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SUPPLEMENTARY ONLINE MATERIAL FOR

A new species of the centrosaurine *Pachyrhinosaurus* from the North Slope (Prince Creek Formation: Maastrichtian) of Alaska.

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SOM_1

Character List – List of characters used in the phylogenetic analysis. Characters 21, 34, and 36 were modified from versions in Currie et al., (2008). Characters 47 through 54 are new, intended to clarify pachyrhinosaur relationships. Character list based mostly upon that of Currie et al., (2008).

1. Rostral, size and shape: triangular in lateral view with short dorsal and ventral processes (0); elongate with deeply concave posterior margin and hypertrophied processes (1) (Serenó, 1986).

2. Premaxilla, septum shape: absent (0); present and subcircular (1); present and anteriorly elongate (2) (Ryan, 2007).

3. Premaxilla, septum within narial chamber: absent (0); thick and has simple, plate-like construction (1); thin, often with transverse perforations (2) (Langston, 1967; Forster, 1996; Holmes et al., 2001).

4. Premaxilla, premaxillary (narial) process extending into the external naris from the caudoventral margin of the premaxillary septum: absent (0); present (1) (Forster, 1990).

5. Premaxilla, thickened narial strut (separating fenestra through septum from narial opening) along posterior border of premaxillary septum: absent (0); present, anteriorly inclined (1); present, caudally inclined (2) (Forster et al., 1993; Holmes et al., 2001).

6. Premaxilla, ventral expansion of posteroventral margin: absent, posteroventral margin of premaxilla unexpanded and level with alveolar margin of maxilla (1); present, expanded ventrally well below alveolar margin of maxilla (1) (Serenio, 1986; Penkas et al., 2001).

7. Premaxilla, posterior tip of posteroventral process inserts into embayment in nasal and is surrounded by the nasal: yes (0); no (1) (Forster et al. 1993; Holmes et al. 2001)

8. Premaxilla contact with lacrimal: separated by nasal and maxilla (0); in contact (1)
(Lull, 1933; Makovicky 2002).

9. External antorbital fenestra size: large, 20% or more length of body of maxilla (0);
greatly reduced to <10% length of body of maxilla (1); reduced to a foramen or absent (2)
(Granger and Gregory 1923; Chinnery and Weishampel 1998).

10. Nasal, (subadult) basal length of horn or boss: short based, restricted in length
anteroposteriorly (0); long-based, ornamentation covers almost entire length of nasal (1)
(Sampson et al. 1997).

11. Nasal, (adult) ornamentation type: absent or poorly developed, <15% basal skull
length (0); elongated horn >20% basal skull length (1); long based, low thickened ridge
(2); boss (3) (Forster et al. 1993; Sampson 1995; Ryan 2007).

12. Nasal, posterior margin of external naris: concave (0); pronounced tab-like process
projecting anteriorly into nasal vestibule (1) (Langston 1975; Sereno 1986).

13. Jugal, infratemporal flange (adult): absent (0); present, contacts jugal flange of
squamosal under infratemporal fenestra (1) (Brown and Schlaikjer 1940; Lehman 1996;
Forster 1996; Ryan 2007).

14. Prefrontal, separated by frontals and excluded from margins of frontal fontenalle (0); contact each other on midline, separate nasals from frontals and form anterior margin of frontal fontenalle (1) (Lambe 1915; Forster 19990; Ryan 2003).

15. Prefrontal and lacrimal: form prominent antorbital buttress (0); do not form antorbital buttress (1) (Currie et al. 2008).

16. Postorbital, (subadult) postorbital ornamentation horn core: conical, at least 3X taller than anteroposterior basal length, rounded base and pointed apex (0); pyramidal, approx. 1:1 ratio length to height (1); longer than high, rounded (2) (Sampson 1999)

17. Supraorbital (adult) ornamentation type: absent (0); present, horn (1); present, boss (2) (Sampson 1995).

18. Postorbital, horn core shape (unmodified adult): elongate, pointed apex, rounded base (0); pyramidal, rounded apex, at least as tall as base length (1); rounded apex, base longer than horn tall (2) (Sampson 1995; Ryan 2007).

