# SUPPLEMENTARY INFORMATION FOR "*EOMAKHAIRA MOLOSSUS*, A NEW SABER-TOOTHED SPARASSODONT (METATHERIA: THYLACOSMILINAE) FROM THE EARLY OLIGOCENE (?TINGUIRIRICAN) CACHAPOAL LOCALITY, ANDEAN MAIN RANGE, CHILE"

## SUPPLEMENTARY DATA FOR PHYLOGENETIC ANALYSIS

### INSTITUTIONAL ABBREVIATIONS

**AC**, Beneski Museum of Natural History, Amherst, U.S.A.

**AMNH**, American Museum of Natural History, New York, U.S.A.

**CORD-PZ**, Museo de Paleontología, Facultad de Ciencias Exactas, Físicas y Naturales de la Universidad Nacional de Córdoba, Córdoba, Argentina

**CM**, Carnegie Museum of Natural History, Pittsburgh, U.S.A.

**CMNH**, Cleveland Museum of Natural History, Cleveland, U.S.A.

**FMNH**, The Field Museum, Chicago, U.S.A.

**IGM**, Instituto Nacional de Investigaciones Geológico-Mineras, Bogotá, Colombia

**MACN-A**, Ameghino collection, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Buenos Aires, Argentina

**MACN-PV**, vertebrate paleontology collection, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Buenos Aires, Argentina

**MB.Ma**, Museum für Naturkunde Berlin, Berlin, Germany

**MLP**, Museo de La Plata, La Plata, Argentina

**MMH**, Museo de Monte Hermoso, Monte Hermoso, Argentina

**MMP**, Museo Municipal de Ciencias Naturales de Mar del Plata, Mar del Plata, Argentina

**MNHC**, Museo de Historia Natural de Cochabamba, Cochabamba, Bolivia

**MNHN**, Muséum National d'Histoire Naturelle, Paris, France

**MNHN-Bol**, Museo Nacional de Historia Natural, La Paz, Bolivia

**MNHN-DP**, Departmento de Paleontología, Museo Nacional de Historia Natural, Montevideo, Uruguay

**MHNT**, Museu de História Natural de Taubaté, Taubaté, Brazil

**MNRJ**, Museu Nacional e Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil

**MPEF-PV**, Museo Paleontológico Edigio Ferugulio, Trelew, Argentina

**MUSM**, Museo de Historia Natural de la Universidad Nacional Mayor San Marcos, Lima, Peru

**NDGS**, North Dakota Geological Survey, Bismakr, U.S.A.

**OMNH**, Sam Noble Museum of Natural History, Norman, U.S.A.

**PIMUZ**, Paläontologisches Institut und Museum Zürich, Zurich, Switzerland

**PIN**, Institute of Paleontology, Russian Academy of Sciences, Moscow, Russia

**PSS-MAE**, Paleontological and Stratigraphical Section (PSS) of the Mongolian Academy of Sciences, Ulan Baatar, Mongolia

**PVL**, Paleontología Vertebrados Lillo, Tucumán, Argentina

**SGOPV**, vertebrate paleontology collections, Museo Nacional de Historia Natural, Santiago, Chile

**UA**, University of Alberta Laboratory for Vertebrate Paleontology, Edmonton, Canada

**UATF-V**, Universidad Autónoma Tomás Frías, Potosí, Bolivia

**UCMP**, University of California Museum of Paleontology, Berkeley, California, U.S.A.

**UF**, Florida Museum of Natural History, University of Florida, Gainesville, U.S.A.

**UM**, University of Michigan Museum of Natural History, Ann Arbor, U.S.A.

**UMMZ**, University of Michigan Museum of Zoology, Ann Arbor, U.S.A.

**UNPSJB PV**, vertebrate paleontology collection, Universidad Nacional de La Patagonia 'San Juan Bosco', Comodoro Rivadavia, Argentina

**USNM**, National Museum of Natural History, Washington D.C., USA

**YPFB Pal**, Yacimientos Petrolíferos Fiscales de Bolivia in the Centro de Tecnología Petrolera, Santa Cruz, Bolivia, paleontology collection

**YPM-VPPU**, Princeton University Collection, Yale Peabody Museum, New Haven, U.S.A.

**ZPAL MgM**, Institute of Paleobiology of the Polish Academy of Sciences, Warsaw, Poland

# CHANGES TO DATA MATRIX FROM SUAREZ ET AL. (2016) AND MUIZON ET AL. (2018)

Contra Muizon et al. (2018), we did not code characters for postcanine teeth based on serial position. Recent studies suggest that the metatherian m1 is homologous to the dp5 of eutherians and stem zatherians, and the metatherian m2-4 is homologous to the m1-3 of non-metatherians (Luckett, 1993; O'Leary et al., 2013). Similarly, many zatherians (e.g., *Maelestes*, peramurans) have five premolars and it is thought that the p3 locus in these taxa is the locus lost in therians with fewer premolars (O'Leary et al., 2013). Therefore, characters dependent on the morphology at a particular tooth locus were addressed based on homology rather than serial position (i.e., p4 of eutherians treated as homologous to p3 of metatherians). Metatherian characters involving m1 morphology were not coded for eutherians, given the potential homology between the metatherian m1 and eutherian dp5.

Similarly, we did not code characters of the postcanine teeth reliant on a specific tooth locus for *Vincelestes*, which has a highly reduced, autapomorphic tooth count consisting of only two premolariform and three molariform teeth, to avoid making assumptions about the homology of the postcanine teeth in this taxon.

## New or Modified Characters Based on Muizon et al., 2018

**Character 3 (expanded apex of rostrum)**

Character 121 of Muizon et al. (2018). The apex of the rostrum is considered to be “expanded” when the rostrum bulges laterally around the alveoli of the canines in dorsal view.

**Character 8 (dimensions of paracanine fossa)**

Character 126 of Muizon et al. (2018).

**Character 13 (tubercle or internarial process on anterodorsomedial surface of premaxilla)**

Wording of character states modified for clarity following Muizon et al. (2018).

**Character 17 (median process of frontals wedged between nasals)**

Character 136 of Muizon et al. (2018).

**Character 21 (postorbital process of jugal)**

Character 172 of Muizon et al. (2018)

**Character 24 (fossa for levator labii)**

Character 147 of Muizon et al. (2018).

**Character 31 (minor palatine foramen)**

Coding states modified as proposed by Muizon et al. (2018: ch. 152).

**Character 36 (palatine contributes to infraorbital canal)**

Wording of character states modified following Muizon et al. (2018).

**Character 37 (size of postpalatine torus foramen)**

**Character 38 (morphology of postpalatine torus foramen)**

Characters 155 and 156 of Muizon et al. (2018). The absent state was coded alongside the character assessing morphology of the postpalatine torus foramen rather than its size (contra Muizon et al., 2018), as the distribution of this character suggests the absence of this foramen is due to the groove for the foramen becoming indistinct (Muizon et al., 2018: p. 392) rather than it being evolutionarily reduced in size.

**Character 57 (proportions of postglenoid process)**

Character 176 of Muizon et al. (2018).

**Character 59 (location of postglenoid foramen)**

**Character 60 (anteroposterior position of postglenoid foramen)**

Forasiepi (2009) originally coded the postglenoid foramina of most sparassodonts as being medial to the postglenoid process. Muizon et al. (2018) stated that this was incorrect and changed the character to being posterior to the postglenoid process in their list of changes, but examination of the published matrix shows no changes to these character states in their analysis. To resolve this issue, we re-examine the position of the postglenoid foramina in all of the taxa discussed, as well as propose a more specific definition for each character state to make it easier for future studies to code.

In most metatherians examined (e.g., non-australidelphians and dasyuromorphians), the postglenoid foramen is located slightly posteromedial to the postglenoid process, with the medial edge typically aligned or just slightly medial to the medial border of the postglenoid process. However, in *Monodelphis* (see Wible, 2003: fig. 6) and *Thylacinus* among the non-sparassodont taxa examined, the foramen is located significantly medial to the postglenoid process and in *Thylacinus* is more anteriorly positioned and directly medial to the postglenoid process (Warburton et al., 2019: fig. 7). Additionally, in most metatherians examined the postglenoid foramen is very close to the postglenoid process. However, in *Monodelphis*, *Herpetotherium*, and *Sminthopsis*, the main foramen is located more posteriorly.

The glenoid region of *Deltatheridium* has never been fully described. Bi et al. (2015) note that in deltatheroidan *Lotheridium* the postglenoid foramen is directly medial to the postglenoid process. Therefore, we tentatively leave this coding as “?”. Similarly, although the basicranium of *Asiatherium* is figured in Szalay and Trofimov (1996), this specimen is too heavily fragmented to determine the location of the postglenoid foramen in the figures published, though the morphology of the glenoid region suggests the postglenoid foramen could be located near the medial border of the postglenoid process, as in most other metatherians.

A postglenoid foramen aligned with the medial border of the postglenoid process clearly occurs in the sparassodonts *Mayulestes*, *Allqokirus*, *Hondadelphys*, *Acyon*, *Cladosictis*, *Sipalocyon*, *Prothylacynus*, and *Thylacosmilus*. The condition in *Callistoe* could not be directly observed, but given the description by Babot et al. (2002) of the foramen being at the anterior end of the external acoustic meatus, it is likely the foramen opened in a similar position, rather than more medial. In *Lycopsis longirostrus* this foramen is located more laterally, on the posteroventral surface of the postglenoid process. The condition in *Sallacyon* could not be confirmed. Part of the postglenoid foramen is preserved in *Paraborhyaena*, but the postglenoid process is not preserved (Petter and Hoffstetter, 1983). However, the position of the postglenoid foramen suggests it was located near the medial edge of the postglenoid process or just medial to it. Given the potential ambiguity of the states, we code *Paraborhyaena* as "?".

In several borhyaenoids, including *Arctodictis sinclairi*, *Borhyaena tuberata*, and *Australohyaena antiquua*, the postglenoid foramen is more medially located than in other sparassodonts, with the opening being entirely medial to the postglenoid process. *Arctodictis munizi* and *Acrocyon riggsi* do not exhibit this condition, instead possessing a postglenoid foramen with its medial edge aligned with the medial edge of the postglenoid process, as in many other sparassodonts.

**Character 43 (posterior process of pterygoids covering alisphenoid-basisphenoid suture**

Character 161 of Muizon et al. (2018).

**Character 62 (squamosal at external acoustic meatus)**

Character 238 of Muizon et al. (2018). Muizon et al. (2018) considered the mediolateral extent of the squamosal contribution to the meatus in addition to the shape of the meatus, following Babot et al. (2002) and Muizon (1999). However, Muizon et al. (2018) coded borhyaenids as having a meatus that is anteroposteriorly longer than wide, contra Forasiepi (2009). First-hand observations of a specimen of *Arctodictis sinclairi* (MLP 85-VII-3-1) show that the squamosal portion of the meatus is mediolaterally wider than anteroposteriorly long, contra Muizon et al. (2018) but agreeing with Forasiepi (2009). The same appears to be true of *Australohyaena* and *Arctodictis munizi* based on Forasiepi et al. (2015) and Forasiepi et al. (2004). *Borhyaena* does not appear to exhibit this condition based on observations of YPM-VPPU 15120, Sinclair (1906), and Forasiepi et al. (2019), the external acoustic meatus appears to be subequal in length and width. However, because we could not confirm this with certainty, the character was coded as “1/2” (thickened with mediolateral width shorter than anteroposterior width or thickened with mediolateral width longer than anteroposterior width).

**Character 63 (Paracondylar process of exoccipital)**

Character 179 of Muizon et al. (2018).

**Character 70 (Hypotympanic sinus)**

**Character 71 (Petrosal contribution of hypotympanic sinus)**

**Character 72 (Squamosal contribution to hypotympanic sinus)**

Previous versions of this matrix only examined whether or not the squamosal contributed to the hypotympanic sinus. However, another important is whether or not there is a petrosal contribution to the sinus. The absence of a petrosal contribution to the hypotympanic sinus differentiates taxa like *Dromiciops*, *Herpetotherium*, and dasyuromorphians from more basal metatherians like stagodontids, pucadelphyids, sparassodonts, and peradectids. Didelphids are coded as having a petrosal contribution to the hypotympanic sinus here based on the description of didelphids hypotympanic sinuses in Gabbert (1998) and observations of *Didelphis*.

In addition, some included taxa (i.e., non-metatherians) lack a hypotympanic sinus. In order to avoid conflating presence/absence of a morphological feature with its morphology (Brazeau, 2011), these characters were separated.

**Character 75 (Squamosal epitympanic sinus excavated in the roof of the external auditory meatus)**

Character 189 of Muizon et al. (2018). This character is also the same as Character 54 in Forasiepi (2009), and subsequent studies, who noted the presence of additional sinuses posterior to the hypotympanic sinus but did not differentiate between them based on their location.

**Character 76 (Intratympanic sinus excavated in the exoccipital)**

Character 186 of Muizon et al. (2018). This character is also the same as Character 54 in Forasiepi (2009), and subsequent studies, who noted the presence of additional sinuses posterior to the hypotympanic sinus but did not differentiate between them based on their location.

**Character 77 (Intratympanic sinus in the pars mastoidea**)

Character 187 of Muizon et al. (2018). This character is also the same as Character 54 in Forasiepi (2009), and subsequent studies, who noted the presence of additional sinuses posterior to the hypotympanic sinus but did not differentiate between them based on their location.

**Character 78 (Dorsal epitympanic expansion of hypotympanic sinus above glenoid fossa)**

Character 184 of Muizon et al. (2018).

**Character 79 (Anterior expansion of middle ear sinus within the lateral wall of the braincase)**

Character 188 of Muizon et al. (2018).

**Character 81 (tensor tympani fossa)**

Character 214 of Muizon et al. (2018).

**Character 83 (composition of primary foramen ovale)**

Additional character state “0” (on petrosal) added for *Vincelestes* and character coded as ordered.

**Character 85 (secondary foramen ovale totally enclosed in alisphenoid)**

Recoded using definitions and character states (character 192 and 193) of Muizon et al. (2018).

**Character 92 (Jugular foramen and foramen for inferior petrosal sinus)**

Character 197 of Muizon et al. (2018).

**Character 94 (median rod or crest of basisphenoid/presphenoid)**

Character recoded so absence is coded as “0” and presence is coded as “1”

**Character 96 (ascending canal)**

**Character 97 (contribution of squamosal to occiput)**

Character 240 of Muizon et al. (2018). Forasiepi (2009) considered this character to be correlated with the exposure of the petrosal on the occiput as a mastoid process, but Muizon et al. (2018) coded the contribution of the squamosal to the occiput as small to absent in *Hondadelphys*, *Callistoe*, and hathliacynids, all of which have an internal petrosal with no mastoid process. Therefore, this character is conservatively retained.

**Character 106 (ectotympanic attachment to skull)**

Character 237 of Muizon et al. (2018).

**Character 108 (Orientation of the pars cochlearis of the petrosal [plane defined by the apex of the promontorium-fenestra vestibuli-fenestra cochleae])**

Character 202 of Muizon et al. (2018).

**Character 109 (Orientation of the major axis of the petrosal [as defined by subarcuate fossa-internal acoustic meatus])**

Character 203 of Muizon et al. (2018).

**Character 112 (cavum epiptericum)**

Additional character state "0" (floored only by petrosal) added for *Vincelestes* and character coded as ordered.

**Character 119 (prootic canal morphology)**

Character 212 of Muizon et al. (2018).

**Character 120 (rostral tympanic process of the petrosal)**

**Character 121 (anterior extent of rostral tympanic process of petrosal)**

Muizon et al. (2018) differentiate between the shape of the rostral tympanic process and its anterior extent. This division of the characters is followed here.

**Character 122 (caudal tympanic process completely floors postpromontorial sinus)**

Character 218 of Muizon et al. (2018).

**Character 123 (petrosal plate)**

Character 217 of Muizon et al. (2018).

**Character 125 (Position of hiatus fallopii)**

Wording of character states modified for clarity and coding states modified as proposed by Muizon et al. (2018: ch. 223). Character coded as ordered, contra Muizon et al. (2018).

**Character 129 (Contribution of squamosal to epitympanic recess)**

Wording of character states modified for clarity and coding states modified as proposed by Muizon et al. (2018: ch. 230).

**Character 132 (Tuberculum tympani)**

Character 228 of Muizon et al. (2018).

**Character 131 (tympanic petrosal crest)**

Nomenclature and character states coded as proposed by Muizon et al. (2018: ch. 227)

**Character (134) - foramina for temporal ramus with well-developed internal branch of stapedial artery**

**Character (135) - location of foramina for temporal rami**

**Character (136) - foramina for veinous drainage of the temporal cavity on parietal or squama of squamosal**

The plesiomorphic condition for mammals is for there to be a well-developed internal temporal (superior) ramus of the stapedial artery, which is associated with a well-developed sulcus on the petrosal. This artery can enter the skull through a foramen that is located either on the petrosal (e.g., *Vincelestes*), between the petrosal and (probably) the squamosal (*Prokennalestes*), or on the parietal or squama of squamosal. By contrast, in most metatherians (and some eutherians), the sulcus for the stapedial artery is greatly reduced and a foramen for the temporal ramus is typically absent (Rougier et al., 1992; Wible et al., 2001). Some metatherians do have small grooves or emissary foramina on the surface of the parietal or squama of the squamosal in the temporal fossa, which some previous studies have apparently treated as homologous to the foramen for the temporal ramus (Forasiepi, 2009; Muizon et al., 2018). This condition can be observed in several metatherians, including *Didelphis* (see Forasiepi 2009, R.K.E. personal obs.), *Eodelphis* (see Matthew, 1916: pl. 3), *Pucadelphys*, *Andinodelphys* (see Muizon et al., 2018), *Mayulestes* (see Muizon, 1998), *Mimoperadectes* (see Horovitz et al., 2009: figs. 2 and S7), *Anatoliadelphys* (see Maga and Beck, 2017: fig. 11) and *Yalkaparidon* (see Beck et al., 2014).

