

Supplementary Information to: “A new Early Cretaceous brachiosaurid from northwestern
Gondwana (Villa de Leiva, Colombia)”
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COMPLETE RESULTS OF THE PHYLOGENETIC ANALYSES

FIGURE S1. Complete strict consensus tree obtained, without modifications, from the 10 most parsimonious trees recovered of 1075 steps (see text).

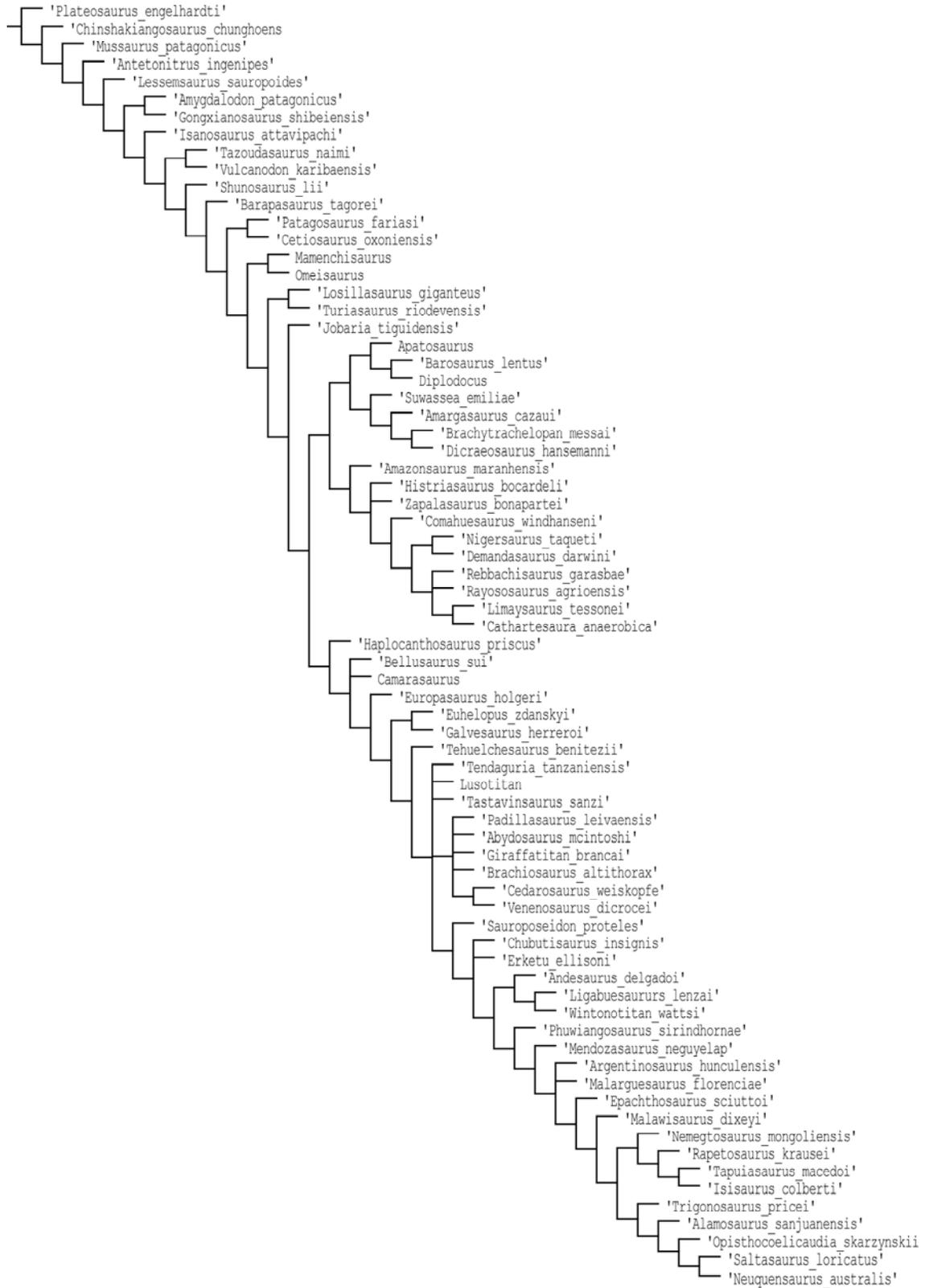


FIGURE S2. Modified Strict Consensus Tree, scoring separately the holotype of *Brachiosaurus* and the skull USNM 5730, assigned to this taxon by Carpenter and Tidwell (1998), in order to determine the systematic affinities of the skull (see text). Although referring it to *Brachiosaurus* Carpenter and Tidwell (1998) noted that its morphology could be regarded as intermediate between *Camarasaurus* and *Brachiosaurus*. Following the same tree search described in the text the present analysis recovered the specimen USNM 5730 as a brachiosaurid as shown in the strict consensus tree of the 268 MPTs obtained. *Lusotitan* was pruned after the tree search, and their different positions are marked with an 'a'.



MODIFICATIONS MADE IN RESPECT TO CARBALLIDO ET AL. (2012) AND
CARBALLIDO AND SANDER (2014)

Modified Characters

Character 19: Jugal, contribution to antorbital fenestra: absent (0); present, but very reduced (1); present and large, bordering approximately one-third its perimeter (2). Modified from Upchurch, 1998 (character 20) and Wilson, 2002 (character 13).

One state was added, which makes reference to the small participation of the jugal to the antorbital fenestra, as is widespread present among basal sauropodomorphs, including basal sauropods (e.g., *Plateosaurus*, *Shunosaurus*), and among neosauropods in the brachiosaurids *Giraffatitan* and *Abydosaurus* and some titanosaurs such as *Rapetosaurus*.

Character 23: Ventral edge of anterior process of the quadratojugal: straight, not expanded ventrally (0); slightly expanded ventrally, forming a small bulge, with a height less than twice the minimum height of the process (1); well expanded ventrally, forming a distinct bulge, with a height twice or more the minimum height of the ramus (2). Modified from Upchurch et al., 2004 (character 26).

Based on new evidence a second state was included here. Therefore, the presence of a ventral bulge or expansion in the quadratojugal can be slightly developed (state 1; as in *Giraffatitan* and *Abydosaurus*) or being more distinct as in *Europasaurus* and *Tapuiasaurus* (state 2). See discussion in Marpmann et al. (2014)

Character 42: Parietal, distance separating supratemporal fenestrae: 0.8 times or less than the long axis of supratemporal fenestra (0); 0.8-1.2 times the the long axis of supratemporal fenestra 0.8-1.2 (1); 1.2 times or more than the long axis of supratemporal (2). Modified from Wilson, 2002 (character 24).

A new intermediate state was added in order to include the morphology observed in *Europasaurus* and other sauropods in which the distance that separate both supratemporal fenestrae (in dorsal view) is almost the same than the total length of the supratemporal fenestra (see Marpmann et al., 2014). The distance that separate the supratemporal fenestra (the total width of the parietals) is measured including the parietal portions that forms the supratemporal fossa in some sauropodomorphs (as in *Plateosaurus*), whereas the length of the supratemporal fenestra is measured lateromedially, and excludes the supratemporal fossa (if present).

Character 102: V-shaped wear facets: present (0); absent (1).

We modified the previous character, splitting the presence absence of V-shaped wear facets from the low and high angled wear facets and the degree of wear observed in the teeth. Therefore, three characters were added in order to score and differentiate the possible morphologies of wear observed in sauropod teeth (see characters 342-344).

Character 139: Dorsal centra, pneumatic structures: absent, dorsal centra with solid internal structure (0); present, dorsal centra with simple and big air-spaces (camerate) (1); present, dorsal centra with small and complex air-spaces (polycamerate) (2); present, dorsal centra with small and complex air spaces (camellate) (3).

Here we introduce a new state, which refers to the polycamerate morphology observed in *Giraffatitan* and *Tastavinsaurus*.

Added Characters

Twenty-eight characters were added at the end of the data matrix (342-370). These characters include some new ones as well as some taken from other analyses.

Character Scoring Modifications

Character 176: Posterior dorsal vertebrae, posterior centrodiapophyseal lamina: single lamina (0) or divided lamina (1).

TABLE 1S. Modifications made in Character 176

Taxon	Old Score	New Score
<i>Paluxysaurus</i>	0	?
<i>Chubutisaurus</i>	0	?
<i>Giraffatitan</i>	?	1
<i>Tastavinsaurus</i>	0	1
<i>Alamosaurus</i>	0	1

Character 119: Cervical vertebrae with an accessory lamina, which runs from the postzygodiapophyseal lamina (PODL) up to the spinoprezygapophyseal lamina (SPRL): absent (0); present (1).

Phuwiangosaurus and *Erketu* were scored as having the lamina (1), following to D'Emic (2013).

Character 257: Humeral distal condyles, articular surface shape: restricted to distal portion of humerus (0); exposed on anterior portion of humeral shaft (1).

Giraffatitan was scored as missing (?).

