Notes on Ceratopsians at the Canadian Museum of Nature

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Introduction and Overview

As part of my dissertation research and general research program focused on horned dinosaurs, I traveled to the Canadian Museum of Nature (CMN [formerly NMC], Ottawa, Ontario, Canada) in the winter of 2008 for a few days of research. The notes were typed in OpenOffice, and are presented in unedited format on the following pages.

Taxa discussed in these notes include specimens referred to *Chasmosaurus russelli*, *Chasmosaurus belli*, *Anchiceratops ornatus*, *Vagaceratops* (formerly *Chasmosaurus*) *irvinensis*, Centrosaurinae indet., *Styracosaurus albertensis*, *Leptoceratops gracilis*, and *Pachyrhinosaurus albertensis*. Note that the taxonomic identifications in the notes may be tentative or outdated in light of new work. In most cases, I simply used the identification in the museum databases (which may or may not match with identifications published in Farke, 2010).

Disclaimer

The sketches, measurements, and notes are all my personal work and interpretations. These data are thus presented "as is", and users should be appropriately cautious when relying upon my notes for their own research. Although I strive to be accurate, inadvertent mistakes or inaccuracies are possible. In the end, there is no substitute for personal examination of a specimen in order to answer some questions.

Acknowledgments

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Key Citations

Farke AA (2010) Evolution, homology, and function of the supracranial sinuses in ceratopsian dinosaurs. J Vertebr Paleontol 30: 1486–1500.

How to Cite This

Some aspects of these notes were incorporated into a previous publication (Farke, 2010), and you may wish to cite those if the data were included there. Otherwise, I do request that you cite these notes through reference to the appropriate page on figshare.com, or another appropriate link if figshare.com is not available at some point in the future.

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CMN 2280 – *Chasmosaurus russelli*

Bilateral measurements given as right / left
1: Minimum width of nasals above external naris 68.63
2: Greatest width across orbits 287.08
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim 77.56 / 69.96
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim 85.95 / 85.07
5: Greatest width across jugals, including epijugal 517.18
6: Least distance from rostral border of orbit to tip of rostral 567.80 /553.3
7: Distance from tip of rostral to caudal end of maxillary tooth row / 585.81
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla 210.6 / 252.48
9: Distance from tip of rostral to end of occipital condyle (basal skull length) 750
10: Minimum distance from caudal end of external naris to rostral end of orbit 194.67 / 212.43
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 87.08 / 138.34
12: Length of jugal from ventral margin of orbit to ventral limit of jugal 216.14 /266.78
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal 303.51 / 371.74

Supracranial sinus very well preserved and completely prepped out. Very little plaster, except a little on walls at caudal end. The sinus is relatively shallow, with measurements on a separate piece of paper.

Caudal portion of sinus is narrowest, and rostral portion is widest. Reaches at least to medial edge of bases of horns, but I can't tell for sure if it actually invaginated postorbital. No transverse buttress is present, at all. Also, no fronto-parietal foramen infloor of sinus. Wall of sinus is perfectly smooth, with no neurovascular impressions. A slight heart-shape, especially at the front (due to a little expansion of wall caudally from rostral end).

CMN 8800
***Chasmosaurus russelli* type**

Measurements (right/left)
1: Minimum width of nasals above external naris 76.11
2: Greatest width across orbits 309.02
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim 85.94 / can't measure due to extensive remodeling
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim 155.87 / can't measure due to extensive remodeling
5: Greatest width across jugals, including epijugal – can't measure
6: Least distance from rostral border of orbit to tip of rostral – (end of rostral reconstructed, but probably pretty close) can't measure / 667
7: Distance from tip of rostral to caudal end of maxillary tooth row can't measure / 700 (est.)
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla

305.50
9: Distance from tip of rostral to end of occipital condyle (basal skull length) - can't measure
10: Minimum distance from caudal end of external naris to rostral end of orbit – can't measure / 220.11
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 101.33 (estimated) / 57.67
12: Length of jugal from ventral margin of orbit to ventral limit of jugal - can't measure
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal – can't measure

Skull is quite well-preserved in terms of bone texture. Slightly torqued, however (see pictures), but most everything is reasonably well

Description of sinuses:
No transverse buttress. Sinus cavity is completely smooth, with no signs of vascularization.