However, these foramina are located more posterodorsally than the foramen for the temporal ramus in eutherians (Wible et al., 2009), and their position combined with the reduction of the internal sulcus for the temporal ramus of the stapedial artery on the petrosal in metatherians suggests these foramina are better interpreted as related to veinous drainage of the temporal muscle rather than transmission of the stapedial artery (Beck, pers. comm. 2018). In *Yalkaparidon* these foramina connect to the transverse sinuses of the endocranium, confirming that at least in this taxon they are related to venous drainage (Beck et al., 2014). Similar foramina may be present in *Arctodictis* (see Forasiepi, 2009), *Paraborhyaena* (see Petter and Hoffstetter, 1983), *Australohyaena*, and *Thylacosmilus* (see Forasiepi et al., 2015), at least, among sparassodonts.

As a result, instead of being coded as a single character as previous studies (e.g., Muizon et al., 2018: ch. 167) this feature was split into three characters: presence of a well-developed temporal ramus of the stapedial artery, the location of the foramen for this artery if such an artery is present, and the presence of foramina for veinous drainage within the temporal fossa. The first character was coded if a well-developed sulcus for the temporal ramus of the stapedial artery was present on the petrosal; such a feature is absent in all metatherians for which the petrosal has been studied, including those previously reported to have a foramen for the temporal ramus (Ladevèze and Muizon, 2007). The coding for the latter character was determined based on location of the foramina, as well as if a foramen for the stapedial artery was present.

**Character 138 (posttemporal sulcus on squamosal surface of petrosal)**

Character 234 of Muizon et al. (2018).

**Character 140 (ventral margin of dentary posterior to last molar in lateral view)**

Wording of character states modified for clarity. Coding states proposed by Muizon et al. (2018) not used as differences between states not clear and states coded in this study do not agree with observed morphology. Muizon et al. (2018) included an additional state “2” (angled), but it is not clear how this character is defined. Many taxa which are coded as having an “angled” margin of the dentary (*Hondadelphys*, *Cladosictis*, *Sipalocyon*) have a gently curved margin, whereas taxa that are coded as having a “curved” ventral margin of the dentary such as *Borhyaena*, *Arctodictis*, and *Australohyaena* have a nearly straight ventral border of the dentary in lateral view. Some of the codings as “angled” in Muizon et al. (2018) appear to be redundant with the shape of the angular process (character 151 of this study) rather than reflecting the actual shape of the horizontal ramus.

Because of the inconsistency regarding the coding of this character and the confusion regarding the definition of the character states, we opted for a more straightforward definition of the character similar to what has been used in previous studies of metatherians. In most metatherians (e.g., *Didelphis*, *Cladosictis*, *Hondadelphys*, etc.), the ventral border of the dentary is strongly curved. By contrast, in some species of sparassodonts (e.g., *Prothylacynus*, *Arctodictis*, *Thylacosmilus*) the ventral border of the dentary is straight. This character is measured just posterior to m4 to account for the anterior ventral curvature in the dentary at the level of the symphysis. This does not appear to be redundant with the position of the mandibular condyle, as in *Callistoe* (see Babot et al., 2002) the condyle is very low but the dentary is curved, whereas in *Chlorocyon* (see Engelman et al., 2018) the ventral border is straight but the condyle is elevated compared to the condition in other taxa.

**Character 142 (anteroventral angle of symphysis relative to tooth row)**

Character 106 of Muizon et al. (2018).

**Character 148 (masseteric fossa)**

Character 108 of Muizon et al. (2018).

**Character 150 (medially inflected angular process)**

Character 114 of Muizon et al. (2018).

**Character 157 (height of first upper incisor)**

Wording of character states modified for clarity and state 2 (I1 absent) removed and character coded as unordered

**Character 158 – Roots of I1 in anterior view**

Character 2 of Muizon et al. (2018).

**Character 159 – Diastema between I1-2**

Character 3 of Muizon et al. (2018).

**Character 160 – Size of I3 versus I2**

Character 6 of Muizon et al. (2018).

**Character 163 (Shape of upper incisors [I2-5])**

Character 8 of Muizon et al. (2018).

**Character 167 – Procumbency of lower incisors**

Character 12 of Muizon et al. (2018).

**Character 176 – Procumbent lower canine**

Character 13 of Muizon et al. (2018).

**Character 177 – Number of premolars**

Added state “0” (four or more) for eutherians and coded character as ordered.

**Character 185 – Shape and position of main cusp of P1**

Character 21 of Muizon et al. (2018).

**Character 202 (size of metacone relative to paracone)**

Coding states modified as proposed by Muizon et al. (2018: ch. 46). This character was based on the mesiodistal length of the two cusps (= size in occlusal view) and not their relative height, as it is often not possible to determine the original height of these cusps in many species due to wear and in some sparassodonts (e.g., *Callistoe*, *Arminiheringia*, and *Patagosmilus*, see main text), the paracone is only slightly shorter than the metacone in height despite being less than 50% the size of this cusp in mesiodistal length.

**Character 205 (Bases of paracone and metacone)**

Coding states modified as proposed by Muizon et al. (2018: ch. 48) and character coded as ordered.

**Character 209 (Size of protocone)**

Wording of character states modified for clarity and coding states modified as proposed by Muizon et al. (2018: ch. 70)

**Character 211 (Trigon basin)**

Coding states modified as proposed by Muizon et al. (2018: ch. 70)

**Character 216 (Extent of postprotocrista)**

Character 61 of Muizon et al. (2018). Several of Muizon et al. (2018)'s character states did not match our own observations, and the character has been recoded based on first-hand observations and the previously published literature.

**Character 221 (Carnassial notch in postmetacrista)**

Character 39 of Muizon et al. (2018).

**Character 224 (width of parastylar lobe relative to metastylar lobe)**

**Character 225 (width of stylar shelf [widest lobe on m3])**

Taxa for which the stylar shelf was vestigial to absent were coded as inapplicable for character 224.

**Character 238 – Relative positions of paraconid and metaconid (considered based on the apices of both cusps)**

Muizon et al. (2018: ch. 76) reworded this character (character 163 in Forasiepi, 2009, and other analyses prior to Muizon et al., 2018) to only consider the position of the paraconid, considering the position of the metaconid to be too variable to be useful. However, in several metatherians, including *Pucadelphys* (see Ladevèze et al., 2011), *Asiatherium* (see Szalay and Trofimov, 1996), and *Mimoperadectes* (see Bown and Rose, 1979), the metaconid is clearly located more labially than the paraconid despite the latter being at the anterolabial edge of the tooth. This character has been reworded from Suarez et al. (2016) to emphasize the focus on the relative positions of the paraconid and metaconid to one another (i.e., aligned or not aligned labiolingually). When the paraconid or metaconid is absent this character is coded as inapplicable.

**Character 240 (Relative length of paracristid and metacristid)**

Character 89 of (Muizon et al., 2018).

**Character 241 (Morphology of talonid)**

Character 73 of (Muizon et al., 2018). The talonid is considered to be a "small basinless heel" when it is not basined and consists of one or more cusps at the posterior end of the tooth, in order to differentiate this character from other characters describing the dimensions of the talonid.

**Character 243 (Dimensions of trigonid)**

Character 68 of (Muizon et al., 2018)

**Character 244 (Width of talonid relative to trigonid [m1-3])**

Coding states modified as proposed by Muizon et al. (2018: ch. 70), but character recoded based on a survey of the literature.

**Character 249 (Volume of metaconid relative to paraconid)**

Character 85 of Muizon et al. (2018).

**Character 252 (Labial extension of protoconid)**

Character 71 of Muizon et al. (2018).

**Character 254 (Anterior keel at anterolingual angle of paraconid with hypoconulid notch)**

Wording of character states modified for clarity following character 78 of Muizon et al. (2018).

**Character 255 (Paraconid elongated with anteroventral projection of the paraconid keel)**

Character 80 of Muizon et al. (2018).

**Character 266 (Hypoconulid of m4)**

Wording of character states modified for clarity. Codings for *Pucadelphys*, *Andinodelphys*, and *Mayulestes* not changed as published photos of dentitions of these taxa (Marshall and Muizon, 1995: fig. 6; Muizon et al., 1997: fig. 1h; Muizon, 1998: figs. 3, 4) show the m4 hypoconulid is distinctly taller than the other cusps of the talonid, contra Muizon et al. (2018). This is not the case for *Allqokirus australis* (see Muizon et al., 2018: fig. 13).

**Character 270 (Posthypocristid)**

Character 99 of Muizon et al. (2018). *Hondadelphys* is coded as having a transverse hypocristid, contra Muizon et al. (2018), as observations show these taxa have a nearly transverse hypocristid (one that is nevertheless more oblique than seen in didelphids, see Engelman et al., In press).

**Character 275 (Labial postcingulid on m4)**

Character 102 of Muizon et al. (2018). Muizon et al. (2018) coded several borhyaenoids (*Australohyaena* and *Borhyaena*) as having a labial postcingulid present or polymorphic on m4. Observations of the holotype of *Pharsophorus lacerans* shows that a cingulid is also present on m4 in this taxon, contra Muizon et al. (2018). However, the morphology of the postcingulid is slightly different than in other taxa in which it is present (mostly basal metatherians such as *Alphadon* and stagodontids), and may be non-analogous to the condition in these species and related to the reduction of the talonid and its associated cusps seen in borhyaenoids.

**Character 278 (Posterior extent of transverse processes of atlas)**

Modified following Muizon et al. (2018) to add and additional character state “2” (Extend caudally far beyond caudal facets for axis and processes much longer than wide) for *Callistoe* and *Thylacosmilus*. Character 247 of Muizon et al. (2018), shape of the transverse process of the atlas, is not considered as a distinct character as the extremely long posterodistal extension of the transverse processes are what cause the transverse processes to extend far beyond the caudal facets, and the two states are therefore correlated.

**Character 284 (Ventral sagittal crest of axis)**

Character 252 of Muizon et al. (2018).

**Character 302 (Anterior extension of acromion process)**

Character 269 of Muizon et al. (2018).

**Character 326 (Posterior border of ulna)**

Wording of character states modified for clarity following definitions of Muizon et al. (2018).

**Character 353 (Orientation of the lateral edge of the astragalus-tibia facet)**

Character 319 of Muizon et al. (2018).

**Character 354 (Anteroposterior length of medial malleolus relative to distal epiphysis)**

Character 320 of Muizon et al. (2018).

**Character 367 (Astragalo-cuboid facet on astragalar head)**

Character 333 of Muizon et al. (2018).

***Characters and character state changes not included from Muizon et al., 2018***

**Anterior edge of nasals (character 134 of Muizon et al., 2018)**

This character is not independent from and partially redundant with the anterior extent of the nasals (character 133 of Muizon et al., 2018, character 15 here). This can be seen in examining the character state codings of Muizon et al. (2018); all taxa in which the nasals protrude anteriorly the nasals overhang the nasal aperture, whereas all taxa in which the anterior edge of the nasals is transverse or notched the nasals do not overhang the nasal aperture. In addition, although Muizon et al. (2018) coded *Thylacinus* as having posteriorly notched nasals, our observations of *Thylacinus* find much more variation in the taxon, most of the specimens we were able to observe had a straight anterior edge of the nasals (Warburton et al., 2019: fig. 2).

**Precingulum (character 62 of Muizon et al., 2018)**

This character was only present in *Maelestes* and *Asiatherium* among the taxa sampled by Muizon et al. 2018. The phylogenetic utility of this character is thus limited in taxonomic scope of the current dataset.

**Trigonid basin floor (character 67 of Muizon et al., 2018)**

The orientation of the trigonid basin floor is a non-independent character whose state is logically dependent on the state of other characters already included in the analysis. Only taxa that have an obliquely oriented paracristid and metacristid exhibit the apomorphic states of having a trigonid basin that is lingually sloping or lost (compare Muizon et al., 2018: chs. 66, 67, and 79). Additionally, whether the trigonid basin is lingually sloping or lost is dependent on the presence of a metaconid, and in Muizon et al. (2018) a trigonid basin is coded as absent in all taxa for which the metaconid is very small or absent.

**Metaconid on molars between first and last molar (character 87 of Muizon et al., 2018)**

Muizon et al. (2018) added an additional character state "present but extremely reduced as a small cuspule at the posterior base of the protoconid" to this character. However, the relative size of the metaconid relative to the paraconid is already addressed in characters examining the height of the metaconid relative to the paraconid (character 84 of Muizon et al., 2018, character 248 here) and the occlusal volume of the metaconid relative to the paraconid (character 85 of Muizon et al., 2018, character 249 here), and the criteria to coding this character as a state distinct from that of other metatherians with small metaconids (e.g., stagodontids, *Hondadelphys*) seems dubious. Therefore, we do not include this state here.

**Greater tuberosity development in proximal view (character 281 of Muizon et al., 2018)**

In the list of changes made to Forasiepi et al. (2015), Muizon et al. (2018) list that they changed the state of the size of the greater tuberosity of the humerus in proximal view from "small (less than half anteroposterior length of head)" to "large (greater than half anteroposterior length of head)" for *Mayulestes*, *Andinodelphys*, and *Pucadelphys*. However, examination of the matrix of Muizon et al. (2018) first-hand shows that the authors of this study actually did not change the coding of this character in the matrix they used for their phylogenetic analysis. Figures of the humerus in Muizon (1998: p. 57-8) and Argot (2001) suggest the size of the greater tubercle in *Mayulestes* and *Pucadelphys* is more similar to didelphids or *Prothylacynus* (which are coded as "small") rather than the enlarged state represented by *Thylacinus* and other sparassodonts.

**Relative heights of the trochlea and capitulum in anterior view (character 284 of Muizon et al., 2018)**

Muizon et al. (2018) changed the codings of *Cladosictis*, *Sipalocyon*, and *Lycopsis* from having a longer proximal extension of the trochlea to having a longer or subequal proximal extension of the capitulum. However, figures of the humerus of all three taxa by Argot (2003, 2004) show a longer proximal extension of the trochlea, agreeing with the original coding of this character by Forasiepi et al. (2015).

TAXON-SPECIFIC CHARACTER CHANGES FROM MUIZON ET AL., 2018

***Eodelphis browni***

– Character 357 (visibility of medial plantar tuberosity in dorsal view) coded as “1” (visible)
– Character 373 (mesiolateral orientation of sustentacular facet) coded as “0” (medial)
– Character 374 (anteroposterior orientation of sustentacular facet) coded as “1” (45° dorsoanteriorly)
– Character 375 (sustentacular facet morphology) coded as “0” (slightly concave or flat)
– Character 379 (orientation calcaneal facet for fibular) coded as “0” (dorsal)

***Didelphodon vorax***

- Character 9 (precanine notch) coded as “0” (absent)
- Character 10 (lateral palatal process of premaxilla) coded as “0” (anterior to or just reaches anterior border of canine alveolus)

- Character 13 (tubercle or internarial process on anterodorsomedial surface of premaxilla) coded as “1” (present)
- Character 93 (median keel in basioccipital) coded as “1” (present)
- Character 94 (median rod or crest of basisphenoid/presphenoid) coded as “1” (present)
- Character 161 (size of I4 versus I3) coded as “0” (I4 subequal to I3)
- Character 359 (visibility of medial plantar tuberosity in dorsal view) coded as “0” (not visible)
- Character 376 (mesiolateral orientation of sustentacular facet) coded as “0” (medial)
- Character 377 (anteroposterior orientation of sustentacular facet) coded as “1” (45° dorsoanteriorly)
- Character 378 (sustentacular facet morphology) coded as “0” (slightly concave or flat)
- Character 382 (orientation calcaneal facet for fibular) coded as “0” (dorsal)
- Character 383 (length of the tuber calci) coded “0” (longer than the body)

***Asiatherium reshetovi***

- Character 64 (Paracondylar process of exoccipital and post-tympanic process of squamosal) changed from “-” to “1” (both processes similar in length)

***Herpetotherium fugax***

- Character 365 (malleolar shelf of astragalus) coded as “0” (absent)
- Character 366 (astragalo-distal tuber) coded as “0” (absent)
- Character 375 (outline of sustentacular process) coded as “1” (rectangular)

- Character 377 (secondary distal calcaneoastragalar facet) coded as "0" (absent)
- Character 384 (angle between proximal and distal areas of calcaneocuboid facet) coded as "1" (oblique calcaneocuboid facet)

Comments: These codings cross-referenced with Horovitz et al. (2008).

