

Supplemental Online Materials to:

**An unusual ‘shovel-billed’ dinosaur with trophic specialisations from the early Campanian
of Trans-Pecos Texas and the ancestral hadrosaurian crest**

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Supplementary Material

Characters used in the maximum parsimony analysis for inferring the phylogenetic position of *Aquilarhinus palimentus*. Internet links correspond to the illustration and documentation of some character states in Morphbank, an online repository site for biological images.

Dental characters

1. Maximum number of tooth positions in the dentary dental battery (DTTH1, <http://www.morphbank.net/Show/?id=460667>; modified from Horner, Weishampel & Forster 2004, character 1): 30 or less (sample mean of 22 alveolar positions) (0); 31 to 42 (sample mean of 37 alveolar positions) (1); more than 42 (sample mean of 49 alveolar positions) (2). Ordered
2. Minimum number of teeth per alveoli arranged dorsoventrally at mid length of the dental battery (DTTH3, <http://www.morphbank.net/Show/?id=461202>; modified from Horner *et al.* 2004, character 2): two (0); three (1); four; (2) five or more (3). Ordered
3. Maximum number of functional teeth exposed on the dentary occlusal plane (DTTH4, <http://www.morphbank.net/Show/?id=461203>; modified from Horner *et al.* 2004, character 3): one (0); one functional tooth rostrally and caudally, and up to two teeth at and approaching the middle of the dental battery (1); three functional teeth throughout most of the dental battery, gradually decreasing to two near the rostral and caudal ends of the dentary (2). Ordered
4. Height/width ratio of the dentary tooth crowns in lingual aspect (DTTH5, <http://www.morphbank.net/Show/?id=461204>; Prieto-Márquez 2010a, character 4): ratio up to 1.95 (sample mean ratio of 1.6) (0); ratio from 1.95 to 2.7 (sample mean ratio of 2.4) (1); ratio

from 2.8 to 3.3 (sample mean ratio of 3.0) (2); ratio greater than 3.3 (sample mean ratio of 3.7) (3). Ordered

5. Maximum number of ridges on the enameled lingual side of dentary tooth crowns (DTTH6, <http://www.morphbank.net/Show/?id=461205>; modified Horner *et al.* 2004, character 6): presence of a primary major ridge extending from the ventral to the dorsal end of the crown, a rostral and slightly shorter secondary ridge and several (three or more) subdisidary, faintly developed and short tertiary ridges (0); presence of primary, secondary, and one or two tertiary ridges (1); presence of a primary ridge and one or two faint and shorter ridges (2); loss of all but the primary ridge (3). Ordered
6. Dentary tooth crowns, position of the primary ridge (DTTH7, <http://www.morphbank.net/Show/?id=461207>; modified from You *et al.* 2003, character 39): well offset caudally from the midline (0); median for most teeth, although some teeth within the same dental battery may display a slight caudal offset of the primary ridge (1).
7. Overall morphology of the dentary marginal denticles (DTTH10, <http://www.morphbank.net/Show/?id=461210>; Norman 2002, character 31): wedge to tongue-shaped (0); curved and mammillated asymmetrical ledge (1); absent or very reduced to small papillae along the apical half of the dorsal half of the crown (2).
8. Denticle size (DTTH12, <http://www.morphbank.net/Show/?id=461212>; Prieto-Márquez 2010a, character 11): the denticles of both mesial and distal margins are equal in size (0); the mesial margin has larger denticles than the distal one (1).
9. Imbrication of dentary tooth crowns (DTTH13, <http://www.morphbank.net/Show/?id=461212>; Prieto-Márquez 2010a, character 12): absent (0); present, the mesial margin overlaps the distal one of the adjacent crown (1).

10. Flat and steeply inclined occlusal surface of the dentary dental battery (DTTH14; Prieto-Márquez 2014, character 4): absent (0); present (1).
11. Maximum number of tooth positions in the maxillary dental battery (MXTH1, <http://www.morphbank.net/Show/?id=461215>; modified from Horner *et al.* 2004, character 1): up to 32 tooth positions (sample mean of 23 teeth) (0); from 33 to 44 tooth positions (sample mean of 40 teeth) (1); 45 or more tooth positions (sample mean of 49 teeth) (2). Ordered
12. Maximum number of functional teeth per alveolus in the maxillary occlusal plane (MXTH4, <http://www.morphbank.net/Show/?id=461218>; modified from Horner *et al.* 2004, character 3): one (0); one tooth for most of the dental battery, with the sporadic presence of a second tooth forming the occlusal plane (1); two functional teeth throughout most of the dental battery length, gradually changing to one near the rostral and caudal ends of the maxilla (2). Ordered
13. Maximum number of ridges on the enameled labial side of maxillary tooth crowns (MXTH5, <http://www.morphbank.net/Show/?id=461219>; Horner *et al.* 2004 character 7): presence of a primary major ridge and three or more much fainter ridges (0); loss of all but the primary ridge in all or, at least, most of the crowns (in the latter situation a few crowns show a fainter secondary ridge) (1). Ordered
14. Maxillary tooth crowns, position of the primary ridge (MXTH6, <http://www.morphbank.net/Show/?id=461220> and <http://www.morphbank.net/Show/?id=461221>; modified from You *et al.*, 2003 character 36): the dental battery contains a mixture of teeth with primary ridge positioned caudally and teeth with the ridge at the center of the crown (0); the majority of teeth in the dental battery have a primary ridge positioned at the midline of the crown (1).

15. Overall morphology of the maxillary marginal denticles (MXTH8, <http://www.morphbank.net/Show/?id=461223>; Norman 2002, character 30): wedge to tongue-shaped (0); curved and mammillated asymmetrical ledge (1); absent or reduced to small papillae along the apical half of the dorsal half of the crown (2).

Mandibular characters

16. Predentary. Ratio between the predentary maximum mediolateral width and the maximum rostrocaudal length along the lateral rami (PDT1, <http://www.morphbank.net/Show/?id=461224>; modified from Horner *et al.* 2004, character 13): up to 1.75 (0); more than 1.75 (1).
17. Predentary. Orientation of the rostral surface relative to the dorsal margin of the lateral rami (PDT3, <http://www.morphbank.net/Show/?id=461226>; modified from Horner *et al.* 2004, character 14): angle of 75° or greater (sample mean angle of 81°) (0); angle between 56° and 74° (sample mean angle of 66°) (1); angle between 40° and 55° (sample mean angle of 47°) (2); angle less than 40°, gently rounded rostral surface (sample mean angle of 34°) (3). Ordered
18. Predentary. Shape of the denticles of the predentary oral margin (PDT4, <http://www.morphbank.net/Show/?id=461227>; modified from Horner *et al.* 2004, character 13): triangular and pointed (0); subrectangular to rectangular (1).
19. Predentary. Number of predentary denticles in adult individuals lateral to the median denticle (not included in the count) (PDT6, <http://www.morphbank.net/Show/?id=461228>, <http://www.morphbank.net/Show/?id=461229>, and <http://www.morphbank.net/Show/?id=461230>; Prieto-Márquez 2010a, character 27): maximum of five (0); six or more (1).

20. Prementary. Extension of the prementary denticulate margin (PDT7, <http://www.morphbank.net/Show/?id=461228>, <http://www.morphbank.net/Show/?id=461229>, and <http://www.morphbank.net/Show/?id=461230>; Prieto-Márquez 2010a, character 28): denticles extending into the lateral process (0); denticles limited to the rostral margin (1).
21. Prementary. Morphology of the prementary rostralateral corner (PDT8, <http://www.morphbank.net/Show/?id=461228>, <http://www.morphbank.net/Show/?id=461229>, and <http://www.morphbank.net/Show/?id=461230>; modified from Horner *et al.* 2004, character 13): gently rounded and continuous with the lateral process, giving the prementary an arcuate dorsal profile (0); subsquared rostralateral corner (1); subsquared, very broad and rostralaterally projected (2). Ordered
22. Prementary. Development of a lateral shelf on the dorsal side of the prementary lateral process (PDT9, <http://www.morphbank.net/Show/?id=460672>, <http://www.morphbank.net/Show/?id=460673>, and <http://www.morphbank.net/Show/?id=460674>; modified from Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001): absence of shelf, presence of a rostrocaudally short and shallow groove limited to the distal region of the lateral process, bounded by a tall lateral wall (0); short and shallow shelf limited to the laterocaudal region of the lateral process (1); short and well-incised shelf that is wider near the rostralateral corner of the prementary (2); shelf extremely narrow mediolaterally and very long rostrocaudally (3); shelf rostrocaudally long, deeply incised and mediolaterally broad, forming half of the mediolateral breadth of the lateral process and becoming wider distally (4).
23. Prementary. Ridge on the dorsal lingual, keel-shaped process (PDT11, <http://www.morphbank.net/Show/?id=461232>; Prieto-Márquez 2010a, character 31): the

process lacks a prominent median ridge on the lingual side of the rostral region of the prementary, and, if present, the former forms and projects caudally from the caudal margin of the prementary rostral region (0); the process has a well-developed ridge on the lingual surface of the rostral segment of the prementary, from which the former extends further caudally to lie dorsal to the dentary symphysis (1).

24. Prementary. Ventral median process, degree of indentation of the split of the process into two distinct lobes (PDT13, <http://www.morphbank.net/Show/?id=461234>; Prieto-Márquez 2010a, character 32): short indentation and deep undivided portion, the splitting originates at a distance from the prementary ventral margin that equals approximately half of the mediolateral width of the ventral process (0); long indentation and shallow undivided portion, the splitting originates at a distance from the prementary ventral margin that is less than the mediolateral width of the process (1).
25. Dentary. Ratio between the length of the proximal edentulous slope of the dentary and the distance between the rostralmost tooth position and the caudal margin of the coronoid process (DT1, <http://www.morphbank.net/Show/?id=461235>; Prieto-Márquez 2010a, character 33): less than 0.20 (sample mean ratio of 0.11) (0); ratio between 0.20 and 0.31 (sample mean ratio of 0.27) (1); ratio between 0.32 and 0.45 (sample mean ratio of 0.35) (2); ratio greater than 0.45 (sample mean ratio of 0.54) (3). Ordered
26. Dentary. Angle of deflection of the rostral ventral margin of the dentary (DT4, <http://www.morphbank.net/Show/?id=461238>; Prieto-Márquez 2010a, character 36): angle less than 17° (sample mean angle of 13°) (0); angle between 17° and 25° (sample mean angle of 22°) (1); angle greater than 25° (sample mean angle of 33°) (2). Ordered

27. Dentary. Location of the origination of the ventral deflection the dentary (measured as the ratio between the distance from the caudal margin of the coronoid process to the inflexion point of the ventral margin and the distance from the caudal margin the coronoid process to the rostralmost alveolus) (DT5, <http://www.morphbank.net/Show/?id=461239>; Prieto-Márquez 2010a, character 37): the deflection occurs near the rostral end of the dentary, ratio greater than 0.78 (sample mean ratio of 0.87) (0); ratio between 0.66 and 0.78 (sample mean ratio of 0.72) (1); deflection originating near the middle of the dental battery, ratio of 0.65 or less (sample mean ratio of 0.59) (2). Ordered
28. Dentary. Medial or lateral profile of the dorsal margin of the rostral edentulous region of the dentary for articulation with the prementary (DT9, <http://www.morphbank.net/Show/?id=461243>; Prieto-Márquez 2010a, character 40): ranging from having a very subtle concavity (almost straight) to straight or even displaying a subtle convexity (0); having a well-pronounced concavity (1).
29. Dentary. Angle between the long axis of the coronoid process and the dorsal margin of the alveolar sulci of the dental battery (DT11; modified from Godefroit *et al.* 2008, character 39): coronoid process subvertical or caudally inclined (0); process rostrally inclined (1).
30. Dentary. Morphology of the apex of the coronoid process (in adults) (DT12, <http://www.morphbank.net/Show/?id=461246>; modified from Horner *et al.* 2004, character 17): slightly expanded rostrocaudally, with very limited development of rostral and caudal expansions resulting in an apex that is taller than wider (0); well developed expansion of both the caudal and, especially, the rostral margins (1).

31. Dentary. Caudodorsal margin of the coronoid process projected dorsally into a sharp point (DT13, <http://www.morphbank.net/Show/?id=461246>; Prieto-Márquez 2010a, character 44): absent (0); present (1).
32. Dentary. Thick and dorsoventrally elongated ridge on the medial side of the coronoid process, located near the caudal margin of the process (DT14, <http://www.morphbank.net/Show/?id=461247>; Prieto-Márquez 2010a, character 45): absent, presence of fine striations (0); present, the ridge forms the rostral boundary of a depressed facet for attachment of the rostrrodorsal process of the surangular; coarse striations present rostral to the ridge (1).
33. Dentary. Lateral expansion of caudal region of the dentary, ventral to the base of the coronoid process (measured as the angle between the lateral surface of the dentary and that of the region caudoventral to the coronoid process) (DT15, <http://www.morphbank.net/Show/?id=461248>; Prieto-Márquez 2010a, character 46): the lateral side of the dentary is only slightly expanded laterally ventral to the coronoid process, with an angle greater than 165° (sample mean angle of 171°) (0); well developed expansion of the lateral side of the dentary ventral to the coronoid process, with an angle up to 165° (sample mean angle of 154°) (1).
34. Dentary. Orientation of the longitudinal axis of the dentary occlusal plane relative to the lateral side of the bone (as seen dorsally and caudal to the edentulous region) (DT16, <http://www.morphbank.net/Show/?id=461249>; Prieto-Márquez 2010a, character 47): diagonal axis, directed rostralaterally and forming approximately 15° with the lateral side of the dentary (0); axis parallel to the lateral side of the dentary (1).

35. Dentary. Lingual bowing of the occlusal plane (DT17, <http://www.morphbank.net/Show/?id=461250>; Horner *et al.* 2004, character 12): absent, rostrocaudally straight occlusal plane (0); present, lingually convex occlusal plane (1).
36. Dentary. Caudal extension of the dental battery (DT18, <http://www.morphbank.net/Show/?id=461251>; modified from Horner *et al.* 2004, character 10): the caudal end of the dental battery is found rostral to the caudal margin of the coronoid process (0); the caudal end of the dental battery is found flush with the caudal margin of the coronoid process (1); the caudal end of the dental battery is found caudal to the caudal margin of the coronoid process (2). Ordered
37. Dentary. Separation between the dentary tooth row and the coronoid process (DT19, <http://www.morphbank.net/Show/?id=461252>; Norman 2002, character 26): the coronoid process is laterally offset (but nearly in contact) with the tooth row, lacking a platform in-between the tooth row and the base of the process (0); the coronoid process is laterally offset relative to the tooth row, with the presence of a concave platform or, in some cases, a laterodorsal concave slope separating the base of the process from the dental battery (1).
38. Dentary. Prominent ventral convexity of the dentary ramus rostral to coronoid process (DT20; modified from Prieto-Márquez, 2010, character 41): absent (0); present (1).
39. Surangular. Morphology of the rostral ascending process of the surangular (SA1, <http://www.morphbank.net/Show/?id=461253>; modified from Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001): rostrocaudally thick process, slightly reduced in thickness rostrally, extensively exposed in lateral view (0); rostrocaudally reduced in thickness, strap-like and wedging dorsally into a thin sliver that becomes concealed in lateral view by the dorsal half of the caudal margin of the coronoid process (1).

40. Surangular foramen (SA2, <http://www.morphbank.net/Show/?id=461254>; Norman 2002, character, character 27): absent (0); present (1).
41. Surangular. Accessory foramen located rostradorsal to the main surangular foramen (SA3, <http://www.morphbank.net/Show/?id=461255>; Kobayashi & Azuma 2003, character 15): absent (0); present (1).
42. Surangular. Orientation of the convex side of the lateral lap and the lateroventral surface of the main body of the surangular (SA4, <http://www.morphbank.net/Show/?id=461256>; Prieto-Márquez 2010a, character 54): facing more laterally than ventrally (0); facing more ventrally than laterally (1).
43. Surangular. Lateral curvature of the retroarticular process of the surangular (SA5, <http://www.morphbank.net/Show/?id=461257>; Prieto-Márquez 2010a, character 55): absent, process rostrocaudally oriented (0); present, process laterally recurved (1).
44. Angular. Position of the angular in the mandible (ANG, <http://www.morphbank.net/Show/?id=461259>; Weishampel *et al.* 1993, character 26): positioned ventrally and slightly medially, exposed in lateral view (0); positioned medially, not exposed in lateral view (1).
45. Prearticular bone (PRAR, <http://www.morphbank.net/Show/?id=461261>; Prieto-Márquez 2010a, character 59): absent (0); present (1).

Facial characters

46. Premaxilla. Mediolateral expansion of the premaxillary oral margin (measured as the ratio between the maximum mediolateral width of the premaxilla and the minimum width at the narrowest point or post-oral constriction) (PMX1,

<http://www.morphbank.net/Show/?id=461264>; modified from Horner *et al.* 2004, character 22):

relatively narrow, ratio less than 1.65 (mean ratio of 1.45) (0); ratio between 1.65 and 2 (mean ratio of 1.84) (1); very wide, with a ratio greater than 2 (mean ratio of 2.22) (2). Ordered

47. Premaxilla. Position of the premaxillary oral margin relative to the occlusal plane of the dentition (PMX2, <http://www.morphbank.net/Show/?id=461265>; modified from Norman 2002): premaxillary margin slightly ventrally offset from occlusal plane (approximately, the dorsoventral distance between the occlusal plane and the level of the premaxillary oral margin is less than the mean depth of the dentary) (0); very strongly deflected ventrally (approximately, the dorsoventral distance between the occlusal plane and the level of the premaxillary oral margin is equal to or larger than the mean depth of the dentary) (1).
48. Premaxilla. Degree of expansion and folding of the oral margin of the premaxilla (modified from Horner *et al.* 2004, character 22): moderately expanded border, dorsoventrally thicker towards the parasagittal plane of the snout, and slightly deflected ventrally (PMX3, <http://www.morphbank.net/Show/?id=461266>) (0); moderately expanded border, becoming thinner towards the parasagittal plane of the snout (<http://www.morphbank.net/Show/?id=461267>) (1); folded caudodorsally into a thin recurved margin (<http://www.morphbank.net/Show/?id=461268>) (2); ventrally deflected and dorsoventrally expanded, forming a very broad “lip-like” margin (<http://www.morphbank.net/Show/?id=461269>) (3).
49. Premaxilla. Premaxillary oral margin with a ‘double layer’ morphology consisting of an external denticle-bearing layer and an internal layer of thickened bone set back slightly from the oral margin and separated from the denticular layer by a deep sulcus bearing vascular

foramina (PMX5, <http://www.morphbank.net/Show/?id=461271>; Horner *et al.* 2004, character 25): absent (0); present (1).

50. Premaxilla. Premaxillary foramen located rostrally and ventrolateral to the rostral margin of the external bony naris (PMX6, <http://www.morphbank.net/Show/?id=461272>; Horner *et al.* 2004, character 23): absent (0); present (1).

51. Premaxilla. Premaxillary accessory foramen entering rostrally through the rostral fossa, located rostral to the premaxillary foramen (PMX7, <http://www.morphbank.net/Show/?id=461273>; Horner *et al.* 2004, character 24): absent (0); present, empties into a common chamber with the premaxillary foramen (1).

52. Premaxilla. Circumnarial depression including a premaxillary rostral fossa set rostral to the circumnarial fossa proper (PMX8, <http://www.morphbank.net/Show/?id=461274>; Horner *et al.* 2004, character 26): absent (0); present, separated from circumnarial depression by a rostrocaudally wide ridge (1).

53. Premaxilla. Accessory rostral fossa located lateral to the rostral fossa and rostromedial to the circumnarial fossa, parallel to the lateral border of the oral margin (PMX9, <http://www.morphbank.net/Show/?id=461275>): absent (0); present (1).

54. Premaxilla. Elongation of premaxillary medial process (PMX10, <http://www.morphbank.net/Show/?id=461276>; modified from Horner *et al.* 2004, characters 27): the premaxillary caudodorsal process does not meet the caudoventral process caudally (0); elongate caudodorsal process that extends caudally to meet the caudoventral process, forming the caudal margin of the external naris (1).

55. Premaxilla. Vertical groove on the caudoventral process of the premaxilla, located rostral to the dorsal process of the maxilla and extending ventrally from a small opening between the two

premaxillary caudal processes; the groove is bounded rostrally by a triangular ventral projection of the caudolateral process of the premaxilla (PMX11, <http://www.morphbank.net/Show/?id=461277>; Evans & Reisz 2007, character 5): absent (0); present (1).

56. Premaxilla. Elongation of the lateral process of the premaxilla (in adults) (PMX12, <http://www.morphbank.net/Show/?id=461278>; modified from Suzuki *et al.* 2004, character 4): relatively short, the caudoventral process extends caudodorsally to end dorsal to the lacrimal or mediodorsal to the rostral end of the prefrontal (0); long, the caudoventral process extends to end medial to the dorsal region of the prefrontal (1); very long, the caudoventral process extends caudodorsal to the prefrontal (2). Ordered
57. Premaxilla. Morphology of the caudal region of the lateral process of the adult premaxilla: mediolaterally compressed and triangular (PMX13, <http://www.morphbank.net/Show/?id=461279>; Prieto-Márquez 2010a, character 71) (0); dorsoventrally broad and directed caudally or caudally and slightly dorsally (<http://www.morphbank.net/Show/?id=461280>) (1); triangular and dorsoventrally expanded, laterally convex lobe, directed rostr dorsally (<http://www.morphbank.net/Show/?id=461281>) (2).
58. Premaxilla. Premaxillary caudodorsal process has an accessory rostroventral flange that overlaps the lateral surface of the nasal in the rostral region of a supracranial crest (PMX14, <http://www.morphbank.net/Show/?id=461282>; Evans & Reisz 2007, character 18): absent (0); present (1).
59. Premaxilla. Laterodorsal profile of the caudodorsal and caudoventral margins of the external bony naris (PMX15, <http://www.morphbank.net/Show/?id=461283> and

<http://www.morphbank.net/Show/?id=461285>; modified from Evans & Resiz 2007, character

4): subrectangular to subellipsoidal (0); triangular and very long (length/width ratio greater than 2.85), caudal constriction gradually closing caudodorsally (1); triangular and moderately long, caudal constriction gradually closing caudodorsally (length/width ratio between 1.85 and 2.85) (2); lacriform (length/width ratio less than 1.85), caudal constriction occurs abruptly and is primarily composed of a lateroventral expansion of the caudodorsal premaxillary process (3); lacriform (length/width ratio less than 1.85), caudal constriction occurs abruptly and is primarily composed of a dorsal expansion of the caudoventral process of the premaxilla (4).

60. Premaxilla. Dorsolateral flange at approximately mid-length of the mediolaterally compressed caudoventral process of the premaxilla (PMX16,

<http://www.morphbank.net/Show/?id=461286>; Gates & Sampson 2007): absent (0); present (1).

61. Premaxilla. One or more foramina on the rostral surface of the premaxilla (PMX17; Prieto-Márquez 2010b, character 287): absent (0); present (1).

62. Premaxilla. Lateral profile of the dorsal margin of the rostral rostrum (PMX18; Prieto-Márquez & Wagner 2013, character 287): convex (0); straight to gently concave (1); strongly concave (2). Ordered

63. Premaxilla. Contour of the rostrolateral region of the thin everted oral margin (PMX19; Prieto-Márquez & Wagner 2013, character 289): broad and arcuate (0); subangular (1).

64. Premaxilla. Orientation of the medial process relative to the lateral process around the external bony naris (PMX20; Prieto-Márquez 2014, character 66): subparallel (0); processes slightly converging caudally (1).

65. Nasal. Location of the nasal bone and nasal cavity in the adult skull (NS1,

<http://www.morphbank.net/Show/?id=461287>; modified from Horner *et al.* 2004, character 33

and partially from Evans & Reisz 2007, character 7): the nasal extends from the rostral region of the skull roof to the rostradorsal region of the snout, rostral or dorsal to the orbit, nasal cavity rostromedial to the orbit (0); nasal retracted caudal to the rostrum and occupying a supracranial position in the skull, with the ventral region of the nasal meeting the prefrontal rostral to the orbit, resulting in a crest that extends caudal to the orbit, yet nasal cavity remains rostromedial to the orbit (1); retracted caudal to the rostrum and occupying a supracranial position in the skull, with the ventral region of the nasal meeting the prefrontal caudal to the rostral margin of the orbit, resulting in a convoluted narial passage and hollow crest that extend supraorbitally (2). Ordered

66. Nasal. Curvature of the caudodorsal region of the nasal (NS2, <http://www.morphbank.net/Show/?id=461288>; modified partially from Evans and Reisz, 2007, character 7): absent, nasal straight caudodorsally (0); present, nasal rotated and folded dorsally or caudodorsally (1).
67. Nasal. Morphology of the rostral end of the supranarial process at the contact with the medial process of the premaxilla (NS3, <http://www.morphbank.net/Show/?id=461289> and <http://www.morphbank.net/Show/?id=461290>; states 3 and 4 modified from Evans & Reisz 2007, character 17): long and wedge-shaped rostral process, gradually decreasing in width rostrally (0); hook-like process, it becomes abruptly deep near its rostral end and then wedges rostrally to a rostroventrally directed (1); long and subrectangular process, with slightly rounded corners (2); small rostral process of the nasal fits along the ventral edge of the premaxilla, the latter briefly overlapping the nasal (3); the nasal bifurcates to meet the premaxilla in a W-shaped interfingering suture, a long and finger-like process of the nasal has

an extensive overlapping joint with the caudodorsal process of the premaxilla; and additional, more caudally located shorter process of the nasal abuts the premaxilla (4).

68. Nasal. Morphology of the nasal contact with the caudodorsal region of the medial premaxillary process at the caudal margin of the external bony naris (NS4, <http://www.morphbank.net/Show/?id=461291>; Prieto-Márquez 2010a, character 78): the nasal forms a subrectangular flange exposed dorsal to the premaxillary caudoventral process (0); the nasal forms a large hook-like rostroventral process, exposed dorsal to the premaxillary caudoventral process (1); the nasal forms a greatly shortened and dorsoventrally narrow hook-like rostroventral process, exposed dorsal to the premaxillary caudoventral process (2).
69. Nasal. Location of the rostral end of the supranarial process relative to the rostral margin of the external bony naris (NS5, <http://www.morphbank.net/Show/?id=461292>; Prieto-Márquez 2010a, character 79): the rostral end of the dorsal process of the nasal does not reach the rostral margin of the external bony naris (0); the rostral end of the rostradorsal process of the nasal reaches the rostral margin of the external bony naris (1).
70. Nasal. Caudoventral region of nasal, in hollow supracranial crest, ventrally recurved and hook-shaped, with a rostral process that inserts under the caudoventral process of the premaxilla (NS6, <http://www.morphbank.net/Show/?id=461293>; Prieto-Márquez 2010a, character 80): absent (0); present (1).
71. Nasal. Caudal end of the nasals forming a pair of broad, strap-like process on top of the frontals, that are separated sagittally by an intervening median sliver of the frontal (NS7, <http://www.morphbank.net/Show/?id=461294>; Gates & Sampson 2007, character 65, in part): absent (0); present (1).

72. Nasal. Caudal end of nasals forming a pair of short processes that insert between the frontals at the sagittal plane of the skull roof (NS8, <http://www.morphbank.net/Show/?id=461295>; Gates & Sampson 2007, character 65, in part): absent (0); present (1).
73. Nasal. Position of the summit of nasal arch crest relative to the caudodorsal margin of the external bony naris (NS9, <http://www.morphbank.net/Show/?id=461296>; Prieto-Márquez 2010, character 83): summit located dorsal to the caudal margin of the external bony naris (0); summit located caudodorsal to the caudal margin of the external bony naris (1).
74. Nasal. Mediolateral breadth of caudal nasal processes that inserts in between the frontals at the sagittal plane of the skull (N10; Prieto-Márquez 2014, character 75): processes broad and converging caudally in width, forming a V-shaped dorsal outline between the frontals (0); processes greatly compressed mediolaterally and finger-like (1).
75. Nasal. Ridge bordering the caudodorsal margin of the circumnarial depression (NS11; Godefroit et al., 2012): absent (0); present, thin and weakly developed (1); present, thick and prominent (2). Ordered
76. Maxilla. Palatal process that is medially offset from the body of the maxilla and extends also medial to the caudoventral process of premaxilla to form part of medial floor of external naris (MX1, <http://www.morphbank.net/Show/?id=461297>; partially after Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001 and Horner *et al.*, 2004, character 42): absent, the rostral end of the maxilla forms a ventrally sloping rostradorsal shelf that underlies the premaxilla (0); present (1).
77. Maxilla. Palatal process exposed through the external bony naris (MX2, <http://www.morphbank.net/Show/?id=461298>; modified from Gates & Sampson 2007, character 45): not exposed or only the distal tip exposed through the external bony naris in

lateral view (0); large segment of the process exposed through the external bony naris in lateral view (1).