Taxon Sampling

Besides the inclusion of *Padillasaurus* the solely modification made into taxon sampling used by Carballido et al. (2012) and Carballido and Sander (2014) was the change of '*Paluxysaurus*' by *Sonidosaurus* as terminal taxa and the inclusion of *Abydosaurus* and *Lusotitan* (see text). Carballido et al. (2012) and Carballido and Sander (2014), have scored '*Paluxysaurus*' mainly based on Rose (2007). Nevertheless, a recent revision (D'Emic, 2013) showed that the material described as '*Paluxysaurus*' by Rose (2007) actually pertains to *Sauroposeidon* Wedel et al., 2000a. Therefore, some scores were added and some characters changed based on Wedel et al. (2000a, b) and Rose (2007).

CHARACTER LIST

The following character list is ordered by anatomical regions.

Skull

- (1) Posterolateral processes of premaxilla and lateral processes of maxilla, shape: without midline contact (0); with midline contact forming marked narial depression, subnarial foramen not visible laterally (1). (Wilson, 2002:ch. 1).
- (2) Premaxillary anterior margin shape: without step (0); with marked step but short step (1); with marked and long step (2) (modified from Wilson, 2002:ch. 2).
- (3) Premaxilla, ascending process shape in lateral view: convex (0); concave, with a large dorsal projection (1); sub-rectilinear and directed posterodorsally (2). (Whitlock, 2011:ch. 3)
- (4) Premaxilla, external surface: without anteroventrally orientated vascular grooves originating from an opening in the maxillary contact (0); vascular grooves present (1). (Whitlock, 2011:ch. 2)
- (5) Maxillary border of external naris, length: short, making up much less than one-fourth narial perimeter (0); long, making up more than one third narial perimeter (1). (Wilson, 2002:ch. 3).
- (6) Maxilla, foramen anterior to the preantorbital fenestra : absent (0); present (1). (Zaher *et al.*, 2011:ch. 244).
- (7) Preantorbital fenestra: absent (0); present, being wide and laterally opened (1). (Modified from Wilson, 2002:ch. 4).
- (8) Subnarial foramen and exterior maxillary foramen, position: well distanced from one another (0); separated by narrow bony isthmus (1). (Wilson, 2002:ch. 5)
- (9) Antorbital fenestra: much shorter than orbital maximum diameter, less than 85% of orbit (0); subequal to orbital maximum diameter, greater than 85% orbit (1). (Modified from Wilson, 2002:ch. 6 following to Whitlock, 2011:ch. 13)
- (10) Antorbital fenestra, shape of dorsal margin: straight or convex (0); concave (1). (Whitlock, 2011:ch. 14).
- (11) Antorbital fossa: present (0); absent (1). (Wilson, 2002:ch. 7)
- (12) External nares position: terminal (0); retracted to level of orbit (1); retracted to a position between orbits (2). (Wilson, 2002:ch. 8). Ordered character.
- (13) External nares, maximum diameter: shorter (0); or longer than orbital maximum diameter (1). (Wilson, 2002:ch. 9)
- (14) Orbital ventral margin, anteroposterior length: broad, with subcircular orbital margin (0); reduced, with acute orbital margin (1). (Wilson, 2002:ch. 10)
- (15) Lacrimal, anterior process: present (0); absent (1). (Wilson, 2002:ch. 11)
- (16) Jugal contribution to the ventral border of the skull: present and long (0); absent or very reduced (1). (Carballido *et al.*, 2012:ch. 16).
- (17) Quadratojugal-Maxilla contact: absent or small (0); broad (1). (Whitlock, 2011:ch. 10).
- (18) Jugal-ectopterygoid contact: present (0); absent (1). (Wilson, 2002:ch. 12)
- (19) Jugal, contribution to antorbital fenestra: absent (0); present, but very reduced (1); present and large, bordering approximately one-third its perimeter (2). (Modified from Wilson, 2002:ch. 13).
- (20) Quadratojugal, position of anterior terminus: posterior to middle of orbit (0); anterior margin of orbit or beyond (1). (Whitlock, 2011:ch. 30).
- (21) Quadratojugal, anterior process length: short, anterior process shorter than dorsal process (0); long, anterior process more than twice as long as dorsal process (1). (Wilson, 2002:ch. 32)
- (22) Quadratojugal, angle between anterior and dorsal processes: less than or equal to 90°, so that the quadrate shaft is directed dorsally (0); greater than 90°, approaching 130°, so that the quadrate shaft slants posterodorsally (1). (Whitlock, 2011:ch. 31).

- (23) Ventral edge of anterior surface of the quadratojugal: straight, not expanded ventrally (0); Slightly expanded ventrally, forming a small bulge, which height is less than twice the ramus height (1); well expanded ventrally, forming a notorious bulge, which height is twice or more the minimum height of the ramus (2). (Modified from Upchurch et al., 2004:ch. 26)
- (24) Squamosal contribution to the supratemporal fenestra: present, the squamosal is well visible in dorsal view (0); reduced or absent (1). (Curry Rogers, 2005:ch. 37).
- (25) Squamosal-quadratojugal contact: present (0); absent (1). (Wilson, 2002:ch. 31)
- (26) Squamosal, posteroventral margin: smooth (0); "with prominent, ventrally directed ""prong"" (1). (Whitlock, 2011:ch. 37).
- (27) Prefrontal posterior process size: small, not projecting far posterior of frontal-nasal suture (0); elongate, approaching parietal (1). (Wilson, 2002:ch. 14)
- (28) Prefrontal, posterior process shape: flat (0); hooked (1). (Wilson, 2002:ch. 15)
- (29) Prefrontal, anterior process: absent (0); present (1). (Curry Rogers, 2005:ch. 30)
- (30) Prefrontal-Frontal contact width: large, equal or longer than the anteroposterior length of the prefrontal (0); narrow, less than half the anteroposterior length of the prefrontal (1). (Zaher *et al.*, 2011:ch. 239).
- (31) Postorbital, ventral process shape: transversely narrow (0); broader transversely than anteroposteriorly (1). (Wilson, 2002:ch. 16).
- (32) Postorbital, posterior process: present (0); absent (1). (Wilson, 2002:ch. 17).
- (33) Postorbital, posterior margin articulating with the squamosal : with tapering posterior process (0); with a deep posterior process (1). (Zaher *et al.*, 2011:ch. 245).
- (34) Frontal contribution to supratemporal fossa: present (0); absent (1). (Wilson, 2002:ch. 18)
- (35) Frontals, midline contact (symphysis): sutured (0); or fused in adult individuals (1). (Wilson, 2002:ch. 19)
- (36) Frontal, anteroposterior length: approximately twice (0); or less than minimum transverse breadth (1). (Wilson, 2002:ch. 20)
- (37) Frontal-nasal suture, shape: flat or slightly bowed anteriorly (0); V-shaped, pointing posteriorly (1). (Whitlock, 2011:ch. 21)
- (38) Frontals, dorsal surface: without paired grooves facing anterodorsally (0); grooves present, extend on to nasal (1). (Whitlock, 2011:ch. 22)
- (39) Frontal, contribution to dorsal margin of orbit: contribution to dorsal margin of orbit: less than 1.5 times the contribution of prefrontal (0); at least 1.5 times the contribution of prefrontal (1). (Whitlock, 2011:ch. 23)
- (40) Parietal occipital process, dorsoventral height: short, less than the diameter of the foramen magnum (0); deep, nearly twice the diameter of the foramen magnum (1). (Wilson, 2002:ch.21)
- (41) Parietal, contribution to post-temporal fenestra: present (0); absent (1). (Wilson, 2002:ch. 22)
- (42) Parietal, distance separating supratemporal fenestrae: less than the long axis of supratemporal fenestra, 0.8 or less (0); almost the same than the long axis of supratemporal fenestra 0.8-1.2 (1); much larger than the long axis of supratemporal fenestra more than 1.2 (2). (Modified from Wilson, 2002: ch. 24).
- (43) Postparietal foramen: absent (0); present (1). (Wilson, 2002:ch. 23)
- (44) Paroccipital process distal terminus:: straight, slightly expanded surface (0); rounded, tongue-like process (1). (Whitlock, 2011:ch. 42)
- (45) Supratemporal fenestra: present (0); absent (1). (Wilson, 2002:ch. 25)
- (46) Supratemporal fenestra, long axis orientation: anteroposterior (0); transverse (1). (Wilson, 2002:ch.26)
- (47) Supratemporal fenestra, maximum diameter: much longer than (0); or subequal to that of foramen magnum (1). (Wilson, 2002:ch. 27)
- (48) Supratemporal region, anteroposterior length: temporal bar longer (0); or shorter anteroposteriorly than transversely (1). (Wilson, 2002:ch. 28)