***Mimoperadectes houdei***

- Character 136 (foramina for veinous drainage of the temporal cavity on parietal or squama of squamosal) coded as "0" (present)

***Monodelphis* spp.**

- Character 80 (pneumatization of the squamosal) coded as "0" (absent)
- Character 332 (angle between transverse axis of proximal and distal epiphyses of metacarpal I) coded as "1" (present)
- Character 345 (parafibula) coded as "1" (absent)
- Character 383 (length of the tuber calci) coded as "1" (shorter than the body)
- Character 384 (medial curvature of the tuber calci) coded as "1" (absent)
- Character 399 (groove on dorsal tip of ungual phalanges) coded as "0" (absent)
- Character 400 (dorsal border of ungual phalanges) coded as "0" (rounded)

***Dromiciops gliroides***

- Character 64 (Paracondylar process of exoccipital and post-tympanic process of squamosal) changed from "-" to "0" (paracondylar process larger)
- Character 80 (pneumatization of the squamosal) coded as "0" (absent)
- Character 99 (connection between condylar articular facets in ventral view) changed from "1" (present) to "0" (absent)

***Dasyurus* spp.**

- Character 61 (suprameatal foramen) changed from “0” (above suprameatal crest) to “1” (below suprameatal crest)
- Character 332 (angle between transverse axis of proximal and distal epiphyses of metacarpal I) coded as “0” (absent)

***Sminthopsis* spp.**

- Character 118 (prootic canal) changed from “0” (present) to “1” (absent)
- Character 332 (angle between transverse axis of proximal and distal epiphyses of metacarpal I) coded as “0” (absent)
- Character 345 (parafibula) coded as “0” (present)

***Thylacinus cynocephalus***

- Character 6 (level of palate relative to basicranium) changed from “0” (palate lower than basicranium) to “1” (palate and basicranium at the same level)
- Character 61 (suprameatal foramen) changed from “0” (above suprameatal crest) to “1” (below suprameatal crest)
- Character 118 (prootic canal) changed from “0” (present) to “1” (absent)
- Character 130 (fossa incudis) coded as “0” (separated from the epitympanic recess)

***Pucadelphys andinus***

- Character 2 (length of rostrum) changed from “0” (less than 1/3 total length of skull) to “0&1” (Less than 1/3 total length of skull & Between 1/2 and 1/3 total length of skull)
- Character 12 (position of medial palatine process of premaxilla) coded as “1” (horizontal)

- Character 30 (major palatine foramen) coded as “0” (one pair opening in maxilla, palatine, or maxillo-palatine suture)
- Character 18 (postorbital processes) changed from “0” (absent or indistinct) to “0&1” (well-developed)
- Character 40 (position of sphenorbital foramen relative to lacrimal) coded as “0” (posterior to the level of the posterior border of the lacrimal)
- Character 42 (development of pterygoids) coded as “0” (well-developed and expanded on medial side, with midline contact)
- Character 52 (shape of fronto-parietal suture) changed from “2” (formed by anterior wedge of parietals) to “0” (formed by posterior wedge of frontals)
- Character 64 (Paracondylar process of exoccipital and post-tympanic process of squamosal) changed from “-“ to “0” (both processes similar in length)
- Character 86 (foramen for the greater petrosal nerve) changed from “1” (without distinct notch or foramen) to “0” (distinct notch or foramen)
- Character 93 (median keel in basioccipital) changed from “0” (absent) to “1” (present)
- Character 94 (median rod or crest of basisphenoid/presphenoid crest) changed from “1” (present) to “0” (absent)
- Character 136 (foramina for veinous drainage of the temporal cavity on parietal or squama of squamosal) changed from “1” (absent) to “0” (present)
- Character 137 (post-temporal canal or notch) changed from “0” (present) to “1” (absent)

- Character 151 (shape of the angular process) changed from “0&1” (intermediate and shelf-like) to “0” (shelf-like)
- Character 152 (angle between anterior border of coronoid process and tooth row) changed from “0” (between 95 and 105 degrees) to “1” (between 106 and 126 degrees)
- Character 153 (position of the mandibular foramen) changed from (posterior to the midpoint of the coronoid process) to “0&1” (posterior to the midpoint of the coronoid process and at the midpoint of the coronoid process)
- Character 157 (height of I1) changed from “1” (subequal to or smaller than other incisors) to “0” (taller than other incisors)
- Character 222 (preparacingulum) changed from “1” (short) to “0” (expanded)
- Character 258 (length versus width of talonid basin) changed from “0” (longer than wide) to “1” (subequal)
- Character 277 (ventral foramen on transverse process of axis) coded as “0” (absent)
- Character 281 (atlas and intercentrum) changed from “1” (fused) to “0” (unfused)
- Character 289 (C7 transverse foramen) changed from “0” (absent) to “2” (complete foramen)
- Character 300 (coracoid process) coded as “1” (large, extends beyond medial border of glenoid cavity)
- Character 304 (width of acromion process at the level of the neck) coded as “0” (wider than infraspinous fossa)

- Character 310 (capitulum for radius on humerus) changed from “1” (cylindrical) to “0&1” (spherical and cylindrical)
- Character 316 (extension of the deltoid crest) changed from “0” (restricted to proximal half of humerus) to “1” (reaches distal half of humerus)
- Character 317 (end of deltoid crest) coded as “0&1” (merging with diaphysis and forming distinct angle or process)
- Character 318 (relative heights of trochlea and capitulum in lateral view) changed from “0” (longer proximal extension of capitulum) to “0&1” (longer proximal extension of capitulum and subequal)
- Character 321 (lateral extension of capitulum) changed from “0” (rounded) to “1” (straight)
- Character 328 (distal shaft of radius) coded as “0” (oval, wider than long)
- Character 332 (angle between transverse axis of proximal and distal epiphyses of metacarpal I) coded as “1” (present)
- Character 333 (orientation of ilium relative to ischium) changed from “1” (aligned with ischium) to “0&1” (prominent dorsally and aligned with ilium)
- Character 336 (greater sciatic notch) changed from “1” (between 95 and 115 degrees) to “0” (greater than 120°)
- Character 340 (torsion between proximal and distal epiphyses of femur) changed from “1” (absent) to “0” (present)
- Character 348 (proximal dimensions of tibia) changed from “0” (larger mediolaterally than anteroposteriorly” to “1” (subequal)

- Character 350 (torsion between proximal and distal epiphyses of tibia) coded as “1” (absent)
- Character 352 (posterior shelf of tibia) changed from “0” (present but does not extend beyond medial astragalotibial facet) to “0&1” (present but does not extend beyond medial astragalotibial facet and present and extends beyond medial astragalotibial facet
- Character 365 (malleolar shelf of astragalus) changed from “0” (absent) to “1” (present)
- Character 366 (astragalo-distal tuber) coded as “1” (present)
- Character 373 (calcaneal peroneal groove for the peroneus longus) changed from “0” (indistinct to weakly developed) to “1” (distinct, deep separation)
- Character 375 (outline of sustentacular process) changed from “0” (triangular or rounded) to “1” (rectangular)
- Character 377 (anteroposterior orientation of sustentacular facet) changed from “-” to “1” (45 degrees dorsoanteriorly)
- Character 382 (orientation of calcaneal facet for fibula) changed from “1” (lateral) to “0” (dorsal)
- Character 397 (median keel on palmar/plantar surface of metapodials) coded as “0&1” (blunt and sharp)
- Character 398 (foot ungual phalanx of digit IV in proximal view) coded as “1” (larger mediolaterally than dorsoventrally)
- Character 399 (groove on dorsal surfaces of tip of ungual phalanges) coded as “1” (present)

- Character 400 (dorsal border of ungual phalanges) changed from “0” (rounded) to “1” (forming a crest-like border)

***Andinodelphys cochabambensis***

- Character 2 (length of rostrum) changed from “0” (less than 1/3 total length of skull) to “1” (Between 1/2 and 1/3 total length of skull)
- Character 12 (position of medial palatine process of premaxilla) coded as “1” (horizontal)
- Character 13 (tubercle or internarial process on anterodorsomedial surface of premaxilla) coded as “1” (present)
- Character 28 (number of palatal pits) coded as “0” (absent)
- Character 40 (position of sphenorbital foramen relative to lacrimal) coded as “0” (posterior to the level of the posterior border of the lacrimal)
- Character 42 (development of pterygoids) changed from “0&1” (well-developed and expanded on medial side, with midline contact and well-developed and expanded on medial side with no midline contact) to “0” (well-developed and expanded on medial side, with midline contact)
- Character 46 (lacrimal tubercle) changed from “1” (absent) to “0” (present)

Comments: The phylogenetic matrix of Muizon et al. (2018) codes the lacrimal tubercle as absent in *Andinodelphys* but the text mentions a tubercle is present in this taxon (Muizon et al., 2018: p. 392).

- Character 48 (number of lacrimal foramina) coded as “0” (two)
- Character 52 (shape of fronto-parietal suture) coded as “0” (formed by posterior wedge of frontals)

- Character 55 (distinct preglenoid process of squamosal) coded as “0” (absent)
- Character 64 (paracondylar process of exoccipital and post-tympanic process of squamosal) changed from “-“ to “0” (both processes similar in length)
- Character 86 (foramen for the greater petrosal nerve) changed from “1” (without distinct notch or foramen) to “0” (distinct notch or foramen)
- Character 89 (groove between hypoglossal foramina and foramen for inferior petrosal sinus) coded as “0” (shallow or absent)
- Character 94 (median rod or crest of basisphenoid/presphenoid crest) coded as (present)
- Character 99 (connection between condylar articular facets in ventral view) coded as “0” (absent)
- Character 107 (position of petrosal) coded as “0” (at the level of the ventral margin of the braincase)
- Character 137 (post-temporal canal or notch) changed from “0” (present) to “1” (absent)
- Character 147 (labial mandibular foramen inside masseteric fossa) coded as “1” (absent)
- Character 151 (shape of the angular process) coded as “0” (shelf-like)
- Character 152 (angle between anterior border of coronoid process and tooth row) changed from “0” (between 95 and 105 degrees) to “1” (between 106 and 126 degrees)
- Character 153 (position of the mandibular foramen) coded as “1” (at the midpoint of the coronoid process)

- Character 154 (morphology of mandibular condyle) coded as “1” (cylindrical)
- Character 161 (size of I4 versus I3) coded as “0” (I4 subequal to I3)
- Character 162 (size of I5 versus I4) changed from “?” to “1” (I5 smaller than I4)
- Character 173 (surface of the roots of canines) coded as “0” (smooth)
- Character 192 (roots of lower premolars) coded as “0” (flat [wide as crown])
- Character 233 (posterior lobe of the crown lower than the anterior one) coded as “0” (absent)
- Character 272 (carnassial notch in cristid obliqua) coded as “1” (present)
- Character 277 (ventral foramen on transverse process of axis) coded as “0” (absent)
- Character 281 (atlas and intercentrum) coded as “0” (unfused)
- Character 285 (C3-C4 ventral sagittal process) coded as “0” (absent)
- Character 286 (C5 transverse process heads overlap transversely) coded as “0” (present)
- Character 287 (C5 and T1 body lengths) coded as “0” (C5 subequal or longer than T1)
- Character 289 (C7 transverse foramen) coded as “2” (complete foramen)
- Character 293 (foramen on dorsal arch of last lumbar vertebra) coded as “0” (present)
- Character 294 (metapophyses on third lumbar vertebra anterior to last) coded as “0” (absent or weak)
- Character 295 (ventral median keel on lumbar vertebra) coded as “1” (present)

- Character 296 (auricular process of sacrum) coded as “1” (developed on one sacral vertebra)
- Character 297 (size of sacral spinous process) coded as “0” (shorter than last lumbar)
- Character 298 (length of the tail) changed from “0” (shorter than twice the length of the precaudal vertebral column) to “1” (greater than twice the length of the precaudal vertebral column)
- Character 300 (coracoid process) coded as “1” (large, extends beyond medial border of glenoid cavity)
- Character 304 (width of acromion process at the level of the neck) coded as “0” (wider than infraspinous fossa)
- Character 306 (scapular notch) coded as “1” (more than 130 degrees)
- Character 307 (clavicle) coded as “0” (present)
- Character 308 (medial process for teres major) coded as “1” (present)
- Character 309 (tricipital line of humerus) coded as “1” (ridge or crest)
- Character 310 (capitulum for radius on humerus) changed from “1” (cylindrical) to “0&1” (spherical and cylindrical
- Character 313 (laminar supinator crest) coded as “0” (large)
- Character 314 (development of greater tuberosity in proximal view) coded as “0” (small, less than half anteroposterior length of head)
- Character 316 (extension of the deltoid crest) changed from “0” (restricted to proximal half of humerus) to “1” (reaches distal half of humerus)

- Character 317 (end of deltoid crest) coded as “0&1” (merging with diaphysis and forming distinct angle or process)
- Character 318 (relative heights of trochlea and capitulum in lateral view) changed from “0” (subequal) to “0&1” (longer proximal extension of capitulum and subequal)
- Character 320 (humerus distal end size) coded as “0” (large)
- Character 321 (lateral extension of capitulum) coded as “1” (straight)
- Character 324 (medial development of the ulnar anconeal process) coded as “0”&”1” (does not protrude beyond medial border of olecranon and medially protruding)
- Character 325 (medial curvature of the on the) coded as “0” (present)
- Character 327 (shape of articular facet for humerus) changed from “0” (anteroposteriorly compressed) to “0&1” (anteroposteriorly compressed and circular)
- Character 328 (distal shaft of radius) coded as “0” (oval, wider than long)
- Character 329 (prepollex) coded as “0” (absent)
- Character 330 (distolateral process of the scaphoid) coded as “0” (absent)
- Character 332 (angle between transverse axis of proximal and distal epiphyses of metacarpal I) coded as “1” (present)
- Character 333 (orientation of ilium relative to ischium) coded as “1” (aligned with ilium)
- Character 337 (iliac and gluteus fossa) coded as “2” (gluteus fossa larger)
- Character 338 (epipubic bones) changed from “1” (absent) to “0” (present)

- Character 339 (proximal size of epipubic bones) changed from “-” to “0” (short)
- Character 340 (torsion between proximal and distal epiphyses of femur) coded as “0” (present)
- Character 341 (relative heights of greater trochanter and femoral head) changed from “1” (greater trochanter higher than humeral head) to “0” (greater trochanter lower or equal in height to femoral head)
- Character 345 (parafibula) coded as “1” (absent)
- Character 346 (femoro-fibular articulation) coded as “0” (present)
- Character 347 (proximal dimensions of tibia) coded as “1” (subequal)
- Character 349 (tibia shape) coded as “1” (straight)
- Character 350 (torsion between proximal and distal epiphyses of tibia) coded as “1” (absent)
- Character 355 (distal malleolus of tibia) coded as “1” (distinct)
- Character 356 (angle between medial and lateral astragalotibial facets) coded as “0” (90 degrees)
- Character 358 (width and height of navicular facet in distal view) coded as “0” (transversely wider)
- Character 365 (malleolar shelf of astragalus) coded as “1” (present)
- Character 366 (astragalo-distal tuber) coded as “1” (present)
- Character 373 (calcaneal peroneal groove for the peroneus longus) coded as “1” (distinct, deep separation)
- Character 374 (position of sustentaculum) coded as “0” (reaches anterior end of calcaneus)

- Character 375 (outline of sustentacular process) coded as “1” (rectangular)
- Character 376 (mesiolateral orientation of sustentacular facet) coded as “0” (medial)
- Character 377 (anteroposterior orientation of sustentacular facet) changed from “-” to “1” (45 degrees dorsoanteriorly)
- Character 378 (sustentacular facet morphology) coded as “0” (slightly concave or flat)
- Character 380 (sustentacular and posterior calcaneoastragalar facets) coded as “0” (separate)
- Character 383 (length of the tuber calci) coded as “1” (shorter than the body)
- Character 384 (medial curvature of the tuber calci) coded as “0” (present)
- Character 386 (proximal calcaneocuboid facet) coded as “0” (absent)
- Character 387 (angle between proximal and distal areas of calcaneocuboid facet) coded as “0” (oblique calcaneocuboid facet)
- Character 388 (spatial relationship between navicular and entocuneiform) coded as “0” (entocuneiform anterior to navicular)
- Character 396 (Mt III thickness relative to Mt I) coded as “1” (Mt III thicker than Mt I)
- Character 398 (foot ungual phalanx of digit IV in proximal view) coded as “1” (larger mediolaterally than dorsoventrally)
- Character 399 (groove on dorsal surfaces of tip of ungual phalanges) coded as “1” (present)

- Character 400 (dorsal border of ungual phalanges) coded as “1” (forming a crest-like border)

***Mayulestes ferox***

- Character 2 (length of rostrum) changed from “0” (less than 1/3 total length of skull) to “1” (Between 1/2 and 1/3 total length of skull)
- Character 9 (precanine notch) changed from “0” (absent) to “1” (present)
- Character 15 (anterior extent of nasals) changed from “0” (protruding anteriorly) to “1” (retracted posteriorly)
- Character 22 (location of infraorbital foramen) changed from “0&1” (anterior to or dorsal to anterior root of P3 and dorsal to midpoint or posterior root of P3) to “1” (dorsal to midpoint or posterior root of P3)
- Character 28 (number of palatal pits) changed from “0” (absent) to “2” (two)
- Character 40 (position of sphenorbital foramen relative to lacrimal) coded as “0” (posterior to the level of the posterior border of the lacrimal)
- Character 52 (shape of fronto-parietal suture) changed from “1” (straight) to “0” (formed by posterior wedge of frontals)
- Character 54 (width of glenoid cavity) changed from “0” (less than twice anteroposterior length) to “1” (more than twice anteroposterior length)
- Character 64 (Paracondylar process of exoccipital and post-tympanic process of squamosal) changed from “-“ to “0” (both processes similar in length)
- Character 86 (foramen for the greater petrosal nerve) changed from “1” (without distinct notch or foramen) to “0” (distinct notch or foramen)