78. Maxilla. Palatal process shape: broad, with extensive subtriangular proximal region (0); narrow, short, finger-like (1). (new)
79. Maxilla. Palatal process orientation: diversing rostrally from premaxillary process (0); more ventrally than rostrally oriented, parallel to premaxillary process (1). (new)
80. Maxilla. Angle between the dorsal margin of the premaxillary process or shelf of the maxilla and the rostral segment of the tooth row (MX4, <http://www.morphbank.net/Show/?id=461300>; Prieto-Márquez 2010a, character 87): rostradorsal region of the maxilla subconical in shape, dorsoventrally narrow, forming an angle of 25° or less with the rostral tooth row (mean angle of 20°) (0); dorsoventrally thicker, forming an angle greater than 25° and up to 39° with the rostral tooth row (mean angle of 31°) (1); rostroventral process dipping steeply ventrally, forming an angle of 40° or greater with the tooth row (mean angle of 43°), rostral region of the maxilla appearing dorsally “swollen” and rostrocaudally compressed (2). Ordered
81. Maxilla. Lateral profile of the lateral surface of the rostradorsal region of the maxilla (MX5; modified from Prieto-Márquez 2010a, character 88): subtriangular profile with broadly arcuate dorsal margin below jugal and lacrimal (0); triangular and rostrocaudally compressed (1); trapezoid, extensive lateral exposure, with horizontal dorsal margin under lacrimal (2).
82. Maxilla. Trapezoid lateral profile of rostradorsal region of maxilla with extensive lateral exposure under lacrimal (MX18; Prieto-Márquez 2014, character 81): length of exposed rostradorsal margin is less than 40% of distance between rostral end of maxilla and caudoventral corner of orbital margin of jugal in articulated skull (0); exposed rostradorsal

margin is at least 40% of distance between rostral end of maxilla and caudoventral corner of orbital margin of jugal in articulated skull (1).

83. Maxilla. Position of the dorsal process and the dorsal margin of the dorsolateral promontory of the maxilla (expressed as the ratio between the distance from its summit to the rostral end of the maxilla and the rostrocaudal length of the element) (MX7, <http://www.morphbank.net/Show/?id=461303>; Prieto-Márquez 2010a, character 90): caudally located dorsolateral promontory (with a ratio greater than 0.57; mean of 0.64), base of dorsal process positioned within the caudal third of the maxilla (0); centrally located dorsolateral promontory (with a ratio between 0.47 and 0.57; mean of 0.51), base of dorsal process positioned slightly caudal to the mid-length of the maxilla (1); dorsolateral promontory located slightly rostral to the mid-length of the maxilla (with a ratio between 0.35 and 0.46; mean of 0.42), base of dorsal process centered around the mid-length of the bone (2); the base of dorsal process and dorsolateral promontory located rostral to the mid-length of the maxilla, with a ratio less than 0.35 (mean of 0.28) for the relative position of the rostradorsal promontory (3).

Ordered

84. Maxilla. Height/width proportions of the dorsal process (MX8, <http://www.morphbank.net/Show/?id=461304>; modified from Horner *et al.* 2004, character 48): subtriangular, wider than or as wide as tall (0); taller than wide (1).
85. Maxilla. Orientation of the caudal margin of the dorsal process: rostrally inclined (0); subvertical or vertical (0); inclined caudally (1). (new)
86. Maxilla. Jugal process projecting caudally from the jugal articular surface: absent, reduced to a tubercle (jugal tubercle) (0); present, finger-like process projecting caudoventrally (1). (new)

87. Maxilla. Union of the ventral margin of the jugal facet and the ectopterygoid shelf: absent, tunnel present at rostral end of coronoid fossa (0); incipient, tunnel present, facet for ventral spur of jugal does not meet the ectopterygoid ridge but instead forms the medial wall of the tunnel (1); present, complete closure of tunnel, facet for jugal spur displaced laterally and ectopterygoid ridge continuous with ventral margin of jugal facet (2). (new) Ordered
88. Maxilla. Location of the articular facet for the jugal: on the lateral surface of the jugal process (0); on the lateral surface of the dorsal process (1). (new)
89. Maxilla. Elevation of facet for ventral spur of rostral process of jugal (modified from Prieto-Márquez et al. 2013): absent, facet level with ectopterygoid ridge (0); present, facet above level of ectopterygoid ridge (1).
90. Maxilla. Smooth acute embayment indenting rostral to ventral jugal tubercle between facet for jugal and ectopterygoid shelf (modified from Prieto-Márquez and Gutarra, 2016): absent (0); present, rostral extent of ectopterygoid ridge recurved caudodorsally (1).
91. Maxilla. Arrangement of maxillary foramina ventral and rostral to the jugal articulation (excluding large rostradorsal or rostralateral foramen): arranged rostrocaudally and scattered throughout the lateral side of the maxilla (MX10, <http://www.morphbank.net/Show/?id=461309>; Prieto-Márquez 2010a, character 93) (0); forming either a row or cluster that is oriented rostradorsally (<http://www.morphbank.net/Show/?id=461310>, <http://www.morphbank.net/Show/?id=461311>, and <http://www.morphbank.net/Show/?id=461312>) (1).
92. Maxilla. Number of maxillary foramina ventral and rostral to the jugal articulation (excluding large rostradorsal or rostralateral foramen) (MX11,

<http://www.morphbank.net/Show/?id=461313>; Prieto-Márquez 2010a, character 94): seven or more (0); six or less (1).

93. Maxilla. Large rostral maxillary foramen (MX12, <http://www.morphbank.net/Show/?id=461314> and <http://www.morphbank.net/Show/?id=461315>; Evans & Reisz 2007, character 22 modified after Horner *et al.* 2004, character 44): exposed laterally and opening ventral to the mid-depth of the premaxillary shelf (0); exposed laterally and opening near the dorsal margin of the premaxillary shelf (1); not exposed laterally and opening on the dorsal surface of the premaxillary shelf (2). Ordered
94. Maxilla-lacrima contact (MX13, <http://www.morphbank.net/Show/?id=461316> and <http://www.morphbank.net/Show/?id=461317>; Evans & Reisz 2007, character 23): present externally (0); largely covered externally by the jugal-premaxilla contact (1).
95. Maxilla. Length of the ectopterygoid shelf relative to the total rostrocaudal length of the alveolar margin of the maxilla (MX14, <http://www.morphbank.net/Show/?id=461318>; partially after You *et al.* 2003, character 12): ratio between the length ectopterygoid shelf and the length of the rostrocaudal alveolar margin up to 0.25 (mean ratio of 0.20) (0); ratio greater than 0.25 and up to 0.35 (mean ratio of 0.30) (1); ratio greater than 0.35 (mean ratio of 0.45) (2). Ordered
96. Maxilla. Slope of the ectopterygoid shelf, measured as the angle between this and the rostrocaudal axis of the caudal segment of the tooth row (MX15, <http://www.morphbank.net/Show/?id=461319>; Prieto-Márquez 2010a, character 98): steeply inclined caudoventrally, with an angle greater than 21° (mean angle of 29°) (0); shelf inclined with an angle greater than 10 and up to 21° (mean angle of 15°) (1); slightly inclined shelf, with

an angle greater than 4° and up to 10° (mean angle of 8°) (2); horizontal shelf, with an angle up to 4° (3). Ordered

97. Maxilla. Morphology of the lateral emargination of the ectopterygoid shelf (MX16, <http://www.morphbank.net/Show/?id=461320>; modified from Godefroit *et al.* 2000, character 14): dorsoventrally thin ridge (0); faint or thin rostrally, then abruptly becoming dorsoventrally thick along the caudal segment of the margin (1); dorsoventrally thick continuous ridge, becoming gradually thicker caudally (2). Ordered
98. Maxilla. Position of the central region of the arcuate row of special foramina on the medial side of the maxilla (MX17, <http://www.morphbank.net/Show/?id=461321>; Prieto-Márquez 2010a, character 100): ventral to, or at the level of the mid-dorsoventral depth of the maxilla (0); above the mid-dorsoventral depth of the maxilla (1).
99. Maxilla, rostradorsal margin bearing a prominent subrectangular flange that rises vertically above the rostroventral process (MX19; Prieto-Márquez *et al.*, 2013): absent (0); present (1).
100. Maxilla. Fossa excavating rostradorsal surface of the premaxillary shelf, separating shelf from a rostradorsal flange (MX22; new character): absent (0); present (1).
101. Lacrimal. General morphology of the adult lacrimal in lateral view (LC1, <http://www.morphbank.net/Show/?id=461325>; Prieto-Márquez 2010a, character 101): triangular and rostrocaudally elongated, with a rostral process that is rostrally (and slightly ventrally) directed (0); triangular, rostrocaudally abbreviated with a relatively shorter and thinner rostral process (1).
102. Lacrimal. Ventral margin of the lacrimal with a prominent convexity rostral to the jugal notch (LC2, <http://www.morphbank.net/Show/?id=461326>; Prieto-Márquez 2010a, character 102): absent (0); present (1).

103.Jugal. Rostral apex of the rostral process of the jugal (J1,

<http://www.morphbank.net/Show/?id=461327> and

<http://www.morphbank.net/Show/?id=461328>; Prieto-Márquez 2010a, character 103): present, wedge-shaped, elongated and sharply pointed, positioned at mid distance along the dorsoventral depth of the rostral process (0); present, wedge-shaped, pointed and less elongated than in (0), positioned within the dorsal half of the rostral process of the jugal; the dorsal margin of the apex forms a steeper angle with the horizontal than in state (0) (1); greatly reduced to a blunt convexity (2); reduced to a short process, only slightly thinner rostrally and ending abruptly (3); absent, straight nearly vertical rostral margin (4); absent, tongue-shaped rostral margin (5).

104.Jugal. Dorsoventral expansion of the caudal margin of the lacrimal margin of the rostral

process of the jugal (J2, <http://www.morphbank.net/Show/?id=461329>; Weishampel *et al.*

1993, character 15): relatively shallow, rostradorsally directed and forming little of the rostroventral margin of the orbital rim (0); relatively deep (about 60-90% as deep as the rostral jugal constriction), dorsally or slightly recurved caudadorsally, forming the rostroventral corner of the orbital rim (1).

105.Jugal. Morphology of the ventral spur the rostral process of the jugal (J3,

<http://www.morphbank.net/Show/?id=461330>; Prieto-Márquez 2010a, character 105): shallow and rostrocaudally wide prominence (wider than deep) (0); ventrally pointed, approximately as deep as or slightly deeper as its proximal end is wide (1); ventrally projected triangular narrow process, at least twice as deep as it is wide, sharply pointed and often recurved caudally (2).

Ordered

106.Jugal. Location of the ventral spur of the rostral process relative to the caudodorsal articulation with the lacrimal (with longitudinal axis of the rostral process oriented horizontally) (J4, <http://www.morphbank.net/Show/?id=461333>; Prieto-Márquez 2010a, character 106): spur caudoventral to the caudal margin of the lacrimal process (0); spur ventral to the caudal margin of the lacrimal process (1).

107.Jugal. Orientation of the articular facet for the palatine (J5, <http://www.morphbank.net/Show/?id=461332>; Prieto-Márquez 2010a, character 107): subhorizontal (0); oblique, rostr dorsally oriented (1); subvertical (2). Ordered

108.Jugal. Ventral expansion of the caudoventral flange (measured as the ratio between the dorsoventral depth of the flange and the minimum depth of the caudal constriction of the jugal) (J8, <http://www.morphbank.net/Show/?id=461336>; modified from Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001): slightly expanded flange, ratio of 1.36 or less (mean ratio of 1.29) (0); moderately expanded flange, ratio greater than 1.36 and up to 1.55 (mean ratio of 1.44) (1); greatly expanded flange, ratio greater than 1.55 (mean ratio of 1.68) (2). Ordered

109.Jugal. Lateral profile of the quadratojugal flange (J9, <http://www.morphbank.net/Show/?id=461337> and <http://www.morphbank.net/Show/?id=461338>; Prieto-Márquez 2010a, character 111) subconical, dorsoventrally tall and rostrocaudally narrow, with a nearly vertical caudal margin (0); auricular in shape, with subparallel concave to nearly straight dorsal and convex ventral margins that converge dorsally into a short apex (1); fan-like, with dorsal and ventral margins that are subparallel and diverge caudodorsally; dorsal and ventral margins can be straight or slightly bowed dorsally (2); auricular in shape, with subparallel concave to nearly straight

dorsal and convex ventral margins that converge dorsally into a recurved or dorsally directed tall apex (this state is similar to (1), but the dorsal region of the flange is rostrocaudally narrower and taller) (3).

110. Jugal. Morphology of the ventral margin located between the caudoventral and quadratojugal flanges (J10, <http://www.morphbank.net/Show/?id=461339>; modified from Weishampel *et al.* 1993, character 18): relatively short and shallow concavity (0); relatively wide and well-pronounced concavity (1).

111. Jugal. Relative depth of the infratemporal bar and orbital constriction (J11, <http://www.morphbank.net/Show/?id=461340>; Prieto-Márquez 2010a, character 113): deeper rostral constriction, ratio of the depth of the infratemporal bar relative to the orbital constriction of 1 or less (mean ratio of 0.93) (0); deeper infratemporal bar, with a ratio greater than 1 and less than 1.35 (mean ratio of 1.18, resulting from merging two K-means clusters with mean ratios of 1.13 and 1.24) (1); extremely deep infratemporal bar, ratio greater than 1.35 (mean ratio of 1.43) (2). Ordered

112. Jugal. Relative width and lateral profiles of the orbital and infratemporal margins of the jugal (J13, <http://www.morphbank.net/Show/?id=461342>; Prieto-Márquez 2010a, character 115): wider orbital margin and relatively constricted ventral margin of the infratemporal fenestra (0); orbital and infratemporal margins are nearly equally wide (1); wider infratemporal margin (2). Ordered

113. Quadrate. Degree of curvature of the caudal margin of the quadrate (Q1, <http://www.morphbank.net/Show/?id=461343>; Prieto-Márquez 2010a, character 116): the caudal margin of the dorsal half or third of the quadrate displays a slight curvature relative to the ventral half of the element, with an angle of 150° or greater (mean angle of 161°) (0); the

caudal margin of the dorsal half or third of the quadrate is strongly curved caudally relative to the ventral half of the element, with an angle less than 150° (mean angle of 143°) (1).

114. Quadrate. Position of the quadratojugal (paraquadrate) notch along the dorsoventral length of the quadrate (measured as the ratio between the distance from the mid-length of the notch to the quadrate head and the dorsoventral length of the element) (Q2,

<http://www.morphbank.net/Show/?id=461344>; Prieto-Márquez 2010a, character 117): the mid point of the notch is located slightly ventral to or centered at mid-length of the quadrate, ratio less than 0.60 (mean ratio of 0.54) (0); the mid point of the notch is located substantially ventral to the mid-length of the quadrate, ratio of 0.60 or greater (mean ratio of 0.64) (1).

115. Quadrate. Orientation of the dorsal margin of the quadratojugal notch of the quadrate (measured as the angle between this and the caudal margin of the element) (Q3,

<http://www.morphbank.net/Show/?id=461345>; Prieto-Márquez 2010a, character 118): angle greater than 45° (mean angle of 52°) (0); angle up to 45° (mean angle of 28°) (1).

116. Quadrate. Morphology of the lateral profile of the quadratojugal notch of the quadrate (Q4,

<http://www.morphbank.net/Show/?id=461346>; Prieto-Márquez 2010a, character 119):

subcircular, with a ventral half of the notch that is recurved and has a horizontal rostral segment (0); wide arcuate and asymmetrical, with the ventral half of the notch having a short horizontal rostral segment (1); wide arcuate and symmetrical, the ventral half of the notch being rostroventrally-directed, nearly straight as it is the dorsal half (2). Ordered

117. Quadrate. Development of the squamosal buttress on the caudal margin of the dorsal end of the quadrate (Q5, <http://www.morphbank.net/Show/?id=461347>; Prieto-Márquez 2010a, character 120): absent or poorly developed as a gentle convexity (0); present, the buttress is a sharp

protuberance hanging from the caudal side of the dorsal fourth of the quadrate, near the head of the element (1).

118. Quadrate. Morphology of ventral surface of the quadrate (Q6,

<http://www.morphbank.net/Show/?id=461349> and

<http://www.morphbank.net/Show/?id=461348>; Weishampel *et al.* 1993, character 22):

mediolaterally broad and rostrocaudally compressed, lateral condyle slightly larger than the medial one (mean ratio between the rostrocaudal width of the lateral condyle and the mediolateral width of the ventral end of the quadrate of 0.59); the ventral surface of the lateral condyle is only slightly offset ventrally relative to the ventral surface of the medial condyle (0); subtriangular in ventral view, lateral condyle rostrocaudally expanded and much larger than the medial one (mean ratio between the rostrocaudal width of the lateral condyle and the mediolateral width of the ventral end of the quadrate of 0.90); the ventral surface of the lateral condyle is well offset ventrally relative to the ventral surface of the medial condyle (1).

119. Prefrontal. Dorsomedial margin of the prefrontal developed into a caudodorsally-oriented crest

(PF1, <http://www.morphbank.net/Show/?id=461350> and

<http://www.morphbank.net/Show/?id=461351>; Godefroit *et al.* 2004, character 16): absent (0); present (1).

120. Prefrontal. Development of the dorsomedial crest of the prefrontal (PF9,

<http://www.morphbank.net/Show/?id=461350> and

<http://www.morphbank.net/Show/?id=461351>; Godefroit *et al.* 2004, character 16): crest not extending caudal to the prefrontal-frontal articulation (0); crest extending caudally over the dorsal surface of the frontal and above the prefrontal-postorbital articulation in lateral view in adults (1).

121. Prefrontal. Lateral profile of the rostrodorsal margin of the prefrontal (PF2, <http://www.morphbank.net/Show/?id=461352>; modified from Horner *et al.* 2004, character 50): smoothly curved, the rostral margin is rostroventrally oriented and forming an obtuse angle with the dorsal orbital margin (0); rostromedially broad with subsquared rostrodorsal corner (1).
122. Prefrontal. Mediolateral breadth of the exposed rostroventral region of the prefrontal (PF3, <http://www.morphbank.net/Show/?id=461353>; partially after Horner *et al.* 2004, character 50): the rostroventral region is mediolaterally expanded (0); the exposed rostroventral region is relatively mediolaterally compressed and narrow (1).
123. Prefrontal. Inclusion of the prefrontal in the circumnarial fossa (PF4, <http://www.morphbank.net/Show/?id=461354> and <http://www.morphbank.net/Show/?id=461355>; Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001): absent (0); present (1).
124. Prefrontal. Exposure of the prefrontal-nasal contact in lateral and/or dorsal view (PF6, <http://www.morphbank.net/Show/?id=461357>; modified from Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001): contact totally exposed in lateral and/or dorsal view (0); contact visible in lateral view along the caudal and half of the dorsal margin of the prefrontal (1); contact visible in lateral view only along the caudal region of the prefrontal in adults, due to the invasion of the premaxilla along the medial side of the prefrontal (2). Ordered
125. Prefrontal. Deep fossa on the ventral surface of the rostrodorsal corner of the orbit, rostrodorsal orbital margin being squared and slightly projected rostrodorsally (PF7; after Campione & Evans 2011): absent (0); present (1).

126. Prefrontal. Caudodorsal process of the prefrontal that joins the caudodorsal frontal process in supporting ventrally a solid nasal caudodorsal crest (PF8; new character): absent (0); present (1).
127. Postorbital. Dorsal promontorium on the rostral process of the postorbital (PO1, <http://www.morphbank.net/Show/?id=461359> and <http://www.morphbank.net/Show/?id=461358>; Godefroit *et al.* 2004, character 17): absent, the dorsal surface of the postorbital above the jugal process is horizontal or slightly concave (0); present in adult specimens, the articular margin for the prefrontal is elevated and the dorsal surface of the postorbital above the jugal process is deeply depressed (1).
128. Postorbital. Narrowing of the dorsal region of the infratemporal fenestra (PO2, <http://www.morphbank.net/Show/?id=461360>; modified from Evans & Reisz 2007, character 36): absent, dorsal margin of infratemporal fenestra being wider than quadrate cotylus, squamosal ramus of the postorbital elongate over the infratemporal fenestra (0); present, dorsal margin of infratemporal fenestra being as wide as or narrower than quadrate cotylus and squamosal ramus of the postorbital relatively short over the infratemporal fenestra (1).
129. Postorbital. Morphology of the central body of the postorbital (PO3, <http://www.morphbank.net/Show/?id=461361>; Prieto-Márquez 2010a, character 130): triangular, rostrocaudally broad, expanded rostroventrally to form a straight and obliquely oriented caudodorsal orbital margin (0); triangular, with a caudodorsal orbital margin that ranges in lateral profile from semicircular to subsquared (1); rostrocaudally expanded, rostrally excavated and bulging laterally (“inflated”), containing a hollow inner cavity (in adults) (2).

130. Postorbital. Morphology of the caudal end of the caudal process of the postorbital at its articulation with the squamosal (PO5, <http://www.morphbank.net/Show/?id=461363>; Evans & Reisz 2007, character 35): oblong or wedge-shaped (0); bifid (1).
131. Postorbital. Caudal extension of the caudal ramus of the postorbital that overlaps the laterodorsal surface of the squamosal (PO6, <http://www.morphbank.net/Show/?id=461364>; modified from Godefroit *et al.* 2000): the caudal end of the postorbital caudal ramus extends to a point rostral to the quadrate cotylus and does not overlap the latter (0); the caudal end of the postorbital caudal ramus extends caudodorsal to the precotyloid process and over as much as the rostral half of the quadrate cotylus (1); the caudal end of the postorbital caudal ramus completely overlaps the laterodorsal side of the squamosal quadrate cotylus (2). Ordered
132. Postorbital. Deeply inflected (Y-shaped) dorsal surface of the central body of the postorbital (in presumably adult larger specimens) (PO7; new character): absent (0); present (1).
133. Squamosal. Length of the precotyloid process of the squamosal (measured as the ratio of its length relative to the width of the quadrate cotylus) (SQ1, <http://www.morphbank.net/Show/?id=461365>; Prieto-Márquez 2010a, character 134): very short precotyloid process, ratio less than 0.95 (mean ratio of 0.74) (0); moderately long precotyloid process, ratio between 0.95 and 1.25 (mean ratio of 1.13) (1); very long precotyloid process, ratio greater than 1.25 (mean ratio of 1.41) (2). Ordered
134. Squamosal. Dorsoventral expansion of the caudolateral surface of the squamosal (SQ2, <http://www.morphbank.net/Show/?id=461366>; Horner *et al.* 2004, character 64): unexpanded, shallowly exposed in caudal view (0); greatly expanded dorsomedially, forming a deep, near vertical, well-exposed face in caudal view (in adults) (1).

135. Squamosal. Separation of the squamosals at the occipital margin of the skull roof (SQ3, <http://www.morphbank.net/Show/?id=461367>; Horner *et al.* 2004, character 63): completely separated by the parietal (0); the squamosal approach the sagittal plane of the skull, separated by a narrow band of parietal (1); extensive intersquamosal joint present at the midline, parietal completely excluded from the sagittal plane of the skull at that particular spot (in adults) (2).

Ordered

136. Squamosal. Rostromedial indenture of the medial ramus of the squamosal (SQ4, <http://www.morphbank.net/Show/?id=461368>; modified from Godefroit *et al.* 1998): absent, medial ramus of the squamosal extends medially, forming a subsquared caudolateral border of the skull roof (0); present, medial ramus of the squamosal curves rostromedially, so that the back of the skull appears to be deeply indented rostrally when viewed dorsally (1).

Neurocranial and palatal characters

137. Frontal. Bifurcation of the rostromedial margin of the frontals at the sagittal plane of the skull roof, leaving a V-shaped space in between (F1, <http://www.morphbank.net/Show/?id=461369>; Prieto-Márquez 2010a, character 138): absent (0); present (1).

138. Frontal fontanelle, present at least at one stage during ontogeny (F2, <http://www.morphbank.net/Show/?id=461370>; Langston 1960): absent (0); present (1).

139. Frontal. Nasal articulation surface of the frontal shaped into a rostroventrally-sloping platform (F3, <http://www.morphbank.net/Show/?id=461371>; Godefroit *et al.* 2004, character 7, in part; Evans & Reisz 2007, character 40, in part): absent (0); present (1).

140. Frontal. Nasal articulation surface of the frontal shaped into a dorsoventrally thickened, tongue-like platform that projects caudodorsally to overhang the parietal in adults (F4,

<http://www.morphbank.net/Show/?id=461372>; Godefroit *et al.* 2004, character 7, in part; Evans and Reisz, 2007, character 40, in part, and character 41): absent (0); present (1).

141. Frontal. Median cleft separating the two striated tongues of the frontal platform (F5, <http://www.morphbank.net/Show/?id=461373>; Evans & Reisz, 2007, character 40, in part): absent (0); present (1).

142. Frontal. Exposure of the frontal at the dorsal margin of the orbit (F6; Horner *et al.* 2004, character 57): frontal completely excluded from the orbital margin by an extensive articulation between the prefrontal and postorbital (0); frontal exposed, forming part of the dorsal orbital margin in between the prefrontal and postorbital (1).

143. Frontal, upward doming dorsal to the braincase in subadult (and perhaps young adult) specimens (F7, <http://www.morphbank.net/Show/?id=461375>; modified after Horner *et al.* 2004, character 58): absent (0); present (1).

144. Frontal, length/width ratio of the ectocranial surface (F8, <http://www.morphbank.net/Show/?id=461376>; Evans & Reisz 2007, character 42): relatively elongated ectocranial surface, with a ratio greater than 0.8 (0); relatively short ectocranial surface, with a ratio of 0.8 or less, but greater than 0.4 (1); greatly shortened ectocranial surface, with a ratio less than 0.4 (2). Ordered

145. Frontal. Morphology of the ventral annular ridge that defines the rostral extent of the cerebral fossa (F9, <http://www.morphbank.net/Show/?id=461377>; Evans & Reisz 2007, character 43): long, low and gently rounded in medial view (0); sharp annular ridge (1).

146. Frontal. Triangular rostrolateral projection ending into narrow apex (F10; Prieto-Márquez, 2014, character 131): absent (0); present (1).

147. Frontal. Caudodorsal process raising from the ectocranial surface of the frontal and that buttress the ventral surface of nasal crest (F11; modified from Prieto-Márquez, 2014, character 136): absent (0); present (1).
148. Frontal. Shape of the base of the caudodorsal process of the frontal (F12; new character): columnar and buttressed by large oblique ridge (0); crescent (1).
149. Frontal. Deeply depressed ectocranial surface and sagittal elevation of the interfrontal suture (F13; new character): absent (0); present (1)
150. Parietal. Maximum length/minimum width proportions of the adult parietal (PAR1, <http://www.morphbank.net/Show/?id=461378>; modified from Godefroit *et al.* 2004, character 18): short, length/width ratio less than 1.40 (sample mean ratio of 1.19) (0); moderate length, ratio between 1.40 and 2.35 (sample mean ratio of 1.98) (1); long, ratio greater than 2.35 (sample mean ratio of 2.75) (2). Ordered
151. Parietal. Orientation of the parietal midline crest (PAR2, <http://www.morphbank.net/Show/?id=461380>; Horner *et al.* 2004; character 69; Evans & Reisz 2007, character 44): straight and level with the skull roof or slightly down-warped along its length (0); the sagittal crest deepens caudally and is strongly down-warped (1).
152. Parietal. Rostral extension of the sagittal crest along the dorsal surface of the parietal (PAR4, <http://www.morphbank.net/Show/?id=461382>; Prieto-Márquez 2010a, character 150): the sagittal crest extends along the entire length of the parietal and remains sharp and well defined at the rostral region (0); the sagittal crest extends along the entire length of the parietal but its sharpness fades away at the rostral region where the parietal is rostrocaudally shorter than it is wide (1); the sagittal crest only extends along the caudal half of the parietal and the rostral half

of the dorsal surface of the parietal is flattened, lacking any ridge or mediolateral compression
(2). Ordered

153. Basioccipital. Participation of the basioccipital in the ventral margin of the foramen magnum (BO1, <http://www.morphbank.net/Show/?id=461383>; Weishampel *et al.* 1993, character 24): absent, the exoccipital condyloids nearly or completely exclude the basioccipital from the ventral margin of the foramen magnum (0); present, the exoccipitals are separated at the sagittal plane of the braincase and allow the basioccipital to become part of the ventral margin of the foramen magnum (1).

154. Basioccipital. Length of basioccipital constriction (BO3, <http://www.morphbank.net/Show/?id=461385>; Godefroit *et al.* 2001): poorly developed and relatively short constriction (0); relatively long and well developed (1).

155. Basisphenoid. Development of the alar process of the basisphenoid (BS2, <http://www.morphbank.net/Show/?id=461387>; Prieto-Márquez 2010a, character 155): moderately developed (0); very well developed, relatively large in size (1).

156. Basisphenoid. Ventral transverse caudal ridge between the basipterygoid processes of the basisphenoid (BS3, <http://www.morphbank.net/Show/?id=461388>; Gates & Sampson 2007, character 78): absent or very poorly developed (0); present, sharply defined ridge (1).

157. Basisphenoid. Short median ventral process located between the basipterygoid processes of the basisphenoid (BS4, <http://www.morphbank.net/Show/?id=461389>; Gates & Sampson 2007, character 79): absent (0); present, ventrally or caudoventrally directed (1).