- (49) Supratemporal fossa, lateral exposure: not visible laterally, obscured by temporal bar (0); visible laterally, temporal bar shifted ventrally (1). (Wilson, 2002:ch. 29)
- (50) Supraoccipital, sagittal nuchal crest: broad, weakly developed (0); narrow, sharp and distinct (1). (Whitlock, 2011:ch. 45).
- (51) Laterotemporal fenestra, anterior extension: posterior to orbit (0); ventral to orbit (1). (Wilson, 2002:ch. 30)
- (52) Quadrate fossa: absent (0); present (1). (Wilson, 2002:ch. 33)
- (53) Quadrate fossa, depth: shallow (0); deeply invaginated (1). (Wilson, 2002:ch. 34)
- (54) Quadrate fossa, orientation: posterior (0); posterolateral (1). (Wilson, 2002:ch. 35)
- (55) Quadrate, articular surface shape: quadrangular in ventral view, oriented transversely (0); roughly triangular in shape or thin, crescent-shaped surface with anteriorly directed medial process (1). (Modified sensu Mannion *et al.*, 2011. from Whitlock, 2011:ch. 32).
- (56) Quadrate, articular surface shape: quadrangular in ventral view, oriented transversely or roughly triangular in shape (0); thin, crescent-shaped surface with anteriorly directed medial process (1). (Modified sensu Mannion *et al.*, 2011 from Whitlock, 2011:ch. 32).
- (57) Palatobasal contact, shape: pterygoid with small facet (0); dorsomedially orientated hook (1); or rocker-like surface for basipterygoid articulation (2). (Wilson, 2002:ch. 36)
- (58) Pterygoid, transverse flange (i.e. ectopterygoid process) position: posterior of orbit (0); between orbit and antorbital fenestra (1); anterior to antorbital fenestra (2). (Wilson, 2002:ch.37). Ordered character.
- (59) Pterygoid, quadrate flange size: large, palatobasal and quadrate articulations well separated (0); small, palatobasal and quadrate articulations approach (1). (Wilson, 2002:ch. 38)
- (60) Pterygoid, palatine ramus shape: straight, at level of dorsal margin of quadrate ramus (0); stepped, raised above level of quadrate ramus (1). (Wilson, 2002:ch.39)
- (61) Pterygoid, sutural contact with ectopterygoid: broad, along the medial or lateral surface (0); narrow, restricted to the anterior tip of the ectopterygoid (1). (Zaher et al. 2011:ch. 240)
- (62) Palatine, lateral ramus shape: plate-shaped (long maxillary contact) (0); rod-shaped (narrow maxillary contact) (1). (Wilson, 2002:ch. 40)
- (63) Epipterygoid: present (0); absent (1). (Wilson, 2002:ch. 41)
- (64) Vomer, anterior articulation: maxilla (0); premaxilla (1). (Wilson, 2002:ch. 42)
- (65) Supraoccipital, height: twice subequal to (0); or less than height of foramen magnum (1). (Wilson, 2002:ch. 43)
- (66) Paroccipital process, ventral non-articular process: absent (0); present (1). (Wilson, 2002:ch. 44)
- (67) Crista prootica, size: rudimentary (0); expanded laterally into dorsolateral process (1). (Wilson, 2002:ch. 45)
- (68) Basipterygoid processes, length: short, approximately twice (0); or elongate, at least four times basal diameter (1). (Wilson, 2002:ch. 46)
- (69) Basipterygoid processes, angle of divergence: approximately 45° (0); less than 30° (1). (Wilson, 2002:ch. 47)
- (70) Basal tubera, anteroposterior depth: approximately half dorsoventral height (0); sheet-like, 20% dorsoventral height (1). (Wilson, 2002:ch. 48)
- (71) Basal tubera, breadth: much broader than (0); or narrower than occipital condyle (1). (Wilson, 2002:ch. 49)
- (72) Basal tubera: distinct from basipterygoid (0); reduced to slight swelling on ventral surface of basipterygoid (1). (Whitlock, 2011:ch. 53)
- (73) Basal tubera, shape of posterior face: convex (0); slightly concave (1). (Whitlock, 2011:ch. 54)
- (74) Basioccipital depression between foramen magnum and basal tubera: absent (0); present (1). (Wilson, 2002:ch. 50)
- (75) Basisphenoid/basipterygoid recess: present (0); absent (1). (Wilson, 2002:ch. 51)
- (76) Basisphenoid/quadrate contact: absent (0); present (1). (Wilson, 2002)

- (77) Basisphenoid, sagittal ridge between basipterygoid processes: absent (0); present (1). (Zaher *et al.*, 2011:ch. 242)
- (78) Basipterygoid processes, orientation: perpendicular to (0); or angled approximately 45° to skull roof (1). (Wilson, 2002:ch. 53)
- (79) Basipterygoid, area between the basipterygoid processes and parasphenoid rostrum: is a mildly concave subtriangular region (0); forms a deep slot-like cavity that passes posteriorly between the bases of the basipterygoid processes (1). (Mannion *et al.*, 2012:ch. 48)
- (80) Occipital region of skull, shape: anteroposteriorly deep, paroccipital processes oriented posterolaterally (0); flat, paroccipital processes oriented transversely (1). (Wilson, 2002:ch. 54)
- (81) Dentary, depth of anterior end of ramus: slightly less than that of dentary at midlength (0); 150% minimum depth (1). (Wilson, 2002:ch. 55)
- (82) Dentary, anteroventral margin shape: gently rounded (0); sharply projecting triangular process (1). (Wilson, 2002:ch. 56)
- (83) Dentary symphysis, orientation: angled 15° or more anteriorly to (0); or perpendicular to axis of jaw ramus (1). (Wilson, 2002:ch. 57)
- (84) Dentary, cross-sectional shape of symphysis: oblong or rectangular (0); subtriangular, tapering sharply towards ventral extreme (1); subcircular (2). (Whitlock, 2011:ch. 60)
- (85) Dentary, tuberosity on labial surface near symphysis: absent (0); present (1). (Whitlock, 2011:ch. 57)
- (86) Mandible, coronoid eminence: strongly expressed, clearly rising above plane of dentigerous portion (0); absent (1). (Whitlock, 2011:ch. 62)
- (87) External mandibular fenestra: present (0); absent (1). (Wilson, 2002:ch. 58)
- (88) Surangular depth: less than twice (0); or more than two and one-half times maximum depth of the angular (1). (Wilson, 2002:ch. 59)
- (89) Surangular ridge separating adductor and articular fossae: absent (0); present (1). (Wilson, 2002:ch. 60)
- (90) Adductor fossa, medial wall depth: shallow (0); deep, prearticular expanded dorsoventrally (1). (Wilson, 2002:ch. 61)
- (91) Splenial posterior process, position: overlapping angular (0); separating anterior portions of prearticular and angular (1). (Wilson, 2002:ch. 62)
- (92) Splenial posterodorsal process: present, approaching margin of adductor chamber (0); absent (1). (Wilson, 2002:ch. 63)
- (93) Coronoid, size: extending to dorsal margin of jaw (0); reduced, not extending dorsal to splenial (1); absent (2). (Wilson, 2002:ch. 64)
- (94) Tooth rows, shape of anterior portions: narrowly arched, anterior portion of tooth rows V-shaped (0); broadly arched, anterior portion of tooth rows U-shaped (1); rectangular, tooth-bearing portion of jaw perpendicular to jaw rami (2). (Wilson, 2002:ch. 65)
- (95) Tooth rows, length: extending to orbit (0); restricted anterior to orbit (1); restricted anterior to antorbital fenestra (2); restricted anterior to subnarial foramen (3). (Modified from Wilson, 2002:ch. 66). Ordered character.
- (96) Dentary teeth, number: greater than 20 (0); 10-17 (1); 9 or fewer (2). (modified from Wilson, 2002:ch.73). Ordered character.
- (97) Replacement teeth per alveolus, number: two or fewer (0); more than four (1). (Wilson, 2002:ch. 74)
- (98) Lateral plate: absent (0); present (1). (Upchurch *et al.*, 2004:ch. 9)
- (99) Teeth, orientation: perpendicular (0); or oriented anteriorly relative to jaw margin (1). (Wilson, 2002:ch. 75)
- (100) Tooth crowns, orientation: aligned along jaw axis, crowns do not overlap (0); aligned slightly anterolingually, tooth crowns overlap (1). (Wilson, 2002:ch. 69)
- (101) Crown-to-crown occlusion: absent (0); present (1). (Wilson, 2002:ch. 67)
- (102) V-shaped wear facets: present (0); absent (1). (Modified from Wilson, 2002:ch. 68)

- (103) Tooth crowns, cross-sectional shape at mid-crown: elliptical (0); D-shaped (1); sub-cylindrical (2); cylindrical (3). (Wilson, 2002:ch. 70)
- (104) Enamel surface texture: smooth (0); wrinkled (1). (Wilson, 2002:ch.71)
- (105) Thickness of enamel asymmetric labiolingually: absent (0); present (1). (Whitlock, 2011:ch. 74)
- (106) Marginal tooth denticles: present (0); absent on posterior edge (1); absent on both anterior and posterior edges (2). (Wilson, 2002:ch. 72). Ordered character.
- (107) Teeth, longitudinal grooves on lingual aspect: absent (0); present (1). (Wilson, 2002:ch. 76)
- (108) SI values for tooth crowns: less than 3.0 (0); 3.0-4.0 (1); 4.0-5.0 (2); more than 5.0 (3). (Upchurch *et al.*, 2004:chs. 67-69). Ordered character.