19. Postorbital, horn core height (unmodified adult): long, >60% length of face (0); short, <40% length of face (1) (Forster 1990; Holmes et al. 2001; Ryan 2007).

20. Postorbital, position of horn core (adult): posterior to orbit (0); over or anterior to orbit (1) (Lehman 1996).

21. Postorbital horn core curvature (adult): no horn, absent (0); straight, dorsally, anteriorly, anterodorsally, or anterolaterally curved (1); posteriorly curved (2) (modified from Forster et al., 1993; Lehman, 1996; Holmes et al., 2001)

22. Parietosquamosal frill, length relative to basal skull length: elongate, 0.80 or more (0); shortened, 0.70 or less (1) (Hatcher et al. 1907; Lehman 1996).

23. Squamosal, length relative to parietal: equal or sub-equal in length (0); squamosal <60% total parietal length (1) (Sereno 1986).

24. Squamosal, shape of posterodorsal (medial) margin: straight (0); posterior portion stepped-up relative to anterior portion, transition where quadrate groove passes from ventral dorsal surface of bone (1) (Dodson 1986; Penklaski and Dodson 1999; Ryan

25. Squamosal, anteromedial lamina forming posterolateral floor of dorsotemporal fossa: absent (0); present (1) (Dodson 1986).

26. Parietal, dorsal surface of medial bar: smooth and flat (0); small rounded midline bumps (1); large spikes (2) (Sampson 1995).

27. Parietal, posterior surface on midline: posteriorly convex or straight (0); deep, U-shaped emargination (1) (Currie et al. 2008)

28. Epoccipital, profile shape of epoccipitals on squamosal: not present (0); crescentic to lozenge shaped (1); triangular (2) (Holmes et al. 2001).

29. Epoccipital, number of loci on parietal rami lateral to midline margin: none (0); three to five (1); six to eight (2) (Ryan 2007).

30. Epoccipital, most medial process (P1): absent (0); unelaborated, posterior margin (1); short (length=base diameter) procurving hook on dorsal margin (2); long (length 2x base diameter) procurving hook on dorsal side (3); triangular on dorsal side of parietal (4) (Currie et al., 2008).

31. Epoccipital, P1 orientation: absent (0); posteriorly directed (1); dorsally directed (2); anteriorly directed in pronounced anterior curl (3) (Sampson 1995; Ryan 2007).

32. Epoccipital, P2: absent (0); unelaborated on posterior margin (1); small medially directed hook (2); large medially curled hook (3); multipronged posteriorly directed (4); large triangular profile (5) (Sampson 1995; Ryan and Russell 2005; Ryan 2007)

33. Epoccipital, P3 length compared to base width: absent (0); small unelaborated on posterior margin (1); length 1-3x base diameter (2); length >4X basal diameter (3) (modified from Sampson 1995; Ryan and Russell, 2005)

34. Epoccipital, P3 orientation: absent or small (0); posteriorly directed (1); posterolaterally directed (2); laterally or anterolaterally directed (3); dorsolaterally directed (4); posteromedially directed (5) (modified from Sampson, 1995; Ryan and Russell, 2005; Ryan, 2007).
35. Epoccipitals, pattern of fusion to frill margin: occurs from rostral to caudal (0); occurs from caudal to rostral (1) (Lehman 1996).
36. Parietal process P4-P6: absent (0); present (1) (modified from Sampson, 1995).
37. Epoccipital, imbrication of lateral marginal undulations of parietal: absent (0); present (1) (Sampson et al. 1997).
38. Prementary, orientation of triturating surface relative to horizontal plane of element: nearly horizontal (0); steeply inclined laterally (1) (Lehman 1990; Forster 1996).
39. Dentary, coronoid process: incipient process with gently convex apex and no neck (0); well developed but lacks anterior extension distally (1); high, powerful and expands anteriorly at the distal end (2) (Lull, 1933).
40. Dentary, posterior extent of tooth row: terminates medial to coronoid process (0); terminates posterior to coronoid process (1) (Brown and Schlaikjer 1940).