Dorsotemporal channels: best preserved on right side, so I will describe it from there. Both channels are completely open, and very smoothly floored. Right channel runs for 50.18 mm before diving in to caudal portion of supracranial sinus. Channel is 57.67 mm wide. A small caudal extension from the channel protrudes under the central "tab" of bone from the dorsal surface of the parietal. The channels are separate for their entire length, before diving separately into the caudal portion of the sinus (can't say caudal / rostral chamber, due to absence of buttress.

Rostrally, rostral margin of frontal fontanelle is completely smooth; I.e., dorsal roof of skull is completely smooth, up until the nasal horn. It is tough to tell if it is an airsac going on to the dorsum of the skull, or if it is a massively pathological area. I suspect the latter. Sinus excavates under the body of the postorbital horncore, but not up into the core itself. So, postorbital is pneumatized.

Rostral end of sinus excavates slightly under dorsum of skull, but not a lot. Interesting to note that dorsotemporal fontanelle is bridged by bone at its middle. This bone is 24 mm thick or so, and runs pretty much between the two brow horns at their caudal ends. Fontanelle is narrowest behind the bridge (32.36 mm wide) and widest anterior to it (97.80 mm). From front to back, fontanelle measures 181.38 mm, with bridge 43.67 mm long and area in front of bridge 63.42 mm long.

Sinus itself is 200 mm long, and 220 mm wide at widest (as preserved); widest area is at middle of brow horns, and narrows caudally (can't get good dimension) and rostrally. There is no central ridge at front of sinus to form a "heart" shape. Sinus is approximately 47 mm deep (but take with grain of salt due to distortion of specimen). This measurement was taken at the midpoint. Rostrally, sinus is shallower, around 30.80 mm deep.

Due to incomplete preservation, I can't determine location of sinus relative to laterosphenoid. It extends approximately to rostral ¼ of the orbit.

No frontoparietal foramen; floor is exceptionally well-preserved.

NMC 8535
Anchiceratops ornatus
Sinus is reasonably well-preserved and prepared, although they have slapped a little bit of plaster here and there. Still, I am reasonably confident of the morphology.

Left / right
1: Minimum width of nasals above external naris 65.30
2: Greatest width across orbits 280.85
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim 101.51 / 93.61
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim 90.35 / 82.29
5: Greatest width across jugals, including epijugal not preserved
6: Least distance from rostral border of orbit to tip of rostral 595.25 / 598.04
7: Distance from tip of rostral to caudal end of maxillary tooth row ? / 610
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla ? / 232.07
9: Distance from tip of rostral to end of occipital condyle (basal skull length) 811
10: Minimum distance from caudal end of external naris to rostral end of orbit 194.74 / 179.34
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 312.03 / 313.5
12: Length of jugal from ventral margin of orbit to ventral limit of jugal ? / ?
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal ? / ?

The caudal chamber is the longest by far. Best preserved on the left side, a little bit of plaster filling on the right. Specimen is slightly crushed, so not all of bone surface is totally nice. Where preserved (especially in back), there are no vascular impressions.

The caudal chamber is relatively long and deep; 93.69 mm at deepest. The dorsotemporal channels are best preserved on the left; 25.45 mm long. Can't get width reliably, but probably quite wide.

Sinus is 245 mm long. 190.21 mm long for caudal chamber.

At front of rostral chamber, a slight projection from the rostral wall creates a slightly heart-shaped sinus. Sinus appears to be relatively constant in depth along its entire length. The caudal chamber projects under the medial margin of the horncore, but only partway.

The frontal fontanelle is relatively elongate, but not "keyhole" shaped. It measures 150.63 mm long by 63.25 mm wide. The roof of frontal bone measures another 100 mm or so ahead of this, and is relatively thin; 14.42 mm.

Caudal chamber is narrow for its posterior portion (approximately length of fontanelle; around 67 mm wide), but widens at end of fontanelle (estimated to 165 mm). Rostral chamber is somewhat narrower.

Can't tell if there is a frontoparietal foramen; glue in floor, and not very clear.