- Character 87 (position of carotid foramen) changed from “1” (at the level of the basisphenoid-basoccipital suture) to “0” (anterior to the basisphenoid-basoccipital suture)
- Character 93 (median keel in basioccipital) changed from “0” (absent) to “1” (present)
- Character 102 (sagittal crest) changed from “1” (weakly developed) to “0” (strongly developed)
- Character 118 (prootic canal) changed from “1” (absent) to “0” (present)
- Character 137 (post-temporal canal or notch) coded as “1” (absent)
- Character 147 (labial mandibular foramen inside masseteric fossa) coded as “1” (absent)
- Character 205 (bases of paracone and metacone) changed from “0” (separate) to “1” (partially adjoined)
- Character 209 (size of protocone) changed from “2” (somewhat expanded anteroposteriorly) to “1” (small)
- Character 219 (postmetacrista) changed from “0” (weakly developed) to “1” (strongly developed)
- Character 242 (length of trigonid versus talonid) changed from “1” (trigonid subequal to talonid) to “2” (trigonid longer than talonid)
- Character 262 (shape of entoconid) changed from “0” (conical) to “1” (labiolingually compressed)
- Character 272 (carnassial notch in cristid obliqua) coded as “1” (present)
- Character 289 (C7 transverse foramen) coded as “2” (complete foramen)

- Character 294 (metapophyses in third to last lumbar vertebra) changed from “0” (absent) to “1” (present)
- Character 295 (ventral median keel on lumbar vertebrae) changed from “0” (absent) to “1” (present)
- Character 304 (infraspinous/supraspinous fossa width at the level of the neck) changed from “0” (supraspinous fossa subequal or wider) to “1” (supraspinous fossa narrower)
- Character 306 (scapular notch) changed from “0” (greater than 130 degrees) to “1” (between 90 and 130 degrees)
- Character 321 (lateral extension of capitulum) changed from “0” (rounded) to “1” (straight)
- Character 332 (angle between transverse axis of proximal and distal epiphyses of metacarpal I) changes from “0” (absent) to “1” (present)
- Character 335 (length of the iliac neck) changed from “0” (longer than 15% total pelvis length) to “1” (between 6 and 15% total pelvis length)
- Character 337 (iliac and gluteus fossa) changed from “1” (two fossa subequal in size) to “2” (gluteus fossa larger)
- Character 340 (torsion between proximal and distal epiphyses of femur) changed from “1” (absent) to “0” (present)
- Character 359 (visibility of medial plantar tuberosity in dorsal view) changed from “1” (visible) to “0” (not visible)
- Character 361 (medial extent of sustentacular facet) changed from “0” (does not reach medial edge of the neck) to “1” (reaches the medial edge of the neck)

- Character 365 (malleolar shelf of astragalus) coded as “1” (present)
- Character 366 (astragalo-distal tuber) coded as “1” (present)
- Character 373 (calcaneal peroneal groove for the peroneus longus) changed from “0” (indistinct to weakly developed) to “1” (distinct, deep separation)
- Character 375 (outline of sustentacular process) changed from “0” (triangular or rounded) to “1” (rectangular)
- Character 377 (anteroposterior orientation of sustentacular facet) changed from “-” to “1” (45 degrees dorsoanteriorly)
- Character 385 (ventral curvature of the tuber calci) changed from “1” (absent) to “0” (present)
- Character 397 (median keel on palmar/plantar surface of metapodials) coded as “1” (sharp)

***Patene simpsoni***

- Character 152 (angle between anterior border of coronoid process and tooth row) coded as “0” (between 95 and 105 degrees)

***Hondadelphys fieldsi***

- Character 93 (median keel in basioccipital) changed from “0” (absent) to “1” (present)
- Character 94 (median rod or crest of basisphenoid/presphenoid crest) changed from “1” (present) to “0” (absent)
- Character 116 (deep sulcus for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “?”

***Sallacyon hoffstetteri***

- Character 28 (number of palatal pits) coded as “2” (two)
- Character 31 (minor palatine foramen) coded as “0” (complete)

  Character 40 (position of sphenorbital foramen relative to lacrimal) coded as “0” (posterior to the level of the posterior border of the lacrimal)
- Character 52 (shape of fronto-parietal suture) coded as “0” (formed by posterior wedge of frontals)
- Character 61 (suprameatal foramen) coded as “0” (above suprameatal crest)
- Character 113 (internal acoustic meatus) coded as “1” (shallow with thin prefacial commissure)
- Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)
- Character 118 (prootic canal) changed from “1” (absent) to “0” (present)
- Character 126 (stylomastoid foramen) coded as “0” (absent)
- Character 127 (floor of cavum supracochleare) coded as “1” (present)
- Character 128 (stapedial ratio) coded as “0” (rounded, less than 1.8)
- Character 137 (post-temporal canal or notch) coded as “1” (absent)
- Character 199 (size of molars increasing posteriorly) coded as “1” (marked posterior increase in size)
- Character 208 (number of roots on M4) coded as “0” (three)
- Character 214 (wing-like cristae associated with para- and metaconules) coded as “1” (present)

***Notogale mitis***

- Character 61 (suprameatal foramen) coded as “0” (above suprameatal crest)

- Character 88 (hypoglossal foramina) coded as “0” (two or more)
- Character 93 (median keel in basioccipital) changed from “1” (present) to “0” (absent)
- Character 94 (median rod or crest of basisphenoid/presphenoid) coded as “0” (absent)
- Character 112 (cavum epiptericum) coded as “1” (floored primarily or exclusively by alisphenoid)
- Character 113 (internal acoustic meatus) coded as “1” (shallow with thin prefacial commissure)
- Character 116 (deep sulcus for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)
- Character 118 (prootic canal) changed from “1” (absent) to “0” (present)
- Character 126 (stylomastoid foramen) coded as “0” (absent)
- Character 127 (floor of cavum supracochleare) coded as “1” (present)
- Character 128 (stapedial ratio) coded as “0” (rounded, less than 1.8)
- Character 137 (post-temporal canal or notch) coded as “1” (absent)

***Sipalocyon gracilis***

- Character 90 (size of jugular foramen relative to fenestra vestibuli) coded as “1” (larger)
- Character 93 (median keel in basioccipital) coded as “0” (absent)
- Character 94 (median rod or crest of basisphenoid/presphenoid) changed from “1” (present) to “0” (absent)

Comments: Characters 93 and 94 coded based on Muizon et al. (2018) and personal observations of AMNH 9254.

- Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)
- Character 118 (prootic canal) changed from “1” (absent) to “0” (present)
- Character 126 (stylomastoid foramen) coded as “0” (absent)
- Character 155 (mandibular condyle) coded as “1” (above tooth row)

***Cladosictis patagonica***

- Character 90 (size of jugular foramen relative to fenestra vestibuli) coded as “1” (larger)
- Character 112 (cavum epiptericum) coded as “1” (floored primarily or exclusively by alisphenoid)
- Character 116 (Deep sulcus for carotid artery on anterior end of promontorium) coded as “1” (present)

***Lycopsis longirostrus***

- Character 93 (median keel in basioccipital) changed from “1” (present) to “0” (absent)
- Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)
- Character 155 (mandibular condyle) coded as “1” (above tooth row)
- Character 359 (visibility of medial plantar tuberosity in dorsal view) coded as “1” (visible)

- Character 376 (mesiolateral orientation of sustentacular facet) coded as “1” (dorsal)
- Character 377 (anteroposterior orientation of sustentacular facet) coded as “1” (45 degrees dorsoanteriorly)
- Character 378 (sustentacular facet morphology) coded as “0” (slightly concave or flat)

***Prothylacynus patagonicus***

- Character 56 (morphology of postglenoid process) coded as “0” (wider than high [height of process less than half its width])

<u>Comments:</u> Based on Muizon et al. (2018) and figures of YPM-VPPU 15700 in posterior view (see Sinclair, 1906: pl. XLVII)

- Character 93 (median keel in basioccipital) changed from “0” (absent) to “1” (present)
- Character 94 (median rod or crest of basisphenoid/presphenoid) changed from “0” (absent) to “1” (present)

<u>Comments:</u> Forasiepi (2009) coded both of these characters as absent, whereas Muizon et al. (2018) coded them as present. Photographs of MACN-A 5931 and YPM-VPPU 15700, which are the two specimens of *Pharsophorus* examined by these authors that preserve the ventral basicranium, show these structures to be unambiguously present.

***Pharsophorus lacerans***

- Character 10 (Lateral palatal process of premaxillae) coded as “1” (Posterior to anterior border of canine alveolus)

- Character 11 (Posterior border of incisive foramen) coded as “1” (Posterior to anterior border of canine alveolus)
- Character 12 (Orientation of medial palatal process of premaxilla) coded as “1” (With posterior end more dorsal, forming an incisive fossa)
- Character 116 (deep sulcus for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)
- Character 161 (size of I4 versus I3) coded as “1” (I4 larger)

***Borhyaena tuberata***

- Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)
- Character 118 (prootic canal) changed from “0” (absent) to “1” (present)

***Arctodictis sinclairi***

- Character 93 (median keel in basioccipital) changed from “1” (present) to “0” (absent)
- Character 94 (median rod or crest of basisphenoid/presphenoid) changed from “0” (absent) to “1” (present)

<u>Comments:</u> Forasiepi (2009: p. 46) specifically mentions that the median keel of the basioccipital is absent in *Arctodictis sinclairi*, contrary to the condition in related taxa. By the same token, a small median crest is noted on the presphenoid (Forasiepi, 2009: p. 37-38) and can be observed in first-hand photos of this specimen.

- Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)

– Character 217 (Orientation of the preparacrista) coded as “1” (oriented anterobuccally to long axis of tooth.

Comments: Coded based on Goin et al. (2007).

***Australohyaena antiquua***

– Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “?”

***Callistoe vincei***

– Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)

– Character 164 (shape of upper incisor arcade) changed from “0” (parabolic) to “-”

Comments: Coded as inapplicable due to incisors not forming an arcade and being telescoped as observed by Muizon et al. (2018). Not coded as a distinct character state because the remaining states form a morphocline.

***Paraborhyaena boliviana***

– Character 89 (groove between hypoglossal foramina and foramen for inferior petrosal sinus) coded as “1” (well-defined with prominent lateral borders)

– Character 90 (size of jugular foramen relative to fenestra vestibuli) coded as “1” (larger)

– Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “1” (present)

– Character 164 (shape of upper incisor arcade) changed from “1” (slightly anteriorly convex) to “-”

Comments: Coded as inapplicable due to incisors not forming an arcade and being telescoped as observed by Muizon et al. (2018). Not coded as a distinct character state because the remaining states form a morphocline.

***Thylacosmilus atrox***

- Character 116 (deep groove for internal carotid artery excavated in ventromedial apex of promontorium) changed from “0” (absent) to “?”

## New or Revised Characters and Character States Added in This Study

**Character 5 (Dimensions of the braincase)**

Codings states fixed after a lapsus in Engelman and Croft (2014).

**Character 22 – Location of the infraorbital foramen**

Character states were revised so taxa for which the infraorbital foramen was located dorsal to the midpoint between the anterior and posterior roots of P3 (e.g., *Stylocynus*) were coded as “1” (dorsal to the midpoint or posterior root of P3) rather than polymorphic.

**Character 25 – Large foramen at anteroventral end of maxilla medial to canines (anteroventral maxillary foramina)**

The anterior palate of most sparassodonts is characterized by a pair of large, paired, anteriorly opening foramina that are positioned medial to the canines and typically slightly posterolateral to the incisive foramina. These foramina can be readily distinguished from the other small foramina that cover the maxilla (which are thought to be homologous with the major palatine foramen; Forasiepi, 2009) in that the latter are smaller, do not open anteriorly, and are irregularly distributed across the palate and not bilaterally symmetrical. These large, paired, anteriorly opening foramina have been repeatedly noted in descriptions of sparassodonts (e.g., Sinclair, 1906; Forasiepi et al., 2006; Forasiepi, 2009; Engelman and Croft, 2014) but have never been named or examined in a phylogenetic context. Here, we name these foramina anteroventral maxillary foramina.

Anteroventral maxillary foramina appear to be a diagnostic feature of the Sparassodonta, as they are consistently present in every member of the Sparassodonta for which this region is known (Fig. S9; Table S13) with the exception of the basal sparassodonts *Allqokirus australis* and *Mayulestes ferox* (Muizon et al., 2018: fig. 4a-b), and are consistently absent in most non-sparassodont metatherians for which this character could be evaluated (Table S14). There are a few metatherians that exhibit a condition that somewhat resembles that in sparassodonts. In the phalangerids *Ailurops ursinus* (USNM 217576) and *Trichosurus vulpecula* (CMNH 18950), there are small paired foramina medial to the numerical first premolar and in *Vombatus ursinus* (CMNH 18946), there are a pair of small paired foramina posterior to the incisive foramina, but these are much smaller than the foramina in sparassodonts and it is unclear if these are homologous.

The dasyurid *Dasyuroides byrnei* and the thylacinid *Thylacinus cynocephalus* consistently exhibit paired accessory foramina on the palate, but in these taxa the paired foramina are smaller, do not open anteriorly, and are located in the premaxillae (Fig. S9, see alsoWarburton et al., 2019: figs. 2-3). The numbat, *Myrmecobius fasciatus* seems to consistently have paired foramina located within its paracanine fossa (CMNH 18914, USNM 83707), but it is not clear if these foramina are homologous to those of sparassodonts. Indeed, small nutrient foramina are present at the ventral border of the premaxilla-maxilla suture, suggesting the paracanine foramina in numbats may be related to these foramina. In *Didelphopsis cabrerai* (MNRJ 1429-V), there is a small, anteriorly-opening foramen present at the level of the P2/3 embrasure, but this foramen differs from that of sparassodonts in being much smaller and narrower.

Anteroventral maxillary foramina are present in *Sarcophilus harrisii*. However, the presence of these foramina was variable between individuals, being present in some specimens (USNM 582023; USNM 582024), but absent in others (USNM 142598, CMNH 18915). The foramina were always bilaterally present or absent, no specimens showed only a single foramen. This seems to be a condition unique to *Sarcophilus harrisii* among extant dasyuromorphians, as no anteroventral maxillary foramina could be observed in several individuals of *Dasyurus viverrinus*, *Dasyurus maculatus*, *Thylacinus cynocephalus*, or one the one individual of *D. albopunctatus* we was able to observe (USNM 521036). Finally, in some didelphine opossums (e.g., *Lutreolina*, *Didelphis*, *Philander*) some individuals exhibit small foramina slightly posterior to the canines (e.g, Voss et al., 2018, fig. 12), but these foramina are often asymmetrical, irregularly placed, and are not bilaterally symmetrical or open anteriorly as in sparassodonts. It is uncertain how these foramina compare to the anteroventral maxillary foramina in sparassodonts.

It is not clear what anatomical structures passed through these foramina, especially since sparassodonts are extinct and it is not possible to simply dissect a living specimen. The most likely possibility is that it transmitted portions of the major palatine artery and nerve, especially given the reduction of the major palatine foramen in sparassodonts. This is supported by the fact that some didelphine opossums exhibit a trough running from the maxillopalatine fenestrae (the normal opening that transmits the major palatine artery and nerve in marsupials) to the approximate location of the anteroventral maxillary foramina in sparassodonts (e.g. MACN-A 17781, *Hyperdidelphys inexpectata*). However, it is also possible that it could have carried a branch of the nasopalatine nerve, which normally passes through the incisive foramina, given how close the anteroventral maxillary foramina are to the major palatine foramen. The presence of anteroventral maxillary foramina and the absence of a single, large major palatine foramen are not completely correlated, given that in other mammals a single, large major palatine foramen is absent without anteroventral maxillary foramina being present (Gaudin and Wible, 2004).

**Character 27 – Shape of the palate**

The overall shape of the palate in ventral view varies significantly in non-diprotodont metatherians. In most non-diprotodont metatherians, the molar rows are nearly parallel to the long axis of the skull, making it appear rectangular in shape in ventral view (Fig. S10). However, in some specialized carnivorous forms, including sparassodonts, as well as dasyuromorphians (except *Myrmecobius*) and the didelphimorphian *Hesperocynus* (see Forasiepi et al., 2009), the molar rows diverge posteriorly, causing the palate to appear triangular in shape (Fig. S10).

This difference is easiest to see in taxa with well-developed protocones like didelphids and hathliacynids. In taxa with rectangular palates, like didelphids, the medialmost extent of the molars, represented by an imaginary line drawn through roughly the medial edge of the protocones, is nearly parallel to the midline suture, whereas in taxa with triangular palates this line is oriented at a distinct angle. However, because this cannot be used in taxa such as borhyaenids, in which the protocone is greatly reduced and there is significant canting of the upper molars, this character was measured by measuring the angle between the greatest length of the upper molar row and the midline suture (Fig. S11). The palate is considered rectangular when this angle is ≤ 10°, and triangular when it is > 10°.

This character is similar to but distinct from Character 26 (palatal length/width ratio) which refers to the proportions of the palate, rather than its overall shape, and is more affected by the overall length and width of the palate (particularly the rostrum) than its shape. This can be seen in taxa like *Prothylacynus*, which has a palatal length/width ratio > 1.5 but a triangular palate, or *Dromiciops*, which has a palatal length/width ratio < 1.5 but has a rectangular palate. In *Patagosmilus* and *Thylacosmilus*, this character is coded as "?" because the molar row is not straight but curved. Measurements for this character can be found in Table S15.