41. Teeth, roots: single (0); double (1) (Brown and Schlaikjer 1940).
42. Teeth, number of vertically stacked replacement teeth per tooth family: one or two (0); more than two (1) (Brown and Schlaikjer 1940).
43. Tooth ornamentation: subsidiary ridges present, extending from margin to base of tooth (0); subsidiary ridges reduced, present only at margin of teeth (1) (Dodson et al. 2004).
44. Sacrum, deep longitudinal channel on ventral surface: present (0); absent (1) (Lambe 1915; Lehman 1990).
45. Ischium, cross-sectional shape of shaft: ovoid (0); laterally compressed and blade like, narrow along dorsal margin (1) (Dodson et al. 2004).
46. Ischium, orientation of shaft: nearly straight (0); slightly decurved (1) | broad and continuously curved (2) (Brown and Schlaikjer 1940).
47. Premaxilla, anterior surface of narial bar between nasal and rostral bears: shallow transverse grooves and ridges (0); two or more large transversely-oriented protrusions that contribute to a rostral comb (1).

48. Nasal ornamentation or boss anterior end in mature individuals: a nearly continuous curved profile from nasal to premaxilla (0); nasal with distinct anteriorly protruding, overhanging 'pommel' in some individuals (1).

49. Nasal ornamentation or boss posterior edge: stops anterior to orbit (0); stops dorsal to orbit (1).

50. Nasal ornamentation or boss mediolateral width in mature individuals: much narrower than underlying rostrum (0); approximately equal width to underlying rostrum (1); widest part of antorbital region of skull (2).

51. Nasal and supraorbital ornamentation separation on dorsal skull surface of mature individuals: widely separated (0); nearly in contact or contacting, separated only by narrow groove (1).

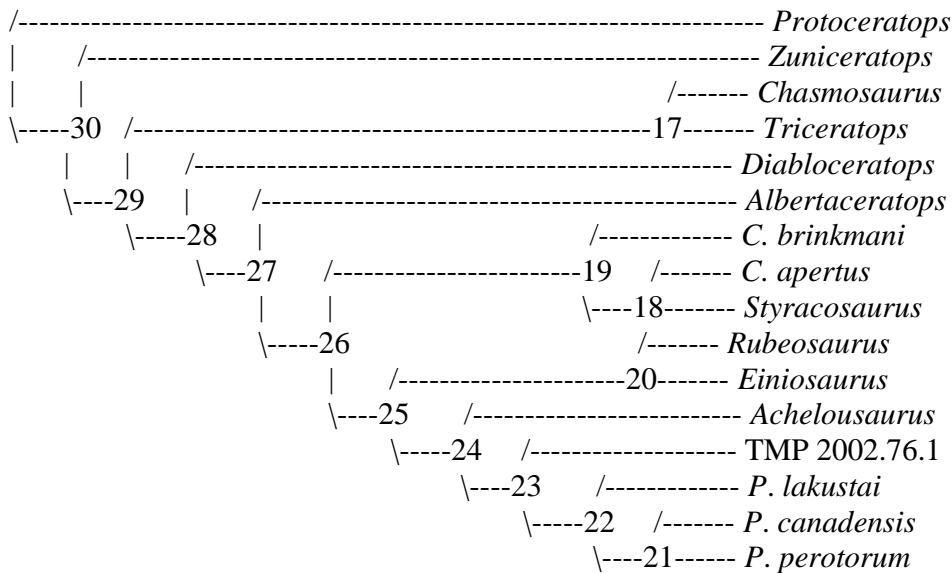
52. Elongate parietal process P3 lateral and medial margins: curved (0); straight (1) (McDonald and Horner, 2010).

53. Parietal process P4: absent (0); small, unmodified epoccipital (1); small spike (2); elongate spike (3) (derived from Sampson, 1995; McDonald and Horner, 2010).