CMN 41357 – *Chasmosaurus irvinensis* (type)

Only part of sinus is preserved. No transverse buttress. Sinus goes up to base of where postorbital ornamentation would be; not much underneath of it, though.

Postorbital ornamentation 40.14 mm tall. 280.5 mm to base of jugal from base of orbit. No vascular impressions in sinus. Dorsum of frontal thin; 13.49 mm thick leading up to edge of frontal fontanelle. Can't say anything about morphology of fontanelle. Sinus at least 39.81 mm deep and 155.23 mm long. Broadens rostrally, but can't say anything more without better preserved material.

Pathology codes

CMN 8861 – Triceratops
right dentary – no
right squamosal – no, but resorption along epiparietals at margin (but no periostitis or fractures)
CMN 1173 – Monoclonius dawsoni
right jugal, left jugal, nasal horn – no on all

NMC 8798 – *Centrosaurus dawsoni* type
left / right

1: Minimum width of nasals above external naris 69.06
2: Greatest width across orbits 281.66
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim can't measure – low horn
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim can't measure; low horn
5: Greatest width across jugals, including epijugal can't measure
6: Least distance from rostral border of orbit to tip of rostral can't measure – rostral gone
7: Distance from tip of rostral to caudal end of maxillary tooth row rostral gone
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla can't measure
9: Distance from tip of rostral to end of occipital condyle (basal skull length) can't measure
10: Minimum distance from caudal end of external naris to rostral end of orbit 254.08 / 243.54
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 53.52 / 62.65
12: Length of jugal from ventral margin of orbit to ventral limit of jugal 240.49 / can't measure
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal 368.59 / can't measure

Notes on sinuses:

Contra Cathy, there is no evidence at all of a frontoparietal foramen. It is completely bone along the floor of the sinus. The rostral chamber may be filled with matrix; otherwise, this thing has a rostral extension along the dorsum of the skull. I suspect it is the former case.

Suture runs up back of transverse buttress. Transverse buttress is quite tall, and extends nearly entire depth of sinus. Can't see suture between parietal and frontal.

The sinus's caudal chamber is divided into a narrow caudal portion (45.30 mm wide) and a

wider rostral portion (measurements given below).

Measurements: 65.66 mm deep at deepest (rostrally): caudal end is 46.03 mm deep. Transverse buttress is 12.59 mm in thickness, and is recessed only 7.49 mm below surface of frontal fontanelle.
Fontanelle: 43.16 mm wide, 178.15 mm long. Roof 11.30 mm thick.
Sinus extends laterally for 53.22 mm on left and 55.89 mm on right.
Can't get good measurements on channels.

NMC 8795 – *Centrosaurus longirostris* type
left / right
1: Minimum width of nasals above external naris 116.63
2: Greatest width across orbits 271.59
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim can't measure – low horn
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim can't measure; low horn
5: Greatest width across jugals, including epijugal 595.63
6: Least distance from rostral border of orbit to tip of rostral – 689 / 680
7: Distance from tip of rostral to caudal end of maxillary tooth row ? / 624
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla ??/ 291.51
9: Distance from tip of rostral to end of occipital condyle (basal skull length) 813
10: Minimum distance from caudal end of external naris to rostral end of orbit 302.33 / 270.99
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 88.6 / 71.47
12: Length of jugal from ventral margin of orbit to ventral limit of jugal 245.6 / 280.8
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal 345.7 / 382.31
Notes on sinuses: Sinus is only partly prepared out, so I can't get all details. Skull is notable in degree to which frontal fontanelle is closed. Frontal fontanelle is 73.96 mm long by 25.94 mm wide. Can't tell how far sinus would have extended forward, due to sandstone at front of sinus. Sinus is prepared to bottom caudally, but I see no evidence of a frontoparietal foramen. 57.34 mm deep, at least.

Dorsotemporal channels are short, and separated for their entire length. Right is 28 mm wide; left 21.9 mm wide. Right inset 7.24 mm; runs for 49.45 mm before diving into back of sinus.

Probable pathologies on both jugals. On right side, a raised ridge runs across middle of bone, for approximately 101 mm (obliquely, highest at rostral end). 2 raised areas on left side.