**Character 34 (palatine torus)**

**Character 35 (medial postpalatine spine)**

Most previous analyses of sparassodont relationships, including Forasiepi (2009), Engelman and Croft (2014), Forasiepi et al. (2015), Suarez et al. (2016), and Muizon et al. (2018), but notably not Muizon (1999) or Forasiepi et al. (2006) have treated the shape of the posterior end of the palate as a single character (Forasiepi, 2009: ch. 26; Muizon et al., 2018: ch 154). Forasiepi (2009) and related analyses mostly focus on the presence of a postpalatine torus, whereas Muizon et al. (2018) reworded this character to focus on the presence of a medial postpalatine spine. However, observation of metatherian taxa shows that these characters actually conflate at least two and possibly as many as three different morphological features: 1) presence/absence of a medial postpalatine spine, 2) development of the postpalatine torus, and 3) the shape of the palate over the choanae (straight or posteriorly curved).

Contrary to Forasiepi (2009) and Muizon et al. (2018), these characters are not correlated, and different combinations of character states occur in different taxa. A medial postpalatine spine is present in *Dromiciops*, *Dasyurus*, *Sminthopsis*, *Pucadelphys*, and *Andinodelphys* in spite of these taxa also having a well-developed post-palatine torus that makes the posterior margin of the palate straight, whereas a medial postpalatine spine is absent in didelphids despite these animals having a similar shape of the posterior palate and well-developed palatine torus. Similarly, *Arminiheringia* and *Allqokirus* have well-developed, bar-like postpalatine tori (rather than a thickening around the border of the choanae as in *Thylacinus* and most sparassodonts), but the posterior margin of the palate is strongly curved around the choanae rather than straight. Some taxa also have a strongly curved posterior palate but lack a medial postpalatine spine, as seen in *Maelestes* (see Wible et al., 2009). Forasiepi (2009) codes the posterior palate of *Deltatheridium* as being similar to *Maelestes*, but we could not confirm this in our observations. As a result, we treat these three features as separate characters, as was previously done by Muizon (1999) or Forasiepi et al. (2006) (who coded the presence of a medial postpalatine spine and well-developed palatine torus as two separate characters), in order to avoid conflating different, non-correlated features into a single character.

**Character 39 – Posterolateral corners of palate inflected ventrally forming distinct lateral corners.**

Character 69 of Voss and Jansa (2009). This character is usually considered to be a synapomorphy of didelphoids exclusive of caluromyines and some basal genera (e.g., *Glironia*). Wilson et al. (2016) said that lateral corners of the palate were present in *Pucadelphys* based on Marshall and Muizon (1995), but photographs of the specimen in this paper do not show prominent lateral corners, only the restoration does. It is likely that the prominent lateral corners of the palate in the restoration of *Pucadelphys* in this paper are due to the missing elements of the skull being restored after extant didelphids, especially given that Marshall and Muizon (1995) refer *Pucadelphys* to this group.

**Character 58 (postglenoid foramen)**

The postglenoid foramen is absent in *Vincelestes*.

**Character 139 – Shape of the dentary (depth below m3–4 embrasure/length of m1–4)**

In previous analyses, this character was coded based on the depth below m3-4 divided by the total length of the dentary, but has been changed here for several reasons. For one, the horizontal ramus is known for several taxa in this analysis (*Kokopellia*, *Mayulestes*, *Stylocynus*) but the complete dentary is not, restricting the number of characters that could be coded using the previous system of classification. Additionally, calculating the depth of the dentary based on m1–4 rather than the total length of the dentary avoids confounding taxa that have short, shallow jaws with those that have deeper but elongated jaws due to diastemata between the premolar row (e.g., *Cladosictis*, *Acyon*, *Thylacinus*). The total length of the dentary is not a reliable proxy for scaling the depth of the lower jaw, as the length of the dentary is also affected by the presence of diastemata between the lower canine and premolars, imbrication or loss of premolar teeth, and the size of the coronoid process and masseteric fossa (e.g., in *Thylacosmilus* the coronoid process and masseteric fossa are very small), which in turn would affect interpretations of the depth of the dentary. A list of revised codings can be found in Supplementary Table S16.

The eutherians in this analysis (*Prokennalestes*, *Maelestes*, *Asioryctes*) were not treated in this fashion due to having only three molars, but all of the specimens examined had extremely shallow dentaries, sometimes only the depth of the length of a single tooth crown (Wible et al., 2009; Lopatin and Averianov, 2017 ), and as a result are clearly "shallow". For *Vincelestes*, which is not directly comparable to tribosphenic taxa, the coding of this taxon was approximated using the previous method of Forasiepi (2009).

**Character 143 (number of mental foramina)**

**Character 144 (enlarged anterior mental foramen)**

Many sparassodonts, particularly borhyaenoids, *Stylocynus*, and some hathliacynids, differ from other metatherians in having a greater number of mental foramina in the dentary. Most metatherians (and most therians in general) are characterized by only one or two pairs of mental foramina (Rougier et al., 1998; Voss and Jansa, 2009). By contrast, many sparassodonts have three or more pairs of mental foramina (Fig. S12) and some taxa such as *Australohyaena antiquua* (see Forasiepi et al., 2015), *Acrocyon riggsi* (see Goin et al., 2007), *Arctodictis sinclairi* (see Marshall, 1978), and *Lycopsis longirostrus* (see Marshall, 1977; Goin, 1997), can have as many as five or six mental foramina on one hemimandible. Although the number of mental foramina can be individually variable in mammals (Wible, 2003; Forasiepi et al., 2006), the higher number of mental foramina in sparassodonts relative to other mammals appears to be a consistent feature. Individuals with three pairs of mental foramina occasionally occur in other metatherians as rare individual variants (Wible, 2003), but three or more mental foramina are consistently present in sparassodont taxa. There appears to be additional phylogenetic signal present in the number of mental foramina than considered here, as borhyaenoids typically have four or more pairs of mental foramina whereas hathliacynids usually have three or less. However, this character was formulated to be as broad as possible given the significant intraspecific variation in the number of mental foramina in sparassodonts (Marshall, 1977; Goin, 1997; Forasiepi et al., 2006; Engelman et al., 2015).

In addition to an increased number of mental foramina, the anterior mental foramen of many sparassodonts opens anteriorly and is greatly enlarged (Fig. S12b-d), especially in comparison to the posterior mental foramina (Babot and Ortiz, 2008; Engelman et al., 2015). By contrast, in other metatherians the anterior and posterior mental foramen are similar in size and in many species the anterior mental foramen does not open anteriorly. In *Australohyaena* it is the serially second mental foramen that is very large (Forasiepi et al., 2015), but comparisons with other sparassodonts suggests the second foramen is likely homologous with the anterior mental foramen of these other taxa as the foramen is located in the same anteroposterior position. Marshall (1978, 1981) considered the enlarged mental foramen in sparassodonts to be related to the pathological "periosteal proliferations" he documented in many hathliacynids, considering the margin of the anterior mental foramen to have been eroded by the "infection". However, this is unlikely to be the case, as an enlarged mental foramen occurs in many specimens of sparassodonts in which there is no sign of periosteal proliferations. Additionally when it does occur its presence is typically consistent within a species, rather than being individually variable as would be expected if the condition were the result of a pathology. It is possible that the presence of “periosteal proliferations” in hathliacynids could have exacerbated the size of the anterior mental foramen, but in these sparassodonts it appears the anterior mental foramen was already larger than the posterior mental foramina to begin with.

The condition in *Thylacosmilus* is unclear. At least one mental foramen is present at the p3/m1 embrasure, but there are a number of small foramina of uncertain homology along the ventral edge of the mandibular flange. Therefore, these characters are tentatively coded as “?”.

**Character 162 (Size of I5 versus I4)**

Character state 2 (I5 absent) removed and character coded as unordered.

**Character 168 – Size of canines**

**Character 170 – Shape of upper canines**

These characters were separated (originally character 115 in Forasiepi, 2009) to avoid confounding canine size with canine shape. In *Patagosmilus* and *Thylacosmilus*, the canines are both relatively large in addition to the upper canines being saber-like. SGOPV 3490 is coded as “?” for this character, as the canine L/W ratios for this taxon show it being on the borderline between the two states, comparable to some very unspecialized saber-toothed placentals like the nimravids *Dinictis* and *Nimravus*.

Muizon et al. (2018) coded this character based solely upon the height of the lower canine relative to the protoconids of the lower molars. However, although readily repeatable, this criterion obscures a great deal of morphological variation within the taxa in question. This can be seen in the fact that almost all of the metatherian taxa examined by Muizon et al. (2018) are coded as having “small” canines with the exception of *Kokopellia* and a few species with premolariform canines (see discussion in Voss and Jansa, 2009: p. 57). The presence of a premolariform versus caniniform canine is probably a useful phylogenetic feature in its own right, however the current sample is not broad enough to use this as a meaningful phylogenetic character (i.e., it is only present in *Asiatherium*, the microbiotheriid *Dromiciops*, and the dasyurid *Sminthopsis* among taxa examined). In some taxa (i.e., *Herpetotherium*) the canine is tall but is very narrow and slender at its base. *Kokopellia* exhibits a similar condition, based on the figures in Cifelli and Muizon (1997: fig. 2) the canine is actually taller than the protoconids of the lower molars. The eutherian *Maelestes* also probably represents a similar condition; the canine of the holotype is almost at the same level as the protoconid and is interpreted as being incompletely erupted, therefore is likely in the adult animal the canine would be taller than the protoconid, despite the canines of this animal being relatively gracile. Finally, because this character is only codable based on the lower molars, it cannot be applied to species for which the dentary is not known, even if they are known from complete crania (e.g., *Patagosmilus*). An additional issue is present for taxa like *Thylacosmilus* in which the upper and lower canines are unequal in size.

In this study, the size of the canines was coded based on the size of the canine alveolus relative to the rest of the dentition. If the canine alveolus was much bigger than the alveoli of the lower molars it was considered large. This was done to deal with the issue of describing canines in terms of their height versus overall size. The codings of several metatherian taxa were changed appropriately.

**Character 171 – Roots of upper canines**

**Character 172 – Roots of lower canines**

In previous versions of this matrix (Forasiepi, 2009; Engelman and Croft, 2014; Forasiepi et al., 2015), as well as other studies of sparassodont interrelationships (Babot et al., 2002), the state of the roots of the upper and lower canines were coded as a single character. However, the way this character was formulated meant that in previous analyses the states of having open roots on the upper canines only and open roots on both the upper and lower canines were treated as morphologically unrelated, and therefore the open roots of the upper canines could not be considered as a potentially shared feature between proborhyaenids (sensu stricto) and thylacosmilines under the parsimony algorithm. As a result, this character has been divided into the two characters here.

It is also worth noting that although the roots of the lower canines are closed in *Thylacosmilus*, it has been suggested by previous authors that they may represent a secondary reversal from a non-thylacosmiline proborhyaenid-like condition based on similarities in morphology (e.g., prominent median sulci) to the canines of the latter taxa (Babot et al., 2002).

**Character 174 – Prominent median sulci on labial faces of canines**

**Character 175 – Prominent median sulci on lingual faces of canines**

<u>References:</u> Babot et al. (2002, character 33).

Proborhyaenids are often diagnosed by the presence of median sulci on their canines, making the canine appear “figure 8-shaped” in cross-section (Babot et al., 2002). These are different from the small longitudinal grooves and ridges that characterize the canines roots of borhyaenoids (character 173), which cover the entire canine. However, observations by the authors have found that median canine sulci are much more widely distributed in sparassodonts than previously thought, occurring in *Pharsophorus lacerans*, *Arctodictis* spp., *Australohyaena antiquua*, *Borhyaena macrodonta*, and an indeterminate sparassodont from the Fitzcarrald Arch (Tejada-Lara et al., 2015). Generally, in non-proborhyaenid sparassodonts that have canine sulci (except *Arctodictis*) there is a lingual sulcus but no labial one. This agrees with the observations of Babot et al. (2002), who noticed that the labial sulcus was generally shallower than the lingual in proborhyaenids.

*Thylacosmilus* is coded as polymorphic for this character because although the upper canines of *Thylacosmilus* lack labial and lingual sulci, these features are still present on the lower canines (Goin and Pascual, 1987). Additionally, an upper canine of *Thylacosmilus* preserved outside of its alveolus (collected as part of FMNH P14531) shows what may be a vestigial median sulcus near its basal end. Similarly, *Patagosmilus* is coded as "?" because the lower dentition is unknown and it is possible this taxon shows a similar lower canine morphology to *Thylacosmilus*. Because *Thylacosmilus* shows sulci on the lower canines but no sulci on the exposed portions of the upper canines, it might be argued that these features should be treated as four characters instead of two (one coding the presence of labial and lingual sulci on the upper and lower canines, respectively). However, as *Thylacosmilus* is the only taxon in which the morphology of the upper and lower canines are dissimilar, coding the state of the upper and lower canines separately runs the risk of placing too much weight on this character by counting their presence twice. The absence of sulci on the exposed portions of the upper canines of

*Thylacosmilus* and *Patagosmilus* may be secondary modifications related to the machairodont morphology of these teeth (Babot et al., 2002).

**Character 179 – Orientation of P/p2**

In several sparassodonts, including *Arctodictis* spp., *Paraborhyaena boliviana,* and *Proborhyaena gigantea*, both P/p1 and P/p2 are oriented obliquely to the tooth row.

**Character 180 (Diastema between C-P1)**

**Character 181 (Diastema between P1-2)**

**Character 182 (Diastema between c-p1)**

**Character 183 (Diastema between p1-2)**

The presence and relative size of diastemata between the teeth of the premolar row have often been used to differentiate and identify different species of sparassodonts (Marshall, 1981; Forasiepi et al., 2006), though exact definitions of their presence and size have often been ambiguous. Here, we provide a revised definition for the identification and coding of diastemata in metatherians, in the hopes that this will create a more unambiguous system for classification.

A diastema was considered to be absent when there was no surface bone between tooth loci, with the alveoli of adjacent teeth only separated by a common alveolar septum (fig. S13a). A diastema was considered to be present if the alveoli of adjacent tooth loci were separated by smooth surface bone (fig. S13b-c). Diastemata were considered to be "large" if the length of the surface bone separating the alveoli were equal to or greater than one adjacent tooth root in length (fig. S13c), and "small" if they were clearly present but less than one adjacent tooth root in length (fig. S13b). This criterion was based on the previous study of Luo et al. (2003), which used the same system; our examinations show this to be a reliable and unambiguous way of classifying diastemata.

In addition, an additional character was added evaluating the presence of diastema between the lower canine and p1. Diastema between the lower canine and p1 were surprisingly rare among the taxa examined, mostly occurring in didelphine opossums and hathliacynids. In some long snouted taxa, such as *Thylacinus* and *Hondadelphys*, diastema between the lower canine and p1 were absent despite the other premolars being well-separated. For a review of this character in sparassodonts, see Engelman et al. (2018).

**Character 186 – Shape and position of main cusp of p1**

In most metatherians, the apex of the p1 protoconid is positioned very far anteriorly on the tooth, either dorsal to or even anterior to the anterior root of this tooth. By contrast, in most sparassodonts (except *Mayulestes ferox*, *Allqokirus australis*, and *Patene coloradensis* among taxa examined) the apex of the protoconid of p1 is more posteriorly located. This condition is not unique to sparassodonts among metatherians, also occurring in the sparassocynid *Hesperocynus* (Forasiepi et al., 2009), peramelemorphians (*Echymipera*, *Perameles*) and some dasyuromorphians (*Barinya*, *Thylacinus*, possibly *Myrmecobius* if the sequentially first premolar is homologous to p1 in this taxon), among taxa examined. This character was coded as "?" for *Dasyurus*, given the uncertain homology of the missing premolar locus (possibly p2; Luckett, 1993). If the anterior premolar in this taxon is homologous with p1, then the apex of the protoconid is also posteriorly positioned.

This character is different from characters used in previous studies (e.g, Rougier et al., 1998, character 11; Luo et al., 2003, character 142; Ladevèze and Muizon, 2007, character 12; 2010, character 70), in that this character primarily looks at the morphology of p1 rather than the procumbency of P1. These two characters are not directly correlated, given that the P1 is not procumbent in taxa for which the p1 protoconid is anteriorly positioned such as *Asiatherium*, *Herpetotherium*, and *Dromiciops*. This character can also be coded for taxa in which p1 is obliquely oriented relative to the tooth row (e.g., stagodontids and some borhyaenoid sparassodonts). In the stagodontids *Didelphodon* (see Clemens, 1966) and *Eodelphis* (see Scott and Fox, 2015), the apex of the p1 protoconid is located directly over the anterior root, whereas in borhyaenoids the apex of the p1 protoconid is positioned more posteriorly, closer to the midpoint of the tooth.

**Character 189 – Posterolabial cingulum on P3.**

A posterolabial cingulum is present in most metatherians examined, but is absent in several taxa including *Lycopsis longirostrus*, *Acyon myctoderos*, *Pharsophorus lacerans*, and *Prothylacynus patagonicus*.

**Character 195 – Replacement of dP3**

In most metatherians, dP3 is replaced. However, in the thylacosmilines *Patagosmilus* and *Thylacosmilus*, dP3 is not replaced and instead the deciduous tooth is retained throughout life (Goin and Pascual, 1987; Forasiepi and Carlini, 2010). In these taxa, the tooth at the P3 locus can be identified as dP3 based on having three gracile roots instead of two robust ones (Forasiepi and Sánchez-Villagra, 2014), making it possible to identify whether dP3 was replaced even in taxa for which only the alveolus of P3 is known (e.g., *Stylocynus*).