Cervical Vertebrae

- (109) Cervical vertebrae, number: 10 or fewer (0); 12 (1); 13-14 (2); 15 (3); 16 or more (4). (Modified from Wilson, 2002:ch. 80 and Upchurch *et al.*, 2004:chs. 96-100).
- (110) Atlas, intercentrum occipital facet shape: rectangular in lateral view, length of dorsal aspect subequal to that of ventral aspect (0); expanded anteroventrally in lateral view, anteroposterior length of dorsal aspect shorter than that of ventral aspect (1). (Wilson, 2002:ch. 79).
- (111) Cervical centra, articulations: amphicoelous (0); opisthocoelous (1). (Salgado *et al.*, 1997:ch. 1 ; Wilson, 2002:ch. 82; Upchurch, 1998:ch. 81 and Upchurch *et al.*, 2004:ch. 103)
- (112) Cervical centra, ventral surface: is flat or slightly convex transversely (0); transversely concave (1). (Upchurch, 1998:ch. 84 and Upchurch *et al.*, 2004:ch. 107)
- (113) Cervical centra, midline keels on ventral surface: prominent and plate-like (0); reduced to low ridges or absent (1). (Upchurch, 1998:ch. 83 and Upchurch *et al.*, 2004:ch. 106)
- (114) Cervical centra, pleurocoels: absent (0); present with well defined anterior, dorsal, and ventral edges, but not the posterior one (1); present, with well defined edges; present but very reduced in size (3). (Carballido *et al.*, 2012)
- (115) Cervical centra, pleurocoels: singles without division (0); with a well defined anterior excavation and a posterior smooth fossa (1); divided by a bone septum, resulting in an anterior and a posterior lateral excavation (2); divided in three or more lateral excavations, resulting in a complex morphology (3); with a well defined anterior excavation and a posterior smooth fossa (Modified from Salgado *et al.*, 1997; Wilson, 2002; Harris, 2006). **Ordered character.**
- (116) Cervical vertebrae, height divided width (measured in its posterior articular surface): higher than 1.1 (0), around 1 (1); between 0.9 and 0.7 (2); smaller than 0.7 (3). (Modified from Wilson, 2002:ch. 84; Upchurch, 1998:ch. 85 and Upchurch *et al.*, 2004:ch. 108). **Ordered character.**
- (117) Cervical centra, small notch in the dorsal margin of the posterior articular surface: absent (0); present (1). (Carballido *et al.*, 2012)
- (118) Cervical vertebrae, neural arch lamination: well developed, with well marked laminae and fossae (0); rudimentary, with diapophyseal laminae absent or very slightly marked (1). (Wilson, 2002:ch, 81)
- (119) Cervical vertebrae with an accessory lamina, which runs from the postzygodiapophyseal lamina (PODL) up to the spinoprezygapophyseal lamina (SPRL): absent (0); present (1). (Modified from Sereno *et al.*, 2007:chs. 50, 51; Whitlock, 2011:chs. 78, 96).
- (120) Cervical centra, internal pneumaticity: absent (0); present with singles and wide cavities (1); present, with several small and complex internal cavities (2). (Modified from Carballido *et al.*, 2011). **Ordered character.**
- (121) Anterior cervical vertebrae, prespinal lamina: absent (0); present (1). (Carballido *et al.*, 2012).
- (122) Anterior cervical vertebrae, neural spine shape: single (0); bifid (1). (Wilson, 2002:ch. 72; Upchurch *et al.*, 2004:ch. 118)

- (123) Middle and posterior cervical vertebrae, prespinal lamina: absent (0); present (1). (Carballido et al., 2012).
- (124) Middle cervical vertebrae, lateral fossae on the prezygapophysis process: absent (0); present (1). (Harris, 2006).
- (125) Middle, cervical vertebrae, height of the neural arch: less than the height of the posterior articular surface (0); higher than the height of the posterior articular surface (1). (Wilson, 2002:ch. 87; similar Upchurch *et al.*, 2004:111 and 112)
- (126) Middle cervical centrum, anteroposterior length divided the height of the posterior articular surface: less than 4 (0); more than 4 (1). (Wilson, 2002:ch. 74; and Upchurch *et al.*, 2004:ch. 102).
- (127) Middle and posterior cervical vertebrae, morphology of the centroprezygapophyseal lamina: single (0); dorsally divided, resulting in a lateral and medial lamina, being the medial lamina linked with the intraprezygapophyseal lamina and not with the prezygapophysis (1); divided, resulting in the presence of a “true” divided centroprezygapophyseal lamina, which is dorsally connected to the prezygapophysis (2). (Carballido et al., 2012).
- (128) Middle and posterior cervical vertebrae, morphology of the centropostzygapophyseal lamina (CPOL): single (0); divided, with the medial part contacting the intrapostzygapophyseal lamina (1) (Carballido et al., 2012)
- (129) Middle and posterior cervical vertebrae, articular surface of zygapophyses: flat (0); transversally convex (1). (Upchurch *et al.*, 2004)
- (130) Posterior cervical vertebrae, lateral profile of the neural spine: displays steeply sloping cranial and caudal faces (0); displays steeply sloping cranial face and noticeably less steep caudal margin (1). (Upchurch *et al.*, 2004:ch. 119)
- (131) Posterior cervical vertebrae, neural spine shape: without a great lateral expansion (0); laterally expanded, being equal or wider than the vertebral centrum (1). (González Riga *et al.*, 2009)
- (132) Posterior cervical and anterior dorsal vertebrae, neural spine shape: single (0); bifid (1). (Wilson, 2002:ch. 90, Upchurch *et al.*, 2004:ch. 118)
- (133) Posterior cervical and anterior dorsal bifid neural spines, median tubercle: absent (0); present (1).

Dorsal Vertebrae

- (134) Number of dorsal vertebrae: 14 or more (0); 13 (1); 12 (2); 10 (3). (Modified from Wilson, 2002:ch. 91; Upchurch *et al.* 2004:ch. 122-125)
- (135) Dorsal centra, pleurocoels: absent (0); present (1). (Wilson, 2002:ch. 78; Upchurch *et al.* 2004:128)
- (136) Dorsal vertebrae, transverse processes: are directed laterally or slightly upwards (0); are directed strongly dorsolaterally (1). (Upchurch *et al.*, 2004:ch. 138)
- (137) Dorsal vertebrae, distal end of the transverse process: curves smoothly into the dorsal surface of the process (0); is set off from the dorsal surface, the latter having a distinct dorsally facing flattened area (1). (Upchurch *et al.*, 2004:ch. 140)
- (138) Dorsal vertebrae, non bifid neural spine in anterior or posterior view: posses subparallel lateral margins (0); posses lateral margins which slightly diverge dorsally (1); posses lateral margins which strongly diverge dorsally (2). (Modified from Wilson, 2002:ch. 107; Upchurch *et al.*, 2004:ch. 155)
- (139) Dorsal centra, pneumatic structures: absent, dorsal centra with solid interna structure (0); present, dorsal centra with simple and big air-spaces (camerate) (1); present, dorsal centra with small and complex air-spaces (polycamerate) (2); present, dorsal centra with small and complex air spaces (semicamellate/camellate) (3). (Modified from Carballido et al., 2011)
- (140) Anterior and middle dorsal neural spines, spinoprezygapophyseal lamina (SPRL): absent (0); present (1).(Modified from Upchurch *et al.* (2007:ch. 131).

- (141) Posterior dorsal neural spines, spinoprezygapophyseal lamina (SPRL): absent (0); present (1). (Modified from Upchurch *et al.*, 2007:ch. 132).
- (142) Dorsal vertebrae, single not bifid neural spines, single prespinal lamina (PRSL): absent (0); present (1). (Modified from Salgado *et al.*, 1997:ch.14)
- (143) Dorsal vertebrae, single not bifid neural spines, single prespinal lamina (PRSL): rough and wide, present in the dorsalmost part of the neural spine (0); rough and wide, extended trough almost all the neural spine (1); smooth and narrow (2). (Carballido *et al.*, 2012)
- (144) Dorsal vertebrae with single neural spines, middle single fossa projected trough the midline of the neural spine: present (0); absent (1). (Carballido *et al.*, 2012)
- (145) Dorsal vertebrae with single neural spines, middle single fossa, projected through the midline of the neural spine: relatively wide median simple fossa (0); a thin median simple fossa (1); extremely reduced median simple fossa (2). (Carballido *et al.*, 2012).
- Ordered character.**
- (146) Anterior dorsal centra, articular face shape: amphicoelous (0); opisthocoelous (1). (Wilson, 2002:ch. 94; Upchurch *et al.*, 2004:ch. 104)
- (147) Anterior and middle dorsal centra, pleurocoels: have rounded caudal margins (0); have tapering, acute caudal margins (1). (Salgado *et al.*, 1997; Upchurch, 1998:ch. 06; Upchurch *et al.*, 2004:ca 127)
- (148) Middle dorsal neural arches in lateral view, anterior edge of the neural spine: project anteriorly to the diapophysis (0); converge with the diapophysis (1); project posteriorly to the diapophysis (2). (Carballido *et al.*, 2012)
- (149) Anterior and middle dorsal vertebrae, zygapophyseal articulation angle: horizontal or slightly posteroventrally oriented (0); posteroventrally oriented (around 30°) (1); strongly posteroventrally oriented (more than 40°) (2). (Carballido *et al.*, 2012)
- (150) Middle to posterior dorsal centra, ventral surface: convex transversely (0); flattened (1); is slightly concave, sometimes with one or two crests (2). (Upchurch *et al.*, 2004)
- (151) Middle dorsal vertebrae, hyosphene-hypantrum system: present (0); absent (1). (Modified from Salgado *et al.*, 1997:ch. 25; Wilson, 2002:ch. 106; Upchurch *et al.*, 2004:ch. 145)
- (152) Posterior dorsal vertebrae, hyosphene-hypantrum system: present and well developed, usually with a rhomboid shape (0); present and weakly developed, mainly as a laminar articulation (1); absent or only present in posteriormost dorsal vertebrae (2). (Carballido *et al.*, 2012). **Ordered character.**
- (153) Middle and posterior dorsal vertebrae, transverse processes length: short (0); long (projecting along 1.5 the articular surface width) (1). (Carballido *et al.*, 2012)
- (154) Mid and posterior dorsal vertebrae with a single lamina (the single TPOL) supporting the hyosphene or postzygapophysis from below: absent (0); present (1). (Modified from Upchurch *et al.*, 2004:ch. 146)
- (155) Middle and posterior dorsal vertebrae, neural canal in anterior view: entirely surrounded by the neural arch (0); enclosed in a deep fossa, enclosed laterally by pedicels (1). (Upchurch *et al.*, 2004:ch. 136)
- (156) Middle and posterior dorsal vertebrae, neural spine height: approximately twice the centrum length (0); for times the centrum length (1). (Upchurch *et al.*, 2004)
- (157) Middle and posterior dorsal neural spines orientation: vertical (0); slightly inclined, with an angle of around 70 degrees (1); strongly inclined, with an angle not bigger than 40 degrees (2). (Modified from Wilson, 2002:ch. 104)
- (158) Middle and posterior dorsal neural arches, centropostzygapophyseal lamina (CPOL), shape: simple (0); divided (1). (Wilson, 2002:ch. 95)
- (159) Middle and posterior dorsal neural arches, anterior centroparapophyseal lamina (ACPL): absent (0); present (1). (Wilson, 2002:ch. 96; Upchurch *et al.*, 2004:ch. 133)
- (160) Middle and posterior dorsal neural arches, prezygoparapophyseal lamina (PRPL): absent (0); present (1). (Wilson, 2002:ch. 97)