158. Basisphenoid. Development of the rostral constriction of the basisphenoid, caudal to the basipterygoid processes (measured as the ratio between the minimum mediolateral width of the rostral constriction and the maximum width of the basisphenoid across the spheno-occipital

- tubercles) (BS5, <http://www.morphbank.net/Show/?id=471320>; Prieto-Márquez 2010a, character 158): very thick constriction, ratio less than 1.45 (sample mean ratio of 1.37) (0); moderately developed constriction, ratio between 1.45 and 1.90 (sample mean ratio of 1.72) (1); very thin constriction, ratio greater than 1.90 (sample mean ratio of 2.25) (2). Ordered
- 159.Laterosphenoid. Complete lateral osseous closure of the ophthalmic sulcus (V₁) of the laterosphenoid (LS1, <http://www.morphbank.net/Show/?id=461391>; Evans & Reisz 2007, character 51): absent (0); present (1).
- 160.Laterosphenoid. Extreme reduction of the length of the postorbital process of the laterosphenoid to 25% or less the length of the mediodorsal flange of this element (LS2, <http://www.morphbank.net/Show/?id=461392>; modified from Prieto-Márquez *et al.* 2006, character 76): absent (0); present (1).
- 161.Exoccipital. Caudal extension of the exoccipital-supraoccipital shelf above the foramen magnum (EX1, <http://www.morphbank.net/Show/?id=461395>; modified from Godefroit *et al.* 2004, character 24): very short rostrocaudal length, approximately less than half the diameter of the foramen magnum (0); moderately long, approximately more than half but less than the diameter of the foramen magnum (1); very long, substantially longer (often twice or more) than the diameter of the foramen magnum (2). Ordered
- 162.Pterygoid. Elevation of the proximodorsal region of the quadrate wing of the pterygoid (PLT1, <http://www.morphbank.net/Show/?id=461397>; Prieto-Márquez *et al.*, 2006, character 72): absent (0); present (1).
- 163.Pterygoid. Ventral extension of the lamina located ventral to the central buttress of the pterygoid (PLT2, <http://www.morphbank.net/Show/?id=461398>; Prieto-Márquez *et al.* 2006, character 75): lamina of moderate size, a relatively large portion of the ventral quadrate process

and the rostroventral process extends beyond the ventral margin of the lamina (0); extensive lamina, only a relatively small portion of the ventral quadrate process and the rostroventral process extends beyond the ventral margin of the lamina (1).

164. Ectopterygoid–jugal contact (PLT3, <http://www.morphbank.net/Show/?id=461399>; Godefroit *et al.* 2001, character 12): present, the ectopterygoid contacts the medial side of the jugal (0); absent, the jugal lacks an articular facet for the ectopterygoid (1).

Other cranial characters

165. Angle between the dorsal margin of the rostrum parallel to the long axis of the external naris and the maxillary tooth row (adults only) (RST2, <http://www.morphbank.net/Show/?id=461401>; Prieto-Márquez 2010a, character 168): angle up to 30° (sample mean angle of 27°) (0); angle greater than 30° and up to 40° (sample mean angle of 34°) (1); angle greater than 40° (sample mean angle of 47°) (2). Ordered
166. Exposure of the nasal passage (NPS1, <http://www.morphbank.net/Show/?id=461402>; modified from Norman 2002, character 5): absent, nasal passage nearly or completely enclosed by bone and formation of internal cavities and passages (such as lateral diverticula and a common median chamber) (0); present, nasal passage open and exposed on the lateral side of the rostrum (1). Distinction is made here between external bony naris (Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001) and bony naris (Evans, 2006). Functionally, both structures formed the external naris. The iguanodontoidean external bony naris was regarded as homologous to the common median chamber of lambeosaurines (Hopson, 1975; Wagner, 2004). Because of caudodorsal migration of the external passage to become enclosed in a supracranial crest forming the common median chamber in lambeosaurines, what remained on

the laterodorsal surface of the premaxilla (the bony naris) in the latter group was not regarded as structurally homologous to the external bony naris.

167. Lateral profile of the external bony naris (NPS2, <http://www.morphbank.net/Show/?id=461403> and <http://www.morphbank.net/Show/?id=461404>; modified from Prieto-Márquez 2010a, character 170): extremely broad with subcircular caudal margin (0); moderately broad and ellipsoidal (1); narrow and ellipsoidal (2); slit-like (3). Ordered

168. Degree of closure of the nasal passage on the lateral crest surface between the caudoventral process of the premaxilla and the nasal (NPS3, <http://www.morphbank.net/Show/?id=461405>; Evans 2007, character 15): present, premaxilla-nasal fontanellae persist into late ontogenetic stages (0); absent, fontanellae completely closed in adults (1).

169. Ratio between the length of the external bony naris and the distance between the rostroventral corner of the premaxilla and the rostroventral margin of the prefrontal (NPS4, <http://www.morphbank.net/Show/?id=461406>; Prieto-Márquez 2010a, character 172): very short external bony naris, ratio up to 0.40 (sample mean ratio of 0.32) (0); moderately long external bony naris, ratio greater than 0.40 but less than 0.60 (sample mean ratio of 0.49) (1); elongated external bony naris, ratio between 0.60 and 0.65 (sample mean ratio of 0.62) (2); extremely long external bony naris, ratio greater than 0.65 (sample mean ratio of 0.72) (3). Ordered

170. Nasal vestibule folded into an S-loop in the enclosed premaxillary passages rostral to the dorsal process of the maxilla (Weishampel 1981; Evans 2007, character 8): absent (Weishampel 1981, Fig. 6) (0); present (Weishampel 1981, Figs. 4-5) (1).

171. Location of the lateral diverticulum relative to the common median chamber (Weishampel 1981): lateral to the common median chamber (Weishampel 1981, Fig. 4 and 6) (0); rostral to

the common median chamber (Weishampel 1981, Fig. 10) (1); caudodorsal to the common median chamber (Weishampel 1981, Fig. 8) (2).

172. Communication between the external bony naris, the lateral diverticulum and the common median chamber (Evans 2006): a tubular premaxillary passage extends caudodorsally from the bony naris to the lateral diverticulum, that is then connected to the common median chamber (Weishampel 1981, Figs. 4-6) (0); a tubular premaxillary passage connects directly the bony naris to the common median chamber (Weishampel 1981, Fig. 7-8) (1).

173. Caudal extent of the nasal passage dorsal and/or caudal to the orbit (NPS8, <http://www.morphbank.net/Show/?id=461407>; modified from Evans 2007, character 9): absent, nasal passage restricted to the antorbital region of the skull (0); present, but not extending caudal to the occiput, with a nasal vestibule that flanks a common median chamber (1); present, nasal vestibule extending caudodorsal to the occipital region of the skull (2). Ordered

174. Composition of the caudal margin of the functional external naris (NPS9, <http://www.morphbank.net/Show/?id=461408>; modified from Horner *et al.* 2004, character 29): formed by the nasal dorsally and the premaxilla ventrally (0); formed entirely by the nasal (1); formed entirely by the premaxilla (2).

175. Circumnarial fossa on the lateral surface of the facial region of the skull (CMN1, <http://www.morphbank.net/Show/?id=461409>; Horner *et al.* 2004, character 31): absent, circumnarial structure entirely enclosed (0); present (1).

176. Caudodorsal extension of circumnarial fossa (homologous to the lateral diverticulum inside hollow supracranial crests) (CMN2, <http://www.morphbank.net/Show/?id=461411> and <http://www.morphbank.net/Show/?id=461412>; Hopson 1975; Wagner 2004; modified from Horner *et al.* 2004, characters 32): the fossa does not reach the caudal margin of the external

bony naris and, thus, lacks a caudal margin (0); the fossa extends as far as to surround the caudal margin of the external bony naris, but does not reach the orbit (1); the fossa extends as far as the rostradorsal region of the orbit (2); the fossa extends beyond the orbit, caudodorsal to its caudal margin (3). Ordered

177. Degree of excavation of the caudal region of the circumnarial fossa (CMN3, <http://www.morphbank.net/Show/?id=461410>; Horner *et al.* 2004, character 32): lightly incised (0); deeply incised (1); invaginated (2). Ordered
178. Position of the circumnarial fossa on lateral surface of solid nasal crest (CMN4; new character): extending onto the medial margin of the nasal (0); extending onto the lateral margin of the nasal (1).
179. Elevation of the dorsal profile of the skull above the ancestral profile to form a cranial crest (CRS1, <http://www.morphbank.net/Show/?id=461413>; Wagner 2004): absent (0); present (1).
180. Composition of the supracranial crest (or the homologous region of the skull from which the crest forms) (excluding supporting elements) (CRS2, <http://www.morphbank.net/Show/?id=461414>; modified from Horner *et al.* 2004, character 40): primarily composed of the nasals (0); primarily composed of the nasals and frontals (1); primarily composed of the nasals and premaxillae (2).
181. Relative contribution of the nasal and premaxilla in the formation of hollow supracranial crests (CRS3, <http://www.morphbank.net/Show/?id=461415>; Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001 and modified in part from Evans & Reisz 2007, character 11): the nasals constitute half or a larger portion of the crest in the form of a caudal plate-like surface (0); the nasals form a smaller portion of the crest relative to the surrounding premaxillae (1).

182. Supracranial crest shape (CRS4, <http://www.morphbank.net/Show/?id=461416>,
<http://www.morphbank.net/Show/?id=461417>, <http://www.morphbank.net/Show/?id=461418>,
and <http://www.morphbank.net/Show/?id=461419>; modified from Horner *et al.* 2004, character
36): dome-like broad and low protuberance (0); mediolaterally compressed arcuate
protuberance, rostral or, in adults, dorsal to the level to the orbits (1); paddle-like caudally
directed solid blade (2); rod-like caudodorsally directed solid crest (3); rostrally excavated and
rostrally-facing protuberance, rostradorsal to the orbit (4); nasal fold that rises dorsally or
caudodorsally to form a laterally excavated promontory, with a caudal region that rests over the
frontals (5); raised into a large vertical fan, formed by a solid plate-like extension of the
premaxilla (“cockscomb”) above the nasal passages in the rostral region of the crest (6); long
and tubular, caudodorsally directed beyond the occiput and slightly arched (7).
183. Hollow crest-snout angle along the dorsal margin of the premaxilla in lateral view (in adults)
(CRS5, <http://www.morphbank.net/Show/?id=461420>; Evans 2007, character 13): absent, the
lateral profile of the snout is continuous with the lateral profile of the dorsal premaxillary
margin of the crest (0); facial profile shallowly concave in lateral view, angle greater than 140°
(1); angle between 110° and 140° (2); crest procumbent and rostrally inclined, angle less than
110° (3). Ordered
184. Caudal extension of the hook-like nasal process on the caudoventral region of helmet-shaped
hollow supracranial crests (CRS6, <http://www.morphbank.net/Show/?id=461421>; Prieto-
Márquez 2010a, character 186): rostral to or at the level of the caudal margin of the occiput (0);
extended caudal to the level of the caudal margin of the occiput (1).
185. Supracranial solid crest significantly elevated dorsally above the skull roof (CRS7; new
character): absent (0); present (1).

186. Distal end of solid nasal crest elongate and bluntly subconical (CRS8; new character): absent (0); present (1).
187. Palpebral (supraorbital) bone (PLP, <http://www.morphbank.net/Show/?id=461422>; Norman, 2002, character 13): absent (0); present (1).
188. Length/width proportions of the orbit (ORB, <http://www.morphbank.net/Show/?id=461424>; Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001): nearly circular, approximately as wide as it is deep (0); elongated, dorsoventrally deeper than it is wide (1).
189. Presence of a gap (paraquadratic foramen) between the quadratojugal and the jugal (PQF, <http://www.morphbank.net/Show/?id=461425>; Prieto-Márquez 2010a, character 189): absent (0); present (1).
190. Size of the infratemporal fenestra relative to that of the orbit (ITF1, <http://www.morphbank.net/Show/?id=461426>; modified from Gates & Sampson 2007): infratemporal fenestra both rostrocaudally wider and dorsoventrally deeper than the orbit (0); infratemporal fenestra rostrocaudally narrower than or approximately as wide as the orbit (1).
191. Shape and rostrocaudal width of the dorsal margin of the infratemporal fenestra relative to that of the ventral margin (ITF2, <http://www.morphbank.net/Show/?id=461427> and <http://www.morphbank.net/Show/?id=461428>; Prieto-Márquez 2010a, character 191): subrectangular, with a dorsal infratemporal margin that is approximately as wide as the ventral margin (0); subtriangular, with a dorsal infratemporal margin that is narrower than the ventral margin (1).
192. Location of the dorsal margin of the infratemporal fenestra relative to the dorsal margin of the orbit (ITF3, <http://www.morphbank.net/Show/?id=461564>; modified from Gates & Sampson 2007, character 86): the dorsal margin of the infratemporal fenestra lies approximately at the

same level than the dorsal margin of the orbit and the caudal region of the skull roof is subhorizontal or slightly sloping caudoventrally relative to the frontal plane (0); the dorsal margin of the infratemporal fenestra is substantially more dorsally located than the dorsal margin of the orbit and the caudal region of the skull roof is rostroventrally inclined relative to the frontal plane (1); the dorsal margin of the infratemporal fenestra lies substantially below the level of the dorsal margin of the orbit, caudal region of the skull roof sloping caudoventrally relative to the frontal plane (2).

193. Morphology of the dorsal outline of the supratemporal fenestra (STF,

<http://www.morphbank.net/Show/?id=461565>; Prieto-Márquez 2010a, character 193):

subrectangular, with the long axis directed rostrally (0); oval, with the long axis directed rostromedially (1); oval and wider mediolaterally than rostrocaudally (2).

194. Depth of the skull (ratio between the skull height along caudal margin of quadrate and distance from rostral prefrontal tip to the level of the caudal margin of quadrate) (SK1; modified from You *et al.* 2003, character 1): ratio less than 0.70 (0); relatively deep skull, ratio of 0.70 or greater (1).

195. Maximum transverse width of the cranium in dorsal view across the postorbitals relative to the width across the quadrate cotylus of the squamosals (SK2,

<http://www.morphbank.net/Show/?id=461699>; modified from Horner *et al.* 2004, character 67):

the skull is more than 25% wider across the postorbitals (sample mean ratio of 0.35) (0); the skull is up to 25% wider across the postorbitals (sample mean ratio of 0.14) (1); the skull is approximately equally wide across the postorbitals than across the squamosals (2). Ordered

Vertebral characters

196. Cervical vertebrae. Morphology of the dorsal flange of the axis (CRV1, <http://www.morphbank.net/Show/?id=461701>; modified from Campione *et al.* 2007): dorsally convex flange extending beyond or to the level of the cranialmost region of the postzygapophyses (0); presence of short cranial flange separated from the postzygapophyseal region by a prominent embayment (1).
197. Number of cervical vertebrae (Horner *et al.* 2004, character 72): 11 or less (0); 12 or more (1).
198. Height of the neural spine relative to that of the centrum of the tallest caudal dorsal or sacral vertebrae (in adults) (DRS1, <http://www.morphbank.net/Show/?id=461703>; modified from Norman, 2002, character 41): short neural spine, ratio up to 2.10 (mean ratio of 1.79) (0); moderate length, ratio greater than 2.10 and up to 3.25 (mean ratio of 2.57) (1); long neural spine, ratio greater than 3.25 (mean ratio of 3.97) (2). Ordered
199. Slightly elongated neural spines in the cranial dorsal vertebrae, forming a ‘wither-like’ region above the pectoral girdle (DRS2, <http://www.morphbank.net/Show/?id=461704>; Wagner, unpub. Master’s thesis, Texas Tech Univ., Austin, 2001): absent (0); present (1).
200. Minimum count of co-ossified vertebrae in the sacral region (including single dorsal and caudal contributions (Godefroit *et al.* 2000, character 27): seven or fewer (0); eight or more (1).
201. Chevron length relative to the length of the neural spines in the caudal vertebrae of the proximal half of the tail (CDL, <http://www.morphbank.net/Show/?id=461705>; Wagner, unpub. Master’s thesis, Texas Tech Univ., Austin, 2001): chevrons shorter or nearly as long as the neural spines (0); chevrons longer than the neural spines (1).
202. Sternum. Length of the “handle-like” caudolateral process of the sternal relative to that of the craniomedial plate (excluding the caudoventral process) (ST, <http://www.morphbank.net/Show/?id=461706>; modified from Prieto-Márquez *et al.* 2006,

character 100): caudolateral process slightly shorter or as long as the rostromedial plate (0); caudolateral process longer than the craniomedial plate (1).

Pectoral and forelimb characters

203. Coracoid size relative to the length of the scapula (COR1,

<http://www.morphbank.net/Show/?id=461707>; Horner *et al.* 2004, character 77): relatively large coracoid, ratio between craniocaudal length of coracoid and length of scapula of approximately 0.2 (0); coracoid reduced in size relative to the scapula (1).

204. Coracoid. Ratio between the length of the lateral margin of the facet for the scapular articulation and the length of the lateral margin of the glenoid (COR2,

<http://www.morphbank.net/Show/?id=461708>; Prieto-Márquez 2010a, character 206): longer scapular facet, with a ratio greater than 1.30 (sample mean ratio of 1.48) (0); slightly longer scapular facet, ratio greater than 1 and up to 1.30 (sample mean ratio of 1.14) (1); glenoid longer than the scapular facet, with a ratio up to 1 (sample mean ratio of 0.75) (2). Ordered

205. Coracoid. Angle between the lateral margins of the facet for scapular articulation and the glenoid (COR3, <http://www.morphbank.net/Show/?id=461709>; Prieto-Márquez 2010a, character 207): angle greater than 115° (sample mean angle of 124°) (0); angle up to 115° (sample mean angle of 102°) (1).

206. Coracoid. Morphology of the craniomedial margin of the coracoid (COR4,

<http://www.morphbank.net/Show/?id=461710>; Horner *et al.* 2004, character 78): convex or straight, associated to a moderate development and slight projection biceps tubercle (0); concave, associated to a relatively large and lateroventrally-projected biceps tubercle (1).

207. Coracoid. Development of the 'hook-like' ventral process of the coracoid, measured as the ratio between the dorsoventral depth and the breadth of the process (COR5, <http://www.morphbank.net/Show/?id=461711>; modified from Godefroit *et al.* 2000, character 25): relatively short, ratio less than 0.65 (sample mean ratio of 0.55) (0); ratio between 0.65 to 0.80 (sample mean ratio of 0.71) (1); long process, nearly as deep as it is wide, with a ratio greater than 0.80 (sample mean ratio of 0.96) (2). Ordered
208. Coracoid. Curvature of the ventral "hook-like" process of the coracoid (COR6, <http://www.morphbank.net/Show/?id=461712>; Godefroit *et al.* 2000, character 25): ventrally directed (0); recurved, so that the process is caudoventrally directed (1).
209. Scapula. Lateral profile of the dorsal margin of the scapula (SCP1, <http://www.morphbank.net/Show/?id=461713>; modified from Sereno 1986): craniocaudally straight from the cranial margin of the coracoid facet to the distal end of the blade (0); curved, dorsally convex, curvature originating at the level of the dorsal margin of the pseudoacromion process and is most pronounced over the dorsoventral constriction (1).
210. Scapular length, ratio between the craniocaudal length of the scapula (from the cranial end of the pseudoacromion process to the distal margin of the blade) and the dorsoventral depth of the cranial end (from the cranial end of the pseudoacromion process to the ventral apex of the glenoidal facet) (SCP2, <http://www.morphbank.net/Show/?id=461714>; Prieto-Márquez 2010a, character 212): relatively short scapula, ratio up to 4 (sample mean ratio of 3.54) (0); relatively long scapula, ratio greater than 4 (sample mean ratio of 4.64) (1).
211. Scapula. Dorsoventral expansion of the distal region of the scapular blade (measured as a ratio between the depth of the distal end of the blade and the depth of the proximal region) (SCP4,

<http://www.morphbank.net/Show/?id=461716>; Prieto-Márquez 2010a, character 213): ratio less than 1 (sample mean ratio of 0.80) (0); ratio of 1 or greater (sample mean ratio of 1.15) (1).

212.Scapula. Proximal constriction (scapular “neck”), ratio between the dorsoventral width of the proximal constriction and the dorsoventral depth of the cranial end of the scapula (SCP5, <http://www.morphbank.net/Show/?id=461717>; Prieto-Márquez 2010a, character 214): narrow “neck”, ratio up to 0.60 (sample mean ratio of 0.53) (0); relatively broad “neck”, ratio greater than 0.60 (sample mean ratio of 0.68) (1).

213.Scapula. Morphology and orientation of the pseudoacromion process (SCP6, <http://www.morphbank.net/Show/?id=461718>; modified from Horner *et al.* 2004, character 80): recurved, so that the cranial region is dorsally or craniodorsally directed (0); horizontal, occasionally with minor and subtle dorsal or ventral curvatures, so that the cranial region is cranially or mostly cranially directed (1).

214.Scapula. Degree of curvature of the dorsally oriented pseudoacromion process of the scapula (SCP7, <http://www.morphbank.net/Show/?id=461718>; modified from Horner *et al.* 2004, character 80): strongly recurved, so that the cranial region of the process is dorsally oriented (0); slightly recurved, with concave lateral profile of the dorsal margin, so that the cranial region of the process is craniodorsally oriented (1).

215.Scapula. Cranial extension of the craniodorsal region of the scapula (bearing the coracoid facet), measured as a ratio between the distance from the coracoid joint and the cranial end of the pseudoacromion process and the height between this and the ventral apex of the glenoidal facet (SCP8, <http://www.morphbank.net/Show/?id=461719>; Prieto-Márquez 2010a, character 217): short craniodorsal region, ratio less than 0.45 (sample mean ratio of 0.35) (0); long craniodorsal region, ratio of 0.45 or greater (sample mean ratio of 0.53) (1).

216.Scapula. Development of the deltoid ridge (SCP9,

<http://www.morphbank.net/Show/?id=461720>; Prieto-Márquez 2010a, character 218):

dorsoventrally narrow convexity limited to the proximal region of the scapula, near the pseudoacromion process from which it develops, with a poorly demarcated ventral margin (0); dorsoventrally deep and craniocaudally long, with a well demarcated ventral margin (1).

217.Humerus. Length of the deltopectoral crest of the humerus (measured as the ratio between the proximodistal length of the crest and the proximodistal length of the humerus (HM1,

<http://www.morphbank.net/Show/?id=461721>; modified from Godefroit *et al.* 2000, character 26): proximodistally short crest, ratio less than 0.48 (sample mean ratio of 0.44) (0); ratio between 0.48 and 0.55 (sample mean ratio of 0.52) (1); very long crest, ratio greater than 0.55 (sample mean ratio of 0.59) (2). Ordered

218.Humerus. Lateroventral expansion of the deltopectoral crest of the humerus (measured as the ratio between the width of the humerus across the distal fourth of the deltopectoral crest and the width of the distal shaft at the point of maximum curvature) (HM2,

<http://www.morphbank.net/Show/?id=461722>; modified from Horner *et al.* 2004): poorly expanded deltopectoral crest, ratio less than 1.65 (sample mean ratio of 1.53) (0); ratio between 1.65 and 1.90 (sample mean ratio of 1.76) (1); very expanded deltopectoral crest, ratio greater than 1.90 (sample mean ratio of 2) (2). Ordered

219.Humerus. Degree of angulation of the ventral margin of the deltopectoral crest (HM3,

<http://www.morphbank.net/Show/?id=471338>; Weishampel *et al.* 1993, character 37): well rounded (0); extending abruptly from the humeral shaft to give a distinct angular profile (1).

220.Humerus. Overall proportions of the humerus (measured as a ratio between the total length and the width of the lateral surface of the proximal end of the humerus) (HM4,

<http://www.morphbank.net/Show/?id=461724>; modified from Weishampel *et al.* 1993, character 36): relatively short and stocky humerus, ratio less than 4.25 (mean ratio of 3.85) (0); ratio between 4.25 and 4.90 (sample mean ratio of 4.60) (1); relatively long and thin humerus, ratio greater than 4.90 (mean ratio of 5.4) (2). Ordered

221.Ulna. Length of the ulna relative to its dorsoventral thickness (measured at mid-shaft) (UL1, <http://www.morphbank.net/Show/?id=461725>; Prieto-Márquez 2010a, character 223): ratio length/width less than 10 (0); ratio length/width equal or larger than 10 (1).

222.Ulnar length relative to humeral length (UL2, <http://www.morphbank.net/Show/?id=461726>; Norman 2002, character 47): ulna shorter than or as long as the humerus (0); longer ulna, up to 20% longer than the humerus (1); longer ulna, being more than 20% longer than the humerus (2). Ordered

223.Composition of the carpus (MN1, <http://www.morphbank.net/Show/?id=461727>; adapted from Horner *et al.* 2004, character 86): presence of fused ulnare, radiale, intermedium and distal carpals (0); number of carpal bones reduced to a maximum of two unfused elements (1).

224.Manual digit I (Norman 2002, character 49) (MN2, <http://www.morphbank.net/Show/?id=461728>): entire digit I absent (0); presence of metacarpal I and one ungual phalanx (1).

225.Elongation of the manus exemplified by elongation of metacarpals II through IV, measured as the ratio between the length of metacarpal III and the width of its mid-shaft (MN3, <http://www.morphbank.net/Show/?id=461729>; modified from Horner *et al.* 2004, character 84): relatively short and blocky, ratio up to 5 (sample mean ratio of 4.25) (0); relatively long and slender, ratio greater than 5 (sample mean ratio of 8.54) (1).

226. Elongation of metacarpal V, so that it is more than twice as long as it is proximally wide (MN4, <http://www.morphbank.net/Show/?id=461730>; Prieto-Márquez 2010a, character 228): absent (0); present (1).
227. Length/width proportions of manual phalanx III1 (MN6, <http://www.morphbank.net/Show/?id=461732>; modified from Prieto-Márquez *et al.* 2006, character 114): proximodistally compressed, mediolaterally wider than it is long (0); slightly longer proximodistally than it is wide mediolaterally (1); very elongated, proximodistal length that is at least twice its mediolateral width at the middle of its longitudinal axis (2). Ordered
228. Shape of manual ungual II (MN7, <http://www.morphbank.net/Show/?id=461733>; Norman 2002, character 53, in part): claw-like (0); hoof-like (1).
229. Proximodistal length of manual phalanx II1 relative to that of II2 (MN8, <http://www.morphbank.net/Show/?id=461734>; modified from You *et al.* 2003, character 55): phalanx II1 less than three times longer than phalanx II2 (0); phalanx II1 three times or more longer than phalanx II2 (1).

Pelvic characters

230. Ilium. Angle of ventral deflection of the preacetabular process of the ilium (IL1, <http://www.morphbank.net/Show/?id=461735>; modified from Suzuki *et al.* 2004, character 69): angle greater than 150° (sample mean angle of 162°) (0); angle of 150° or less (sample mean angle of 143°) (1).
231. Ilium. Dorsoventral depth of the proximal region of the preacetabular process (measured as a ratio between this and the dorsoventral distance between the pubic peduncle and the dorsal margin of the ilium) (IL3, <http://www.morphbank.net/Show/?id=461737>; Prieto-Márquez

2010a, character 233): shallow, less than half the depth of the cranial central plate, ratio less than 0.50 (sample mean ratio of 0.42) (0); approximately as deep as the cranial central plate depth, ratio between 0.50 and 0.55 (sample mean ratio of 0.51) (1); deeper than half the depth of the cranial central plate, ratio greater than 0.55 (sample mean ratio of 0.62) (2). Ordered

232.Ilium. Depth of the central plate of the ilium (expressed as a ratio between this and the distance between the pubic peduncle and the caudodorsal prominence of the ischiadic peduncle) (IL4, <http://www.morphbank.net/Show/?id=461738>; Prieto-Márquez 2010a, character 234): ratio of 0.80 or greater (sample mean ratio of 0.90) (0); ratio less than 0.80 (sample mean ratio of 0.71) (1).

233.Ilium. Position of the ventral-most margin of the supraacetabular crest relative to the caudoventral margin of the lateral ridge of caudal protuberance of the ischiadic peduncle of the ilium (IL5, <http://www.morphbank.net/Show/?id=461739>; Brett-Surman & Wagner 2007): apex located caudodorsally (0); apex located above caudoventral margin of protuberance (1); apex located craniodorsally (2). Ordered

234.Ilium. Development of the lateroventral projection of the supraacetabular crest of the ilium (IL6, <http://www.morphbank.net/Show/?id=461740>; modified from Horner *et al.* 2004, character 91): forms a longitudinal and continuous “swelling” or reflected border along the dorsal margin of the central plate and the proximal region of the postacetabular process, with a depth up to 25% the depth of the ilium (0); projected lateroventrally at least 25% (but less than half) the depth of the ilium (1); projects lateroventrally between half and three quarters of the dorsoventral depth of the ilium (2); projects lateroventrally to overlap totally or at least half of the lateral ridge of the caudal prominence of the ischiadic peduncle (3). Ordered

235.Ilium. Craniocaudal breadth of the supraacetabular process, measured as the ratio between the breadth of the process across its dorsal region and the craniocaudal length of the central iliac blade from the caudal ischiadic peduncle to the pubic one (IL7,

<http://www.morphbank.net/Show/?id=461741>; Prieto-Márquez 2010a, character 237):

craniocaudally nearly as wide as or wider than the central plate of the ilium, ratio greater than 0.85 (sample mean ratio of 1.16) (0); craniocaudally broad, ratio between 0.70 and 0.85

(sample mean of 0.73) (1); slightly broader than half the length of the central iliac blade, ratio between 0.55 and 0.69 (sample mean ratio of 0.62) (2); short, ratio less than 0.55 (sample mean ratio of 0.48) (3). Ordered

236.Ilium. Symmetry of the lateral profile of the supraacetabular crest (IL8,

<http://www.morphbank.net/Show/?id=461742>; Prieto-Márquez 2010a, character 238):

asymmetrical, with a caudally skewed lateral profile (0); symmetrical or with a slightly caudally skewed profile (1).

237.Ilium. Morphology of the lateroventral margin of the supraacetabular crest (IL9,

<http://www.morphbank.net/Show/?id=461743>; Prieto-Márquez 2010a, character 239):

craniocaudally sinuous (0); widely arched (1); U or V-shaped (2); subrectangular, with a shallow notch that divides the ventral margin in two poorly demarcated lobes (3).

238.Ilium. Demarcation of the caudodorsal margin of the lateroventral rim of the supraacetabular process (IL10, Prieto-Márquez 2010a, character 240): the caudodorsal margin is poorly defined and appears discontinuous with the dorsal margin of the proximal region of the postacetabular process due to the lack of a well demarcated caudodorsal ridge

(<http://www.morphbank.net/Show/?id=461744>) (0); the caudodorsal margin is a well-defined

ridge that is continuous with the dorsal margin of the proximal region of the postacetabular process (<http://www.morphbank.net/Show/?id=461799>) (1).