**Character 196 – Timing of eruption between p3 and m3-4**

**Character 197 – Timing of eruption between M3-4 and m4**

Character 138 is derived in part from Character 130 of previous versions of this matrix. However, it has been reworded and recoded to focus solely on the lower dentition given the variation in the eruption sequences of the upper dentition in sparassodonts (Forasiepi and Sánchez-Villagra, 2014; Engelman et al., 2015). In addition, an extra character was added given variation in the eruption of M3-4 relative to m4. In the groups of extant marsupials examined (didelphids, microbiotheres, dasyurids), M3 and m4 erupt in synchrony, whereas in *Allqokirus* and *Pucadelphys* M/m4 erupt in synchrony (Cifelli and Muizon, 1998a; Muizon et al., 2018). The borhyaenoids *Arminiheringia*, *Lycopsis*, and *Prothylacynus* also exhibit a synchronous eruption of M/m4 (Forasiepi and Sánchez-Villagra, 2014), but in *Acyon*, the only hathliacynid for which the eruption sequence of the postcanine teeth is known, M3 and m4 erupt synchronously (Engelman et al., 2015).

**Character 200 – Shape of upper molar row**

In most sparassodonts, as well as most metatherians, the upper molar row is straight (Fig. S10). However, in thylacosmilines (primarily *Patagosmilus goini* and *Thylacosmilus atrox,* but to a lesser degree also *Anachlysictis gracilis*), the molar row is distinctly bowed (Goin, 1997; Forasiepi and Carlini, 2010)

**Character 207 (Metacone on M4)**

Wording of character states changed to better explain how codings were determined.

**Character 210 (Eccentric/procumbent protocone)**

An eccentric/procumbent protocone has been used as a character in many phylogenetic analyses (e.g., Rougier et al., 2015; Wilson et al., 2016; Carneiro, 2018, and others), however, the definition of this character and its states have often not been made clear. Here, a protocone is considered procumbent when the preprotocrista is straight and almost perpendicular whereas the postprostocrista slants posteriorly in lingual view, making the protocone appear canted anteriorly in this view.

**Character 220 – Orientation of postmetacrista (based on M3 if possible)**

Notes: Character 55 of Williamson et al. (2012)

In most Cenozoic metatherians (e.g., *Herpetotherium*, Sparassodonta, Didelphidae, *Dromiciops*, Dasyuromorphia), as well as some Mesozoic groups such as deltatheroidans, the postmetacrista are oriented at an oblique angle to the tooth row. By contrast, in other Mesozoic metatherians (e.g., pediomyids, stagodontids, *Kokopellia*), the postmetacrista are nearly perpendicular to the tooth row. Postmetacrista were coded as "oblique" if they were oriented at an angle of more than 10° to the centrocrista (or the imaginary line between the apices of the paracone and metacone in species where the centrocrista is discontinuous or absent), and "nearly perpendicular" if the angle between these two features was less than 10°. In species where the paracone is located slightly lingual to the metacone, this difference was not enough to affect the coding of the character.

**Character 227 – Stylar Cusp A**

Additional state "0" (absent) to this character. This character represents a clear morphocline and so has been coded as ordered.

**Character 228 – Stylar Cusp B**

The states of this character represent a clear morphocline, and so this character has been recoded as ordered.

**Character 230 – Stylar Cusp D**

The states of this character represent a clear morphocline, and so this character has been recoded as ordered.

**Character 242 – Trigonid versus talonid length**

This character represents a clear morphocline, so it has been reordered and coded as ordered.

**Character 234 – Roots of lower molars (based on m3 when possible)**

The lower molars of most sparassodonts have anterior and posterior roots that are similar in size. However, in several borhyaenoid sparassodonts, including *Borhyaena macrodonta*, *Borhyaena tuberata*, *Arctodictis sinclairi*, *Arctodictis munizi*, *Acrocyon riggsi*, *Acrocyon sectorius*, MLP 88-V-10-4 (the proborhyaenid from Antofagasta de la Sierra), *Arminiheringia auceta*, *Paraborhyaena boliviana*, *Proborhyaena gigantea*, and *Thylacosmilus atrox*, the anterior root of the lower molars is much larger than the posterior root (see main manuscript text for more details). This appears to have evolved independently in borhyaenids and proborhyaenids, as the geologically oldest members of these clades (*Australohyaena* and *Callistoe*) lack this feature.

This feature was measured in species for which isolated teeth with roots, X-rays, or CT scans were not available by comparing the anteroposterior length of the anterior root to that of the posterior root. This character was based on m3 whenever possible because some sparassodonts show variation in this condition (e.g., in *Arctodictis sinclairi* and *Arminiheringia auceta* this condition is only present on m3-4, whereas in others it is present on m2-4). It is likely future studies may find this variation significant enough to treat as distinct states within a multi-state ordered character, but for now we simply focus on presence or absence here. Similarly, the m4s of sparassodonts often have very small talonids, and so it can be difficult to tell if a small posterior root in these teeth also characterizes more anterior molar loci.

**Character 247 – Metaconid on m2–4**

Based on observations in several groups of carnivorous marsupials, the loss of the metaconid in the posterior molars (m2-4) appears to occur in a stepwise fashion, starting from the m4 and occurring in the more anterior molars (m2-3). In sparassodonts, metaconids are present on m2-4 in the Oligocene borhyaenoids *Pharsophorus* and *Australohyaena*, variably present on m4 in the borhyaenid *Borhyaena*, and then lost on m4 (only present on m2-3) in specimens of the early Miocene *Arctodictis* (see Forasiepi et al., 2015). Similarly, in several species of thylamyin opossums, the metaconid is much smaller on m4 than in the anterior molars, and may even be lost in the m4 of *Zygolestes paranensis* (Goin, 1997a). Therefore, due to this variability, we added an additional character state to this character, reflecting the presence or loss of the metaconid on m4. This character follows a logical sequence and was thus coded as ordered. Although it is likely that a further intermediate state was present (metaconid on m2, absent on m3-4), none of the taxa examined exhibited this state. The loss of the metaconid of m1 (character 180) appears to be decoupled from that of m2-4 (Forasiepi et al., 2015), likely because the m1 of metatherians appears to be homologous to the dp5 of eutherians (O'Leary et al., 2013).

**Character 251 (Location of protoconid relative to midline of tooth [on m2-4])**

In most metatherians, the apex of the protoconid is located close to the labial edge of the trigonid. By contrast, in most sparassodonts (as well as the thylacinid *Thylacinus*), with the exceptions of *Allqokirus* (see Muizon et al., 2018: fig. 11), *Patene* (see Rangel et al., 2018: fig. 6), and *Mayulestes* (see Muizon, 1998: fig. 4), and *Hondadelphys* (see Marshall, 1976: fig. 6), the protoconid is located at the labiolingual midpoint of the tooth. This character is not correlated to the loss of the metaconid, as in several sparassodonts with a metaconid (e.g., *Stylocynus* and borhyaenids; see also Forasiepi et al., 2015: fig. 10) the protoconid is located at the labiolingual midpoint of the tooth.

**Character 259 – Presence of hypoconid (on m2-4)**

The lower molars of borhyaenids and proborhyaenids (including thylacosmilines) are often characterized by a large paraconid and protoconid and a smaller posterolingual cusp. The homologies of this cusp have been debated, with suggestions of it being a metaconid, entoconid, or hypoconid (e.g., Goin et al., 2007; Forasiepi et al., 2015). The most recent review of the talonid of borhyaenoids (Forasiepi et al., 2015), based on comparative morphology, came to the conclusion that the posterolingual cusp is non-homologous between m1 and m2-4, representing a hypoconid in the anterior tooth and a metaconid in the posterior ones (at least in borhyaenids). This would mean the hypoconid is absent in borhyaenids.

The state in proborhyaenids is uncertain. *Callistoe* could not be examined firsthand, but Babot et al. (2002) states that the m4 has only a single talonid cusp and both Forasiepi et al. (2015) and Muizon et al. (2018) code the state of the hypoconid as inapplicable for *Callistoe*. *Arminiheringia* has a slightly larger talonid, and in the holotype the largest talonid cusp appears to be the hypoconid. *Proborhyaena gigantea* has a posterolingual cusp (in AMNH 29576, fig. S14a), but it is not clear if this represents the metaconid (which has previously been considered to be absent in proborhyaenids) or the hypoconid. As a result, we coded the state of the hypoconid in proborhyaenids as "?".

The hypoconid has traditionally been considered to be absent in *Thylacosmilus* (Forasiepi, 2009; Forasiepi et al., 2015; Muizon et al., 2018). However, if this is the case, it raises the question as to what is the homology of the remaining talonid cuspule in this taxon (fig. S14b), as both the metaconid and hypoconid are considered to be absent. Nevertheless, the homology of the cusps in *Thylacosmilus* is beyond the scope of this study and we code this taxon as in previous analyses.

**Character 391 – MtI length relative to MtIII**

One major difference between dasyuromorphians and sparassodonts is that the pes of most dasyuromorphians has a very short or absent MtI (Tate, 1947; Szalay, 1994). In *Herpetotherium* (see Horovitz et al., 2008), *Pucadelphys* (Argot, 2002; Muizon and Argot, 2003), *Andinodelphys* (see Muizon and Argot, 2003), as well as extant caenolestids and peramelemorphians (Szalay, 1994), MtI is also very short (less than 50% the length of MtIII). Didelphids and *Dromiciops* have a well-developed MtI that is at least half the length of MtIII and has well-developed articular surfaces (Szalay, 1994).

The MtI is only known for a few sparassodonts, but in these species MtI is generally long compared to the other metatarsals, unlike the condition in dasyuromorphians. In the sparassodonts *Arctodictis sinclairi* (see Forasiepi, 2009) and *Callistoe vincei* (see Argot and Babot, 2011 ) the MtI is slightly greater than 50% the length of MtIII. The MtI is also known in *Sipalocyon gracilis* (see Argot, 2003) and

*Lycopsis longirostrus* (see Argot, 2004). The hallux in these taxa is very large and well-developed compared to the condition in dasyuromorphians, but only the proximal and distal ends are preserved, respectively, and their length relative to MtIII cannot be evaluated.

## TAXON-SPECIFIC CHARACTER CHANGES ADDED IN THIS STUDY

Codings for new or revised characters are listed above unless otherwise noted.

***Deltatheroides cretacicus***

- Character 10 (lateral palatal process of premaxilla) coded as “0” (anterior or just reaches anterior border of canine alveolus)
- Character 11 (posterior border of incisive foramen) coded as “0” (anterior or just reaches anterior border of canine alveolus)
- Character 22 (location of the infraorbital foramen) coded as “1&2” (dorsal to posterior root of P3 or dorsal to M1)
- Character 26 (palatal length/width ratio) coded as “0” (less than 1.5)
- Character 177 (number of premolars) coded as “0” (three)
- Character 180 (diastema between C-P1) coded as “0” (absent)
- Character 181 (diastema between P1-2) coded as “0” (absent)

<u>Comments:</u> Characters coded following Rougier et al. (2004)

- Character 140 (ventral margin of jaw posterior to last molar in ventral view) coded as “0” (curved)

<u>Comments:</u> Coded based on Kielan-Jaworowska (1975).

***Deltatheridium pretrituberculare***

- Character 126 (stylomastoid foramen) coded as “0” (absent)

Comments: Based on Beck (2012)

- Character 140 (ventral margin of jaw posterior to last molar in ventral view) changed from “1” (straight) to “0” (curved)

Comments: Changed based on the revised criteria for coding this character.

- Character 168 (size of canines) changed from “0” (relatively small) to “1” (enlarged).

***Holoclemensia texana***

- Character 237 (trigonid configuration posterior to m1) coded as “1” (acute, with paraconid more posteriorly placed)
- Character 254 (anterior keel at anterolingual angle of paraconid with hypoconulid notch) changed from “0” (rounded) to “1” (forming a keel)

***Kokopellia juddi***

- Character 140 (ventral margin of jaw posterior to last molar in ventral view) coded as “0” (curved)
- Character 214 (wing-like cristae associated with para- and metaconules) coded as “1” (present) based on Cifelli and Muizon (1997)

Comments: These characters coded based on Cifelli and Muizon (1997)

***Asiatherium reshetovi***

- Character 5 (dimensions of braincase) coded as “0” (as wide as long or slightly wider than long)
- Character 28 (number of palatal pits) coded as “0” (zero) after Szalay and Trofimov (1996).

- Character 29 (maxillopalatine fenestrae) coded as “?”

Comments: The palate of the holotype of *Asiatherium reshetovi* (PIN 3907) is highly damaged, and as a result it is not possible to determine if the maxillopalatine fenestrae were present in this taxon.

- Character 102 (sagittal crest) coded as “2” (absent).

The holotype of *A. reshetovi* preserves no sagittal crest on its frontals or the preserved extent of the parietals.

- Character 117 (epitympanic wing of petrosal) coded as “0” (present) based on Beck (2012).
- Character 140 (ventral margin of jaw posterior to last molar in ventral view) changed from “1” (straight) to “0” (curved)

Comments: Changed based on the revised criteria for coding this character.

- Character 147 (labial mandibular foramen in masseteric fossa) coded as “0/1” (present or absent)

Comments: Figures of the right dentary of *Asiatherium* in Szalay and Trofimov (1996: fig. 7) show what appears to be a distinct foramen near the anteroventral border of the masseteric fossa, in the same location as the labial mandibular foramen in other therians and stem metatherians. Examination of a cast of the holotype of *Asiatherium* suggests that this feature really does represent a foramen, rather than a pathology or postmortem damage (T.E. Williamson, pers. comm. 2018). However, the condition in the left dentary cannot be determined, it is not possible to tell if the foramen is present or absent based on the figures in Szalay and Trofimov (1996) and this region is not discernible in the cast (T.E. Williamson, pers. comm. 2018). Nevertheless, based on the condition in the right dentary it is necessary to at least consider the possibility that a labial mandibular foramen was present in *Asiatherium*, contra previous studies where this foramen was coded as unequivocally absent (e.g, Wilson et al., 2016; Muizon et al., 2018)

***Alphadon* spp.**

For many years, almost all dentally unspecialized Cretaceous North American metatherians were assigned to the genus *Alphadon* (e.g., Clemens, 1966; Lillegraven, 1969). However, more recent studies have recognized that *Alphadon* sensu lato is a wastebasket taxon and the taxa previously assigned to this genus do not form a monophyletic group (Cifelli, 1990; Johanson, 1996; Williamson et al., 2012). Some taxa previously assigned to *Alphadon* have been reassigned to their own genera (*Eoalphadon*, *Protalphadon*, *Turgidodon*, *Varalphadon*) whereas others have not been recovered as part of a monophyletic *Alphadon* in phylogenetic analyses (e.g., "*Alphadon" halleyi*) or have not been evaluated in a phylogenetic context to test if they belong to *Alphadon* (e.g., "*Alphadon" eatoni*). Forasiepi (2009) coded a composite terminal taxon for *Alphadon* using several taxa that are no longer referred to *Alphadon* sensu stricto or whose assignment to *Alphadon* is uncertain, including *Turgidodon russelli*, *Protalphadon lulli*, "*Alphadon*" *halleyi*, and "*Alphadon*" *eatoni*. As a result, we re-evaluated the codings of *Alphadon* spp. in this matrix using the previously published literature (Clemens, 1966; Lillegraven, 1969) to ensure the codings for this terminal taxon are based only on specimens that belong to the core clade of *Alphadon* (*A. marshi*, the type species; *A. sahnii*, and *A. wilsoni*) recovered by Williamson et al. (2012).

- Character 164 (shape of incisor arcade) changed from "0" (parabolic) to"?"
- Character 165 (number of lower incisors) coded as "?"

- Character 166 (staggered lower incisor) coded as "?"

The morphology of the lower incisor row is unknown in undoubted species of *Alphadon.* Previous iterations of this matrix used codings from Rougier et al. (1998), who coded *Alphadon* as having four lower incisors and no "staggered" incisor. However, it is not clear what specimens these authors used to code these characters. Three lower incisor alveoli are known in a specimen of *Protalphadon lulli* (Clemens, 1966). Cifelli and Muizon (1998b) suggest that three incisors were present in "*Alphadon*" *eatoni* (and at least three are in the holotype), but this is not certain. The incisors have not been described for any other species of *Alphadon* sensu lato (Williamson et al., 2012).

- Character 187 (cusp on the posterior heel of P3) coded as "0" (absent or vestigial)

Comments: The posterior cusp of P3 in a specimen of *A. marshi* (UALVP 2389; Lillegraven, 1969) is comparable in development to that of *Pucadelphys* and *Asiatherium*, and so has also been coded "0" here.

- Character 191 (change in height of the lower premolars) coded as "0" (increase gradually in height)

Comments: In specimens assigned to the species *Alphadon marshi* (UCMP 50299 and 50300; Clemens, 1966), the premolars gradually increase in size from p1–3. It is not clear where the original character coding of "2" (abrupt change in size between p1-2 and p3) came from, but it may be based on UCMP 46882, which has since been assigned to the genus *Protalphadon* (Cifelli, 1990). As a result, I code this character as "0" here.

- Character 196 (timing or eruption between p3 and m3–4) and 149 (morphology of dp3) coded as "?"

Comments: These characters appear to be coded based on *Alphadon eatoni*, which is the only member of this genus that is known from deciduous dentition is preserved in situ (Cifelli and Muizon, 1998b, a). However, given that *A. eatoni* has never been tested to determine if it really does belong to *Alphadon sensu stricto*, I code these characters as "?" for the time being.

- Character 215 (relative position of para- and metaconule) coded as "0" (at or lingual to the midpoint between paraconule and metaconule) based on Clemens (1966) and Williamson et al. (2012).