- (161) Middle and posterior dorsal neural arches, posterior centroparapophyseal lamina (PCPL): absent (0); present (1). (Wilson, 2002:ch. 98, Upchurch *et al.*, 2004:ch. 137)
- (162) Middle and posterior dorsal centrum in transverse section (height: width ratio): subcircular (ratio, similar to 1 or a bit higher) (0); slightly dorsoventrally compressed (ratios between 0.8 and 1) (1); strongly compressed (ratios below 0.8) (2). (Modified from Upchurch *et al.*, 2004)
- (163) Middle and posterior dorsal vertebrae neural spine, triangular aliform processes: absent (0); present but do not project far laterally (not as far as caudal zygapophyses) (1); present and project far laterally (as far as caudal zygapophyses) (2). (Modified from Wilson, 2002:ch. 102 and Upchurch *et al.*, 2004:chs. 153-154). **Ordered character.**
- (164) Middle and posterior dorsal vertebrae, spinodiapophyseal lamina (SPDL): absent (0); present (1). (Upchurch *et al.*, 2004:ch. 157)
- (165) Middle and posterior dorsal vertebrae, accessory spinodiapophyseal lamina: absent (0); present (1). (Upchurch *et al.*, 2004:ch. 151)
- (166) Dorsal vertebrae, spinodiapophyseal webbing: lamina follows curvature of neural spine in anterior view (0); lamina "festooned" from spine, dorsal margin does not closely follow shape of neural spine and diapophysis (1). (Whitlock, 2011:ch.104)
- (167) Anterior dorsal vertebrae, spinopostzygapophyseal lamina (SPOL): absent (0); present (1). (Upchurch *et al.*, 2007:ch.133)
- (168) Middle and posterior dorsal neural spines, lateral spinopostzygapophyseal lamina (ISPOL): absent (0); present (1). (Wilson, 2002: 100; Upchurch *et al.*, 2004:ch. 159)
- (169) Middle and posterior dorsal neural arches, spinodiapophyseal lamina (SPDL) and spinopostzygapophyseal lamina (ISPOL) contact: absent (0); present (1). (Wilson, 2002:ch. 101)
- (170) Middle and posterior dorsal vertebrae, spinodiapophyseal (SPDL) and spinopostzygapophyseal lamina (ISPOL) contact: ventral, well separated from the triangular aliform process (0); dorsal, forms part of the triangular aliform process (1). (Carballido *et al.*, 2012)
- (171) Middle and posterior dorsal vertebrae, height of neural arch below the postzygapophyses (pedicel): less than height of centrum (0); subequal to or greater than height of centrum (1). (Whitlock, 2011:ch. 109)
- (172) Posterior Dorsal vertebrae, medial spinopostzygapophyseal lamina (mSPOL): absent (0); present and forms part of the median posterior lamina (1). (Carballido *et al.*, 2012)
- (173) Posterior dorsal vertebrae, transverse processes: lie posterior, or posterodorsal, to the parapophysis (0); lie vertically above the parapophysis (1). (Upchurch *et al.*, 2004:ch. 139)
- (174) Posterior dorsal centra, articular face shape: amphicoelous (0); slightly opisthocoelous (1); opisthocoelous (2). (Modified from Wilson, 2002:ch. 105)
- (175) Posterior dorsal vertebrae, neural spine: narrower transversely than anteroposteriorly (0); broader transversely than anteroposteriorly (1). (Wilson, 2002: ch. 92)
- (176) Posterior dorsal vertebra, posterior centrodiapophyseal lamina (PCDL): has an unexpanded ventral tip (0); expands and may bifurcate toward its ventral tip (1). (Salgado *et al.*, 1997)
- (177) Cervical ribs, distal shafts of longest cervical ribs: are elongate and form overlapping bundles (0); are short and do not project beyond the caudal end of the centrum to which they are attached (1). (Wilson, 2002:ch. 140)
- (178) Cervical ribs, angle between the capitulum and tuberculum: greater than 90°, so that the rib shaft lies close to the ventral edge of the centrum (0); less than 90°, so that the rib shaft lies below the ventral margin of the centrum (1). (Wilson, 2002:ch. 139)
- (179) Dorsal ribs, proximal pneumatopores: absent (0); present (1). (Wilson, 2002:ch. 141)
- (180) Anterior dorsal ribs, cross-sectional shape: subcircular (0); plank-like, anteroposterior breadth more than three times mediolateral breadth (1). (Wilson, 2002).

Sacrum

- (181) Sacral vertebrae, number:: 3 or fewer (0); 4 (1); 5 (2); 6 (3). (Wilson, 2002:ch. 108)
- (182) Sacrum, sacricostal yoke: absent (0); present (1). (Wilson, 2002:ch. 109)
- (183) Sacral vertebrae contributing to acetabulum: numbers 1-3 (0); numbers 2-4 (1). (Wilson, 2002:ch. 110)
- (184) Sacral neural spines length: approximately twice length of centrum (0); approximately four times length of centrum (1). (Wilson, 2002:ch. 111)
- (185) Sacral ribs, dorsoventral length: low, not projecting beyond dorsal margin of ilium (0); high extending beyond dorsal margin of ilium (1). (Wilson, 2002:ch. 112)
- (186) Pleurocoels in the lateral surfaces of sacral centra: absent (0); present (1). (Upchurch *et al.*, 2004:ch. 165)

Caudal Vertebrae

- (187) Caudal vertebrae, number: 35 or fewer (0); 40 to 55 (1); increased to 70-80 (2). (Wilson, 2002:ch. 114)
- (188) Caudal bone texture: solid (0); spongy, with large internal cells (1). (Wilson, 2002:ch. 113)
- (189) Caudal transverse processes: persist through caudal 20 or more posteriorly (0); disappear by caudal 15 (1); disappear by caudal 10(2). (Wilson, 2002:ch. 115)
- (190) First caudal centrum or last sacral vertebra, articular face shape: flat (0); procoelous (1); opisthocelous (2); biconvex (3). (Wilson, 2002)
- (191) First caudal neural arch, coel on lateral aspect of neural spine: absent (0); present (1). (Wilson, 2002:ch. 117)
- (192) Anterior caudal vertebrae, transverse processes: ventral surface directed laterally or slightly ventrally (0); directed dorsally (1). (Whitlock, 2011:ch. 125)
- (193) Anterior caudal centra (excluding the first), articular face shape: amphiplatyan or amphicoelous (0); procoelous/distoplatyan (1); slightly procoelous (2); procoelous (3); posterior surface markedly more concave than the anterior one (4). (Modified from González Riga *et al.*, 2009)
- (194) Anterior caudal centra, pleurocoels: absent (0); present (1). (Wilson, 2002:ch. 119)
- (195) Anterior caudal vertebrae, ventral surfaces: convex transversely (0); concave transversely (1). (Upchurch *et al.*, 2004:ch. 182)
- (196) Anterior and middle caudal vertebrae, ventrolateral ridges: absent (0); present (1). (Upchurch *et al.*, 2004:ch. 183)
- (197) Anterior and middle caudal vertebrae, triangular lateral process on the neural spine: absent (0); present (1). (Whitlock, 2011:ch. 123)
- (198) Anterior caudal transverse processes shape: triangular, tapering distally (0); "wing-like", not tapering distally (1). (Wilson, 2002:ch. 128)
- (199) Anterior caudal neural spines, transverse breadth: approximately 50% of (0); or greater than anteroposterior length (1). (Wilson, 2002:ch. 126)
- (200) Anterior caudal transverse processes, proximal depth: shallow, on centrum only (0); deep, extending from centrum to neural arch (1). (Wilson, 2002:ch. 127)
- (201) Anterior caudal transverse processes, diapophyseal laminae (ACDL, PCDL, PRDL, PODL): absent (0); present (1). (Wilson, 2002:ch. 129)
- (202) Anterior caudal transverse processes, anterior centrodiapophyseal lamina (ACDL), shape: single (0); divided (1). (Wilson, 2002:ch. 130)
- (203) Anterior caudal vertebrae, hyposphene ridge: absent (0); present (1). (Upchurch *et al.*, 2004:ch. 187)
- (204) Anterior caudal centra, length: approximately the same (0); or doubling over the first 20 vertebrae (1). (Wilson, 2002:ch. 120)
- (205) Anterior caudal neural arches, spinoprezygapophyseal lamina (SPRL): absent, or present as small short ridges that rapidly fade out into the anterolateral margin of the spine (0); present, extending onto lateral aspect of neural spine (1). (Modified from Wilson, 2002:ch. 121)

