, to whom he is indebted for a better understanding of the true nature of this bone.

Viewed from below, or from the inner side, the squamosal is seen to be thin for a short distance inward from the inner border along three-fifths of its hinder length for the accommodation of the forwardly directed prolongation of the posterior parietal bar. A sudden thickening of the bone marks the outer limit of the surface of contact. A deep pit *c*, figure 6, in continuation of the outer and larger emargination of the front border, directed obliquely backward and inward, received an elongate conical process from the quadrate which in this manner effected a strong union with the squamosal. The narrow, raised surface, *d*, figure 6, beneath this pit marks the junction of the outer end of the exoccipital. This surface is broken and reveals the pit for the quadrate more clearly than it would otherwise be seen. Behind this and outward from the longitudinal depression for the parietal the bone is relatively and rather uniformly thick, its surface being undulating and smooth. The bone in advance of the pit for the quadrate and the anterior termination of the depression for the parietal is thin with the inner border bent abruptly downward and inward at some distance from the edge so as to form what may be referred to as a deep triangular excavation in the inner front portion of the squamosal. The inner front border of this excavation indicates that the squamosal here overlapped the postfrontal to some extent, the contact with the jugal being limited to a small surface exterior to this which would include the marginal pit shown in figure 4 at *e*. A shallow groove, *f*, figures 6 and 4, extends inward from the raised surface for the exoccipital to the inner border; in its inner course it turns backward, becoming narrower and deeper, and crosses the anterior end of the depression for the parietal obliquely, finally passing to the upper surface over the inner border and ending in the concavity shown at *h* in figure 4. The surface of the bone behind this concavity, as well as that in the neighbourhood of the well defined depressions or grooves toward the front end of the inner border (figure 4) is roughened as if for muscular attachment. Linear vascular impressions are present anteriorly as indicated in the same figure.

The anterior termination of the posterior bar of the parietal, shown in figures 5 and 7, is flat on the side next to the squamosal, and keeled on the lower side, the keel passing from the inner edge behind to the middle of its anterior end where it is most prominent. Beyond its contact with the squamosal it is slightly twisted, so as to accommodate itself more exactly to the general plane of the upper surface of the squamosal, and curves a little inward, but so little as to suggest a sudden bending inward of the bone more to the rear, or if the inward curve were gradual a very great backward development of the parietal portion of the crest along the median line of the head would be

necessary. In either case the fontanelle, lying on the inner side of the squamosal and the attenuated lateral extension of the posterior part of the parietal, must have been of considerable size, probably much larger than the fontanelles of the crest of *Centrosaurus apertus*. The undulations of the outer border of the squamosal are continued in that of the free part of the parietal (figures 4—7). The dotted outlines in figures 4 and 6 indicate the position of the parietal extension, when applied to the squamosal, and as it was found in the rock. The figures 7a, 7b and 7c give the outlines of transverse sections of the bone at the points indicated.

It is seen then that in *Monoclonius canadensis* the posterior crest extended far backward, that it was made up of the parietals (probably coalesced so as to have somewhat the form of the corresponding portion of the frill of *Monoclonius belli*) and the squamosals, the latter entering largely into the composition of the sides of the crest, and that fontanelles of very large size were present. We know also that the fontanelles were not included entirely within the parietals, as in *Centrosaurus*, but were bounded laterally in front by the squamosals.

Measurements of squamosal, etc.

	M.
Length on curve of outer border	·576
Length on curve of inner border	·573
Length from posterior end to centre of front margin	·533
Breadth across front margin	·355
Thickness near outer border, at mid-length	·028
Thickness near inner border, at mid-length	·038
Length of fragment of parietal extension	·502
Breadth of same at mid-length	·064
Greatest thickness of same at mid-length	·030

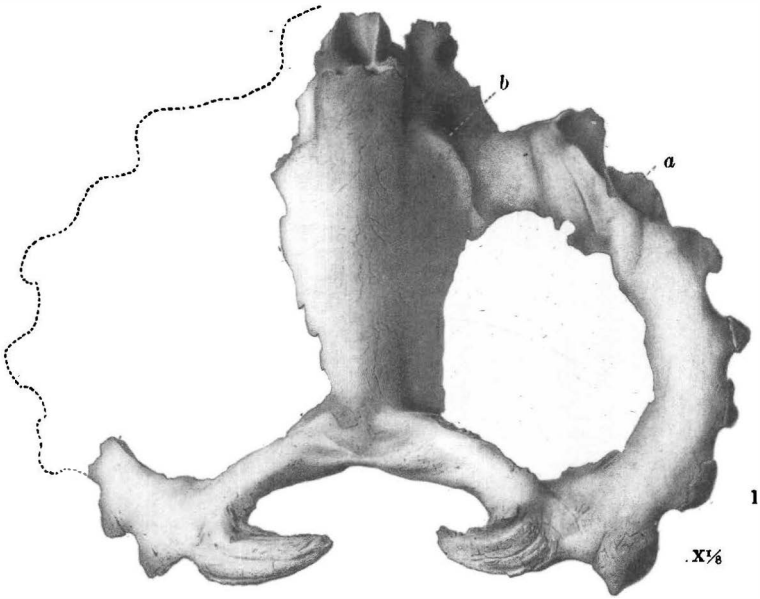
Plate I.