**Pediomyidae**

- Character 134 (foramina for temporal ramus with well-developed internal branch of stapedial artery) changed from "0/1" (present/absent) to "1" (absent)

Comments: Rougier et al. (1998) coded Pediomyidae as uncertain (either/or) for the state of the foramina for temporal rami because although they lacked a well-developed groove for the stapedial artery on the petrosal, the presence of foramina on the squamosal/parietal could not be ruled out. However, the absence of a well-developed groove for the stapedial artery suggests that such a foramen was absent.

- Character 153 (position of the mandibular foramen) coded as "1" (at the midpoint of the coronoid process)

Comments: Based on Lillegraven (1969: fig. 23).

- Character 238 (Relative positions of paraconid and metaconid [considered based on the apices of both cusps]) changed from "0" (paraconid and metaconid aligned labiolingually) to "0&1" (paraconid and metaconid aligned labiolingually and metaconid located more lingual)

Comments: Based on observations in Davis (2007)

***Eodelphis browni***

A review of previously published literature has found that AMNH 14169, the specimen examined by Forasiepi (2009) to provide character state information for *Eodelphis cutleri*, is actually the holotype of the stagodontid *E. browni* (Matthew, 1916). As a result, the name of this terminal taxon has been changed and additional information has been added from the primary literature.

– Character 22 (location of the infraorbital foramen) coded as “1” (dorsal to the posterior root of P3)
– Character 23 (flaring of maxillary “cheeks” behind infraorbital foramen) coded as “1” (absent)
– Character 56 (morphology of postglenoid process) coded as “0” (wide and low)
– Character 181 (diastema between P1-2) coded as “1” (absent)
– Character 187 (cusp on the posterior heel of P3) coded as “1” (well-developed)

Comments: Coded based on Scott and Fox (2015).

- Character 134 (foramina for temporal rami) changed from “0/1” (present/absent) to “1” (absent)
- Character 136 (foramina for veinous drainage of the temporal cavity on parietal or squama of squamosal) coded as “0” (present)

Comments: Rougier et al. (1998) coded *Eodelphis* as uncertain (either/or) for the state of the foramina for temporal rami because although it lacks a well-developed groove for the stapedial artery on the petrosal, the presence of foramina on the squamosal/parietal could not be ruled out. *Eodelphis*, however, does exhibit emissary foramina on the squama of the squamosal (Matthew, 1916: pl. III).

- Character 168 (size of canines) changed from “0” (relatively small) to “1” (enlarged).

***Didelphodon vorax***

- Character 1 (length of the skull) coded as “0” (short, less than twice width of skull at level of zygomatic arches)
- Character 2 (length of rostrum) coded as “0” (less than 1/3 length of skull)
- Character 4 (width of braincase versus maximum postorbital width) coded as “0” (braincase wider than maximum postorbital width)
- Character 5 (dimensions of braincase) coded as “0” (as wide as long, or slightly wider than long)
- Character 6 (level of palate relative to the basicranium) coded as “1” (palate lower than basicranium)
- Character 7 (paracanine fossa) coded as “0” (formed by both maxilla and premaxilla)
- Character 10 (lateral palatal process of premaxilla) coded as “1” (posterior to anterior border of canine alveolus)
- Character 11 (posterior border of incisive foramen) coded as “1” (posterior to anterior border of canine alveolus)
- Character 14 (posteriormost point of premaxilla-nasal contact) coded as “0” (posterior to the canine)

- Character 15 (anterior extent of nasals) coded as “1” (retracted posteriorly, exposing the narial opening in dorsal view)
- Character 20 (angle of maxilla-jugal contact) coded as “0” (more than 140 degrees)
- Character 22 (location of the infraorbital foramen) coded as “2” (dorsal to M1)
- Character 26 (palatal length/width ratio) coded as “1” (greater than 1.5)
- Character 31 (minor palatine foramen) coded as “1” (small)
- Character 32 (posterior extent of palatines) coded as “1” (extend beyond the level of the last molar)
- Character 36 (palatine contributes to infraorbital canal) coded as “1” (present)
- Character 51 (interparietal) coded as “0” (present)
- Character 53 (parietal-alisphenoid or fronto-squamosal contact) coded as “0” (parietal-alisphenoid contact)
- Character 54 (width of glenoid cavity) coded as “1” (more than twice anteroposterior width)
- Character 69 (tympanic process of alisphenoid) coded as “1” (present)
- Character 83 (composition of primary foramen ovale) coded as “1” (on alisphenoid)
- Character 102 (sagittal crest) coded as “0” (extending to frontals)
- Character 156 (number of upper incisors) coded as “1” (four)
- Character 162 (size of I5 versus I4) coded as “2” (I5 absent)
- Character 171 (roots of upper canines) coded as “0” (closed in adults)
- Character 172 (roots of lower canines) coded as “0” (closed in adults)

– Character 173 (surface of the roots of the canines) coded as “0” (smooth

– Character 180 (diastema between C-P1) coded as “0” (absent)

– Character 181 (diastema between P1-2) coded as “1” (absent)

Comments: Modified based on Wilson et al. (2016).

- Character 198 (morphology of dp3) coded as “0” (with trigonid and talonid)

Comments: Coded based on Clemens (1966)

***Mayulestes ferox***

- Character 137 (post-temporal notch/foramen) coded as “1” (present)

Comments: According to Muizon (1998), the mastoid portion of the petrosal is disarticulated in the holotype of *M. ferox*, but it preserves a notch for a posttemporal notch/foramen.

- Character 168 (size of canines) changed from “0” (relatively small) to “1” (enlarged).

***Pucadelphys andinus***

- Character 140 (Ventral margin of dentary posterior to last molar in lateral view) changed from “0” (straight) to “1” (curved)

Comments: Changed based on the revised criteria for coding this character.

- Character 153 (position of the mandibular foramen) coded as “0” (posterior to the midpoint of the coronoid process.

Comments: In all specimens of *Pucadelphys* for which the position of the mandibular foramen could be observed (YPFB Pal 6108; MNHC 8266), the foramen was located posterior to the midpoint of the coronoid process.

- Character 157 (height of first upper incisor) coded as “1” (subequal to smaller than remaining incisors)

Comments: According to Ladevèze and Muizon (2007), an undescribed specimen of *Pucadelphys* indicates that I1 was not enlarged relative to the other incisors.

- Character 168 (size of canines) changed from “0” (relatively small) to “1” (enlarged).
- Character 178 (orientation of P/p1 relative to tooth row) changed to “0&1” based on Ladevèze et al. (2011)

Comments: As shown in Ladevèze et al. (2011, fig. 4), in some specimens of *P. andinus* the first premolar is oriented obliquely to the tooth row (MNHC 8381), whereas in other individuals it is straighter (MNHC 8266). Additionally, in some specimens p1 is in line with the lower tooth row while P1 is obliquely oriented (MNHC 8381).

- Character 70 (hypotympanic sinus) coded as “1” (present)
- Character 71 (petrosal contribution to hypotympanic sinus) coded as “1” (present)
- Character 72 (squamosal contribution to hypotympanic sinus) coded as “1” (present)

Comments: According to Beck et al. (2014), a hypotympanic sinus is present in *P. andinus* and has a squamosal contribution.

- Character 400 (dorsal border of ungual phalanges) coded as “1” (rounded) based on Argot (2002)

***Andinodelphys cochabambensis***

- Character 18 (postorbital processes) coded as “1” (well-developed) based on Muizon et al. (1997).

- Character 20 (angle of maxilla-jugal suture) coded as “0” (more than 140 degrees) based on Muizon et al. (1997).
- Character 140 (Ventral margin of dentary posterior to last molar in lateral view) changed from “0” (straight) to “1” (curved)

Comments: Changed based on the revised criteria for coding this character.

- Character 235 (talonid of m4 relative to m3) coded as “0” (talonid of m4 reduced and narrower than m3)

Comments: Coded from Ladevèze and Muizon (2007)

- Character 224 (width of parastylar lobe relative to metastylar lobe [on M3]) changed from “2” (parastylar lobe slightly narrower) to “1&2” (parastylar lobe slightly narrower & parastylar and metastylar lobes uniform in width)

Comments: Observations of the upper molars of *Andinodelphys* in Muizon et al. (1997: fig. 1f) and Muizon et al. (2018: fig. 10f) show that in at least. By contrast, the holotype (Marshall and Muizon, 1988: fig. 6a) has a parastylar lobe that is slightly narrower than the metastylar lobe.

- Character 168 (size of canines) changed from “0” (relatively small) to “1” (enlarged).

***Herpetotherium fugax***

- Character 7 (paracanine fossa) coded “0” (formed by premaxilla and maxilla)
- Character 9 (precanine notch) coded “0” (absent)
- Character 11 (posterior border of incisive foramen) coded as “1” (posterior to the anterior border of canine alveolus)

- Character 14 (posteriormost point of premaxillo-nasal contact) coded as “0&1” anterior or at the level of the canine and posterior to the canine)
- Character 22 (location of the infraorbital foramen) coded “1&2” (dorsal to posterior root of P3 and dorsal to M1)
- Character 157 (height of first upper incisor) coded as “1” (taller than other incisors)
- Character 335 (length of iliac neck) coded as “0” (longer than 15% pelvis length)
- Character 343 (femoral condyles) coded as “0” (lateral condyle wider than medial condyle)
- Character 373 (calcaneal peroneal groove for the peroneus longus) coded as “0’ (indistinct or weakly developed)
- Character 383 (length of the tuber calci) coded as “0” (shorter than the body)
- Character 384 (medial curvature of the tuber calci) coded as “0” (absent)
- Character 385 (ventral curvature of the tuber calci) coded as “0” (absent)

Comments: These characters were coded based on Sánchez-Villagra et al. (2007), Horovitz et al. (2008), and observations of PIMUZ 2613, MB.Ma.50672, and MB.Ma.50672.

- Character 36 (palatine contributes to infraorbital canal) coded as “1” (present)

Comments: Coded based on personal observations of several specimens (e.g., AMNH 23304) in the American Museum of Natural History.

- Character 51 (interparietal) coded as “1” (absent or fused with parietal)

Comments: According to Voss and Jansa (2009, p. 88), the interparietal is absent in *Herpetotherium*

- Character 85 (secondary foramen ovale completely enclosed in alisphenoid) coded as “1” (absent)

Comments: Coded based on Gabbert (1998).

- Character 168 (size of canines) changed from “1” (enlarged) to “0” (relatively small).

***Mimoperadectes* spp.**

Previous phylogenetic analyses (e.g., Forasiepi, 2009; Horovitz et al., 2009; Muizon et al., 2018) coded Peradectidae based on both *Mimoperadectes* and *Peradectes*. In order to reduce the number of assumptions made in coding the OTUs, we recoded all characters based only on character states observable in species of *Mimoperadectes* spp. (*M. labrus* and *M. houdei*).

- Character 5 (dimensions of braincase) coded as “0” (as wide as long or slightly wider than long)
- Character 44 (anterior extent of lacrimal) coded as “1” (extending onto orbit)
- Character 50 (orbital crest) coded as “1” (present)
- Character 67 (optic foramen and sphenorbital fissure) coded as “1” (joined)
- Character 93 (median crest of basisphenoid) coded as “1” (absent)
- Character 171 (roots of upper canines) coded as “0” (closed)

These codings are based on observations of the holotype of *M. houdei* in Horovitz et al. (2009).

- Character 72 (squamosal contribution to hypotympanic sinus) coded as “1” (present)

Comments: The holotype of *M. houdei* has been observed to have a squamosal contribution to the hypotympanic sinus (Voss in Beck et al., 2014).

***Didelphis* spp.**

Specimens of *Didelphis albiventris* were not readily available for this analysis and so some characters were evaluated based on the closely related *Didelphis virginiana*.

- Character 56 (proportions of postglenoid process) changed from “0” (as wide as glenoid cavity) to “1” (narrower than glenoid cavity).
- Character 153 (position of the mandibular foramen) coded as “0” (posterior to the midpoint of the coronoid process

Comments: Based on personal observations by R.K. Engelman.

- Character 168 (size of canines) changed from “0” (relatively small) to “1” (enlarged).

***Metachirus nudicaudatus***

- Character 95 (dorsal margin of foramen magnum) changed from “1” (formed by exoccipitals and supraoccipital) to “0” (formed only by exoccipitals)

Comments: *Metachirus*, like most didelphines, has a foramen magnum formed only by exoccipitals in adults (see Voss and Jansa, 2003: fig. 10c).

- Character 97 (contribution of squamosal to occiput) coded as “0” (small or absent)

Comments: Coded based on Voss and Jansa (2003: fig. 10c)

***Monodelphis* spp.**

- Character 56 (proportions of postglenoid process) changed from “0” (as wide as glenoid cavity) to “1” (narrower than glenoid cavity).

Comments: Based on Wible (2003).

***Dromiciops gliroides***

- Character 118 (prootic canal) coded as "1" (absent) based on Beck (2012)

***Dasyurus* spp.**

- Character 124 (paroccipital process of petrosal) coded as "1" (indistinct to absent)

Comments: Coded based on Beck (2012)

- Character 115 (medial expansion of the crista petrosa that forms a thin and straight lamina covering the anterolateral part of the fossa subarcuata) coded as "1" (present)

Comments: Coded based on Macrini (2005)

- Character 383 (length of the tuber calci) coded as "0&1" (longer than body and shorter than body)

Comments: Measurements from Bassarova et al. (2008) show that individuals of *Dasyurus* are polymorphic for this character, even within a single species (*D. maculatus*). Therefore, this character has been recoded as polymorphic.

***Sminthopsis* spp.**

Specimens of *Sminthopsis crassicaudata* were not readily available for this analysis and so some characters were evaluated based on the closely related *Sminthopsis fuliginosa*. *S. crassicaudata* was used as the basis of codings wherever possible.

- Character 115 (medial expansion of the crista petrosa that forms a thin and straight lamina covering the anterolateral part of the fossa subarcuata) coded as "1" (present)

Comments: This character coded based on Macrini (2009).

***Thylacinus cynocephalus***

- Character 46 (lacrimal tubercle) changed to “1” (absent).

Comments: In sparassodonts, as well as most metatherians with a lacrimal tubercle, the tubercle is a small knoblike structure located dorsal to the lacrimal foramina. By contrast, other metatherians, most notable peramelemorphians as well as some dasyuromorphians, have a lacrimal crest: a sharp blade-like protrusion along the orbital rim located posterior to the lacrimal foramina, which is probably not homologous with the lacrimal tubercle (Travouillon, pers. comm. 2014). The lacrimal “tubercle” in *Thylacinus* is a blade-like structure along the orbital rim, suggesting it actually represents a lacrimal crest.

***Patene simpsoni***

- Character 142 (Anteroventral angle of symphysis relative to tooth row) changed from “1” (pronounced angle [>25 degrees]) to “?”
- Character 145 (posteriormost mental foramen) changed from “0/1” (below p3/at p3-m1 embrasure) to “0” (below p3)
- Character 165 (number of lower incisors) changed from “1” (three) to “?”
- Character 167 (procumbent lower incisors) changed from “1” (not procumbent) to “?”
- Character 176 (procumbency of lower canine) changed from “0” (absent) to “?”
- Character 178 (orientation of P/p1 relative to tooth row) changed from “1” (Obliquely oriented to tooth row [20 degrees or more]) to “?”
- Character 182 (diastema between c-p1) changed from “0” (absent [alveolar margins in contact]) to “?”

- Character 191 (change in height of lower premolars) changed from “1” (abrupt change in size between p1 and p2-3) to “?”
- Character 194 (symmetry of main cusp on p3) changed from “0&1” (anterior edge of cusp more convex than posterior edge and both edges similar in curvature) to “0” anterior edge of cusp more convex than posterior edge).

<u>Comments:</u> The previous nine characters were coded for *Patene simpsoni* in previous analyses (Forasiepi, 2009; Engelman and Croft, 2014; Muizon et al., 2018) based on PVL 2618, a specimen assigned to “*P.*” *simpsoni* from the Quebrada de los Colorados Formation of northwestern Argentina (Goin et al., 1986). However, the *Patene* material from the Quebrada de Los Colorados Formation has been re-evaluated and assigned to its own taxon, “*P.” coloradensis* (Rangel et al., 2018). As a result, we have coded all of these characters as unknown because the state of these characters is unknown in the current hypodigm of “*P.” simpsoni* from Itaboraí, or else recoded them based solely on the Itaboraí material.

- Character 140 (ventral margin of jaw behind m4) coded as “1” (curved)
- Character 145 (posteriormost mental foramen) coded as “0&1” (below p3 and below p3/m1 embrasure
- Character 146 (retromolar space) coded as “1” (present)
- Character 147 (labial mandibular foramen inside masseteric fossa) coded as “0” (absent)

<u>Comments:</u> Codings for these characters based on MNRJ 1351-V

- Character 265 (position of hypoconulid) coded as “1” (lingually placed and twinned with entoconid”

Comments: Coded based on DGM 798-M.