239. Ilium. Morphology of the pubic peduncle of the ilium (IL11, <http://www.morphbank.net/Show/?id=461745> and <http://www.morphbank.net/Show/?id=461746>; modified from Sereno 1986; Horner *et al.* 2004; character 92): relatively large and dorsoventrally deep (longer than wide), subconical, with a proximal region that is only slightly craniocaudally wider than the distal end of the process (0); relatively shorter (wider or as wide as long) and triangular, with a proximal region that is much craniocaudally wider than the distal end (1).

240. Ilium. Morphology of the ischiadic peduncle of the ilium (IL12, <http://www.morphbank.net/Show/?id=461747> and <http://www.morphbank.net/Show/?id=461748>; modified from Godefroit *et al.* 2001, character 30): formed by a single and large, oval ventral protrusion (0); composed of a large and oval ventral protrusion and by a smaller, caudodorsally located prominence emerging from the caudodorsal ridge (1); formed by two protrusions of similar size, the caudal-most one located slightly caudodorsally (2). Ordered

241. Ilium. Ratio between the craniocaudal length of the postacetabular process and the craniocaudal length of the central plate of the ilium (IL13, <http://www.morphbank.net/Show/?id=461749>; Prieto-Márquez 2010a, character 243): short postacetabular process, ratio up to 0.80 (sample mean ratio of 0.70) (0); postacetabular process nearly as long as the central plate, ratio greater than 0.80 but less than 1.1 (sample mean ratio of 0.90) (1); postacetabular process substantially longer than the central plate, ratio of 1.1 or greater (sample mean ratio of 1.23) (2). Ordered

- 242.Ilium. Brevis shelf at the base of the postacetabular process of the ilium (IL14, <http://www.morphbank.net/Show/?id=461750>; modified in part from Horner *et al.* 2004, character 93): absent (0); present (1).
- 243.Ilium. Medioventral ridge on the medial side of the postacetabular process, crossing the bone surface from the proximoventral to the caudodorsal margins and orientation of the brevis shelf (IL15, <http://www.morphbank.net/Show/?id=468875>; Prieto-Márquez 2010a, character 245): absent or presence of a faint ridge (0); well-defined ridge bounding the medial margin of the brevis shelf; the latter faces medioventrally and in medial view appears restricted to the caudal region of the postacetabular process (1); well-defined ridge forming the medial margin of a medioventrally-facing shelf, with a postacetabular process that is progressively expanded mediolaterally towards the caudal end (2); well-developed, oblique and expanded flange forming the medial margin of an extensive brevis shelf that faces more ventrally than medially (3).
- 244.Ilium. Craniocaudally-oriented median ridge on the laterodorsal surface of the postacetabular process (IL16, <http://www.morphbank.net/Show/?id=461752>; Prieto-Márquez 2010a, character 246): absent (0); present (1).
- 245.Ilium. Geometry of the lateral profile of the postacetabular process of the ilium (IL17, <http://www.morphbank.net/Show/?id=461753> and <http://www.morphbank.net/Show/?id=461754>; modified from Horner *et al.* 2004, character 93): the ventral margin converges caudodorsally to meet the horizontal dorsal margin, forming a tapering caudal end and producing a triangular lateral profile of the process (0); dorsal and ventral margins parallel or slightly convergent, forming a distinct (rectangular or subcircular) caudal margin (1).

- 246.Ilium. Orientation of the dorsal margin of the postacetabular process relative to the acetabular margin (IL18, <http://www.morphbank.net/Show/?id=461755>; Prieto-Márquez 2010a, character 248): ventrally deflected or horizontal dorsal margin, parallel or nearly parallel to the acetabular margin (0); caudodorsally oriented dorsal margin, rising dorsally relative to the acetabular margin (1).
- 247.Ilium. Position of the medial sacral ridge within the medial surface of the central plate of the ilium (IL19, <http://www.morphbank.net/Show/?id=461756>; Prieto-Márquez 2010a, character 249): ridge well separated ventrally from the dorsal margin of the ilium, set between 50% and 30% the dorsoventral depth of the central plate (0); ridge located more dorsally, closer to the dorsal margin, within the dorsal third (less than 30% the depth) of the central plate (1).
- 248.Ilium. Lateral profile of the dorsal or laterodorsal margin of the ilium (IL21, <http://www.morphbank.net/Show/?id=461758>; modified from Horner *et al.* 2004, character 100): straight or slightly convex (0); distinctly depressed over the supraacetabular process and dorsally bowed over the proximal region of the preacetabular process (1).
- 249.Pubis. Orientation of the dorsoventral expansion of the prepubic process (PB1, <http://www.morphbank.net/Show/?id=461759>; Prieto-Márquez 2010a, character 252): the dorsal region of the expansion is more expanded than the ventral region, so that distally the process is dorsally-directed (0); the ventral region is more expanded than the dorsal region, so that the distal expansion is ventrally-directed (1).
- 250.Pubis. Geometry of the dorsoventral expansion of the prepubic process of the pubis (in lateral or medial views) (PB2, <http://www.morphbank.net/Show/?id=461760>, <http://www.morphbank.net/Show/?id=461761>, and <http://www.morphbank.net/Show/?id=461762>; modified in part from Wagner, unpub. Master's

thesis, Texas Tech Univ., Austin, 2001): circular to oval expansion, extensive and convex ventral margin (0); subsquared distal dorsal margin, expansion dorsoventrally taller than cranioventrally long, very pronounced proximal dorsal concavity and nearly straight distal ventral margin (1); ellipsoidal, expansion craniocaudally longer than dorsoventrally tall, well pronounced concavities of the dorsal and ventral proximal margins (2); oval expansion, dorsoventrally taller than craniocaudally long, well pronounced concave profiles of dorsal and ventral proximal margins (3); rectangular, craniocaudally longer than dorsoventrally tall, nearly straight profiles of the dorsal and ventral proximal margins (4).

251.Pubis. Depth of the dorsoventral expansion of the distal region of the prepubic process relative to the width of the acetabular margin of the pubis (PB3, <http://www.morphbank.net/Show/?id=461763>; Prieto-Márquez 2010a, character 254): distal expansion as wide as or shallower than width of the acetabular margin (0); dorsoventral expansion deeper than the acetabular margin (1).

252.Pubis. Craniocaudal length of the proximal constriction of the prepubic process of the pubis relative to length of the dorsoventral expansion (PB4, <http://www.morphbank.net/Show/?id=461764>; modified from Horner *et al.* 2004, character 96): constriction longer than the dorsoventral expansion, that is restricted to the distal region of the process (0); constriction and distal expansion have approximately the same length (1); constriction slightly shorter than the dorsoventral expansion, that begins at the proximal region of the process (2). Ordered

253.Pubis. Relative position of maximum concavity of the dorsal and ventral margins of the prepubic process of the pubis (PB5, <http://www.morphbank.net/Show/?id=461765>; Prieto-Márquez 2010a, character 256): maximum ventral concavity achieved adjacent to the proximal

region of the postpubic process, maximum dorsal concavity located further distally (0); maximum ventral concavity located ventral to or slightly caudal to the maximum dorsal concavity (1).

254. Pubis. Morphology of the acetabular margin, ventral to the lateral edge of the iliac peduncle (PB6, <http://www.morphbank.net/Show/?id=461766>; Prieto-Márquez 2010a, character 257): the lateral margin of the iliac peduncle extends ventrally forming a prominent ridge that merges with the proximal region of the ischiadic peduncle (0); the lateral margin of the iliac peduncle progressively disappears ventrally into the lateral surface of the region adjacent to the acetabular margin (1).

255. Pubis, obturator foramen (PB7, <http://www.morphbank.net/Show/?id=461767>; modified from Horner *et al.* 2004, character 97): absent, proximal postpubic ramus lacks a dorsocaudally oriented process (0); present, proximal postpubic ramus has a caudodorsally oriented short process that contacts totally or partially with the ischiadic peduncle to form the obturator foramen (1).

256. Pubis. Length/width ratio of the ischiadic peduncle of the pubis (PB8, <http://www.morphbank.net/Show/?id=461768>; Prieto-Márquez 2010a, character 259): short ischiadic peduncle, ratio less than 1.85 (sample mean ratio of 1.5) (0); moderate length, ratio ranging from 1.85 to less than 3 (sample mean ratio of 2.4) (1); long, ratio of 3 or more (with a sample mean ratio of 4) (2). Ordered

257. Pubis. Lateroventral protuberance on the proximal region of the ischiadic peduncle of the pubis (PB9, <http://www.morphbank.net/Show/?id=461769>; Prieto-Márquez 2010a, character 260): absent or very faintly developed (0); present (1).

258.Pubis. Depth/width proportions of the iliac peduncle of the pubis (PB10,

<http://www.morphbank.net/Show/?id=461770>; Prieto-Márquez 2010a, character 261):

craniocaudally broader than dorsoventrally tall (0); taller dorsoventrally than broad

craniocaudally (1).

259.Pubis. Total length of the pubis, as the ratio between the craniocaudal distance from the

acetabular margin to the distal margin of the prepubic process and the distance from the dorsal

margin of the iliac peduncle and the ventral margin of the proximal postpubic shaft (PB11,

<http://www.morphbank.net/Show/?id=471324>; Prieto-Márquez 2010a, character 262): short,

ratio less than 2.70 (sample mean ratio of 2.30) (0); long, ratio between 2.70 and 3 (sample

mean ratio of 2.84) (1); very long, ratio greater than 3 (sample mean ratio of 3.53) (2). Ordered

260.Ischium. Development of a caudal curvature of the distal margin of the iliac peduncle of the

ischium (IS1, <http://www.morphbank.net/Show/?id=461772> and

<http://www.morphbank.net/Show/?id=461773>; Brett-Surman & Wagner 2007): curvature

absent, distal margin slightly rounded and, in some exemplars, slightly curved cranially (0);

presence of a very short and slight curvature in the caudodorsal corner (1); presence of a well

developed curvature in the caudodorsal corner, so that the peduncle appears “thumb-like” in

lateral and medial profiles (2). Ordered

261.Ischium. Elongation of the iliac peduncle of the ischium (ratio between the proximodistal

length and the craniocaudal width of the distal margin) (IS3,

<http://www.morphbank.net/Show/?id=461775>; Prieto-Márquez 2010a, character 265):

relatively short peduncle, ratio less than 1.5 (sample mean ratio of 1.27) (0); ratio between 1.5

and 2 (sample mean ratio of 1.78) (1); relatively long peduncle, ratio greater than 2 (sample

mean ratio of 2.30) (2). Ordered

262. Ischium. Relative orientation of the acetabular and caudodorsal margins of the iliac peduncle of the ischium (IS4, <http://www.morphbank.net/Show/?id=461776>; Prieto-Márquez 2010a, character 266: margins are either parallel or divergent distally (correlated with a greater expansion of the craniodorsal corner of the peduncle) (0); margins converge distally (1).
263. Ischium. Orientation of the craniocaudal axis of the pubic peduncle (perpendicular to its articular margin) relative to the ischiadic shaft (IS5, <http://www.morphbank.net/Show/?id=461777>; Prieto-Márquez 2010a, character 267): ventrally inclined, angle up to 130° (sample mean angle of 118°) (0); slightly inclined ventrally, angle greater than 130 and up to 170° (sample mean angle of 157°) (1); pubic peduncle parallel to the ischiadic shaft (2). Ordered
264. Ischium. Length/width proportions of the pubic peduncle of the ischium (IS6, <http://www.morphbank.net/Show/?id=461778>; Prieto-Márquez 2010a, character 268): proximodistally longer than the distal articular surface is wide (0); approximately as long proximodistally as the distal articular surface is dorsoventrally wide (1); proximodistally shorter than the dorsoventral width of the distal articular surface (2). Ordered
265. Ischium. Relative position of the dorsal acetabular margin of the pubic peduncle (IS7, <http://www.morphbank.net/Show/?id=461779>; Prieto-Márquez 2010a, character 269): ventral to or at the same level as the dorsal margin of the ischiadic shaft (0); peduncular margin set dorsal to the dorsal margin of the ischiadic shaft (1).
266. Ischium. Dorsoventral thickness of the mid-shaft of the ischium (measured as a ratio between this and the length of the entire shaft) (IS8, <http://www.morphbank.net/Show/?id=461780>; modified from Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001): very thin shaft, up to 5% of the length of the ischiadic shaft (sample mean of 4.6%)(0); thickness ranging

from more than 5% and up to 7.5% of the length of the ischiadic shaft (sample mean of 6.7%)

(1); very thick shaft, thickness greater than 7.5% of the length of the ischiadic shaft (sample mean of 8.4%) (2). Ordered

267. Ischium. Morphology of the distal region of the ischiadic shaft (IS9,

<http://www.morphbank.net/Show/?id=461781> and

<http://www.morphbank.net/Show/?id=462510>; modified from Godefroit *et al.* 2001, character

31): slightly expanded into a blunt end (0); ventrally expanded forming a large “foot” or “boot-like” process (1).

268. Ischium. Degree of ventral projection of the distal expansion of the ischium (expressed as the ratio between the length of the ischiadic shaft and the length of the distal ventral expansion)

(IS10, <http://www.morphbank.net/Show/?id=461783>; Evans & Reisz 2007, character 90): ratio less than 0.25 (sample mean ratio of 0.18) (0); ratio of 0.25 or greater (sample mean ratio of 0.28) (1).

269. Ischium. Morphology of the cranial margin of the ventral expansion of the distal ischiadic

shaft (IS11, <http://www.morphbank.net/Show/?id=461784>; Prieto-Márquez 2010a, character

273): slightly concave and directed caudoventrally to meet the caudal margin to nearly a point (0); strongly concave, recurved cranial margin (1).

270. Ischium. Orientation of the long axis of the distal “foot” relative to the ischiadic shaft (IS12,

<http://www.morphbank.net/Show/?id=461785>; Prieto-Márquez 2010a, character 274): straight,

ventrally directed (0); cranioventrally directed, the inclination starting at the dorsal margin of the “foot” (1).

Hindlimb characters

271. Femur. Degree of curvature of the distal half of the femoral shaft (FM1, <http://www.morphbank.net/Show/?id=461786>; Norman 2002, character 62): slightly curved caudomedially (0); absence of curvature, straight distal shaft (1).
272. Femur. Lateral profile of the caudoventral margin of the fourth trochanter of the femur (FM2, <http://www.morphbank.net/Show/?id=461787>; modified from Wagner, unpub. Master's thesis, Texas Tech Univ., Austin, 2001): triangular and ending in a caudally, and slightly ventrally, directed point (0); smooth and arcuate (1).
273. Tibia. Extension of the cnemial crest of the tibia (TB, <http://www.morphbank.net/Show/?id=461788>; Godefroit *et al.* 2000, character 31): the cnemial crest is restricted to the proximal end of the tibia (0); cnemial crest further extended along the cranial surface of the proximal half of the diaphysis (1).
274. Astragalus. Development of the medial platform of the astragalus (AS, <http://www.morphbank.net/Show/?id=461790>; Prieto-Márquez 2010a, character 279): it extends medially to completely underlie the medial malleolus of the tibia (0); short, wedges laterally underlying only part of the medial malleolus of the tibia (1).
275. Metatarsal I (modified from Norman, 2002, character 66): absent (0); slender and splint-like element (1).
276. Length/width proportions of pedal phalanx II2 (PES3, <http://www.morphbank.net/Show/?id=461792>; Prieto-Márquez 2010a, character 283): proximodistally shortened, being twice as wide mediolaterally as it is proximodistally long (0); subsquared, only slightly shorter proximodistally than it is wide mediolaterally (1).
277. Length/width proportions of the disc-shaped pedal phalanx III2-III3 (PES4, <http://www.morphbank.net/Show/?id=461793>; modified from Horner *et al.* 2004, character

104): up to three times (or less) wider than they are proximodistally long (0); more than three times wider than they are proximodistally long (1).

278. Morphology of the pedal unguals (PES6, <http://www.morphbank.net/Show/?id=461795>;

Norman 2002, character 67): proximodistally elongated and arrow-shaped, with a bluntly truncated tip and prominent claw grooves (0); mediolaterally broad and proximodistally shortened, rounded shield or hoof-like shaped, with reduced or absent claw grooves (1).

279. Ridge on the plantar surface of pedal unguals (PES7,

<http://www.morphbank.net/Show/?id=461796>; Prieto-Márquez 2005, character 47): absent (0); present (1).

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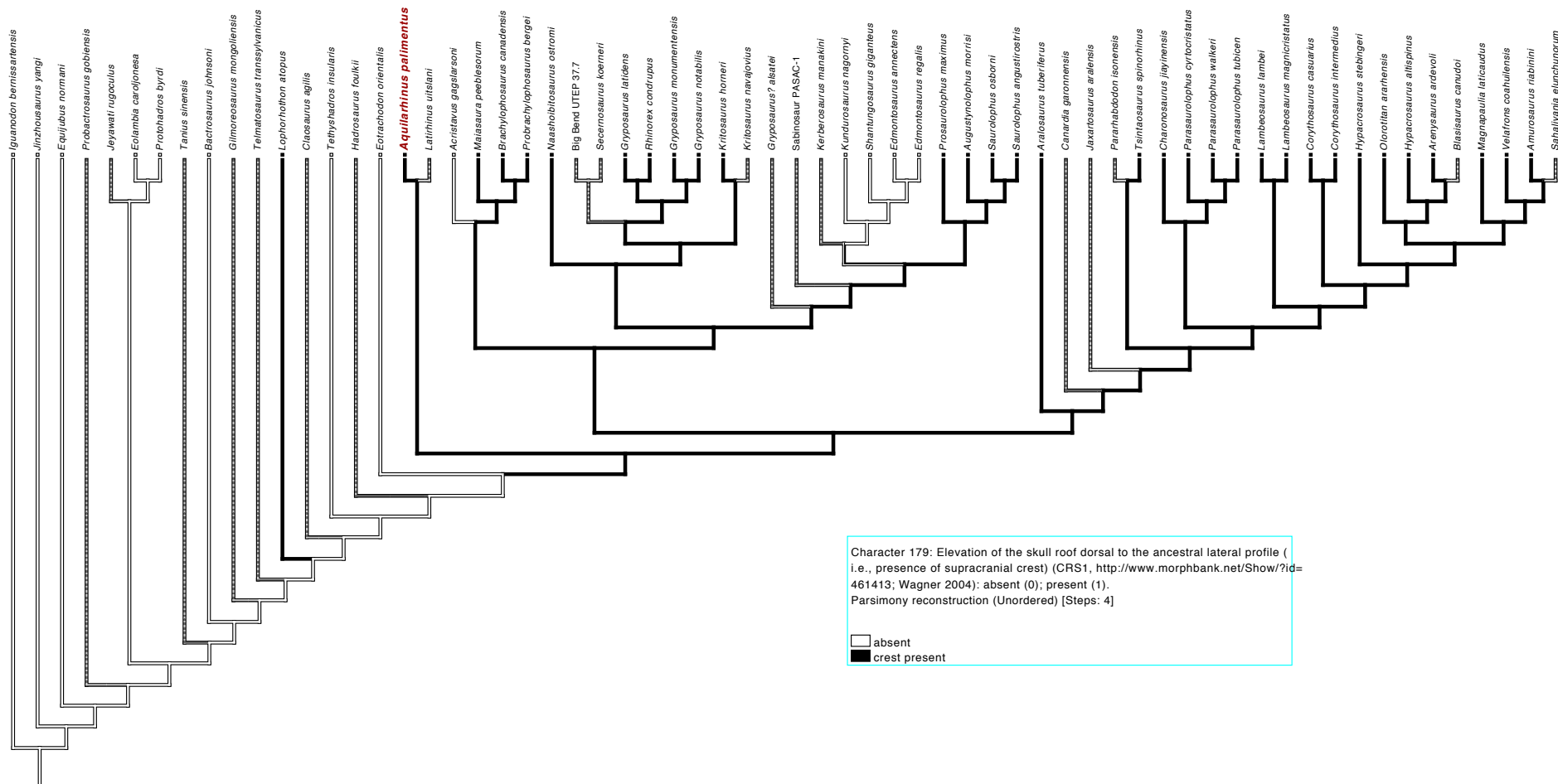
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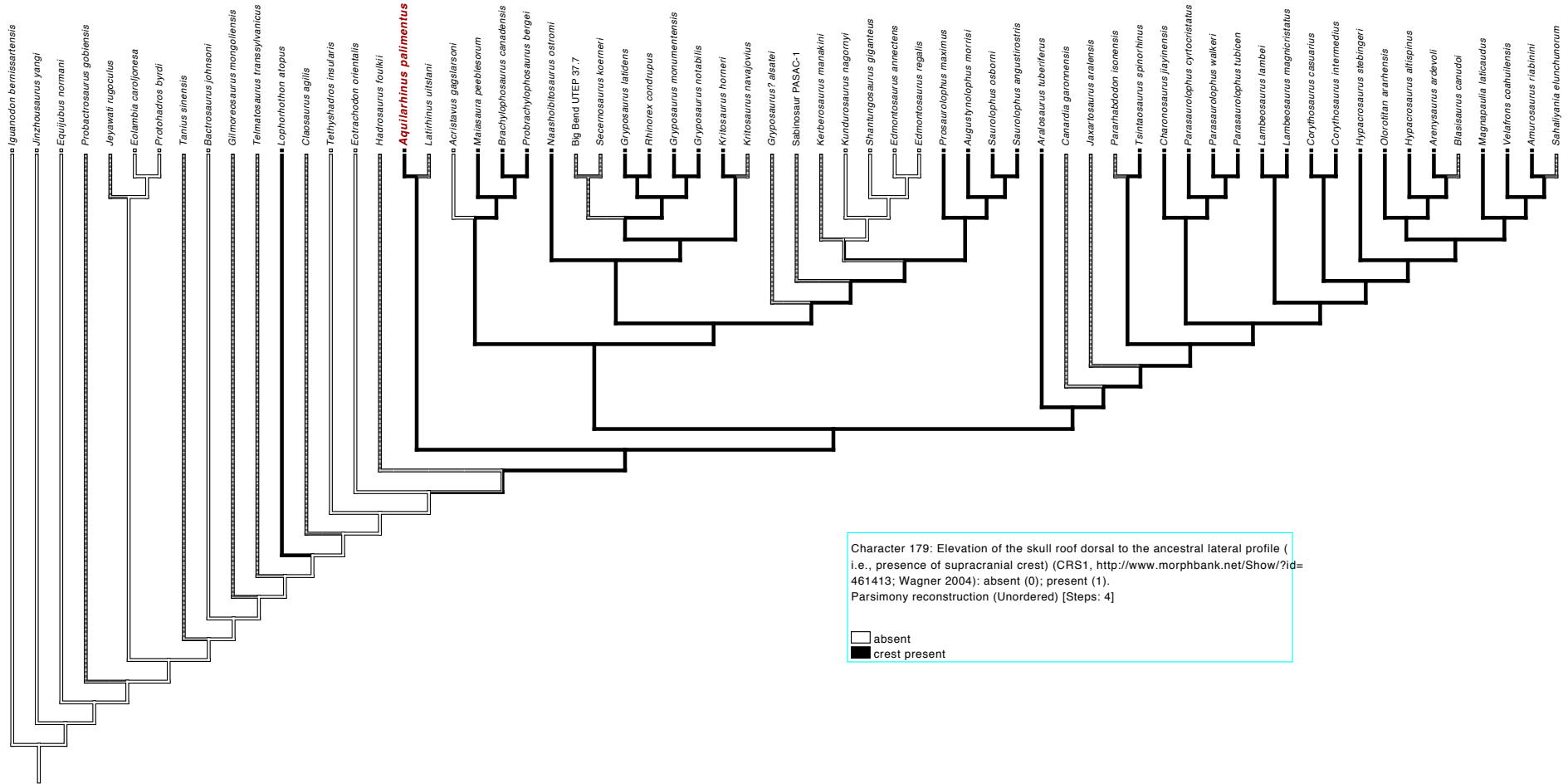
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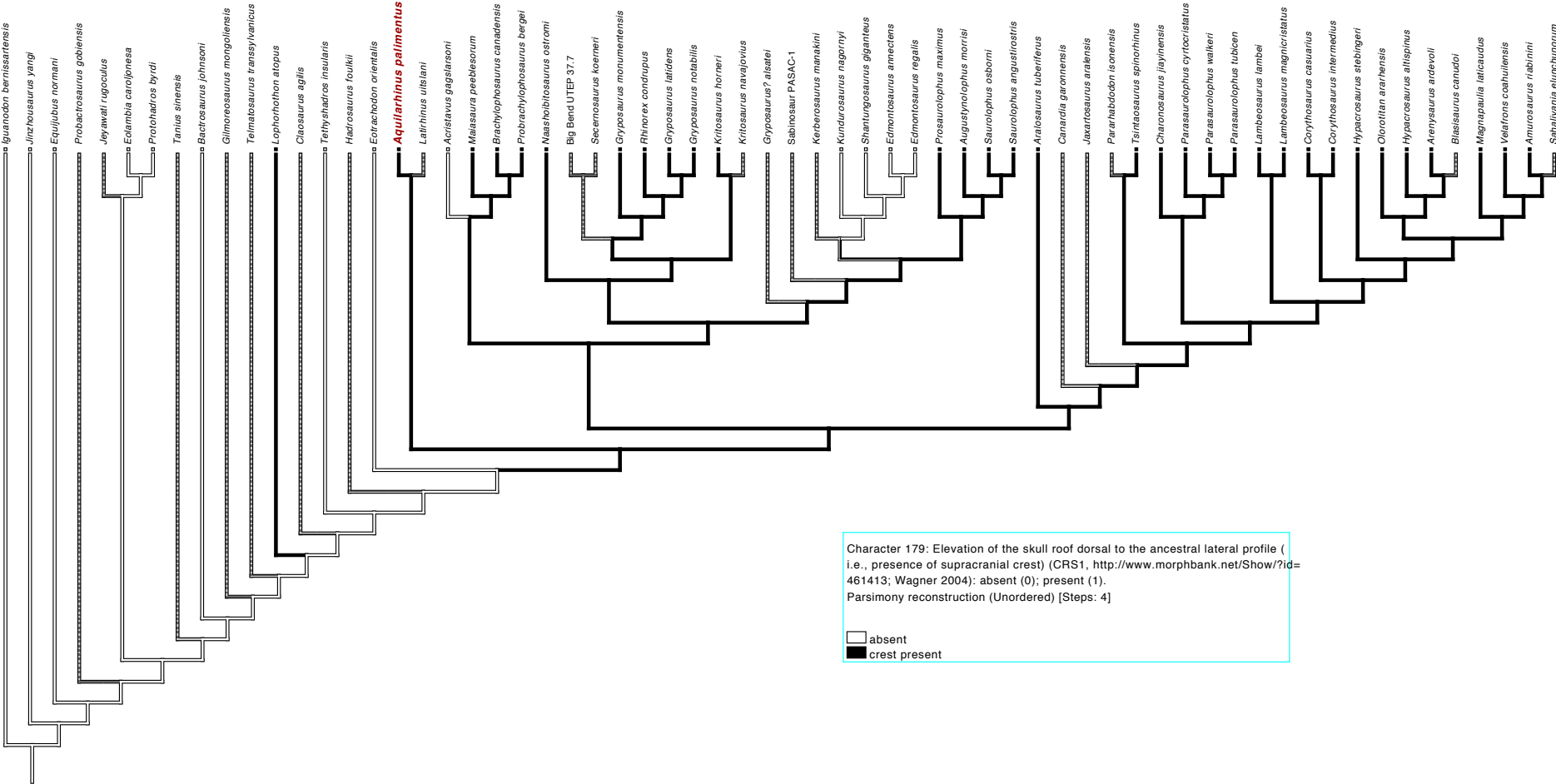
Supracranial crest presence/absence optimized on most parsimonious tree #1