NMC 348 – too crappy preservation to tell on sinus
Two little periostitis areas on left and right jugal
left/right
1: Minimum width of nasals above external naris 55.59
2: Greatest width across orbits 295.26
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim 75.19

/ 72.95
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim 93.02 / 100.42
5: Greatest width across jugals, including epijugal 471.27
6: Least distance from rostral border of orbit to tip of rostral 263.76 / 263.17
7: Distance from tip of rostral to caudal end of maxillary tooth row can't get
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla 316.43 / 374.14
9: Distance from tip of rostral to end of occipital condyle (basal skull length) 710
10: Minimum distance from caudal end of external naris to rostral end of orbit 262.45 / 263.45
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 167.12 / 115.10
12: Length of jugal from ventral margin of orbit to ventral limit of jugal 273.92 / 272.05
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal 362.68 / 402.25

CMN 8790
1: Minimum width of nasals above external naris 61.54
2: Greatest width across orbits 274.30
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim can't measure
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim can't measure
5: Greatest width across jugals, including epijugal 493.41
6: Least distance from rostral border of orbit to tip of rostral 619 / 589
7: Distance from tip of rostral to caudal end of maxillary tooth row ? / 621
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla ? / 172.01
9: Distance from tip of rostral to end of occipital condyle (basal skull length) 843
10: Minimum distance from caudal end of external naris to rostral end of orbit 296.85 / ?
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 41.28 / 44.65
12: Length of jugal from ventral margin of orbit to ventral limit of jugal 238.80 / 238.69
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal ??

Subadult – not coding pathologies.
Supracranial sinus is pretty based up, and skull is completely crushed dorsoventrally. Most of roof of frontal.

Sinus measured 252.51 mm long; can't estimate width, because laterally is reconstructed (grass and crap in there). Depth is 19.61 mm rostrally, 15.66 caudally. Can't say much else. No good evidence of transverse buttress, but pretty crappily preserved.

Caudal end of sinus is pretty deep; steps up rostrally (just ahead of matrix in floor of sinus – foramen?). Rostral chamber 26.27 mm long. "Real" frontoparietal foramen at very back of sinus, 31.55 from rear. Caudal end of frontoparietal foramen is very nicely rounded, and I have no doubt that this is a genuine feature in this specimen. But. . .this structure sits directly over the foramen magnum!!!! Deep portion further forward is more

plausible. . .

Good interfrontal suture at rostral end of specimen.

Channels not preserved.

CMN 344 – *Styracosaurus albertensis* holotype
1: Minimum width of nasals above external naris 87.82
2: Greatest width across orbits 307.32
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim can't measure
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim can't measure
5: Greatest width across jugals, including epijugal can't measure
6: Least distance from rostral border of orbit to tip of rostral 640 / 655 (both estimated)
7: Distance from tip of rostral to caudal end of maxillary tooth row / 631
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla 307.95 / ?
9: Distance from tip of rostral to end of occipital condyle (basal skull length) 851
10: Minimum distance from caudal end of external naris to rostral end of orbit ? / 276.95
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 67.14 / 64.71
12: Length of jugal from ventral margin of orbit to ventral limit of jugal 275.26
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal 372.89

The sinus complex is pretty well-preserved. Unfortunately, the back end is tweaked down. But, it offers additional clarity on what others have called the frontoparietal foramen. In fact, this is a pneumatic pocket, that overhangs the foramen magnum (but has no relation to that flexure on the endocranial cavity). The "frontoparietal foramen" is actually an interfrontal foramen!!!! Cool! I have verified the position of the more posterior structure on several specimens.

Dorsotemporal channels are very poorly preserved.

Rostral chamber is 36.83 mm deep at midline, and 29.60 mm long on midline. Laterally, it is divided into a left and right chamber by a thick midline strut, 17.55 mm in width. Chamber on lateral sides extends for 54.93 mm. Estimated as 80 mm in width at greatest width.

Transverse buttress is in same plane as caudal ¼ of orbit. 9.18 mm thick, 27.73 mm tall rostrally and 51.62 mm tall caudally. 16.07 mm set below dorsum of skull. Sinus narrows just above it, clearly separating rostral and caudal chambers. Strut also runs pretty much horizontally, without the "V" seen in other specimens.