- (206) Anterior caudal neural arches, spinoprezygapophyseal lamina (SPRL)-spinopostzygapophyseal lamina (SPOL) contact: absent (0); present, forming a prominent lamina on lateral aspect of neural spine (1). (Wilson, 2002:ch. 122)
- (207) Anterior caudal neural arches, prespinal lamina (PRSL): absent (0); present (1). (Wilson, 2002:ch. 123)
- (208) Middle caudal centra, shape: cylindrical (0); with flat ventral margin (1); quadrangular, flat ventrally and laterally (2). (Modified from Wilson, 2002:ch. 131)
- (209) Anterior and middle caudal centra, ventral longitudinal hollow: absent (0); present (1). (Wilson, 2002:ch. 132)
- (210) Middle caudal centra, articular face shape: amphiplatyan or amphicoelous (0); procoelous/distoplastyan (1); slightly procoelous (2); procoelous (3). (González Riga *et al.*, 2009)
- (211) Middle caudal vertebrae, location of the neural arches: over the midpoint of the centrum with approximately subequal amounts of the centrum exposed at either end (0); on the anterior half of the centrum (1). (Upchurch *et al.*, 2004:ch. 185)
- (212) Middle caudal vertebrae, height of the pedicels below the prezygapophysis: low with curved anterior edge of the pedicel (0); high with vertical anterior edge of the pedicel (1). (Carballido *et al.*, 2012)
- (213) Middle caudal vertebrae, orientation of the neural spines: anteriorly (0); vertical (1); slightly directed posteriorly (2); strongly directed posteriorly (3). (Modified from Wilson, 2002:ch. 133). **Ordered character.**
- (214) Posterior caudal vertebrae, neural spine strongly displaced posteriorly: absent (0); present (1). (Carballido *et al.*, 2012).
- (215) Middle caudal vertebrae, ratio of centrum length to centrum height: less than 2, usually 1.5 or less (0); 2 or higher (1). (Upchurch *et al.*, 2004:ch. 179)
- (216) Anterior-posterior caudal vertebrae (those with still well developed neural spine), neural spine orientation: vertical (0); slightly directed posteriorly (1); strongly directed posteriorly (2). (Carballido *et al.*, 2012). **Ordered character.**
- (217) Posterior Caudals centra, articular face shape: anphyplatic (0); procoelous (1); opisthocelous (2). (Modified from González Riga *et al.*, 2009)
- (218) Posterior caudal centra, shape: cylindrical (0); dorsoventrally flattened, breadth at least twice height (1). (Wilson, 2002:ch. 135)
- (219) Posterior caudal vertebrae, ratio of length to height: less than 5, usually 3 or less (0); 5 or higher (1). (Upchurch *et al.*, 2004:ch. 180)
- (220) Distalmost caudal centra, articular face shape: platycoelous (0); biconvex (1). (Wilson, 2002:ch. 136)
- (221) Distalmost biconvex caudal centra, number: 10 or fewer (0); more than 30 (1). (Wilson, 2002:ch. 137)
- (222) Distalmost biconvex caudal centra, length-to height ratio: less than 4 (0); greater than 5 (1). (Wilson, 2002:ch. 138)
- (223) Forked chevrons with anterior and posterior projections: absent (0); present (1). (Wilson, 2002:ch. 143)
- (224) Forked chevrons, distribution: distal tail only (0); throughout middle and posterior caudal vertebrae (1). (Wilson, 2002:ch. 144)
- (225) Chevrons, crus bridging dorsal margin of haemal canal: present (0); absent (1). (Wilson, 2002:ch. 145)
- (226) Chevron haemal canal, depth: short, approximately 25% (0); or long, approximately 50% chevron length (1). (Wilson, 2002:ch. 146)
- (227) Chevrons: persisting throughout at least 80% of tail (0); disappearing by caudal 30 (1). (Wilson, 2002:ch. 147)
- (228) Posterior chevrons, distal contact: fused (0); unfused (open) (1). (Wilson, 2002:ch. 148)
- (229) Posture: bipedal (0); columnar, obligatory quadrupedal posture (1). (Wilson, 2002:ch. 149)

Scapular Girdle

- (230) Scapular acromion process, size: Narrow (0); broad, width more than 150% minimum width of blade (1). (Wilson, 2002:ch. 150)
- (231) Scapular blade, orientation respect to coracoid articulation: perpendicular (0); forming a 45° angle (1). (Wilson, 2002:ch. 151)
- (232) Scapular blade, shape: acromial edge not expanded (0); rounded expansion on acromial side (1); racquet-shaped (2). (Wilson, 2002:ch. 152). Ordered character.
- (233) Scapula, acromion process dorsal margin: concave or straight (0); with V-shaped concavity (1); with U-shaped concavity (2). (Serenio *et al.*, 2007: 88). Ordered character.
- (234) Scapula, highest point of the dorsal margin of the blade: lower than the dorsal margin of the proximal end (0); at the same height than the dorsal margin of the proximal end (1); higher than the dorsal margin of the proximal end (2). (Carballido *et al.*, 2012 from Mannion, 2009). Ordered character.
- (235) Scapula, development of the acromion process: undeveloped (0); well developed (1). (Carballido *et al.*, 2012)
- (236) Scapular length/minimum blade breadth: 5.5 or less (0); 5.5 or more (1). (Carballido *et al.*, 2012)
- (237) Scapula, ventral margin with a well developed ventro medial process: absent (0); present (1). (Carballido *et al.*, 2011)
- (238) Scapular, acromial process position: lies nearly glenoid level (0); lies nearly midpoint scapular body (1). (Carballido *et al.*, 2012)
- (239) Scapular acromion length: less than 1/2 scapular length (0); at least 1/2 scapular length (1). (Mannion *et al.*, 168)
- (240) Glenoid scapular orientation: relatively flat or laterally facing (0); strongly beveled medially (1). (Wilson, 2002:ch. 153)
- (241) Scapular blade, cross-sectional shape at base: flat or rectangular (0); D-shaped (1). (Wilson, 2002:ch. 154)
- (242) Coracoid, proximodistal length: less than the length of scapular articulation (0); approximately twice the length of scapular articulation (1). (Wilson, 2002:ch. 155)
- (243) Coracoid, anteroventral margin shape: rounded (0); rectangular (1). (Wilson, 2002:ch. 156)
- (244) Dorsal margin of the coracoid in lateral view: reaches or surpasses the the level of the dorsal margin of the scapular expansion (0); lies below the level of the scapular proximal expansion and separated from the latter by a V-shaped notch (1). (Upchurch *et al.*, 2004:ch. 207)
- (245) Coracoid, Infraglenoid deep groove: absent (0); present (1).
- (246) Coracoid, infraglenoid lip: absent (0); present (1). (Wilson, 2002:ch. 157)
- (247) Sternal plate, shape: oval (0); crescentic (1). (Wilson, 2002:ch. 158)
- (248) Prominent posterolateral expansion of the sternal plate producing a kidney-shaped profile in dorsal view: absent (0); present (1). (Upchurch *et al.*, 2004:ch.211)
- (249) Prominent parasagittal oriented ridge on the dorsal surface of the sternal plate: absent (0); present (1). (Upchurch *et al.*, 2004: :ch.212)
- (250) Ridge on the ventral surface of the sternal plate: absent (0); present (1). (Upchurch *et al.*, 2004:ch.213)
- (251) Ratio of maximum length of sternal plate to the humerus length: less than 0,75, usually less than 0,65 (0); greater than 0,75 (1). (Upchurch *et al.*, 2004:ch.209)

Fore Limbs

- (252) Humerus-to-femur ratio: less than 0.60 (0); 0.60 to 0.90 (1); greater than 0.90 (2). (Upchurch *et al.*, 2004:ch. 216). Ordered character.
- (253) Humeral deltopectoral attachment, development: prominent (0); reduced to a low crest or ridge (1). (Wilson, 2002:ch.160)
- (254) Humeral deltopectoral crest, shape: relatively narrow throughout length (0); markedly expanded distally (1). (Wilson, 2002:ch.161)