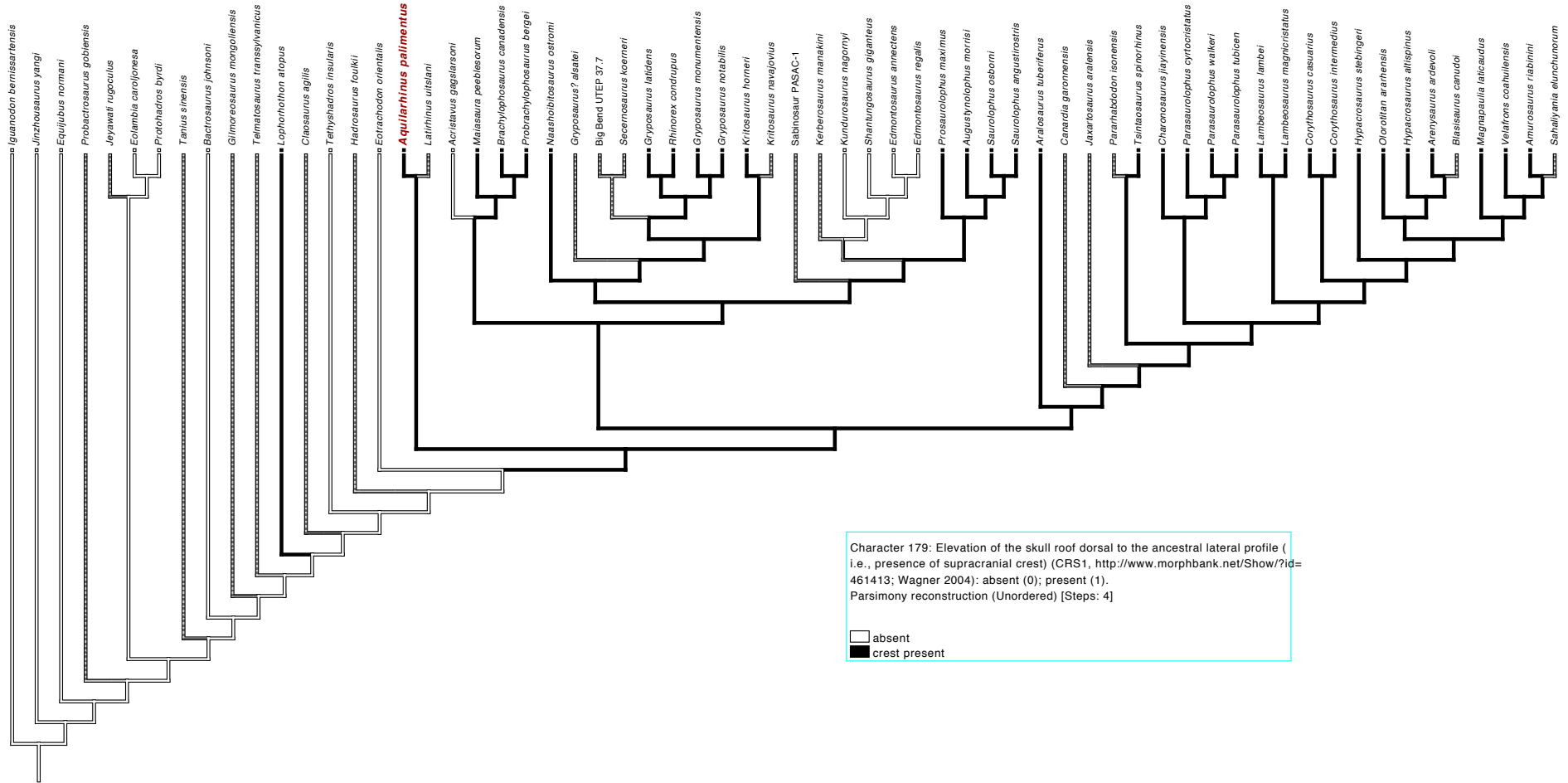
Supracranial crest presence/absence optimized on most parsimonious tree #2



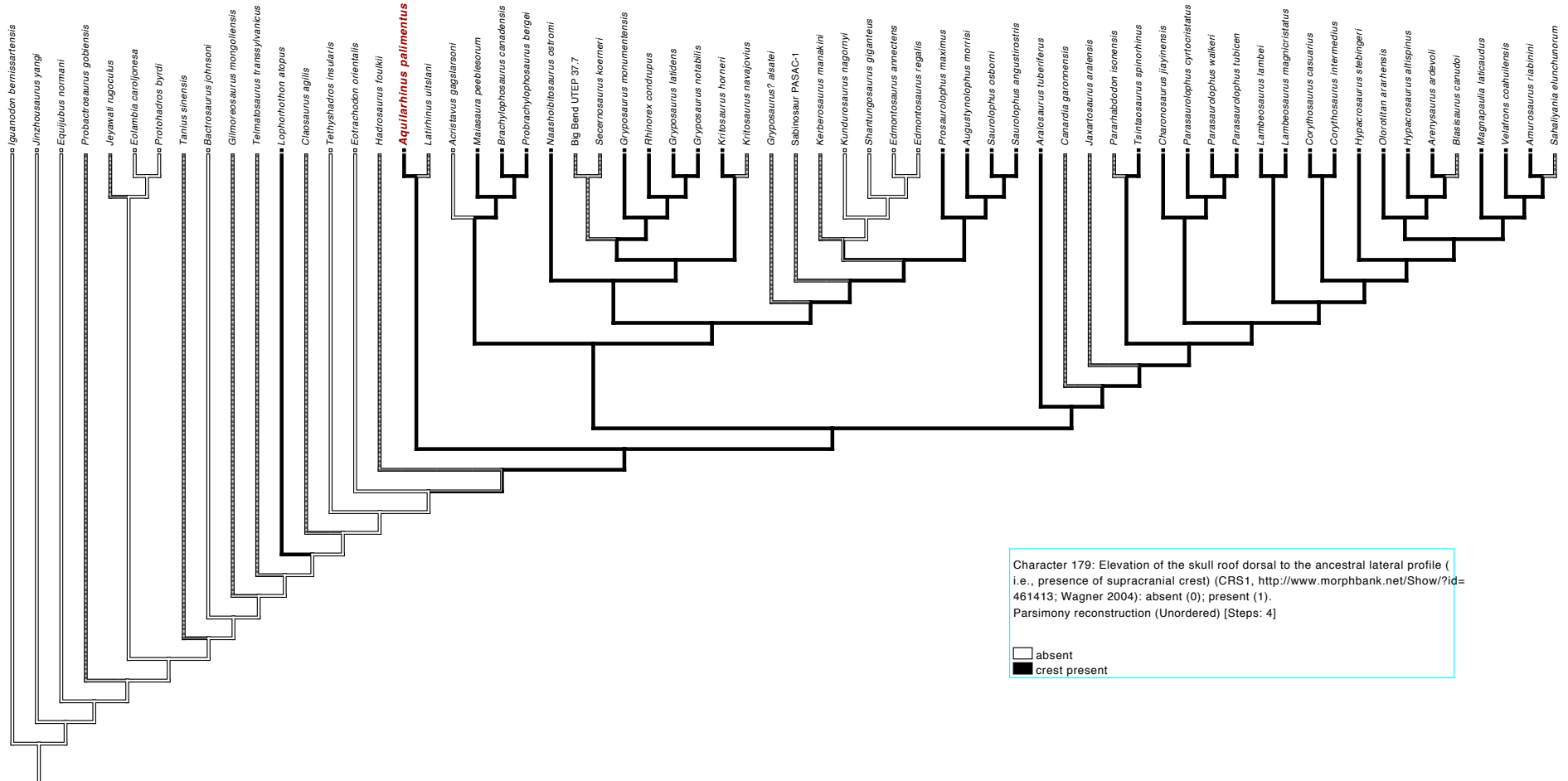
Supracranial crest presence/absence optimized on most parsimonious tree #3



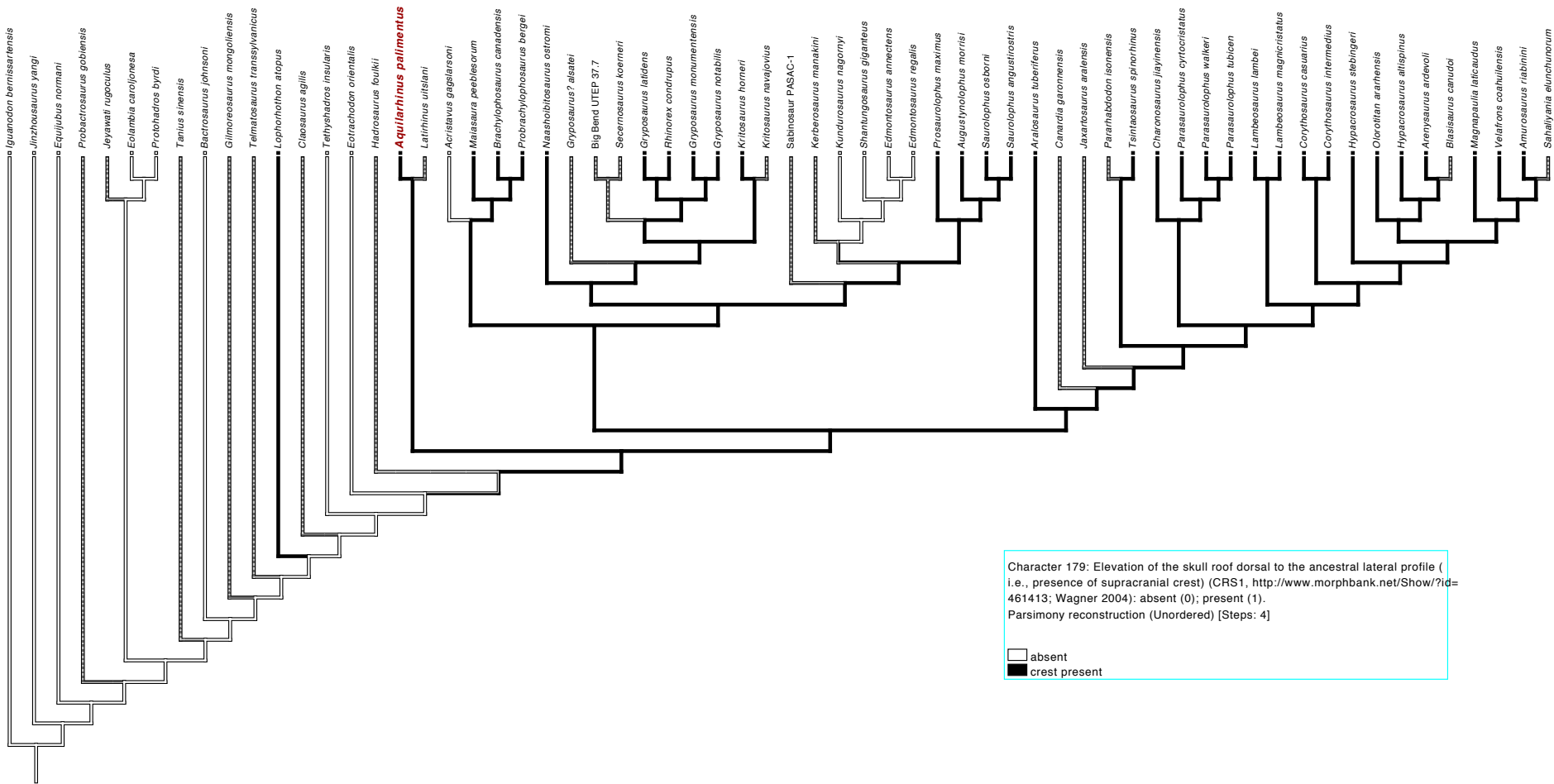
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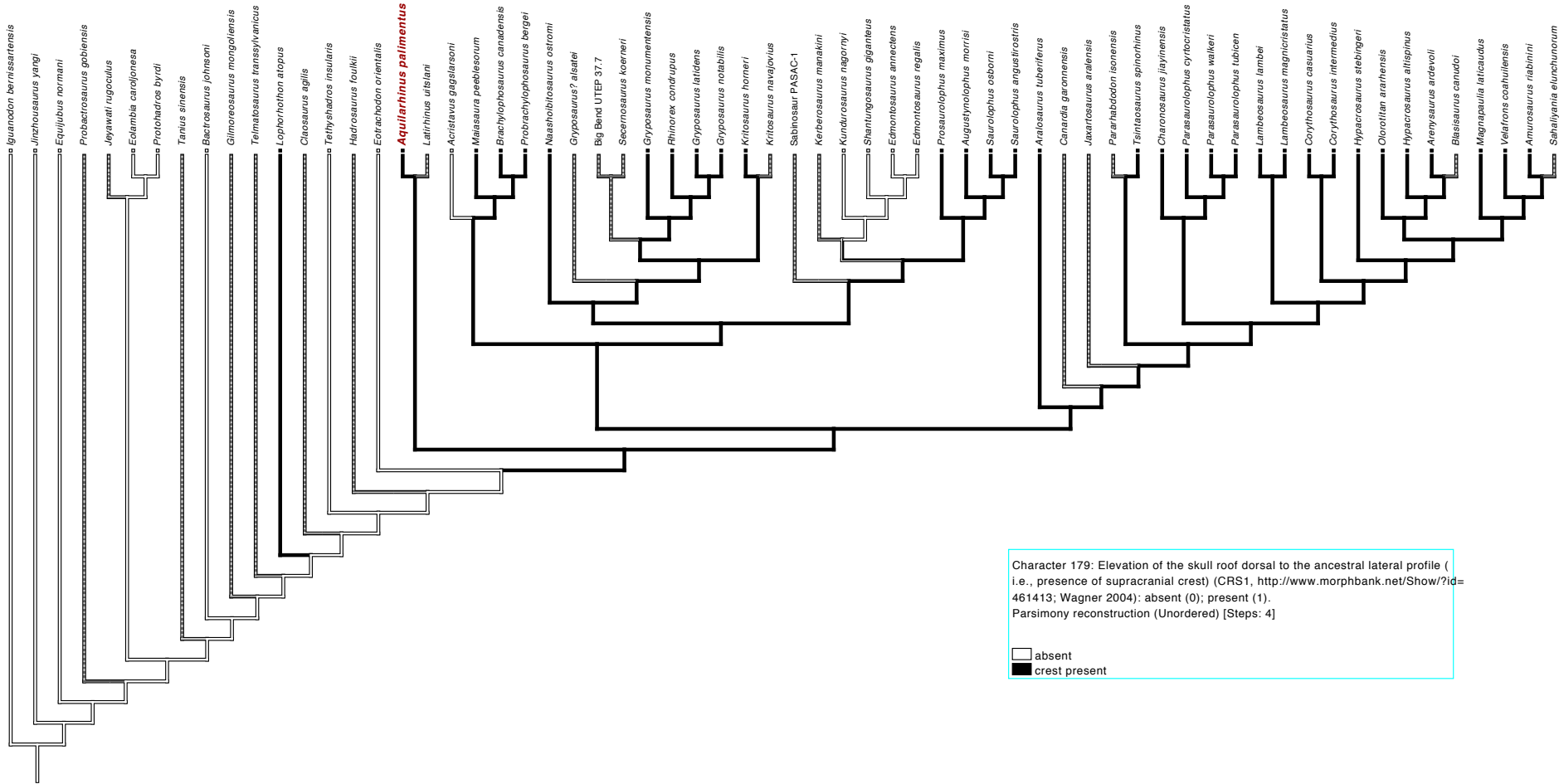
Supracranial crest presence/absence optimized on most parsimonous tree #5



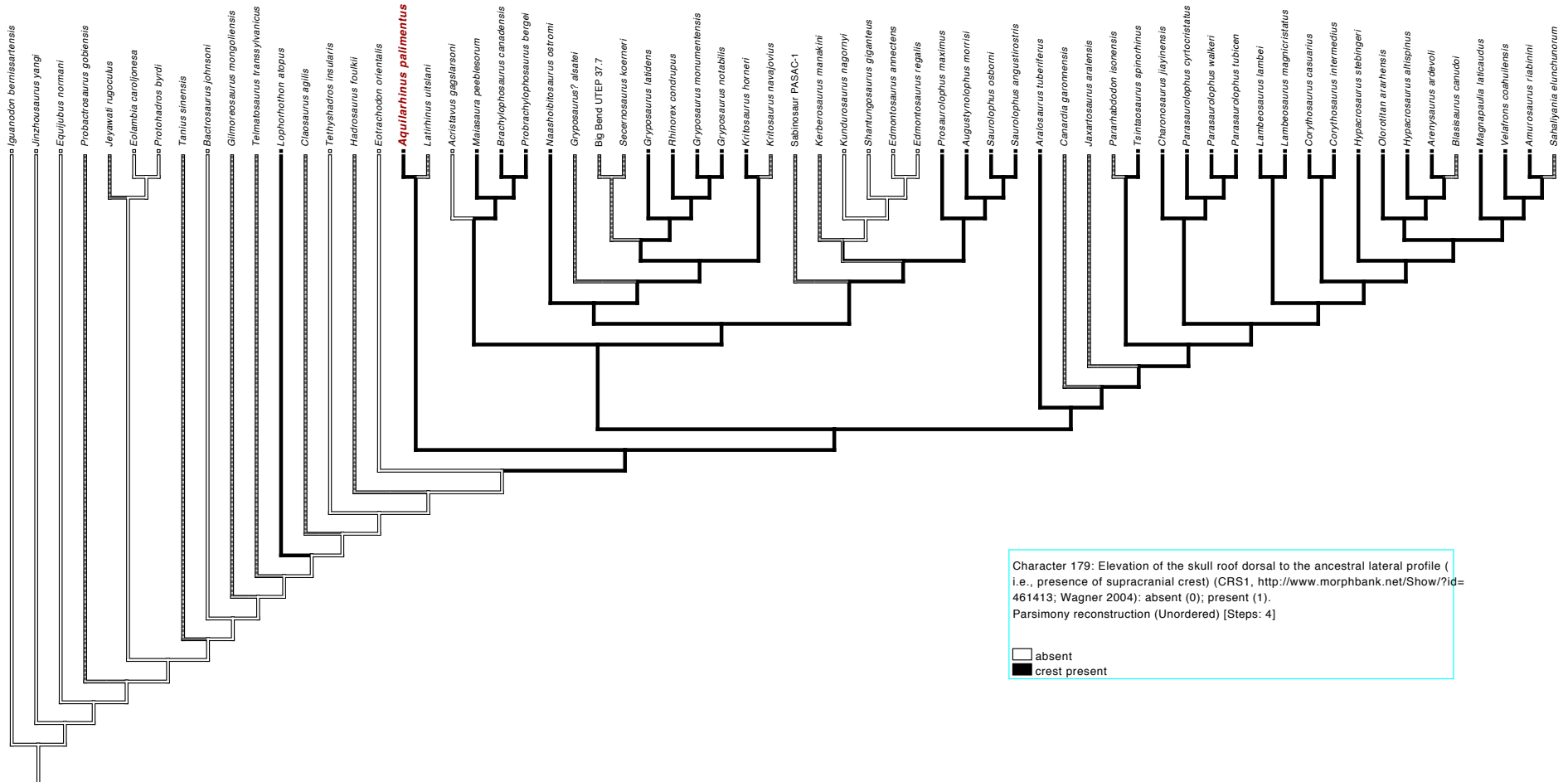
Supracranial crest presence/absence optimized on most parsimonious tree #6



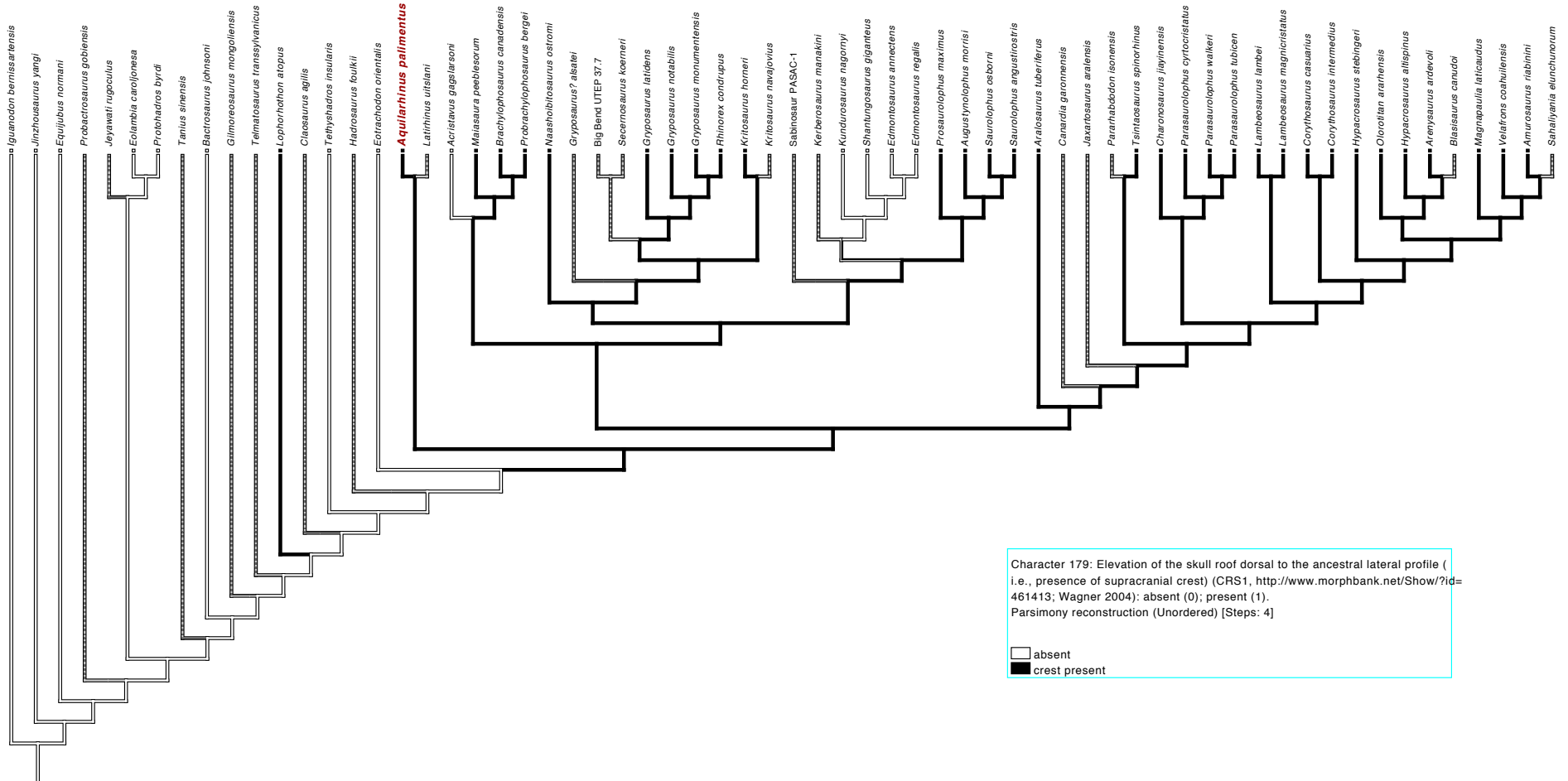
Supracranial crest presence/absence optimized on most parsimonious tree #7



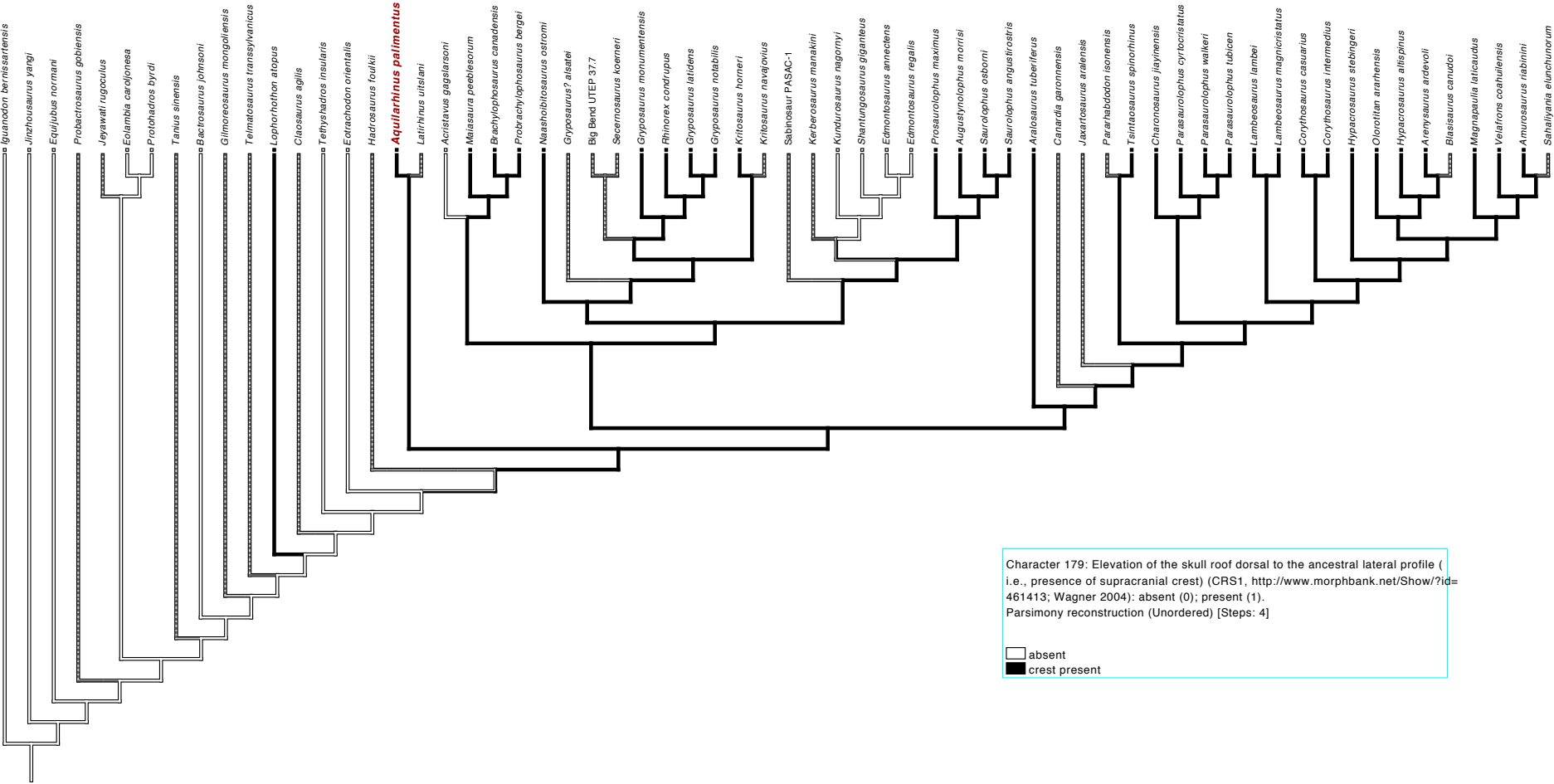
Supracranial crest presence/absence optimized on most parsimonious tree #8



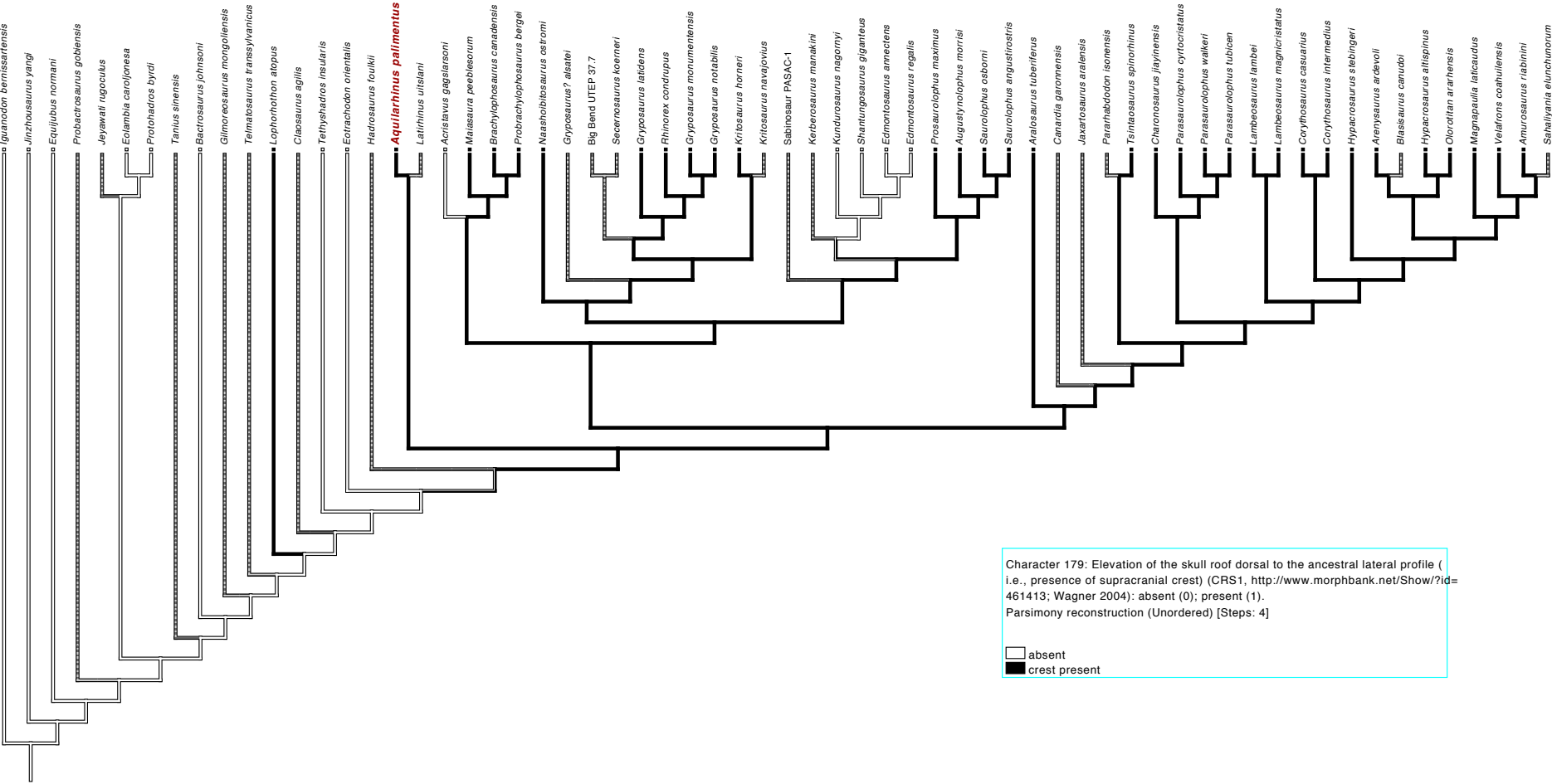
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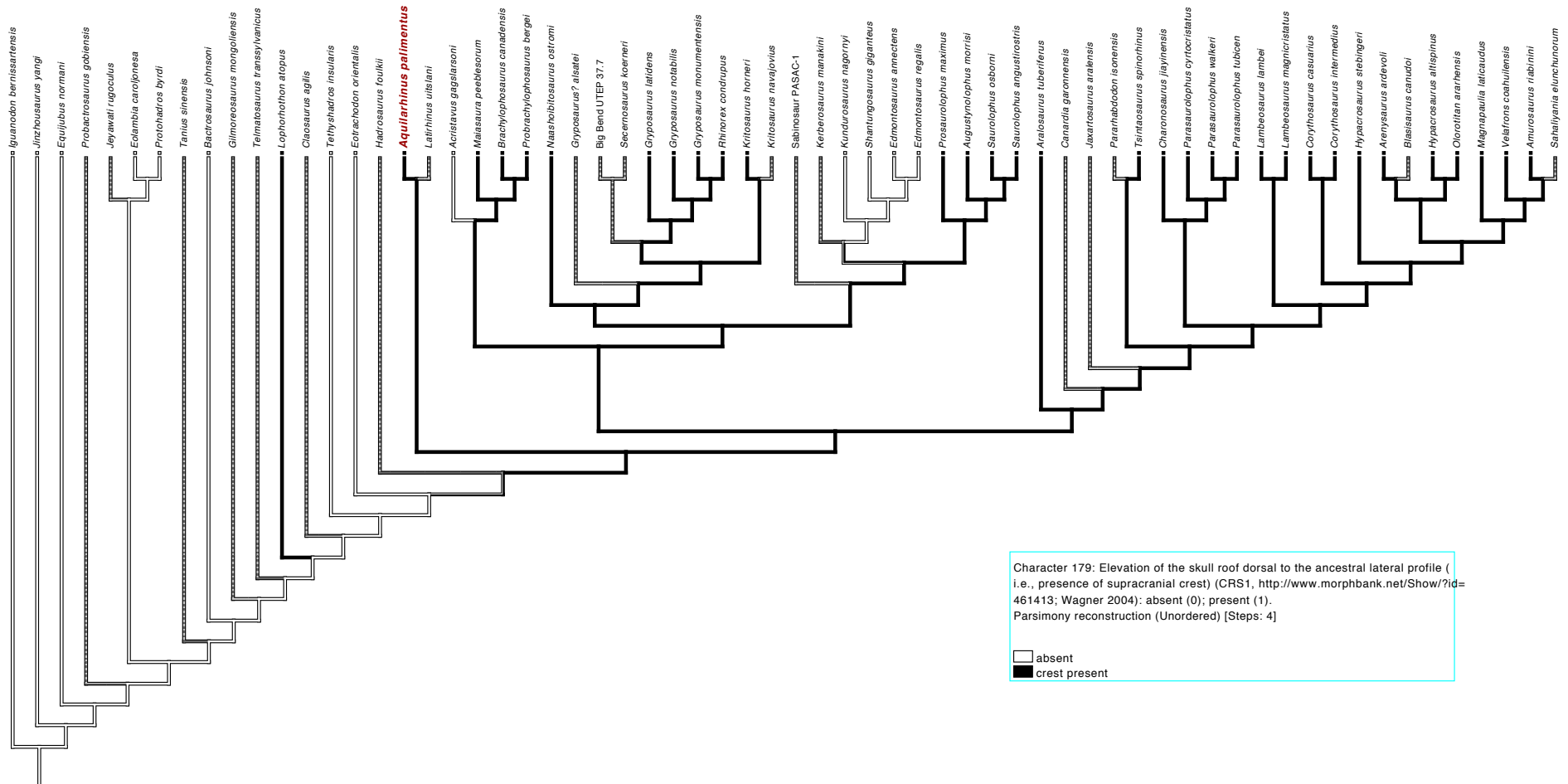
Supracranial crest presence/absence optimized on most parsimonious tree #10