54. Parietal process P5: absent (0); small, unmodified epoccipital (1); small spike (2); elongate spike (3) (derived from Sampson, 1995; McDonald and Horner, 2010).

SOM_3

Apormophy List – List and distribution of apomorphies generated by the phylogenetic analysis, based upon the cladogram in Figure 7. This hypothesis of phylogeny was one of three equally most parsimonious trees generated by our analysis. Character distribution is first given for ACCTRAN, then DELTRAN character state optimizations. Analysis run using PAUP* Version 4.0b10 for Macintosh(PPC).



Character-state optimization: Accelerated transformation (ACCTRAN)

Tree number 2 (rooted using user-specified outgroup)

Tree length = 107
Consistency index (CI) = 0.8131
Homoplasy index (HI) = 0.1963
CI excluding uninformative characters = 0.8095
HI excluding uninformative characters = 0.1905
Retention index (RI) = 0.8291
Rescaled consistency index (RC) = 0.6741

Protoceratops --> node_30
7 0 ==> 1
9 0 ==> 1
13 0 --> 1
15 1 ==> 0
17 0 ==> 1

21 0 ==> 2
22 0 --> 1
27 0 --> 1
28 0 --> 1
29 0 --> 1
33 0 --> 1
39 0 --> 1
46 0 ==> 1

node_30 --> *Zuniceratops*
20 0 --> 1

node_30 --> node_29 Ceratopsidae
2 0 --> 1
3 0 --> 1
11 0 --> 1
39 1 --> 2
40 0 ==> 1
41 0 ==> 1
42 0 ==> 1
43 0 ==> 1
53 0 --> 1
54 0 --> 1

node_29 --> node_17
1 0 ==> 1
2 1 --> 2
3 1 --> 2
4 0 ==> 1
5 0 ==> 1
28 1 --> 2
30 0 ==> 1
31 0 --> 1
32 0 ==> 1
44 0 ==> 1
45 0 ==> 1
46 1 ==> 2

node_17 --> *Chasmosaurus*
7 1 ==> 0
20 0 --> 1
22 1 --> 0
31 1 --> 2

node_17 --> *Triceratops*
13 1 --> 0
21 2 ==> 1
27 1 --> 0

node_29 --> node_28
12 0 ==> 1
24 0 ==> 1
25 0 ==> 1
29 1 --> 2
33 1 --> 3
34 0 ==> 2
35 0 --> 1
36 0 ==> 1
37 0 ==> 1
38 0 --> 1

node_28 --> node_27
6 0 ==> 1

```
8 0 --> 1
23 0 ==> 1
26 0 ==> 1

node_27 --> node_26
16 0 --> 1
18 0 --> 1
19 0 ==> 1
32 0 ==> 2
33 3 ==> 2

node_26 --> node_19
30 0 ==> 3
31 0 ==> 3

node_19 --> node_18
14 0 ==> 1

node_18 --> Centrosaurus apertus
32 2 --> 3
33 2 ==> 1
34 2 ==> 0

node_18 --> Styracosaurus
21 2 ==> 0
30 3 ==> 2
53 1 ==> 3
54 1 ==> (23)

node_19 --> Centrosaurus brinkmani
32 2 ==> 4
34 2 ==> 4

node_26 --> node_25
15 0 ==> 1
16 1 --> 2
18 1 --> 2
21 2 ==> 0

node_25 --> node_20
32 2 ==> 1
34 2 --> 1
52 0 ==> 1

node_20 --> Rubeosaurus
34 1 --> 5
53 1 ==> 3

node_25 --> node_24 Pachyrostra nov.
10 0 ==> 1
11 1 ==> 3
17 1 ==> 2

node_24 --> node_23
9 1 ==> 2
26 1 --> 2
32 2 --> 3
34 2 --> 3
48 0 --> 1
50 0 --> 1

node_23 --> node_22
47 0 --> 1
```