- (255) Humeral midshaft cross-section, shape: circular (0); elliptical (1). (Mannion *et al*, 2011:ch. 170)
- (256) Humerus, RI (sensu Wilson and Upchurch, 2003): Gracile (less than 0,27) (0); medium (0,28-0,32) (1); Robust (more than 0,33) (2). (Carballido *et al.*, **2012**). Ordered character.
- (257) Humeral distal condyles, articular surface shape: restricted to distal portion of humerus (0); exposed on anterior portion of humeral shaft (1). (Wilson, 2002:ch. 163)
- (258) Humeral distal condyle, shape: divided (0); flat (1). (Wilson, 2002:ch. 164)
- (259) Humeral, lateral margin: medially deflected (0); almost straight until the half length or even more (1). (Carballido *et al.*, **2012**)
- (260) Humeral proximolateral corner, shape: rounded, the dorsal surface is well convex (0); pronounced / square, the dorsal surface low, almost flat (1). (Wilson, 2002:ch. 159)
- (261) Ulnar proximal condyle, shape: subtriangular (0); triradiate, with deep radial fossa (1). (Wilson, 2002ch. 165)
- (262) Ulnar proximal condylar processes, relative lengths: subequal (0); unequal, anterior arm longer (1). (Wilson, 2002:ch. 166)
- (263) Ulnar olecranon process, development: prominent, projecting above proximal articulation (0); rudimentary, level with proximal articulation (1). (Wilson, 2002:ch. 167)
- (264) Ulna, length-to-proximal breadth ratio: gracile (0); stout (1). (Wilson, 2002:ch. 168)
- (265) Radial distal condyle, shape: round (0); subrectangular, flattened posteriorly and articulating in front of ulna (1). (Wilson, 2002:ch. 169)
- (266) Radius, distal breadth: slightly larger than midshaft breadth (0); approximately twice midshaft breadth (1). (Wilson, 2002:ch.170)
- (267) Radius, distal condyle orientation: perpendicular to long axis of shaft (0); beveled approximately 20° proximolaterally relative to long axis of shaft (1). (Wilson, 2002:ch.171)
- (268) Carpal bones, number: 3 or more (0); 2 or fewer (1). (Wilson, 2002:ch.173)
- (269) Carpal bones, shape: round (0); block-shaped, with flattened proximal and distal surfaces (1). (Wilson, 2002:ch.174)
- (270) Metacarpus, shape: spreading (0); bound, with subparallel shafts and articular surfaces that extend half their length (1). (Wilson, 2002:ch.175)
- (271) Metacarpals, shape of proximal surface in articulation: gently curving, forming a 90arc (0); U-shaped, subtending a 270arc (1). (Wilson, 2002:ch.176)
- (272) Longest metacarpal-to-radius ratio: close to 0.3 (0); 0.45 or more (1). (Wilson, 2002:ch.177)
- (273) Metacarpal I, length: shorter than metacarpal IV (0); longer than metacarpal IV (1). (Wilson, 2002:ch.178)
- (274) Metacarpal I, distal condyle shape: divided (0); undivided (1). (Wilson, 2002:ch. 179)
- (275) Metacarpal I distal condyle, transverse axis orientation: beveled approximately 20° respect to axis of shaft (0); proximodistally or perpendicular with respect to axis of shaft (1). (Wilson, 2002:ch. 180)
- (276) Manual digits II and III, phalangeal number: 2- 3-4-3-2 or more (0); reduced, 2-2-2-2-2 or less (1); absent or unossified (2). (Wilson, 2002:ch. 181)
- (277) Manual phalanx I.1, shape: rectangular (0); wedge-shaped (1). (Wilson, 2002:ch. 182)
- (278) Manual nonungual phalanges, shape: longer proximodistally than broad transversely (0); broader transversely than long proximodistally (1). (Wilson, 2002:ch. 183)

Pelvic Girdle

- (279) Pelvis, anterior breadth: narrow, ilia longer anteroposteriorly than distance separating preacetabular processes (0); broad, distance between preacetabular processes exceeds anteroposterior length of ilia (1). (Wilson, 200:ch. 1842)
- (280) Ilium, ischial peduncle size: large, prominent (0); low, rounded (1). (Wilson, 2002:ch. 185)

- (281) Ilium, dorsal margin shape: flat (0); semicircular (1). (Wilson, 2002:ch. 186)
- (282) Ilium, preacetabular process shape: pointed, arching ventrally (0); semicircular, with posteroventral excursion of cartilage cap (1). (Wilson, 2002:ch. 188)
- (283) Ilium, preacetabular process orientation: anterolateral to body axis (0); perpendicular to body axis (1). (Wilson, 2002:ch. 189)
- (284) Highest point on the dorsal margin of the ilium: lies caudal to the base of the pubic process (0); lies cranial to the base of the pubic process (1). (Upchurch *et al.*, 2004:ch. 245)
- (285) Pubis length respect to ischium: pubis slightly smaller or subequal to ischium (0); pubis larger (120% +) than ischium (1). (Carballido *et al.*, **2012**)
- (286) Pubis, ambiens process development: small, confluent with anterior margin of pubis prominent, (0); projects anteriorly from anterior margin of pubis (1). (Wilson, 2002:ch. 189)
- (287) Pubic apron, shape: flat (straight symphysis) (0); canted anteromedially (gentle S-shaped symphysis) (1). (Wilson, 2002:ch. 190).
- (288) Puboischial contact, length: approximately one third total length of pubis (0); one-half total length of pubis (1). (Wilson, 2002:ch. 191)
- (289) Ischium, acetabular articular surface: maintains approximately the same transverse width throughout its length (0); is transversely narrower in its central portion and strongly expanded as it approaches the iliac and pubic articulations (1). (Mannion *et al.*, **2012**:ch. 180)
- (290) Ischium, iliac peduncle with constriction or "neck": absent (0); present (1). (Whitlock, 2011:ch. 173).
- (291) Ischium, elongate muscle scar on proximal end: absent (0); present (1). (Whitlock, 2011:ch. 174)
- (292) Ischial blade, shape: emarginate distal to pubic peduncle (0); no emargination distal to pubic peduncle (1). (Wilson, 2002:ch. 193)
- (293) Ischia pubic articulation: less or equal to the anteroposterior length of pubic pedicel (0); greater than the anteroposterior length of pubic pedicel (1). (Salgado *et al.*, 1997)
- (294) Ischia, anteroposterior pubic pedicel width divided the total length of the ischium: less than 0,5 (0); 0,5 or grate (1); Large (2). (Carballido *et al.*, **2012**).
- (295) Ischial distal shaft, shape: triangular, depth of ischial shaft increases medially (0); blade-like, medial and lateral depths subequal (1). (Upchurch *et al.*, 2004:ch. 194)
- (296) Ischial distal shafts, cross-sectional shape: V-shaped, forming an angle of nearly 50° with each other (0); flat, nearly coplanar (1). (Wilson, 2002:ch. 195)
- (297) Ischia, distal end: is only slightly expanded (0); is strongly expanded dorsoventrally (1). (Upchurch, 1998:ch. 183)
- (298) Ischium, angle formed between the shaft and the acetabular line: forming an almost right angle (80-110°) (0) or; a close angle (less than 70°) (1). (Carballido *et al.*, **2012**)

Hindlimb

- (299) Femur, fourth trochanter development: prominent (0); reduced to crest or ridge (1); extremely reduced (2). (Modified from Wilson, 2002:ch. 196, following to Whitlock, 2011:ch. 186). Ordered character.
- (300) Femur, lesser trochanter: present (0); absent (1). (Wilson, 2002:ch. 197)
- (301) Femur midshaft, transverse diameter: subequal to anteroposterior diameter (0); 125-150% anteroposterior diameter (1); at least 185% anteroposterior diameter (2). (Wilson, 2002:ch. 198). Ordered character.
- (302) Femur, lateral bulge (marked by the lateral expansion and a dorsomedial orientation of the laterodorsal margin of the femur, which starts below the femur head ventral margin): absent (0); present (1). (Salgado *et al.*, 1997)
- (303) Femur, pronounced ridge on posterior surface between greater trochanter and head: absent (0); present (1). (Whitlock, 2011:ch. 181)