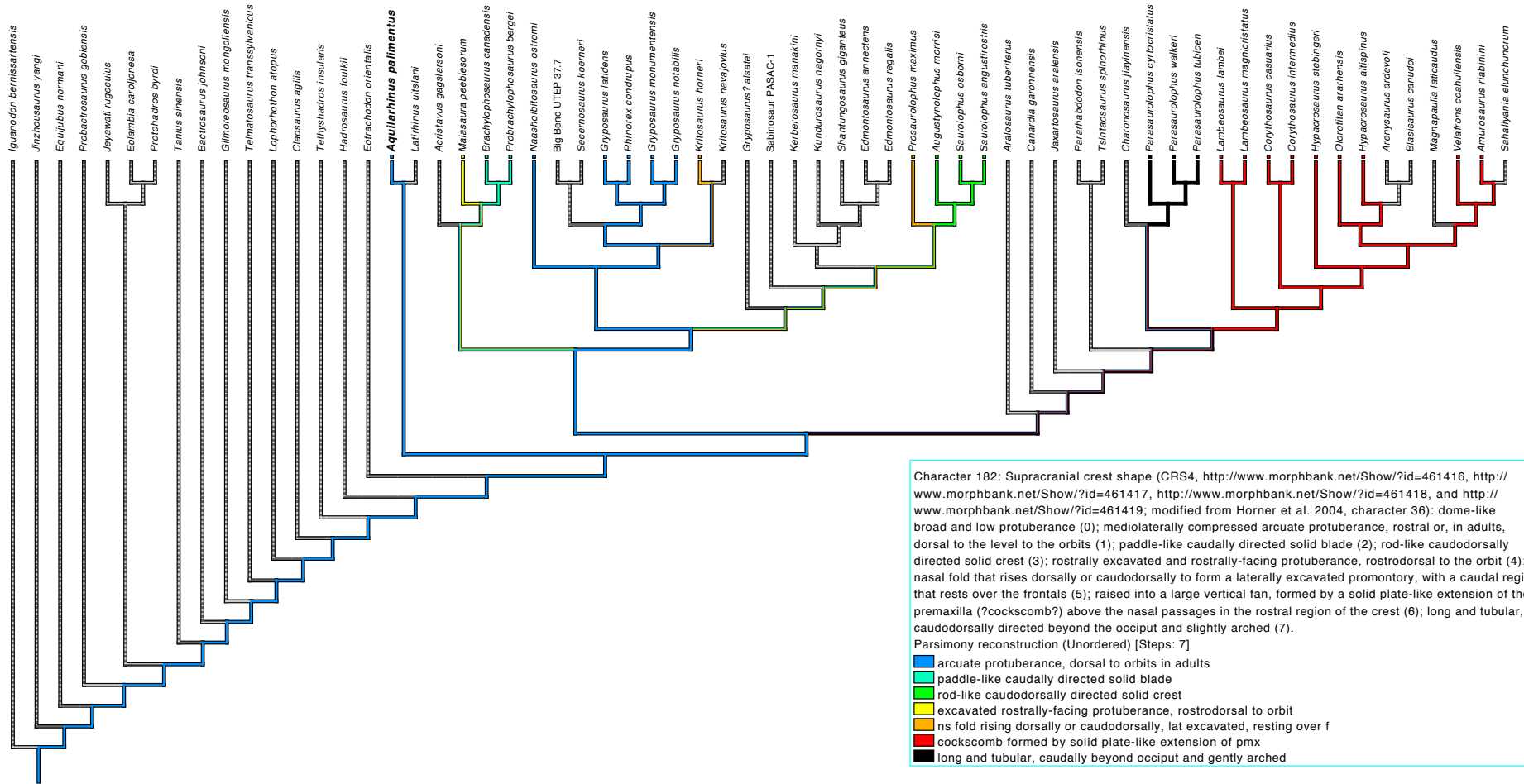
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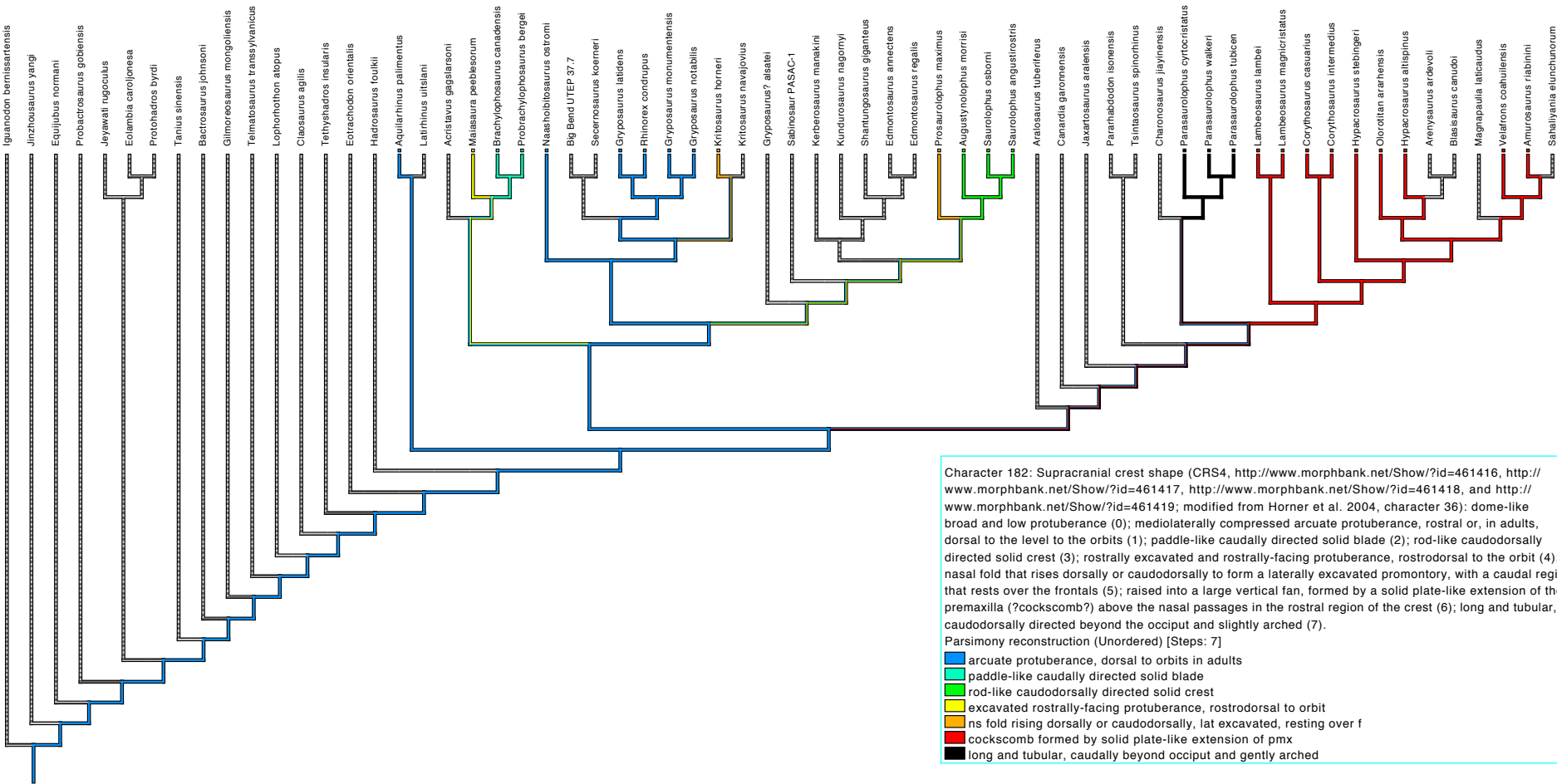
Supracranial crest presence/absence optimized on most parsimonious tree #12



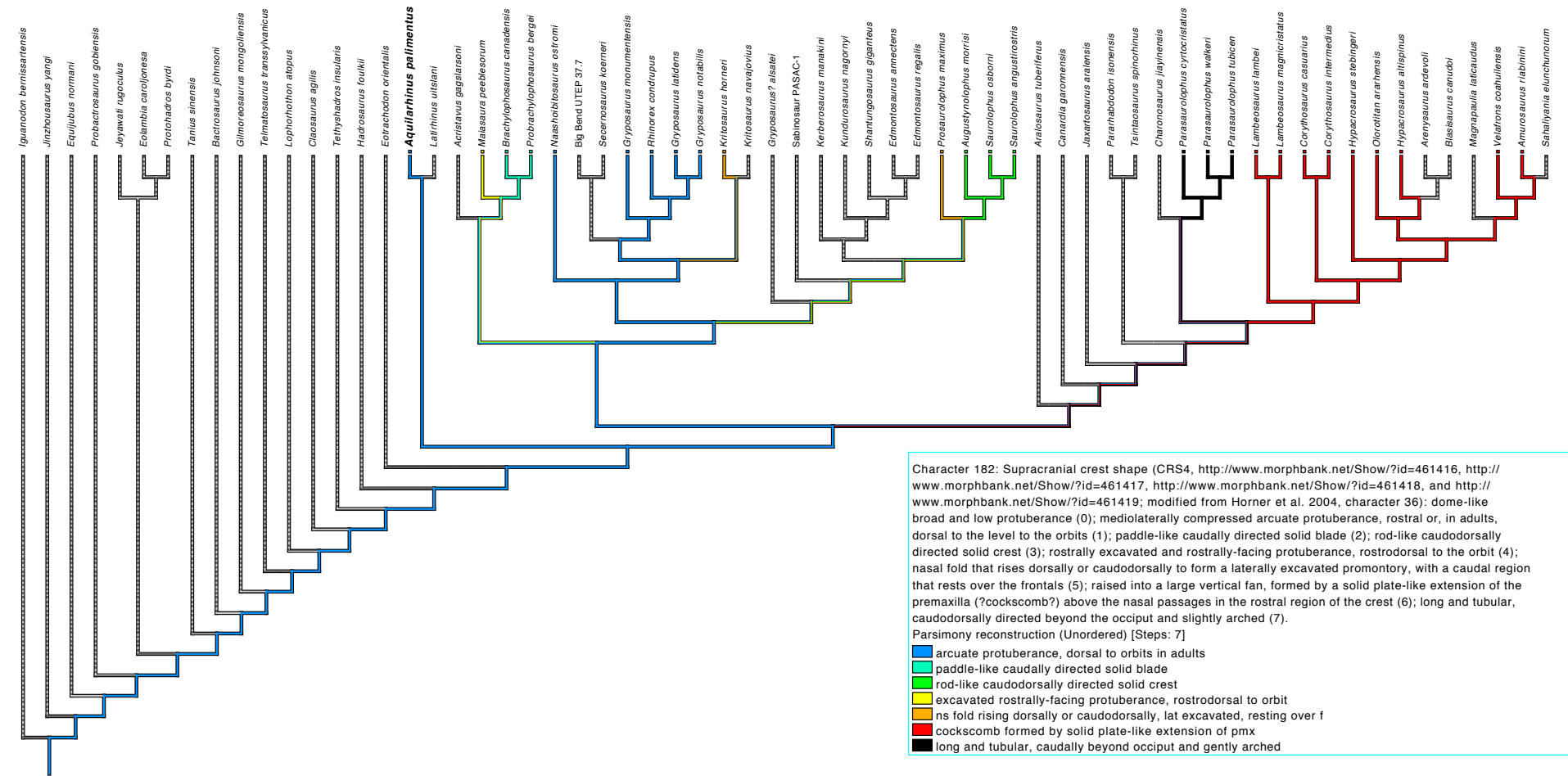
Supracranial crest shape optimized on most parsimonious tree #1



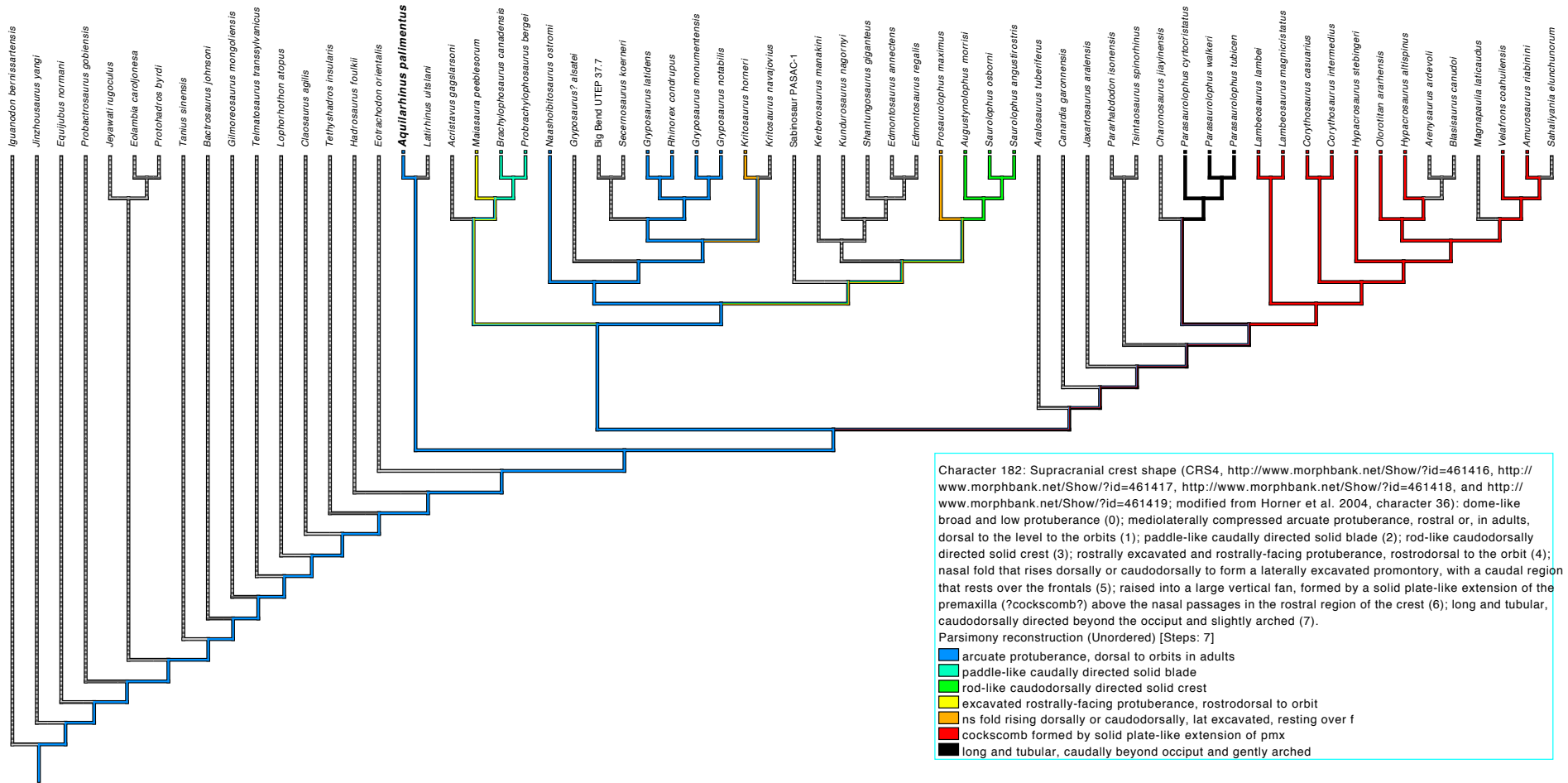
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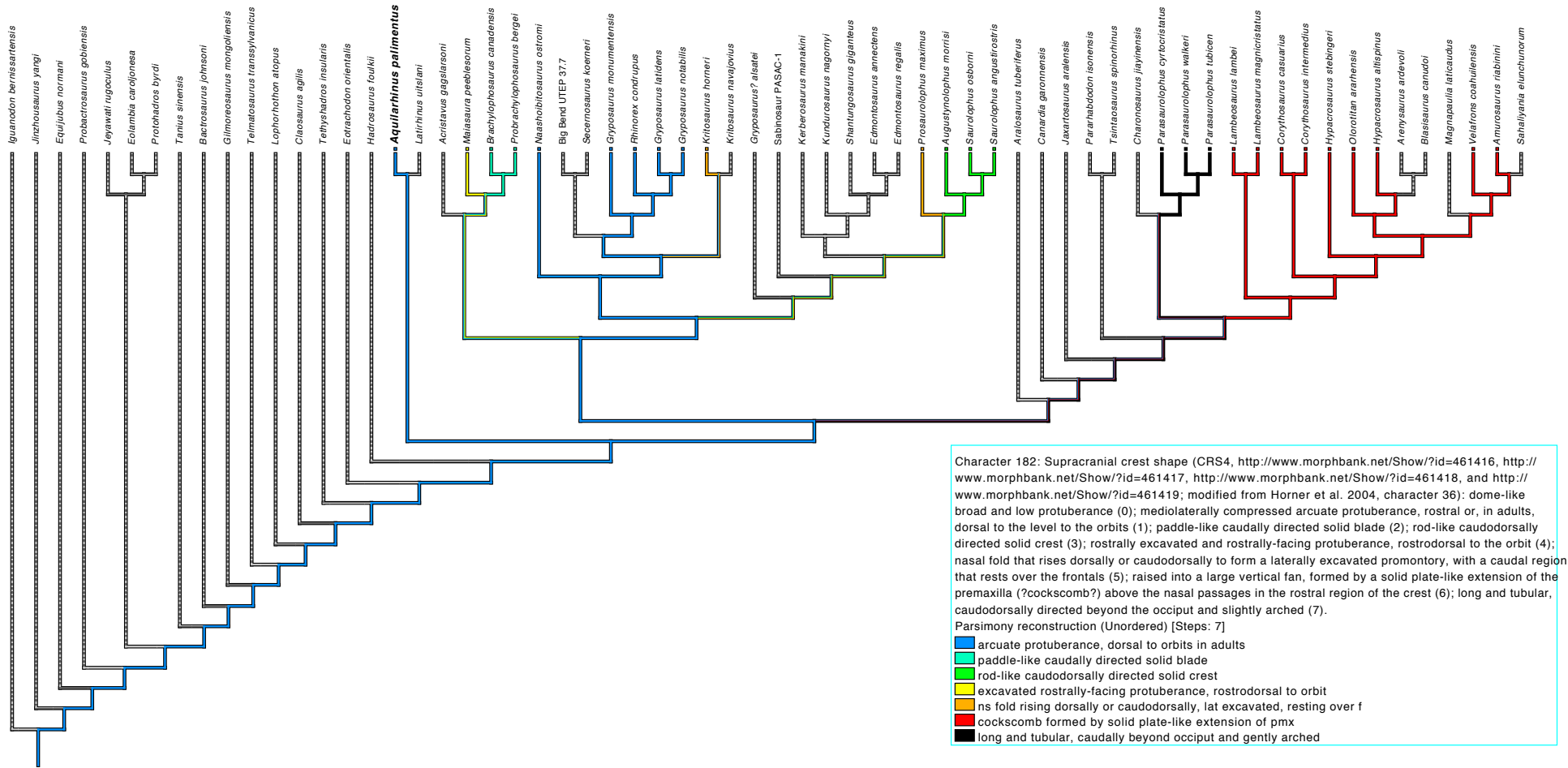
Supracranial crest shape optimized on most parsimonon tree #3