49 0 ==> 1
50 1 --> 2

node_22 --> *Pachyrhinosaurus lakustai*
33 2 ==> 3

node_22 --> node_21
48 1 --> 0
51 0 ==> 1

node_21 --> *Pachyrhinosaurus canadensis*
47 1 --> 0

Character-state optimization: Delayed transformation (DELTRAN)

Tree number 2 (rooted using user-specified outgroup)

Tree length = 107
Consistency index (CI) = 0.8131
Homoplasy index (HI) = 0.1963
CI excluding uninformative characters = 0.8095
HI excluding uninformative characters = 0.1905
Retention index (RI) = 0.8291
Rescaled consistency index (RC) = 0.6741

Protoceratops --> node_30
7 0 ==> 1
9 0 ==> 1
15 1 ==> 0
17 0 ==> 1
21 0 ==> 2
46 0 ==> 1

node_30 --> *Zuniceratops*
20 0 --> 1
39 0 --> 1

node_30 --> node_29 Ceratopsidae
39 0 --> 2
40 0 ==> 1
41 0 ==> 1
42 0 ==> 1
43 0 ==> 1

node_29 --> node_17
1 0 ==> 1
2 0 --> 2
3 0 --> 2
4 0 ==> 1
5 0 ==> 1
11 0 --> 1
28 0 --> 2
29 0 --> 1
30 0 ==> 1
32 0 ==> 1
33 0 --> 1
44 0 ==> 1
45 0 ==> 1
46 1 ==> 2

```
node_17 --> Chasmosaurus
7 1 ==> 0
13 0 --> 1
20 0 --> 1
27 0 --> 1
31 0 --> 2

node_17 --> Triceratops
21 2 ==> 1
22 0 --> 1
31 0 --> 1

node_29 --> node_28
2 0 --> 1
3 0 --> 1
12 0 ==> 1
13 0 --> 1
22 0 --> 1
24 0 ==> 1
25 0 ==> 1
27 0 --> 1
28 0 --> 1
29 0 --> 2
33 0 --> 3
34 0 ==> 2
36 0 ==> 1
37 0 ==> 1
53 0 --> 1
54 0 --> 1

node_28 --> Diabloceratops
52 0 --> 1

node_28 --> node_27
6 0 ==> 1
23 0 ==> 1
26 0 ==> 1
38 0 --> 1

node_27 --> Albertaceratops
10 0 ==> 1
11 0 --> 2
34 2 ==> 3

node_27 --> node_26
8 0 --> 1
11 0 --> 1
19 0 ==> 1
32 0 ==> 2
33 3 ==> 2
35 0 --> 1

node_26 --> node_19
16 0 --> 1
18 0 --> 1
30 0 ==> 3
31 0 ==> 3

node_19 --> node_18
14 0 ==> 1

node_18 --> Centrosaurus apertus
```


32 2 --> 3
33 2 ==> 1
34 2 ==> 0

node_18 --> *Styracosaurus*
21 2 ==> 0
30 3 ==> 2
53 1 ==> 3
54 1 ==> (23)

node_19 --> *Centrosaurus brinkmani*
32 2 ==> 4
34 2 ==> 4

node_26 --> node_25
15 0 ==> 1
16 0 --> 2
21 2 ==> 0

node_25 --> node_20
18 0 --> 2
32 2 ==> 1
52 0 ==> 1

node_20 --> *Rubeosaurus*
34 2 --> 5
53 1 ==> 3

node_20 --> *Einosaurus*
34 2 --> 1

node_25 --> node_24 *Pachyrostra nov.*
10 0 ==> 1
11 1 ==> 3
17 1 ==> 2

node_24 --> node_23
9 1 ==> 2

node_23 --> TMP 2002.76.1
48 0 --> 1
50 0 --> 1

node_23 --> node_22
32 2 --> 3
34 2 --> 3
49 0 ==> 1
50 0 --> 2

node_22 --> *Pachyrhinosaurus lakustai*
26 1 --> 2
33 2 ==> 3
47 0 --> 1
48 0 --> 1

node_22 --> node_21
51 0 ==> 1

node_21 --> *Pachyrhinosaurus perotorum*
47 0 --> 1