Figure 1.—Coalesced parietals of *Centrosaurus apertus* as seen from above; one-eighth natural size.

Figure 2.—Right lateral aspect of the same; similarly reduced.

Figure 3.—Lateral aspect of nasal horn core of *C. apertus;* one-eighth natural size.

Figure 3a.—Outline of transverse section of the same, similarly reduced.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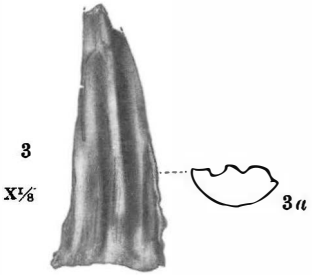
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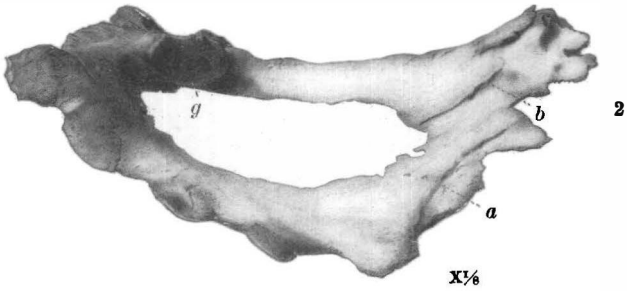
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Plate II.

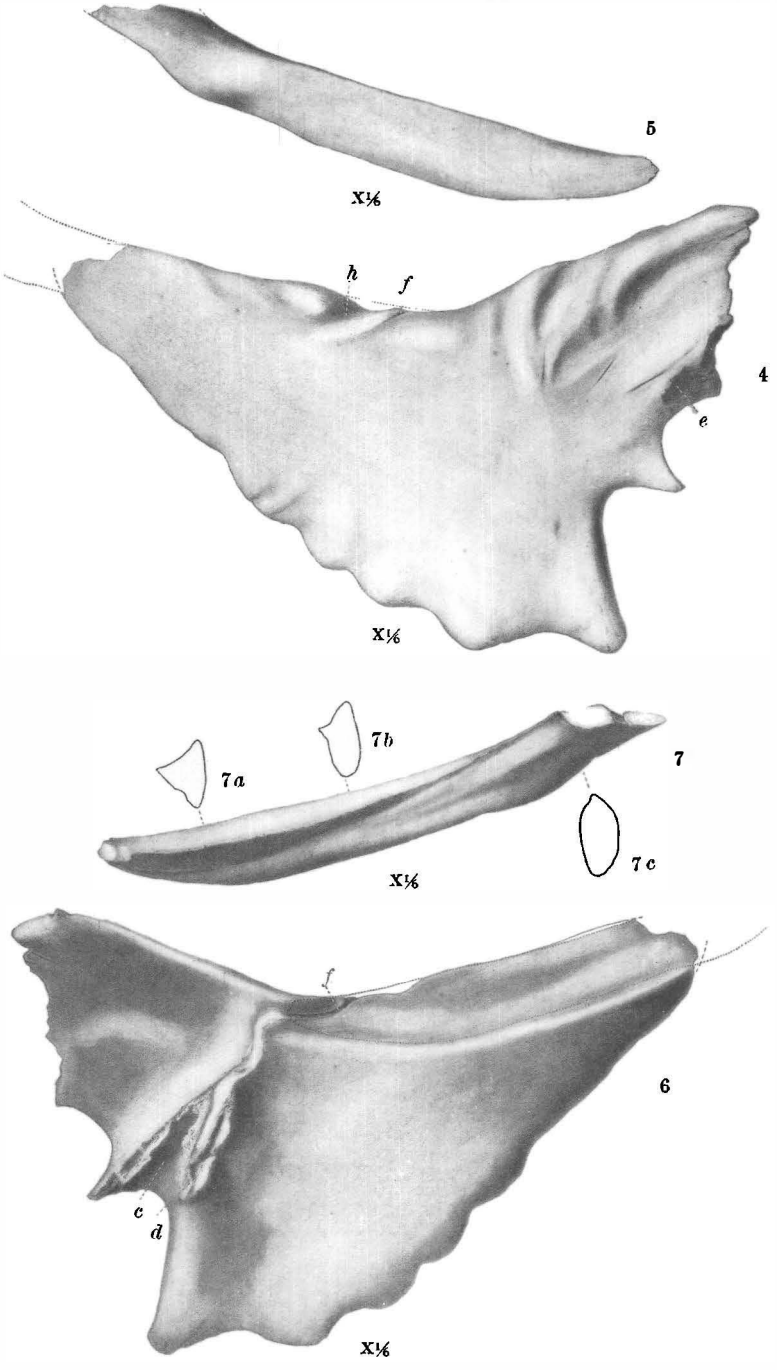
Figure 4.—Exterior aspect of right squamosal of *Monoclonius canadensis;* one-sixth natural size.

Figure 5.—Upper surface of front end of right lateral posterior extension of parietal of *M. canadensis;* similarly reduced.

Figure 6.—Interior view of the squamosal shown in figure 4; similarly reduced. The dotted line in this figure and in figure 4 indicates the position of the parietal extension when applied to the squamosal.

Figure 7.—Lower surface of bone shown in figure 5; similarly reduced.

Figures 7a, 7b, 7c.—Outlines of cross sections of the same at the points indicated.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