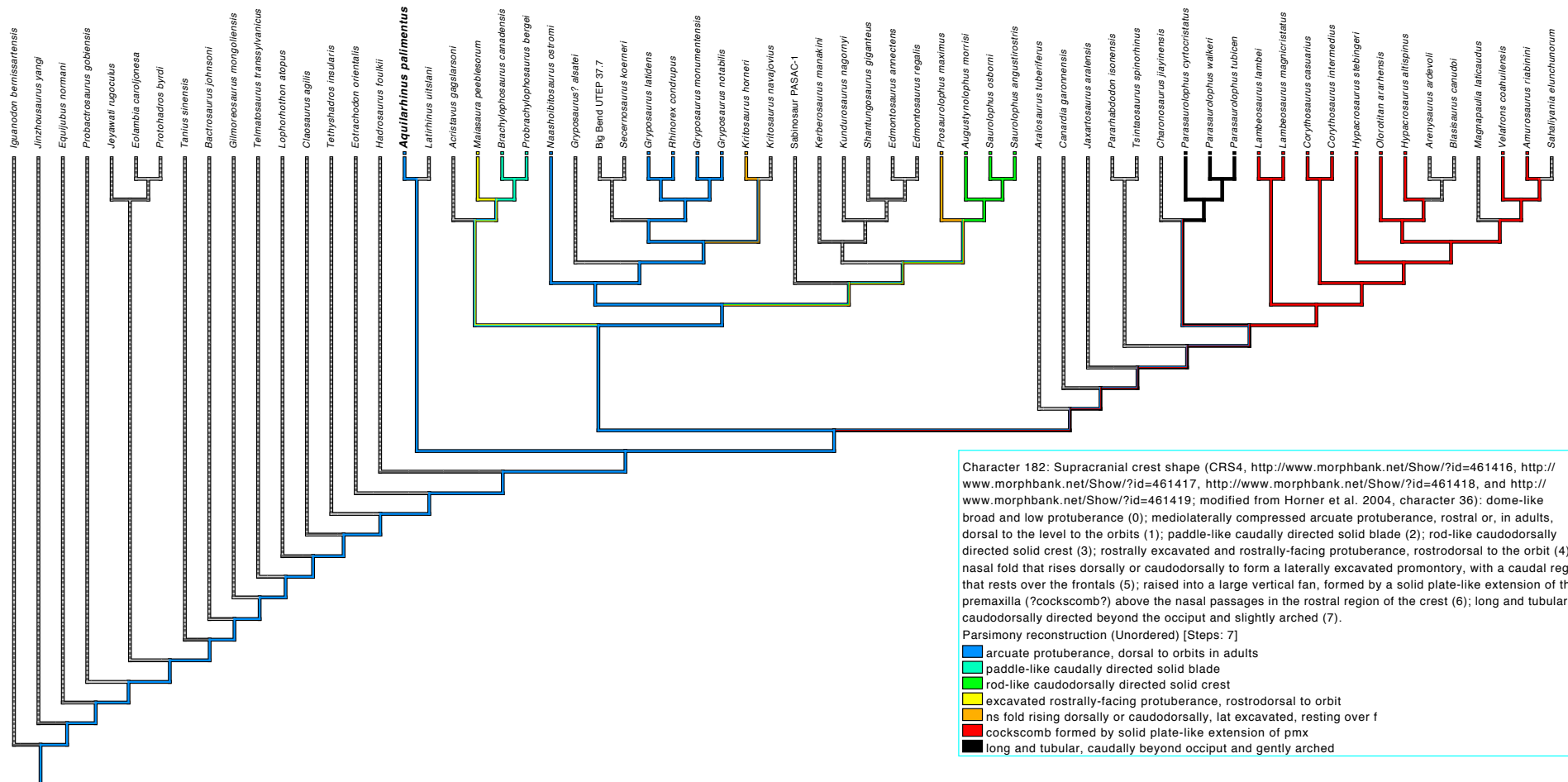
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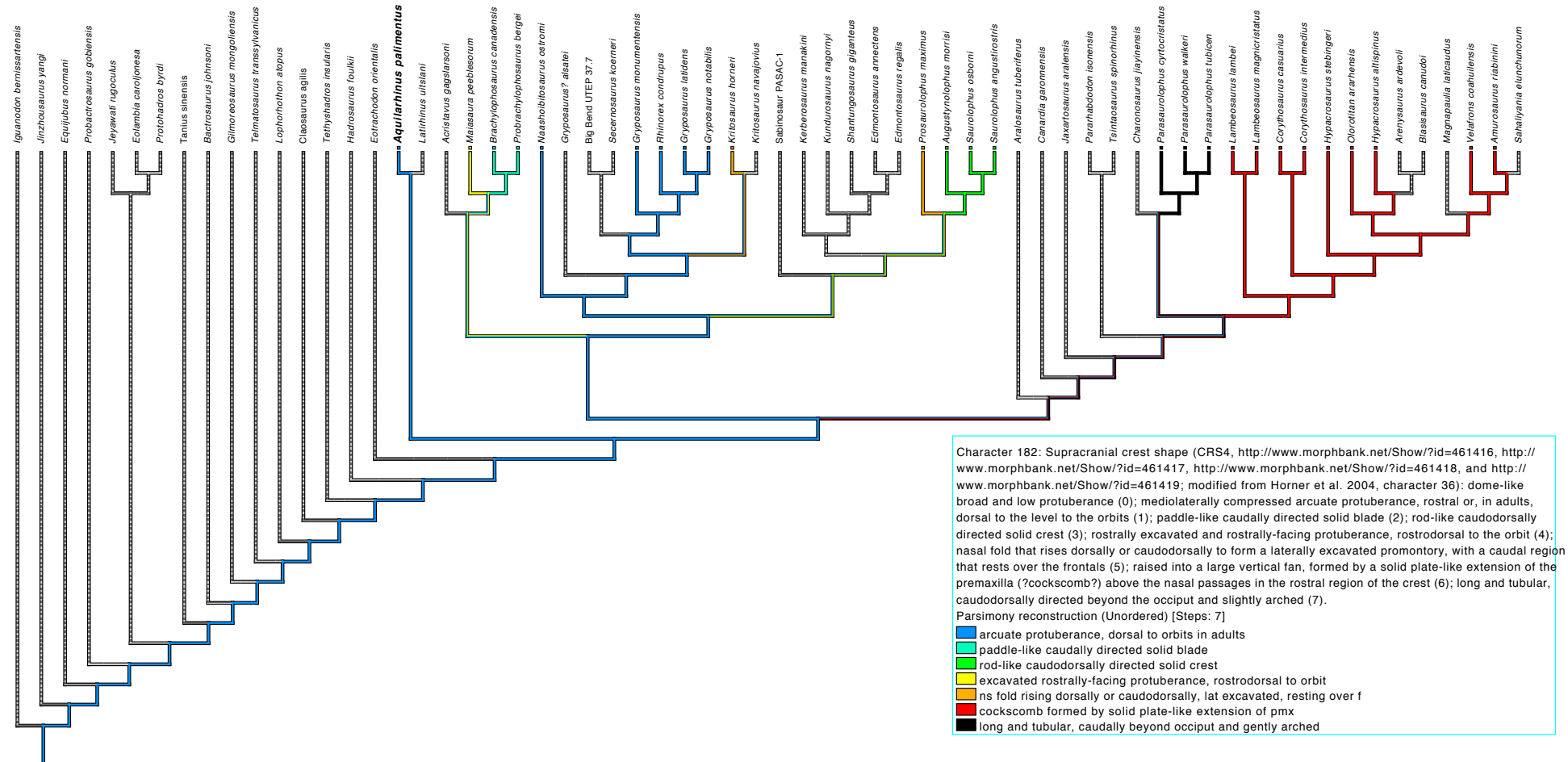
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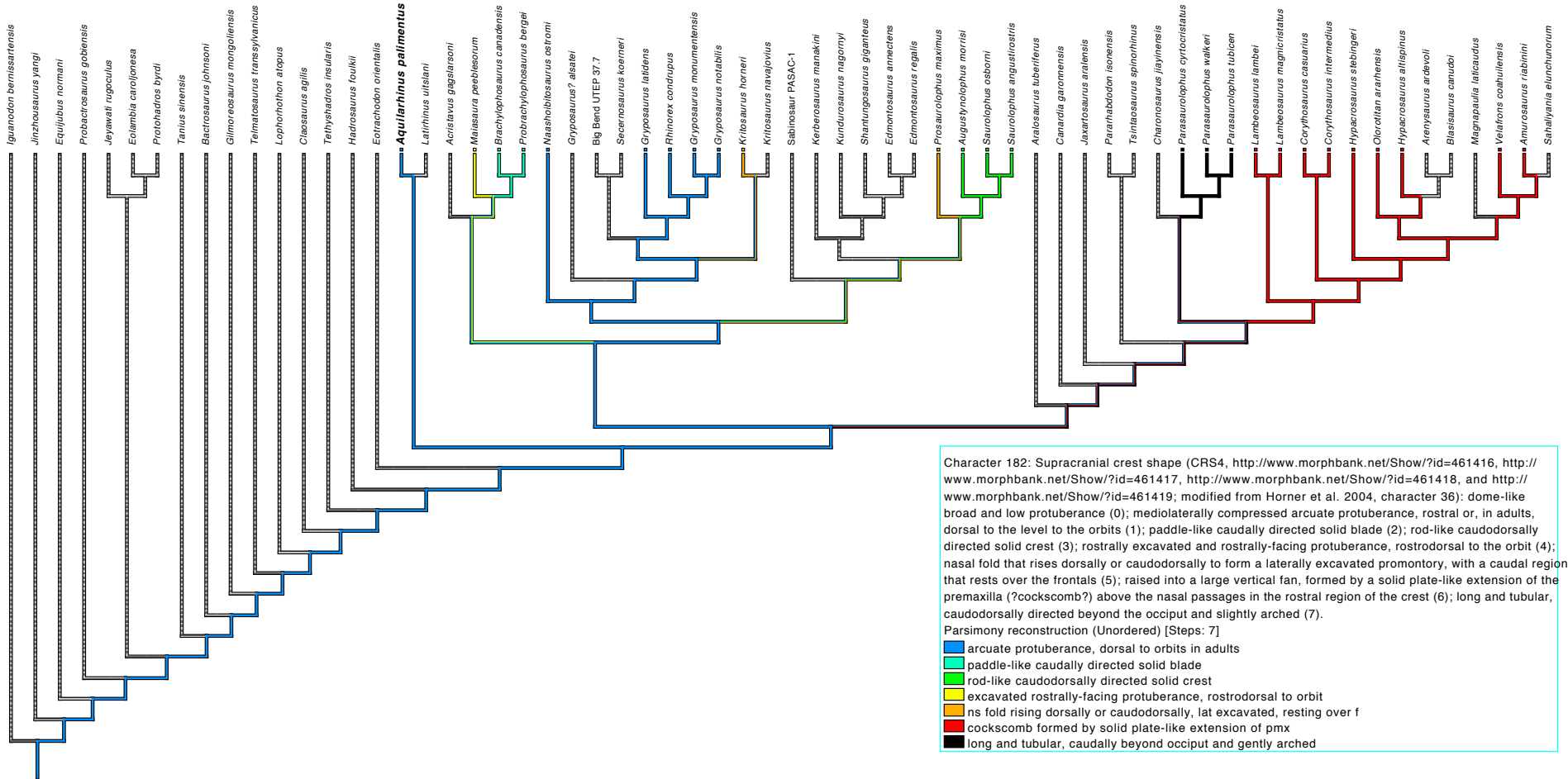
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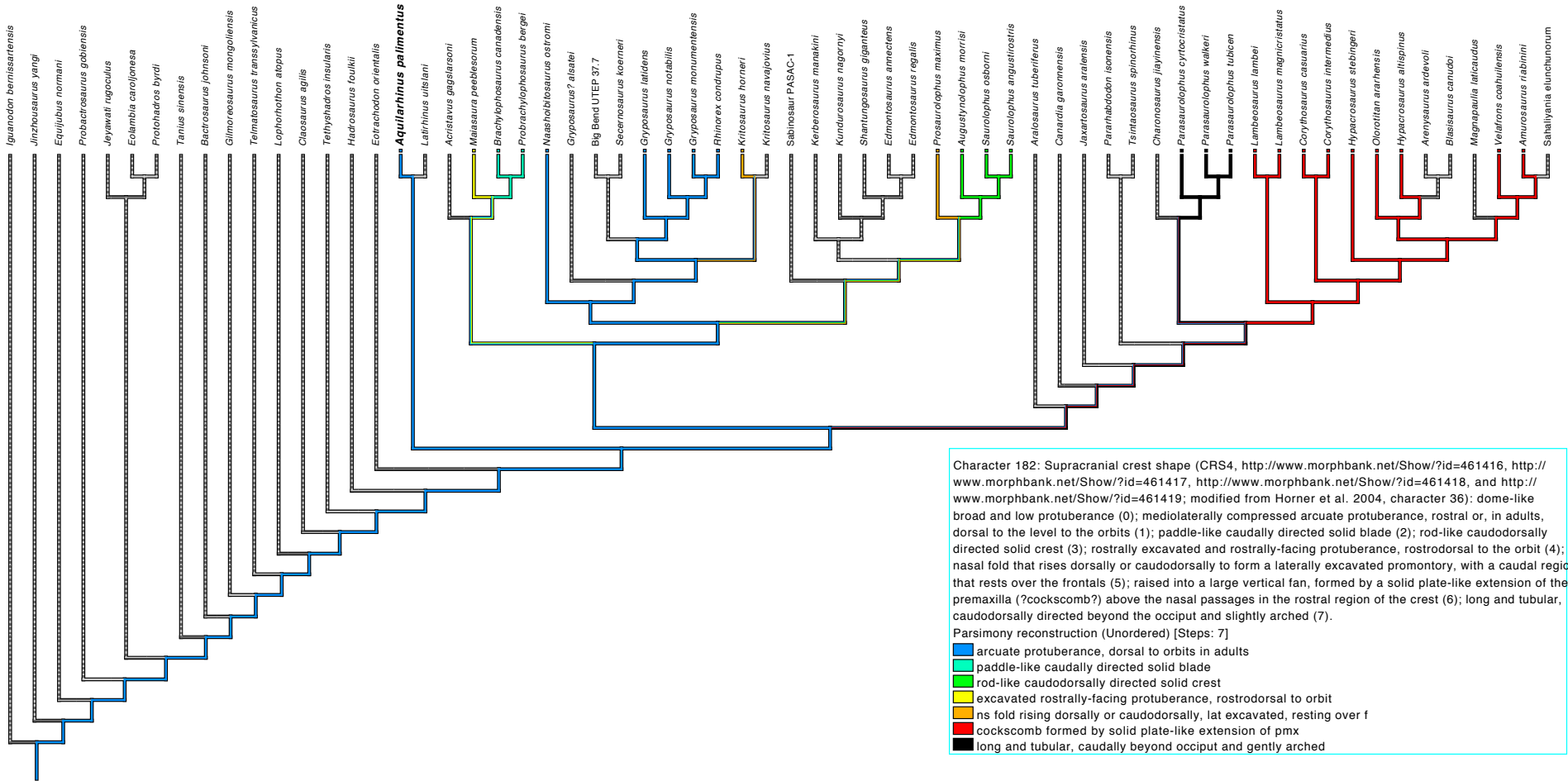
Supracranial crest shape optimized on most parsimonous tree #7



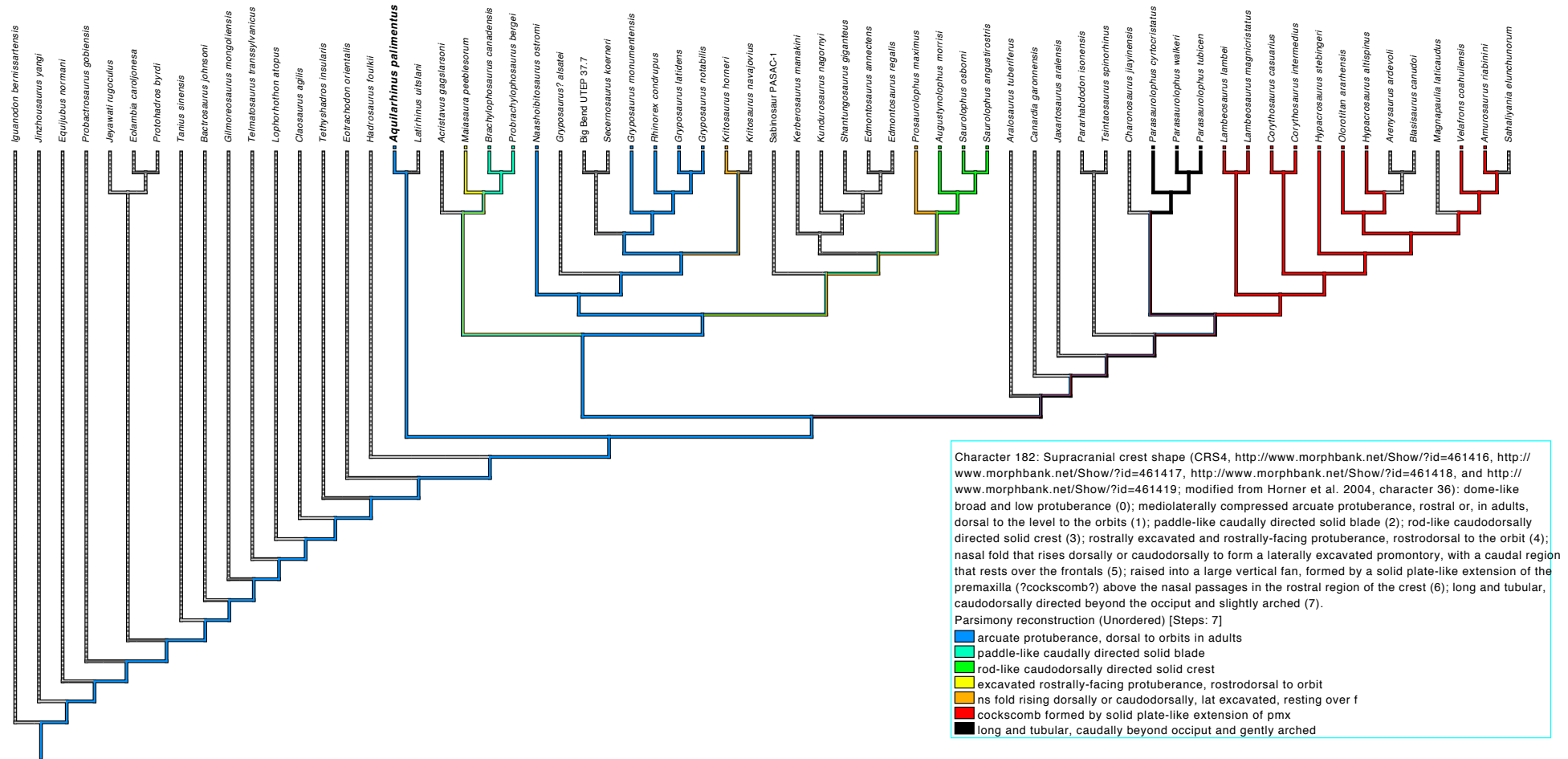
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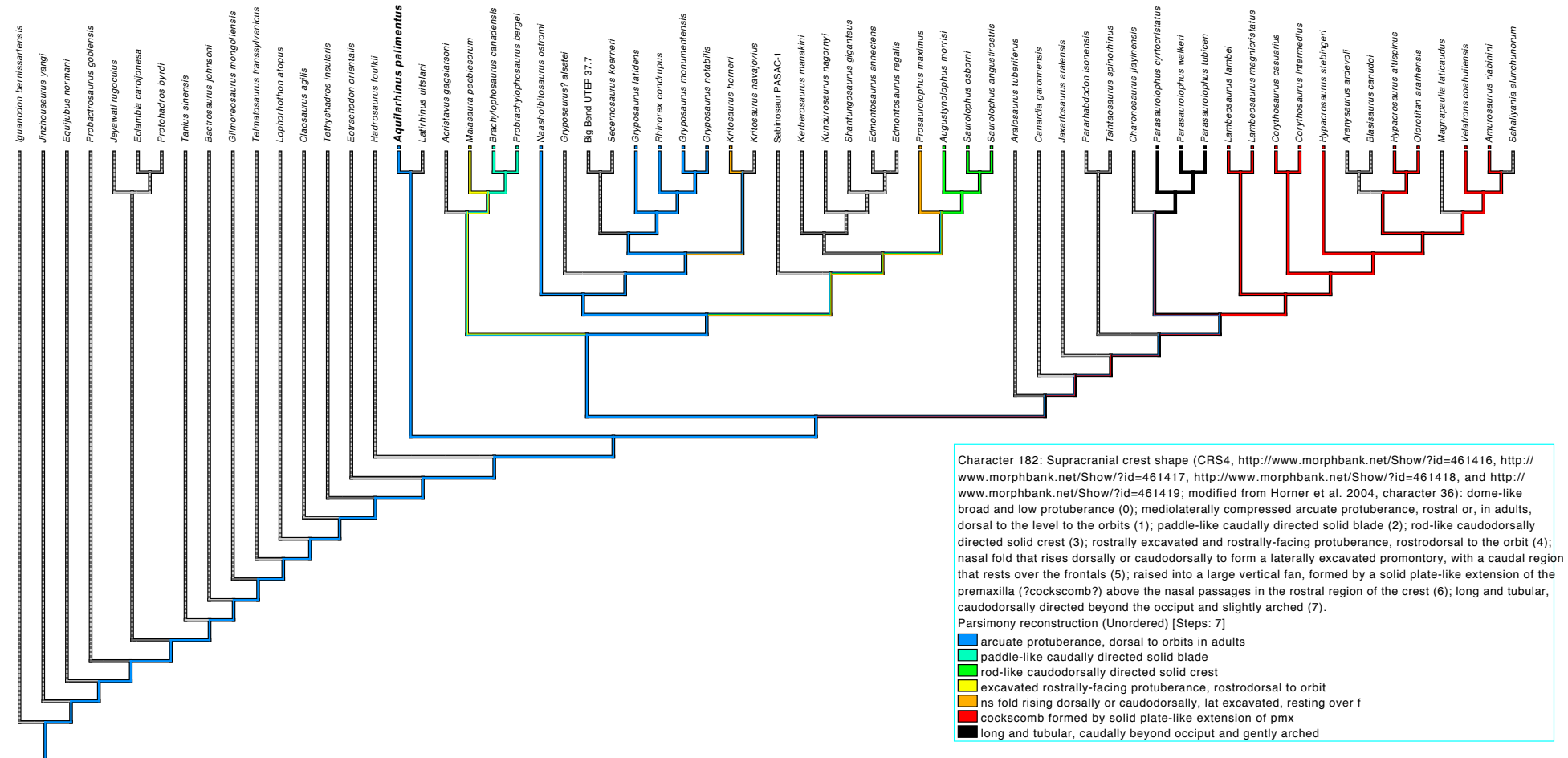
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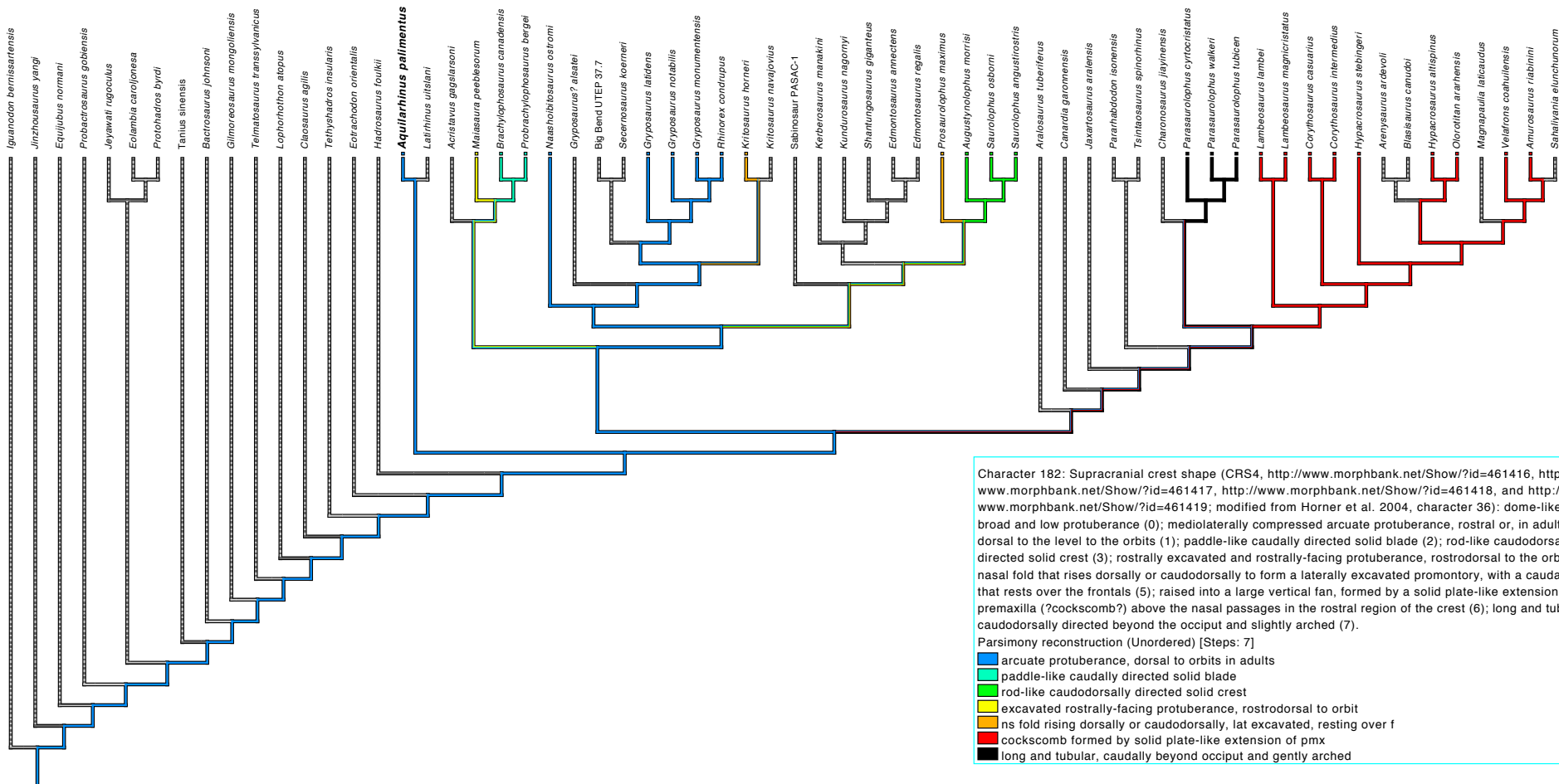
Supracranial crest shape optimized on most parsimonious tree #10



Supracranial crest shape optimized on most parsimonious tree #11



Supracranial crest shape optimized on most parsimonous tree #12



Mesquite version 3.5 (build 888) Date: Sun Mar 31 14:41:45 CDT 2019
Window refers to project with home file palimentus.nex
File path: C:\Users\jrwma\Desktop\RSM\Second submission\
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Tree window for taxa "Taxa"

Showing Tree block: Imported trees

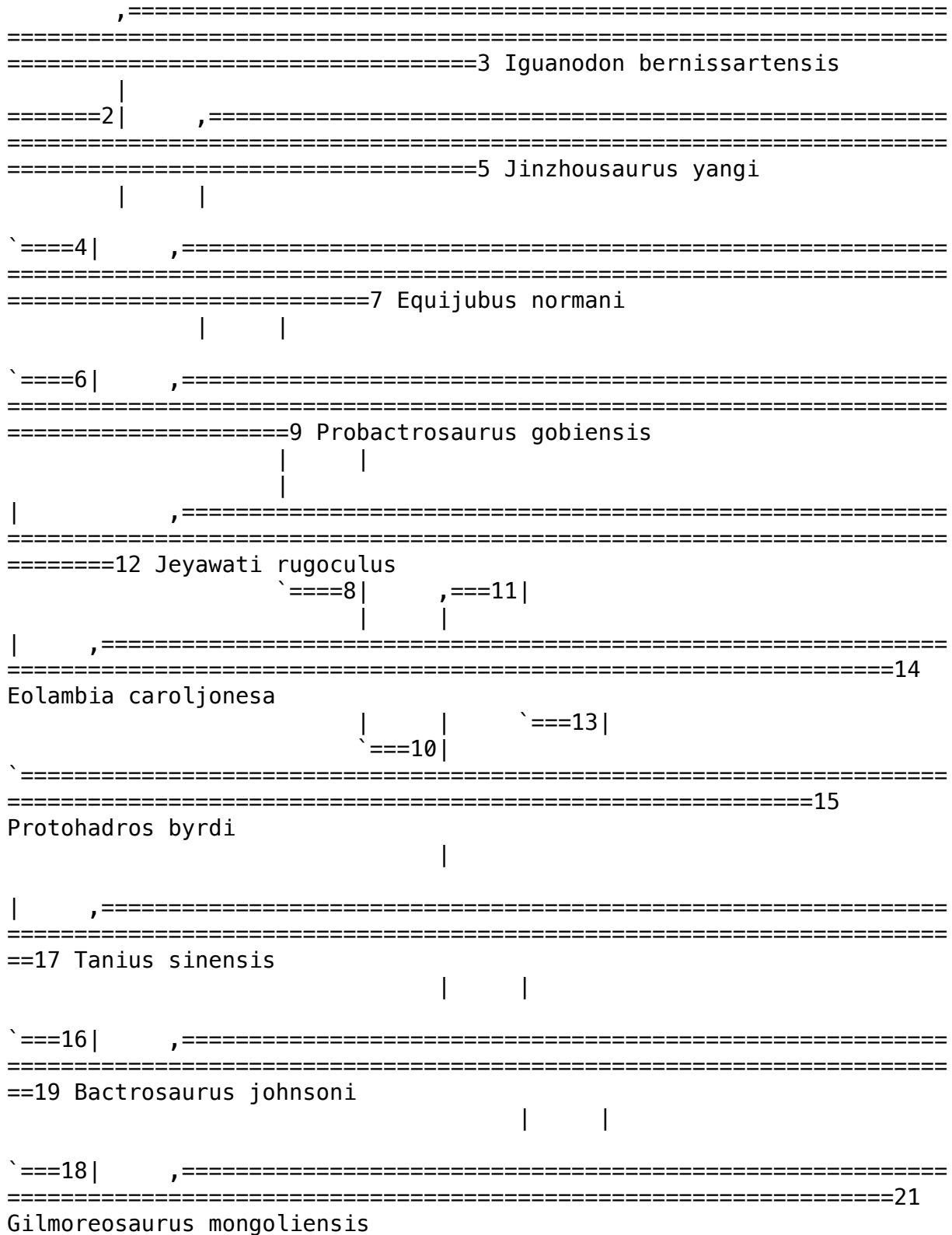
Notes:
tree(s) from TNT, for data in Z:\Users\Kobresia\Desktop\47-MS
Aquilarhinus from Rattlesnake Mountain\Phylogeny \hadromatrix 7 June
2018.tnt

Original Tree: Imported tree 1 (id 1, version 382)

Tree Description: (Iguanodon_bernissartensis,(Jinzhousaurus_yangi,
(Equijubus_normani,(Probactrosaurus_gobiensis,((Jeyawati_rugoculus,
(Eolambia_caroljonesa,Protohadros_byrdi)),(Tanius_sinensis,
(Bactrosaurus_johnsoni,(Gilmoreosaurus_mongoliensis,
(Telmatosaurus_transsylvanicus,(Lophorhynchon_atopus,
(Claosaurus_agilis,(Tethyshadros_insularis,(Hadrosaurus_foulkii,
(Eotrachodon_orientalis,
((Aquilarhinus_palimentus,Latirhinus_uitslani),
((Aralosaurus_tuberiferus,(Canardia_garonnensis,
(Jaxartosaurus_aralensis,
((Pararhabdodon_isonensis,Tsintaosaurus_spinorhinus),
((Charonosaurus_jiayinensis,(Parasaurolophus_cyrtocristatus,
(Parasaurolophus_walkerii,Parasaurolophus_tubicen))),
((Hypacrosaurus_stebingeri,((Olorotitan_ararhensis,
(Hypacrosaurus_altispinus,
(Arenysaurus_ardevoli,Blasisaurus_canudoii))), (Magnapaulia_laticaudus,
(Velafrons_coahuilensis,
(Amurosaurus_riabinini,Sahaliyanian_elunchunorum)))))
(Corythosaurus_casuaris,Corythosaurus_intermedius)),
(Lambeosaurus_lambeii,Lambeosaurus_magnicristatus)))))
((Acristavus_gagslarsoni,(Maiasaura_peeklesorum,
(Brachylophosaurus_canadensis,Probrachylophosaurus_bergei))),
(Naashoibitosaurus_ostromi,
((Big_Bend_UTEP_37.7,Secernosaurus_koernerii),
((Gryposaurus_latidens,Rhinorex_condrumpus),
(Gryposaurus_monumentensis,Gryposaurus_notabilis))),
(Kritosaurus_horneri,Kritosaurus_navajovius))), (Gryposaurus?_alsatei,
('Sabinosaurus_PASAC-1',((Prosaurolophus_maximus,
(Augustynolophus_morrisi,
(Saurolophus_osborni,Saurolophus_angustirostris))),
(Kerberosaurus_manakini,(Kundurosaurus_nagornyii,
(Shantungosaurus_giganteus,

(Edmontosaurus_annectens,Edmontosaurus_regalis))))))))))))))))))
);

Tree with node numbers:



`===20		,	=====	
			=====23	
Telmatosaurus transsylvanicus				
`===22		,	=====	
			=====25 Lophorhothon	
atopus				
`===24		,	=====	
			=====27 Claosaurus agilis	
`===26		,	=====	
			=====29 Tethyshadros insularis	
		,	=====	
			=====31 Hadrosaurus foulkii	
`===28				
		,	=====	
			=====33 Eotrachodon orientalis	
		,	=====	
			=====36 Aquilarhinus palimentus	
`===30		,	===35	
			=====	
=====37 Latirhinus uitslani				
		,	=====	
			=====40 Aralosaurus tuberiferus	

| |
| ,===39| ,=====

=====42 Canardia garonnensis

`===32| | | |

| | |
| ,=====44
Jaxartosaurus aralensis

| | | `===41| |

| | |
| ,=====47
Pararhabdodon isonensis

| | | | | ,===46|

| | | | |
`=====48 Tsintaosaurus
spinorhinus

| | | `===43| |

| | |
| ,=====51 Charonosaurus
jiayinensis

| | | | | ,===50|

`===34| | | |
| ,=====53 Parasaurolophus
cyrtocristatus

| | | | | `===52|

| | | |
| ,=====55 Parasaurolophus walkeri

| | `===45| | `===54|

| | | |
`=====56 Parasaurolophus tubicen

| | | |

| | |
| ,=====60 Hypacrosaurus
stebingeri

		,=====63	Olorotitan	ararhensis
			,==59	,==62
		,=====65	Hypacrosaurus	altispinus
		`==49		
		`==64		
		,==67	Arenysaurus	ardevoli
				`==61
		`==66		
		`==68	Blasisaurus	canudo
		`==38		
		,=====70	Magnapaulia	laticaudus
			,==58	`==69
		,=====72	Velafrons	coahuilensis
				`==71
		,==74	Amurosaurus	riabinini
		`==73		
		`==75	Sahaliyana	elunchunorum
			`==57	
		,=====77	Corythosaurus	casuarius
			`==76	

```

|
|=====78 Corythosaurus intermedius
|
|
|
|,=====80 Lambeosaurus lambei
|
|`===79|
|
|=====81 Lambeosaurus magnicristatus
|
|
|,=====
=====84 Acristavus gagslarsoni
|
|,===83|
|
|
|,=====86
Maiasaura peeblesorum
|
|`===85|
|
|
|,=====88
Brachylophosaurus canadensis
|
|`===87|
|
|
|=====89
Probrachylophosaurus bergei
|
|
|
|,=====
92 Naashoibitosaurus ostromi
|
|
|
|`===82|
|
|,=====96 Big Bend
UTEP 37.7
|
|,===95|

```



```

|      |      |
|=====97 Secernosaurus koerneri
|      ,==91|      |
|      |
|      ,==94|      ,=====100
Gryposaurus latidens
|      |      |      |      |      ,==99|
|      |      |      |      |      |
|=====101 Rhinorex condrupus
|      |      |      |      `==98|
|      |      `==93|
|      ,=====103 Gryposaurus monumentensis
|      |      |      |      `==102|
|=====90|      |
|=====104 Gryposaurus notabilis
|      |
|      |      ,=====106
Kritosaurus horneri
|      `==105|
|      `=====107
Kritosaurus navajovius
|
|      ,=====109
Gryposaurus? alsatei
|      |
|=====108|      ,=====111
Sabinosaur PASAC-1
|      |
|      |      ,=====114
Prosaurolophus maximus
|=====110|      ,==113|

```

```

|      |      |      ,=====116 Augustynolophus
morrisi

|      |      `==115|

|      |      |      ,=====118 Saurolophus
osborni

`==112|      `==117|

|      `=====119 Saurolophus
angustirostris

|

|      ,=====121 Kerberosaurus
manakini

`==120|

|      ,=====123 Kundurosaurus nagorny

`==122|

|      ,=====125 Shantungosaurus giganteus

`==124|

|      ,=====127 Edmontosaurus annectens

`==126|

`=====128 Edmontosaurus regalis

```

----- Trace Character History -----

Character 179: Elevation of the skull roof dorsal to the ancestral lateral profile (i.e., presence of supracranial crest) (CRS1, <http://www.morphbank.net/Show/?id=461413>; Wagner 2004): absent (0); present (1).