- (304) Femur head position: perpendicular to the shaft, rises at the same level than the greater trochanter (0); dorsally directed, rises well above the level of the greater trochanter (1). (Modified from Upchurch *et al.*, 2004:ch. 263)
- (305) Femur, distal condyles relative transverse breadth: subequal (0); tibial much broader than fibular (1). (Wilson, 2002:ch. 2000)
- (306) Femur, distal condyles orientation: perpendicular or slightly beveled dorsolaterally (0); or beveled dorsomedially approximately 10 relative to femoral shaft (1). (Wilson, 2002:ch. 201)
- (307) Femur, distal condyles articular surface shape: restricted to distal portion of femur (0); expanded onto anterior portion of femoral shaft (1). (Wilson, 2002:ch. 202)
- (308) Situation of the femoral fourth trochanter: on the caudal surface of the shaft, near the midline (0); on the caudomedial margin of the shaft (1). (Upchurch *et al.*, 2004:ch. 268)
- (309) Tibial proximal condyle, shape: narrow, long axis anteroposterior (0); expanded transversely, condyle subcircular (1). (Wilson, 2002:ch. 203)
- (310) Tibial cnemial crest, orientation: projecting anteriorly (0); or laterally (1). (Wilson, 2002:ch. 204)
- (311) Tibia, distal breadth: approximately 125% (0); more than twice midshaft breadth (1). (Wilson, 2002:ch. 205)
- (312) Tibial distal posteroventral process, size: broad transversely, covering posterior fossa of astragalus (0); shortened transversely, posterior fossa of astragalus visible posteriorly (1). (Wilson, 2002:ch. 206)
- (313) Fibula, proximal tibial scar, development: not well-marked (0); well-marked and deepening anteriorly (1). (Wilson, 2002:ch. 207)
- (314) Fibula, lateral trochanter: absent (0); present (1). (Wilson, 2002:ch. 208)
- (315) Fibular distal condyle, size: subequal to shaft (0); expanded transversely, more than twice midshaft breadth (1). (Wilson, 2002:ch. 209)
- (316) Astragalus, shape: rectangular (0); wedge shaped, with reduced anteromedial corner (1). (Wilson, 2002:ch.210)
- (317) Astragalus, fibular facet: faces laterally (0); faces posterolaterally, anterior margin visible in posterior view (1). (Whitlock, 2011:ch. 186)
- (318) Astragalus, foramina at base of ascending process: present (0); absent (1). (Wilson, 2002:ch. 211)
- (319) Astragalus, ascending process length: limited to anterior two-thirds of astragalus (0); extending to posterior margin of astragalus (1). (Wilson, 2002:ch. 212)
- (320) Astragalus, posterior fossa shape: undivided (0); divided by vertical crest (1). (Wilson, 2002:ch. 213)
- (321) Astragalus, transverse length: 50% more than (0); or subequal to proximodistal height (1). (Wilson, 2002:ch. 214)
- (322) Calcaneum: present (0); absent or unossified (1). (Wilson, 2002:ch. 215)
- (323) Distal tarsals 3 and 4: present (0); absent or unossified (1). (Wilson, 2002:ch. 216)
- (324) Metatarsus, posture: bound (0); spreading (1). (Wilson, 2002:ch. 217)
- (325) Metatarsal I proximal condyle, transverse axis orientation: perpendicular to (0); angled ventromedially approximately 15° to axis of shaft (1). (Wilson, 2002:ch. 218)
- (326) Metatarsal I distal condyle, transverse axis orientation: perpendicular to (0); angled dorsomedially to axis of shaft (1). (Wilson, 2002:ch. 219)
- (327) Metatarsal I distal condyle, posterolateral projection: absent (0); present (1). (Wilson, 2002:ch. 220)
- (328) Metatarsal I, minimum shaft width: less than that of metatarsals IIIIV (0); or greater than that of metatarsals IIIIV (1). (Wilson, 2002:ch. 221)
- (329) Metatarsal I and V proximal condyle, size: smaller than (0); or subequal to those of metatarsals II and IV (1). (Wilson, 2002:ch. 222)
- (330) Metatarsal III length: more than 30% (0); or less than 25% that of tibia (1). (Wilson, 2002:ch. 223)

- (331) Metatarsals III and IV, minimum transverse shaft diameters: subequal to (0); or less than 65% that of metatarsals I or II (1). (Wilson, 2002:ch. 224)
- (332) Metatarsal V, length: shorter than (0); or at least 70% length of metatarsal IV (1). (Wilson, 2002:ch. 225)
- (333) Pedal nonungual phalanges, shape: longer proximodistally than broad transversely (0); broader transversely than long proximodistally (1). (Wilson, 2002:ch. 226)
- (334) Pedal digits II-IV, penultimate phalanges, development: subequal in size to more proximal phalanges (0); rudimentary or absent (1). (Wilson, 2002:ch. 227)
- (335) Pedal unguals, orientation: aligned with (0); or deflected lateral to digit axis (1). (Wilson, 2002:ch. 228)
- (336) Pedal digit I unguual, length relative to pedaldigit II unguual: subequal (0); 25% larger than that of digit II (1). (Wilson, 2002:ch. 229)
- (337) Pedal digit I unguual, length: shorter (0); or longer than metatarsal I (1). (Wilson, 2002:ch. 230)
- (338) Pedal unguual I, shape: broader transversely than dorsoventrally (0); sickle-shaped, much deeper dorsoventrally than broad transversely (1). (Wilson, 2002:ch. 231)
- (339) Pedal unguual IIII, shape: broader transversely than dorsoventrally (0); sickle-shaped, much deeper dorsoventrally than broad transversely (1). (Wilson, 2002:ch. 232)
- (340) Pedal digit IV unguual, development: subequal in size to unguals of pedal digits II and III (0); rudimentary or absent (1). (Wilson, 2002:ch. 233)
- (341) Unguals of pedal digit II and III, proximal dimensions: as broad as deep (0); significantly broader than deep (1). (Allain and Aquesbi, 2008:ch. 253)

Added Characters

- (342) Development of v-shaped wear facets: well developed (forming “shoulders”) (0); slightly developed as marginal facets (1).
- (343) Single planar wear facet on labial or lingual surface of teeth: absent (0); present (1).
- (344) One high angled wear facet and a second low angle wear facet: absent (0); present (1).
- (345) Tooth crown shape: narrow crowns (0); broad crowns (1).
- (346) Middle to posterior dorsal vertebrae, pleurocoel dorsal margin: rounded (0) angular (1).
- (347) Middle to posterior dorsal vertebrae, pleurocoel dorsal margin: well below the dorsal margin of the centrum (0) at the level of the dorsal margin of the centrum or higher (1).
- (348) Middle to posterior dorsal vertebrae, small fossa anterior to anteroventral to the pleurocoel: absent (0) present (1)
- (349) Premaxilla-maxilla suture, shape: planar (0) twisted along its length, giving the contact a sinuous appearance in lateral view (1). (D’Emic, 2012:ch. 2)
- (350) Premaxilla, small finger-like, vertically oriented premaxillary process near anteromedial corner of external naris: absent (0); present (1). (D’Emic, 2012:ch. 3)
- (351) Lacrimal, anteriorly projecting vertical plate of bone: absent (0); present (1). (D’Emic, 2012:ch. 4)
- (352) Dentary, posteroventral process shape: single (0) divided (1). (D’Emic, 2012:ch. 10)
- (353) Maxillary teeth, shape: straight along axis (0); twisted axially through an arc of 30-45° (1). (D’Emic, 2012:ch. 15)
- (354) Axis, centrum shape: over two and a half times as long as tall (0); less than twice as long as tall (1). (D’Emic, 2012:ch. 20)
- (355) Cervical vertebrae, epiphyses shape: stout, pillar-like expansions above postzygapophyses (0); posteriorly projecting prongs (1). (D’Emic, 2012:ch. 24)
- (356) Middle and posterior cervical vertebrae, parapophyses shape: subcircular (0); elongate (1). (D’Emic, 2012:ch. 28)
- (357) Middle and posterior dorsal vertebral centra, ventral keel: absent (0); present (1). (D’Emic, 2012:ch. 49)
- (358) Anterior caudal vertebrae (mainly the first and second): ventral bulge on transverse process: absent (0); present (1). (D’Emic, 2012:ch. 52)

- (359) Anterior and middle caudal vertebrae, blind fossae in lateral centrum: absent (0); present (1). (D’Emic, 2012:ch. 56)
- (360) Middle caudal vertebrae, transverse processes orientation: perpendicular (0); swept backwards, reaching the posterior margin of the centrum (1). (D’Emic, 2012:ch. 59)
- (361) Sternal plate, shape: posterolateral margin curved (0); posterolateral margin expanded as a corner (1). (D’Emic, 2012:ch. 76)
- (362) Humerus, strong posterolateral bulge on around level of the deltopectoral crest: absent (0); present (1). (D’Emic, 2012:ch. 80)
- (363) Humerus, radial and ulnar condyles, shape: radial condyle divided on anterior face by a notch (0); undivided (1). (D’Emic, 2012:ch. 83)
- (364) Ilium, preacetabular process, kink on ventral margin: absent (0); present (1). (D’Emic, 2012:ch. 99)
- (365) Femur, longitudinal ridge on anterior face: absent (0); present (1). (D’Emic, 2012:ch. 107)
- (366) Fibula, proximal end, anterior crest: absent or poorly developed (0); well developed creating interlocking proximal cruz (1). (D’Emic, 2012:ch. 111)
- (367) Fibula, shaft shape: straight, or slightly sigmoidal (0); sigmoid, such that the proximal and distal faces are angled relative to midshaft (1). (D’Emic, 2012:ch. 113)
- (368) Astragalus, shape: at least 1.5 times wider than anteroposteriorly long (0); anteroposterior and transverse dimensions subequal (1). (D’Emic, 2012:ch. 115)
- (369) Metatarsal IV, proximomedial end, shape: flat or slightly concave (0); possesses a distinct embayment (1). (D’Emic, 2012:ch. 117)
- (370) Metatarsal IV, distal end, orientation: roughly perpendicular to long axis of bone (0); bevelled upwards medially (1). (D’Emic, 2012:ch. 118)

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