Caudal chamber is divided into a relatively narrow caudal portion and a relatively wide rostral portion. Total length estimated as 151.55 mm on midline.
Caudal chamber (rostral portion) is 81.75 mm deep at deepest, and 130 mm wide. Absolutely

does not underlie postorbital or postorbital ornamentation. This part of the chamber measures 117.54 mm long. Roof overhangs 35.14 on right and 31.71 mm on left. It slopes up caudally, to reach the caudal portion of the caudal chamber.

The old "frontoparietal foramen" may be there, but it is bathed in glue. It's positioned just behind the transverse buttress. The real frontoparietal foramen is 149.22 mm behind transverse buttress.

Caudalmost part of caudal chamber is 53.77 mm deep, 66.46 mm wide, and has no real overhang. Real frontoparietal foramen is about 23.87 mm wide, and probably circular, but I can't get a good length. It sits 37.71 mm forward of rear of sinus.

Frontal fontanelle is 65.87 mm wide, est. 197.66 mm long.

Leptoceratops gracilis

CMN 8889

Frontal region is a little crushed, but looks to not have a real prominent frontoparietal depression with the sharply separated region seen in other animals.

1: Minimum width of nasals above external naris 13.94 mm
2: Greatest width across orbits 105.4
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim
5: Greatest width across jugals, including epijugal 339.19
6: Least distance from rostral border of orbit to tip of rostral 213.14 / 227.66
7: Distance from tip of rostral to caudal end of maxillary tooth row 294.37 / 298.07
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla 133.05 / 124.38
9: Distance from tip of rostral to end of occipital condyle (basal skull length) 349.43
10: Minimum distance from caudal end of external naris to rostral end of orbit 141.61 / 116.82
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 7.21 / 9.88
12: Length of jugal from ventral margin of orbit to ventral limit of jugal 138.01 / 127.5
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal 167

1: Minimum width of nasals above external naris 14.24 mm
2: Greatest width across orbits 88.18
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim
5: Greatest width across jugals, including epijugal 152.95
6: Least distance from rostral border of orbit to tip of rostral 171.79 / 175.17
7: Distance from tip of rostral to caudal end of maxillary tooth row ???
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla 133.08 / 122.35
9: Distance from tip of rostral to end of occipital condyle (basal skull length) 286.32
10: Minimum distance from caudal end of external naris to rostral end of orbit 86.20 / 90.53
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit 5.64
12: Length of jugal from ventral margin of orbit to ventral limit of jugal 130.96 / 128.45
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal 175.49 /

175.06

CMN 254 – Kaiseni type horn, showing sinus up to base of postorbital ornamentation
Eoceratops type – similar

CMN 8528 – other half of braincase sectioned at USNM. Shows "frontoparietal foramen". This foramen is mostly broken edged, except for its most rostral portion. So, I would say that this animal does have it.

CMN 8741 – Triceratops partial skull. Has rostro-caudally trending area of periostitis on middle portion of blade of squamosal. Lesion is 127 mm long, 19.49 mm wide, and raised 5-6 mm above surrounding bone.

Pachyrhinosaurus albertensis
CMN 8867 – big sinus, extends at least to middle of orbit, but not completely prepped and specimen is quite crushed.
9485 – slit like frontal fontanelle; not preserved at back to get measurements. Has sinus, but can't tell extent.

Measurement Key

1: Minimum width of nasals above external naris
2: Greatest width across orbits
3: Minimum medio-lateral width of postorbital horn at base, immediately above orbital rim
4: Minimum rostro-caudal length of postorbital horn at base, immediately above orbital rim
5: Greatest width across jugals, including epijugal
6: Least distance from rostral border of orbit to tip of rostral
7: Distance from tip of rostral to caudal end of maxillary tooth row
8: Minimum dorso-ventral depth from dorsal surface of nasals to ventral surface of maxilla
9: Distance from tip of rostral to end of occipital condyle (basal skull length)
10: Minimum distance from caudal end of external naris to rostral end of orbit
11: Length of postorbital horncore from tip of horn to dorsal margin of orbit
12: Length of jugal from ventral margin of orbit to ventral limit of jugal
13: Depth of skull, from rostral limit of supratemporal fenestra to distal tip of epijugal