Marginal prob. recon. with model Mk1 (est.) [rate 0.05294292 [est.]]
 -log L.:16.59456179 (Opt.: width 0.0) Reporting likelihoods as Proportional Likelihoods; Threshold when decisions made: 2 Calc. by Maximum likelihood reconstruct (Generic categorical) (id# 1168)

```

node 2:  absent: 0.99705445*, crest present: 0.00294555
node 3:  absent: 1
node 4:  absent: 0.99968698*, crest present: 0.00031302

```

node 5: absent: 1
node 6: absent: 0.99981112*, crest present: 0.00018888
node 7: absent: 1
node 8: !
node 9: !
node 10: absent: 0.9995394*, crest present: 0.0004606
node 11: !
node 12: !
node 13: absent: 0.99982897*, crest present: 0.00017103
node 14: absent: 1
node 15: absent: 1
node 16: !
node 17: !
node 18: absent: 0.99466935*, crest present: 0.00533065
node 19: absent: 1
node 20: !
node 21: !
node 22: !
node 23: !
node 24: absent: 0.90214613*, crest present: 0.09785387
node 25: crest present: 1
node 26: !
node 27: !
node 28: absent: 0.95001013*, crest present: 0.04998987
node 29: absent: 1
node 30: !
node 31: !
node 32: absent: 0.90759492*, crest present: 0.09240508
node 33: absent: 1
node 34: absent: 0.05309514, crest present: 0.94690486*
node 35: !
node 36: crest present: 1
node 37: !
node 38: absent: 0.00836845, crest present: 0.99163155*
node 39: absent: 0.00059755, crest present: 0.99940245*
node 40: crest present: 1
node 41: !
node 42: !
node 43: !
node 44: !
node 45: absent: 0.00018828, crest present: 0.99981172*
node 46: !
node 47: !
node 48: crest present: 1
node 49: absent: 0.00017585, crest present: 0.99982415*
node 50: absent: 0.00016544, crest present: 0.99983456*
node 51: crest present: 1
node 52: absent: 0.00016446, crest present: 0.99983554*
node 53: crest present: 1
node 54: absent: 0.0001562, crest present: 0.9998438*

node 55: crest present: 1
node 56: crest present: 1
node 57: absent: 0.00017465, crest present: 0.99982535*
node 58: absent: 0.00017413, crest present: 0.99982587*
node 59: absent: 0.00016586, crest present: 0.99983414*
node 60: crest present: 1
node 61: absent: 0.00017404, crest present: 0.99982596*
node 62: absent: 0.00016491, crest present: 0.99983509*
node 63: crest present: 1
node 64: absent: 0.00015622, crest present: 0.99984378*
node 65: crest present: 1
node 66: !
node 67: crest present: 1
node 68: !
node 69: absent: 0.00016491, crest present: 0.99983509*
node 70: crest present: 1
node 71: absent: 0.00015622, crest present: 0.99984378*
node 72: crest present: 1
node 73: !
node 74: crest present: 1
node 75: !
node 76: absent: 0.00015668, crest present: 0.99984332*
node 77: crest present: 1
node 78: crest present: 1
node 79: absent: 0.00015671, crest present: 0.99984329*
node 80: crest present: 1
node 81: crest present: 1
node 82: absent: 0.01164701, crest present: 0.98835299*
node 83: absent: 0.06335324, crest present: 0.93664676*
node 84: absent: 1
node 85: absent: 0.00348752, crest present: 0.99651248*
node 86: crest present: 1
node 87: absent: 0.00032264, crest present: 0.99967736*
node 88: crest present: 1
node 89: crest present: 1
node 90: absent: 0.00889175, crest present: 0.99110825*
node 91: absent: 0.00062513, crest present: 0.99937487*
node 92: crest present: 1
node 93: absent: 0.00018965, crest present: 0.99981035*
node 94: !
node 95: !
node 96: !
node 97: !
node 98: absent: 0.00017444, crest present: 0.99982556*
node 99: absent: 0.0001567, crest present: 0.9998433*
node 100: crest present: 1
node 101: crest present: 1
node 102: absent: 0.0001567, crest present: 0.9998433*
node 103: crest present: 1
node 104: crest present: 1

node 105: !
node 106: crest present: 1
node 107: !
node 108: !
node 109: !
node 110: !
node 111: !
node 112: absent: 0.0582347, crest present: 0.9417653*
node 113: absent: 0.00322641, crest present: 0.99677359*
node 114: crest present: 1
node 115: absent: 0.00032544, crest present: 0.99967456*
node 116: crest present: 1
node 117: absent: 0.00016426, crest present: 0.99983574*
node 118: crest present: 1
node 119: crest present: 1
node 120: !
node 121: !
node 122: absent: 0.95019234*, crest present: 0.04980766
node 123: absent: 1
node 124: absent: 0.99722484*, crest present: 0.00277516
node 125: absent: 1
node 126: absent: 0.99971304*, crest present: 0.00028696
node 127: absent: 1
node 128: absent: 1

Mesquite version 3.5 (build 888) Date: Sun Mar 31 13:07:32 CDT 2019
Window refers to project with home file palimentus.nex
File path: C:\Users\jrwma\Desktop\RSM\Second submission\
=====

Tree window for taxa "Taxa"

Showing Tree block: Imported trees

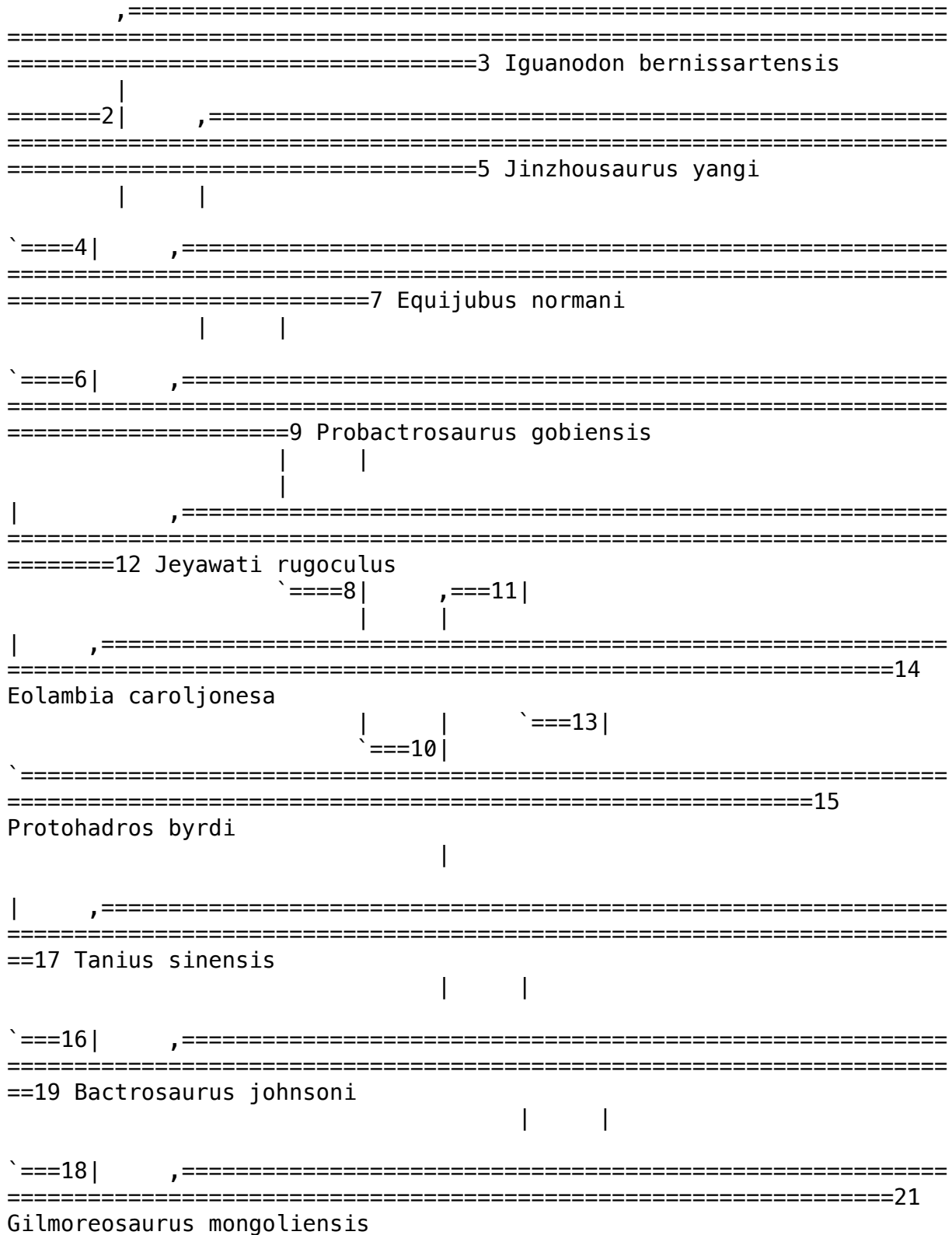
Notes:
tree(s) from TNT, for data in Z:\Users\Kobresia\Desktop\47-MS
Aquilarhinus from Rattlesnake Mountain\Phylogeny \hadromatrix 7 June
2018.tnt

Original Tree: Imported tree 1 (id 1, version 382)

Tree Description: (Iguanodon_bernissartensis,(Jinzhousaurus_yangi,
(Equijubus_normani,(Probactrosaurus_gobiensis,((Jeyawati_rugoculus,
(Eolambia_caroljonesa,Protophadros_byrdi)),(Tanius_sinensis,
(Bactrosaurus_johnsoni,(Gilmoreosaurus_mongoliensis,
(Telmatosaurus_transsylvanicus,(Lophorhynchon_atopus,
(Claosaurus_agilis,(Tethyshadros_insularis,(Hadrosaurus_foulkii,
(Eotrachodon_orientalis,
((Aquilarhinus_palimentus,Latirhinus_uitslani),
((Aralosaurus_tuberiferus,(Canardia_garonnensis,
(Jaxartosaurus_aralensis,
((Pararhabdodon_isonensis,Tsintaosaurus_spinorhinus),
((Charonosaurus_jiayinensis,(Parasaurolophus_cyrtocristatus,
(Parasaurolophus_walkerii,Parasaurolophus_tubicen))),
((Hypacrosaurus_stebingeri,((Olorotitan_ararhensis,
(Hypacrosaurus_altispinus,
(Arenysaurus_ardevoli,Blasisaurus_canudoii))), (Magnapaulia_laticaudus,
(Velafrons_coahuilensis,
(Amurosaurus_riabinini,Sahaliyanian_elunchunorum)))))
(Corythosaurus_casuaris,Corythosaurus_intermedius)),
(Lambeosaurus_lambeii,Lambeosaurus_magnicristatus)))))
((Acristavus_gagslarsoni,(Maiasaura_peeklesorum,
(Brachylophosaurus_canadensis,Probrachylophosaurus_bergei))),
((Naashoibitosaurus_ostromi,
((Big_Bend_UTEP_37.7,Secernosaurus_koernerii),
((Gryposaurus_latidens,Rhinorex_condrumpus),
(Gryposaurus_monumentensis,Gryposaurus_notabilis))),
(Kritosaurus_horneri,Kritosaurus_navajovius))), (Gryposaurus?_alsatei,
('Sabinosaurus_PASAC-1',((Prosaurolophus_maximus,
(Augustynolophus_morrisi,
(Saurolophus_osborni,Saurolophus_angustirostris))),
(Kerberosaurus_manakini,(Kundurosaurus_nagornyii,
(Shantungosaurus_giganteus,

(Edmontosaurus_annectens,Edmontosaurus_regalis))))))))))))))))))
);

Tree with node numbers:



`===20		,	=====	
			=====23	
Telmatosaurus transsylvanicus				
`===22		,	=====	
			=====25 Lophorhothon	
atopus				
`===24		,	=====	
			=====27 Claosaurus agilis	
`===26		,	=====	
			=====29 Tethyshadros insularis	
		,	=====	
			=====31 Hadrosaurus foulkii	
`===28				
		,	=====	
			=====33 Eotrachodon orientalis	
		,	=====	
			=====36 Aquilarhinus palimentus	
`===30		,	===35	
			=====	
			=====37 Latirhinus uitslani	
		,	=====	
			=====40 Aralosaurus tuberiferus	

| |
| ,===39| ,=====

=====42 Canardia garonnensis

`===32| | | |

| | |
| ,=====44
Jaxartosaurus aralensis

| | | `===41| |

| | |
| ,=====47
Pararhabdodon isonensis

| | | | | ,===46|

| | | | |
`=====48 Tsintaosaurus
spinorhinus

| | | `===43| |

| | |
| ,=====51 Charonosaurus
jiayinensis

| | | | | ,===50|

`===34| | | |
| ,=====53 Parasaurolophus
cyrtocristatus

| | | | | `===52|

| | | |
| ,=====55 Parasaurolophus walkeri

| | `===45| | `===54|

| | | |
`=====56 Parasaurolophus tubicen

| | | |

| | |
| ,=====60 Hypacrosaurus
stebingeri

		,=====63	Olorotitan	ararhensis
			,==59	,==62
		,=====65	Hypacrosaurus	altispinus
		`==49		
		`==64		
		,==67	Arenysaurus	ardevoli
			`==61	
		`==66		
		`==68	Blasisaurus	canudoii
		`==38		
		,=====70	Magnapaulia	laticaudus
			,==58	`==69
		,=====72	Velafrons	coahuilensis
				`==71
		,==74	Amurosaurus	riabinini
		`==73		
		`==75	Sahaliyana	elunchunorum
			`==57	
		,=====77	Corythosaurus	casuarius
			`==76	

```

|
|=====78 Corythosaurus intermedius
|
|
|
|,=====80 Lambeosaurus lambei
|
|`===79|
|
|=====81 Lambeosaurus magnicristatus
|
|
|,=====
=====84 Acristavus gagslarsoni
|
|,===83|
|
|
|,=====86
Maiasaura peeblesorum
|
|`===85|
|
|
|,=====88
Brachylophosaurus canadensis
|
|`===87|
|
|
|=====89
Probrachylophosaurus bergei
|
|
|
|,=====
92 Naashoibitosaurus ostromi
|
|
|
|`===82|
|
|,=====96 Big Bend
UTEP 37.7
|
|,===95|

```

```

|      |      |
|=====97 Secernosaurus koerneri
|      ,==91|      |
|      |
|      ,==94|      ,=====100
Gryposaurus latidens
|      |      |      |      |      ,==99|
|      |      |      |      |      |
|=====101 Rhinorex condrupus
|      |      |      |      `==98|
|      |      `==93|
|      ,=====103 Gryposaurus monumentensis
|      |      |      |      `==102|
|=====90|      |
|=====104 Gryposaurus notabilis
|      |
|      |      ,=====106
Kritosaurus horneri
|      `==105|
|      `=====107
Kritosaurus navajovius
|
|      ,=====109
Gryposaurus? alsatei
|      |
|=====108|      ,=====111
Sabinosaur PASAC-1
|      |
|      |      ,=====114
Prosaurolophus maximus
|=====110|      ,==113|

```

```

|      |      |      ,=====116 Augustynolophus
morrisi

|      |      `==115|

|      |      |      ,=====118 Saurolophus
osborni

`==112|      `==117|

|      `=====119 Saurolophus
angustirostris

|

|      ,=====121 Kerberosaurus
manakini

`==120|

|      ,=====123 Kundurosaurus nagorny

`==122|

|      ,=====125 Shantungosaurus giganteus

`==124|

|      ,=====127 Edmontosaurus annectens

`==126|

`=====128 Edmontosaurus regalis

```

----- Trace Character History -----

Character 182: Supracranial crest shape (CRS4, <http://www.morphbank.net/Show/?id=461416>, <http://www.morphbank.net/Show/?id=461417>, <http://www.morphbank.net/Show/?id=461418>, and <http://www.morphbank.net/Show/?id=461419>; modified from Horner et al. 2004, character 36): dome-like broad and low protuberance (0); mediolaterally compressed arcuate protuberance, rostral or, in adults, dorsal to the level to the orbits (1); paddle-like caudally directed solid blade (2); rod-like caudodorsally directed solid crest (3); rostrally excavated and rostrally-facing protuberance, rostradorsal to the orbit (4); nasal fold that rises dorsally or caudodorsally to form a laterally excavated promontory, with a caudal region that rests over the frontals (5); raised into a large vertical fan, formed by a solid

plate-like extension of the premaxilla (?cockscornb?) above the nasal passages in the rostral region of the crest (6); long and tubular, caudodorsally directed beyond the occiput and slightly arched (7). Marginal prob. recon. with model Mk1 (est.) [rate 0.02874319 [est.]] -log L.:30.67663148 (Opt.: width 0.0) Reporting likelihoods as Proportional Likelihoods; Threshold when decisions made: 2 Calc. by Maximum likelihood reconstruct (Generic categorical) (id# 1168)

node 2: !
node 3: !
node 4: !
node 5: !
node 6: !
node 7: !
node 8: !
node 9: !
node 10: !
node 11: !
node 12: !
node 13: !
node 14: !
node 15: !
node 16: !
node 17: !
node 18: !
node 19: !
node 20: !
node 21: !
node 22: !
node 23: !
node 24: !
node 25: !
node 26: !
node 27: !
node 28: !
node 29: !
node 30: !
node 31: !
node 32: !
node 33: !

node 34: dome-like broad and low protuberance: 0.0491173, arcuate protuberance, dorsal to orbits in adults: 0.81484384*, paddle-like caudally directed solid blade: 0.0256736, rod-like caudodorsally directed solid crest: 0.01496153, excavated rostrally-facing protuberance, rostrorodorsal to orbit: 0.02626239, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.02007894, cockscornb formed by solid plate-like extension of pmx: 0.04906241
node 35: !
node 36: arcuate protuberance, dorsal to orbits in adults: 1
node 37: !

node 38: dome-like broad and low protuberance: 0.09701039*, arcuate protuberance, dorsal to orbits in adults: 0.66144801*, paddle-like caudally directed solid blade: 0.04489804, rod-like caudodorsally directed solid crest: 0.0210865, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.04620685, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.03246183, cockscomb formed by solid plate-like extension of pmx: 0.09688838*
node 39: !
node 40: !
node 41: !
node 42: !
node 43: !
node 44: !
node 45: !
node 46: !
node 47: !
node 48: !
node 49: dome-like broad and low protuberance: 0.35138124*, arcuate protuberance, dorsal to orbits in adults: 0.2184202*, paddle-like caudally directed solid blade: 0.02259667, rod-like caudodorsally directed solid crest: 0.01503384, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.02301236, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.01864678, cockscomb formed by solid plate-like extension of pmx: 0.35090892*
node 50: !
node 51: !
node 52: dome-like broad and low protuberance: 0.97686618*, arcuate protuberance, dorsal to orbits in adults: 0.00715, paddle-like caudally directed solid blade: 0.00130219, rod-like caudodorsally directed solid crest: 0.00107634, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.0013146, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00118423, cockscomb formed by solid plate-like extension of pmx: 0.01110646
node 53: dome-like broad and low protuberance: 1
node 54: dome-like broad and low protuberance: 0.99903221*, arcuate protuberance, dorsal to orbits in adults: 0.00025643, paddle-like caudally directed solid blade: 0.00008756, rod-like caudodorsally directed solid crest: 0.00008104, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00008792, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00008416, cockscomb formed by solid plate-like extension of pmx: 0.00037067
node 55: dome-like broad and low protuberance: 1
node 56: dome-like broad and low protuberance: 1
node 57: dome-like broad and low protuberance: 0.01152845, arcuate protuberance, dorsal to orbits in adults: 0.00741242, paddle-like caudally directed solid blade: 0.00135036, rod-like caudodorsally directed solid crest: 0.00111624, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00136323, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00122808, cockscomb formed by solid plate-like extension of pmx: 0.97600122*

node 58: dome-like broad and low protuberance: 0.00041087, arcuate protuberance, dorsal to orbits in adults: 0.0002836, paddle-like caudally directed solid blade: 0.00009616, rod-like caudodorsally directed solid crest: 0.00008892, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00009655, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00009238, cockscomb formed by solid plate-like extension of pmx: 0.99893153*
node 59: dome-like broad and low protuberance: 0.00004377, arcuate protuberance, dorsal to orbits in adults: 0.00003996, paddle-like caudally directed solid blade: 0.00003435, rod-like caudodorsally directed solid crest: 0.00003414, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00003437, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00003424, cockscomb formed by solid plate-like extension of pmx: 0.99977916*
node 60: cockscomb formed by solid plate-like extension of pmx: 1
node 61: dome-like broad and low protuberance: 0.00003305, arcuate protuberance, dorsal to orbits in adults: 0.00003294, paddle-like caudally directed solid blade: 0.00003276, rod-like caudodorsally directed solid crest: 0.00003276, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00003276, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00003276, cockscomb formed by solid plate-like extension of pmx: 0.99980297*
node 62: dome-like broad and low protuberance: 0.0000305, arcuate protuberance, dorsal to orbits in adults: 0.0000305, paddle-like caudally directed solid blade: 0.0000305, rod-like caudodorsally directed solid crest: 0.0000305, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.0000305, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.0000305, cockscomb formed by solid plate-like extension of pmx: 0.99981702*
node 63: cockscomb formed by solid plate-like extension of pmx: 1
node 64: !
node 65: cockscomb formed by solid plate-like extension of pmx: 1
node 66: !
node 67: !
node 68: !
node 69: !
node 70: !
node 71: dome-like broad and low protuberance: 0.0000305, arcuate protuberance, dorsal to orbits in adults: 0.0000305, paddle-like caudally directed solid blade: 0.0000305, rod-like caudodorsally directed solid crest: 0.0000305, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.0000305, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.0000305, cockscomb formed by solid plate-like extension of pmx: 0.99981702*
node 72: cockscomb formed by solid plate-like extension of pmx: 1
node 73: !
node 74: cockscomb formed by solid plate-like extension of pmx: 1
node 75: !
node 76: dome-like broad and low protuberance: 0.00004219, arcuate protuberance, dorsal to orbits in adults: 0.00003851, paddle-like

caudally directed solid blade: 0.0000331, rod-like caudodorsally directed solid crest: 0.00003289, excavated rostrally-facing protuberance, rostrorodorsal to orbit: 0.00003311, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00003299, cockscomb formed by solid plate-like extension of pmx: 0.9997872*
node 77: cockscomb formed by solid plate-like extension of pmx: 1
node 78: cockscomb formed by solid plate-like extension of pmx: 1
node 79: dome-like broad and low protuberance: 0.00038363, arcuate protuberance, dorsal to orbits in adults: 0.00026477, paddle-like caudally directed solid blade: 0.00008973, rod-like caudodorsally directed solid crest: 0.00008297, excavated rostrally-facing protuberance, rostrorodorsal to orbit: 0.0000901, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00008619, cockscomb formed by solid plate-like extension of pmx: 0.99900262*
node 80: cockscomb formed by solid plate-like extension of pmx: 1
node 81: cockscomb formed by solid plate-like extension of pmx: 1
node 82: dome-like broad and low protuberance: 0.04474706, arcuate protuberance, dorsal to orbits in adults: 0.62928265*, paddle-like caudally directed solid blade: 0.09027149*, rod-like caudodorsally directed solid crest: 0.03587777, excavated rostrally-facing protuberance, rostrorodorsal to orbit: 0.09326126*, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.06186292, cockscomb formed by solid plate-like extension of pmx: 0.04469686
node 83: !
node 84: !
node 85: dome-like broad and low protuberance: 0.02236495, arcuate protuberance, dorsal to orbits in adults: 0.20574517*, paddle-like caudally directed solid blade: 0.34499939*, rod-like caudodorsally directed solid crest: 0.01958248, excavated rostrally-facing protuberance, rostrorodorsal to orbit: 0.35722428*, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.02773453, cockscomb formed by solid plate-like extension of pmx: 0.0223492
node 86: excavated rostrally-facing protuberance, rostrorodorsal to orbit: 1
node 87: dome-like broad and low protuberance: 0.00125813, arcuate protuberance, dorsal to orbits in adults: 0.00655339, paddle-like caudally directed solid blade: 0.97741235*, rod-like caudodorsally directed solid crest: 0.00117779, excavated rostrally-facing protuberance, rostrorodorsal to orbit: 0.01092748, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00141318, cockscomb formed by solid plate-like extension of pmx: 0.00125768
node 88: paddle-like caudally directed solid blade: 1
node 89: paddle-like caudally directed solid blade: 1
node 90: dome-like broad and low protuberance: 0.01870698, arcuate protuberance, dorsal to orbits in adults: 0.69491849*, paddle-like caudally directed solid blade: 0.03392779, rod-like caudodorsally directed solid crest: 0.06948091, excavated rostrally-facing protuberance, rostrorodorsal to orbit: 0.0349274, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.12934823*, cockscomb formed by solid plate-like extension of pmx: 0.0186902

node 91: dome-like broad and low protuberance: 0.00221998, arcuate protuberance, dorsal to orbits in adults: 0.91128844*, paddle-like caudally directed solid blade: 0.00345468, rod-like caudodorsally directed solid crest: 0.00633874, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00353577, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.07094378, cockscomb formed by solid plate-like extension of pmx: 0.00221862
node 92: arcuate protuberance, dorsal to orbits in adults: 1
node 93: dome-like broad and low protuberance: 0.0018084, arcuate protuberance, dorsal to orbits in adults: 0.88638311*, paddle-like caudally directed solid blade: 0.00219605, rod-like caudodorsally directed solid crest: 0.00310153, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00222151, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.10248143, cockscomb formed by solid plate-like extension of pmx: 0.00180797
node 94: !
node 95: !
node 96: !
node 97: !
node 98: dome-like broad and low protuberance: 0.00019547, arcuate protuberance, dorsal to orbits in adults: 0.99565353*, paddle-like caudally directed solid blade: 0.00020745, rod-like caudodorsally directed solid crest: 0.00023541, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00020823, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00330445, cockscomb formed by solid plate-like extension of pmx: 0.00019546
node 99: dome-like broad and low protuberance: 0.00003889, arcuate protuberance, dorsal to orbits in adults: 0.99967504*, paddle-like caudally directed solid blade: 0.00003923, rod-like caudodorsally directed solid crest: 0.00004004, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00003926, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00012866, cockscomb formed by solid plate-like extension of pmx: 0.00003889
node 100: arcuate protuberance, dorsal to orbits in adults: 1
node 101: arcuate protuberance, dorsal to orbits in adults: 1
node 102: dome-like broad and low protuberance: 0.00003889, arcuate protuberance, dorsal to orbits in adults: 0.99967504*, paddle-like caudally directed solid blade: 0.00003923, rod-like caudodorsally directed solid crest: 0.00004004, excavated rostrally-facing protuberance, rostrrodorsal to orbit: 0.00003926, ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 0.00012866, cockscomb formed by solid plate-like extension of pmx: 0.00003889
node 103: arcuate protuberance, dorsal to orbits in adults: 1
node 104: arcuate protuberance, dorsal to orbits in adults: 1
node 105: !
node 106: ns fold rising dorsally or caudodorsally, lat excavated, resting over f: 1
node 107: !
node 108: !
node 109: !

node 110: !
node 111: !
node 112: !
node 113: dome-like broad and low protuberance: 0.01406166, arcuate
protuberance, dorsal to orbits in adults: 0.22628275*, paddle-like
caudally directed solid blade: 0.01883853, rod-like caudodorsally
directed solid crest: 0.32098981*, excavated rostrally-facing
protuberance, rostrorodorsal to orbit: 0.01915225, ns fold rising
dorsally or caudodorsally, lat excavated, resting over f: 0.3866186*,
cockscomb formed by solid plate-like extension of pmx: 0.01405639
node 114: ns fold rising dorsally or caudodorsally, lat excavated,
resting over f: 1
node 115: dome-like broad and low protuberance: 0.00107528, arcuate
protuberance, dorsal to orbits in adults: 0.00741277, paddle-like
caudally directed solid blade: 0.00121793, rod-like caudodorsally
directed solid crest: 0.97579078*, excavated rostrally-facing
protuberance, rostrorodorsal to orbit: 0.0012273, ns fold rising
dorsally or caudodorsally, lat excavated, resting over f: 0.01220082,
cockscomb formed by solid plate-like extension of pmx: 0.00107512
node 116: rod-like caudodorsally directed solid crest: 1
node 117: dome-like broad and low protuberance: 0.00008197, arcuate
protuberance, dorsal to orbits in adults: 0.00026497, paddle-like
caudally directed solid blade: 0.00008609, rod-like caudodorsally
directed solid crest: 0.99899542*, excavated rostrally-facing
protuberance, rostrorodorsal to orbit: 0.00008636, ns fold rising
dorsally or caudodorsally, lat excavated, resting over f: 0.00040323,
cockscomb formed by solid plate-like extension of pmx: 0.00008197
node 118: rod-like caudodorsally directed solid crest: 1
node 119: rod-like caudodorsally directed solid crest: 1
node 120: !
node 121: !
node 122: !
node 123: !
node 124: !
node 125: !
node 126: !
node 127: !
node 128: !