***Hondadelphys fieldsi***

- Character 1 (length of the skull) coded as “0” (short, less than twice width of skull at level of zygomatic arches)
- Character 2 (length of rostrum) coded as “1” (between 1/2 and 1/3 total length of skull)

Comments: The holotype of *Hondadelphys fieldsi*, UCMP 37960, consists of a partial skeleton from a single individual that includes much of the skull, including the left and right maxillae, left dentary, and the basicranium (including the glenoid fossa). Based on these elements, it is possible to estimate the total length of the skull, the width of the skull at the level of the zygomatic arch, and the length of the rostrum (preorbital length of skull). The estimated total length of the skull of *Hondadelphys* is about 122 mm (based on the total length of the dentary plus the anteroposterior length of the basicranium posterior to the glenoid fossa), and the width of the skull is approximately 32.74 mm based on the distance from the lateral edge of the zygomatic arch to the midpoint of the skull. This means the length of the skull is less than twice its width across the zygomatic arches, and therefore “short” by the definition of Forasiepi (2009). The lacrimal is not preserved, but the facial process of the maxilla suggests the anterior border of the orbit extended to about the level of the talonid of m3, if not slightly more posterior. This roughly agrees with what is observed in a specimen assigned to ?*Hondadelphys* (IGM 25034) by Goin (1997). This would make the rostrum of *Hondadelphys* about 39% the length of the skull, categorizing the specimen as state “1” (rostral length between 1/2 and 1/3 total skull length), similar to many sparassodonts. Increasing the estimated length of the rostrum to account for a greater contribution by the lacrimal does not affect the estimated proportion enough to categorize it as a different state.

- Character 30 (major palatine foramen) coded as “1” (many small foramina on the maxilla)
- Character 32 (posterior extent of palatines) coded as “1” (extend beyond the level of the last molar)
- Character 214 (wing-like cristae associated with para- and metaconules) coded as “1” (present).
- Character 244 (width of talonid relative to trigonid [m1-3]) coded as “2” (subequal to wider than trigonid)

<u>Comments:</u> These characters were coded based on observations of the holotype (UCMP 37960). In the case of the major palatine foramen (character 25), the preserved regions of the palatal processes of the maxilla are covered in numerous small foramina, as in other sparassodonts.

- Character 145 (posteriormost mental foramen) changed from “0” (below p3) to “?”

<u>Comments:</u> *Hondadelphys fieldsi* was originally described as having two mental foramina with the more posterior located below p3 (Marshall, 1976), an interpretation that has been followed by earlier codings of this matrix (e.g., Forasiepi, 2009). However, the dentary of the holotype of *H. fieldsi* (UCMP 37960) is damaged and is heavily reconstructed below m2 (Fig. S12b), exactly where the posteriormost mental foramen is located in many sparassodonts (e.g., *Stylocynus paranensis*, *Pseudothylacynus rectus*, *Prothylacynus patagonicus*, *Acyon myctoderos*). Mental foramina are not easily visible on the paratype

(UCMP 39251) due to its preservation but there is a circular area of matrix suggestive of a mental foramen below the trigonid of m2. Therefore, the condition in *Hondadelphys* cannot be determined with certainty based on the available material.without more material that preserves the surface of the dentary below m2.

- Character 164 (shape of upper incisor arcade) coded as "?".

Comments: The upper incisor row is unknown in *Hondadelphys*, and only the alveoli and roots of the lower incisors are known (Goin, 1997). Although it is possible that the shape of upper incisor arcade is as it was coded in previous versions of this matrix, in the absence of more direct evidence this character is better coded as "?".

- Character 196 (timing of eruption between p3 and m3-4) coded as "2" (p3 erupts simultaneously with or after m4)

Comments: In UCMP 39251, p3 is in the process of erupting whereas m3 has already erupted based on the presence of an interradicular process at this locus, indicating that p3 erupted after m3 was already erupted, as in other sparassodonts (Forasiepi and Sánchez-Villagra, 2014).

- Character 255 (paraconid elongated with anteroventral projection of the paraconid keel) coded as "1" (present)

Comments: Observations of the holotype UCMP 37960 show this feature to be unambiguously present, contra Muizon et al. (2018)

***Stylocynus paranensis***

- Character 22 (location of the infraorbital foramen) coded as "0/1"

Comments: Observations of a specimen of *S. paranensis* (MACN-PV 13203) shows that the infraorbital foramen in this taxon opens roughly over the middle of P3.

- Character 23 (flaring of maxillary "cheeks" coded as "1" (absent)

Comments: Coded based on observations of MACN-A 5893 and MACN-PV 13203.

- Character 164 (shape of upper incisor arcade) coded as "?".

Comments: The upper incisor row is unknown in *Stylocynus*, and only the alveoli of the lower incisors are known (Marshall, 1979). Although it is possible that the shape of upper incisor arcade is as it was coded in previous versions of this matrix, in the absence of more direct evidence this character is better coded as "?".

**UF 27881**

- Character 40 (position of sphenorbital foramen) coded as "0" (posterior to the posterior border of the lacrimal) based on observations of UF 27881.
- Character 199 (size of molars increasing posteriorly) coded as "0" (moderate posterior increase)

Comments: As noted by Engelman and Croft (2014), the M3 of UF 27881 appears similar in size to M1, and does not exhibit the pronounced increase in size seen in other sparassodonts like *Borhyaena*.

- Character 10 (lateral palatal process of premaxilla) coded as "?"
- Character 11 (posterior border of incisive foramen) coded as "?"

Comments: Additional observations of UF 27881 and comparisons with the condition in other sparassodonts suggest that the state of these characters cannot be determined in this specimen.

***Notogale mitis***

- Character 23 (flaring of maxillary "cheeks" behind infraorbital foramen) coded as "1" (absent)

Comments: No expansion of the maxillary "cheeks" is present in AC 3117

- Character 28 (number of palatal pits) coded as "1/2" (one or two)

Comments: At least one palatal pit is present between M3–4 of AC 3117, and a second pit may have been present between M2–3.

- Character 9 (precanine notch) coded as "0" (absent)
- Character 10 (lateral process of premaxilla) coded as "1" (posterior to anterior border of canine alveolus)
- Character 11 (posterior border of the incisive foramina) coded as "1" (posterior to the anterior border of the canine alveolus)
- Character 12 (position of medial palatal process of the premaxilla) coded as "0" (horizontal)
- Character 14 (posteriormost point of premaxilla-nasal contact) coded as "1/2" (posterior to the canine/posterior to p2)
- Character 30 (major palatine foramina) coded as "1" (many small foramina opening on the surface of the maxilla)
- Character 156 (number of upper incisors) coded as "1" (four)
- Character 157 (height of first upper incisor [serially homologous I1]) coded as "1" (subequal to smaller than other incisors)
- Character 164 (shape of upper incisor arcade) coded as "1" (slightly anteriorly convex)
- Character 173 (surface of the roots of the canines) coded as "0" (smooth)

Comments: These characters were all coded based on personal observations of YPM-VPPU 21871.

- Character 176 (procumbent lower canines) coded as “0” (absent)

Comments: Coded based on Villarroel and Marshall (1982)

***Sallacyon hoffstetteri***

- Character 6 (level of the palate relative to the basicranium) coded as “1” (palate and basicranium at the same level)
- Character 47 (position of lacrimal foramina coded as “0” (within orbit)
- Character 47 (number of lacrimal foramina) coded as “1” (exposed on face)
- Character 207 (metacone on M4) coded as “1” (present but adjoined to paracone or poorly distinct from crista)
- Character 232 (size of m4) coded as “1” (m4 larger than m3)
- Character 266 (hypoconulid of m4) coded as “1” (subequal to other talonid cusps)

Comments: These characters coded based on (Petter and Hoffstetter, 1983)

- Character 36 (palatine reaches level of infraorbital canal) coded as “1” (absent) based on Petter and Hoffstetter (1983)

Comments: According to Petter and Hoffstetter (1983), the infraorbital canal of MNHN SAL 92 opens at the level of the lacrimal foramen, which is approximately over M2. By contrast, the palatines only extend anteriorly to the level of M3. Therefore, this character is coded as “absent”.

- Character 85 (secondary foramen ovale completely enclosed in alisphenoid) coded as “1” (present)

Comments: This character is coded following Ladevèze and Muizon (2007)

- Character 44 (location of postglenoid foramen) coded as “1” (medial to postglenoid process)

Comments: Coded following observations of MNHN SAL 92 in Muizon (1994) and Muizon (1999)

– Character 171 (roots of upper canines) coded as "?"

– Character 172 (roots of lower canines) coded as "?"

Comments: The canines are unknown for *Sallacyon*.

***Sipalocyon* spp.**

- Character 207 (metacone on M4) coded as "1&2" (absent or present but adjoined to paracone or poorly distinct from cingulum)

Comments: Observations of specimens of *S. gracilis* show that the metacone of M4 is absent in some specimens (YPM-VPPU 15373) and present in others (MACN-A 692).

***Cladosictis patagonica***

- Character 152 (angle between anterior border of coronoid process and tooth row) coded as "0&1" (between 95 and 105 degrees and 106 and 125 degrees) based on observations of MACN-A 5927.
- Character 228 (Stylar cusp B) coded as "0&1" (small or forming an ectocingulum and vestigial or absent)

Observation of some specimens of *C. patagonica* (e.g., MACN-A 5950, MACN-A 6280) show the presence of a small cuspule contributing to the ectocingulum at the StB locus (especially on M3).

- Character 261 (presence of entoconid) coded as "0&1" (absent and present)

Observations of specimens assigned to *C. patagonica* indicate that the entoconid is present in most individuals, but is absent in others (e.g., MACN-A 674).

***Acyon myctoderos***

- Character 11 (posterior border of incisive foramen) coded as “1” (posterior to anterior border of canine alveolus)
- Character 14 (posteriormost point of premaxilla-nasal contact) coded as “1” (posterior to the canine)
- Character 26 (palatal length/width ratio) coded as “1” (greater than 1.5)
- Character 47 (position of lacrimal foramina) coded as “0” (within orbit)
- Character 48 (number of lacrimal foramina) coded as “1” (one)
- Character 56 (location of postglenoid foramen) coded as “1” (medial to postglenoid process)
- Character 64 (paracondylar process of exoccipital and post-tympanic process of squamosal) coded as “1” (both processes similar in length)
- Character 90 (size of jugular foramen relative to fenestra vestibuli) coded as “1” (larger)
- Character 116 (deep sulcus for carotid artery on anterior end of promontorium) changed from “0” (absent) to “?”
- Character 152 (angle between anterior border of coronoid process and tooth row) coded as “1” (between 106 and 125 degrees)
- Character 153 (position of the mandibular foramen) coded as “1” (at the midpoint of the coronoid process)
- Character 171 (roots of upper canines) coded as “0” (closed in adults)
- Character 172 (roots of lower canines) coded as “0” (closed in adults)
- Character 280 (shape of cranial facets) coded as “1” (dorsal edge curved)

- Character 284 (ventral sagittal crest of axis) coded as "1" (distinctly concave because of the development of a prominent ventral process posteriorly)

Comments: These characters were coded based Forasiepi et al. (2006).

- Character 28 (number of palatal pits) coded as "1&2" (one and two)
- Character 214 (wing-like cristae associated with para- and metaconules) coded as "0&1" (present and absent).

Comments: Changes in these characters were coded following recognition of individual variation in new specimens of this species (UF 26921–26941 and UATF-V-000926; Engelman et al., 2015).

- Character 196 (timing of eruption between dp3 and m3–4) coded as "2" (p3 and m4 erupt almost simultaneously)
- Character 197 (timing of eruption between M3–4 and m4) coded as "0" (M3 and m4 erupt simultaneously)
- Character 198 (morphology of dp3) coded as "1" (with a main cusp and smaller accessory cusps)
- Character 206 (shape of centrocrista) coded as "0" (straight)
- Character 228 (stylar cusp B) coded as "0&1" (absent or small or forming an ectocingulum)

Comments: These characters are coded based on the juvenile specimen described by Engelman et al. (2015)

- Character 261 (presence of entoconid) coded as "0&1" (absent and present)
- Character 262 (shape of the entoconid) coded as "1" (labio-lingually compressed)
- Character 263 (height of the entoconid) coded as "0" (smaller than the hypoconid)

- Character 264 (location of entoconid) coded as “1” (between metaconid and posterior tooth margin)
- Character 267 (pre-entocristid) coded as “0&1” (present and absent)
- Character 268 (direction of pre-entocristid) coded as “0” (to the base of the trigonid)

Comments: Observations of specimens assigned to *A. myctoderos* indicate that the entoconid is present in some specimens (UATF-V-000926), but is absent in others (e.g., MNHN-Bol-V-003668). When present, the morphology of this cusp is similar to other hathliacynids.

***Lycopsis longirostrus***

- Character 163 (shape of upper incisor row) coded as “?”

Comments: The premaxilla, upper incisor row, and lower incisor row are all unknown for the holotype (Marshall, 1977) and only other known specimen (Goin, 1997) of *L. longirostrus*, and as a result the shape of the incisor row in this taxon cannot be evaluated.

***Lycopsis torresi***

- Character 191 (change in height of lower premolars) coded as “0/1” (increase gradually in height/abrupt change in size between p1 and p2-3) as this character was coded on a single specimen for which only the right premolar row is complete (MLP 11-113) in Suarez et al. (2016) and therefore represents an uncertainty rather than a polymorphism.

***Lycopsis viverensis***

- Character 26 (palatal length/width ratio) coded as “1” (greater than 1.5)

Comments: The holotype of *L. viverensis* (MMH 87-6-1) preserves most of the postcanine portion of the maxilla including the midline suture (Forasiepi et al., 2003). Based on this it is possible to extimate the proportions of the palatal process of the maxillary to some extent (the width is known, but the length is not). The ratio of the greatest preserved length of the maxilla versus the estimated bilateral width of the palate in this specimen is much greater than 1.5, and would have been even higher if the maxilla anterior to P1 was preserved. Therefore this character can be safely coded as “1” (greater than 1.5).

- Character 191 (change in height of lower premolars) changed from “0&1” (flat [as wide as crown] and bulbous on only one premolar to “?”
- Character 192 (roots of lower premolars) changed from “0&2” (increase gradually in height/abrupt change in size between p1-2 and p3) to “?”

Comments: These characters were changed to “?” because p3 is unknown in *L. viverensis* (Forasiepi et al., 2003)

- Character 207 (metacone on M4) changed to “1/2” (present but adjoined to paracone or poorly distinct from crista or absent) as Forasiepi et al. (2003) note that there is a small structure on this tooth that could correspond to a vestigial metacone.

***Prothylacynus patagonicus***

- Character 6 (level of palate relative to basicranium) coded as “0” (palate lower than basicranium) based on observation of MACN-PV 14453

***Pharsophorus lacerans***

- Character 22 (location of the infraorbital foramen) was coded as “0” (anterior or dorsal to anterior root of P3)

Comments: In MNHN SAL 96/YPM-VPPU 20551 (the only specimen that can be confidently assigned to *Pharsophorus* that preserves the infraorbital foramen), the infraorbital foramen is located over the anterior root of P3.

- Character 18 (postorbital processes) changed from “0” (absent or indistinct) to “1” (well-developed) based on observations of MNHN SAL 96/YPM-VPPU 20551
- Character 140 (ventral margin of dentary posterior to last molar in lateral view) was coded as “0” (straight), based on observations of the holotype of this species

Comments: The ventral margin of the jaw of a specimen tentatively assigned to *P. lacerans* (MPEF-PV 4190; Goin et al., 2010) appears to be curved, but this specimen has not been studied in detail to determine if it belongs to *P. lacerans* (see main text).

- Character 203 (position of the metacone relative to the paracone) coded as “0” (approximately at the same level).
- Character 205 (bases of paracone and metacone) coded as “2” (almost completely connate)

Comments: Coded based on Patterson and Marshall (1978)

***Borhyaena tuberata***

- Character 6 (level of palate relative to basicranium) coded as “0” (palate lower than basicranium) based on observation of MACN-A 5780 and observations of specimens in Sinclair (1906)

***Australohyaena antiquua***

- Character 1 (length of the skull) coded as “1” (short, less than twice width of skull at level of zygomatic arches)

Comments: Although the only known skull of *Australohyaena* (UNPSJB-PV 113) does not preserve a complete zygomatic arch, the preserved width of this skull across the zygomatic arches is nearly 228 mm. The skull of the same specimen is only estimated to have been about 300 mm long, making the width of the zygoma easily more than half the length of the skull. In order for the skull to be considered “long”, the glenoid region of this specimen would need to be nearly 70 mm shorter than it actually is.

- Character 140 (ventral margin of dentary posterior to last molar in lateral view) changed from “0” (curved) to “1” (straight)

Comments: Changed based on the revised criteria for coding this character.

- Character 244 (trigonid versus talonid width) coded as “1” (narrow, but wider than the base of the metaconid or protoconid)

***Arctodictis sinclairi***

- Character 6 (level of palate relative to basicranium) coded as “0” (palate lower than basicranium) based on observation of MLP 85-VII-3-1
- Character 140 (ventral margin of dentary posterior to last molar in lateral view) changed from “0” (curved) to “1” (straight)

Comments: Changed based on the revised criteria for coding this character.

- Character 392 (metatarsal V proximal process) coded as “0” (does not extend ventral to cuboid)

Comments: Observations of the pes of MLP 85-VII-3-1 (Forasiepi, 2009, fig 46) show that the proximal process of MtV does not extend proximally.

***Arctodictis munizi***

- Character 6 (level of palate relative to basicranium) coded as “0” (palate lower than basicranium) based on observation of CORD-PZ 1210-1/2 in Forasiepi et al. (2004)
- Character 94 (median rod or crest of basisphenoid /presphenoid) changed from “0” (absent) to “1” (present)

Comments: Based on Forasiepi et al. (2004: fig 3c)

- Character 140 (ventral margin of dentary posterior to last molar in lateral view) changed from “0” (curved) to “1” (straight)

Comments: Changed based on the revised criteria for coding this character.

***Callistoe vincei***

- Character 6 (level of palate relative to basicranium) coded as “1” (palate and basicranium at same level)
- Character 51 (interparietal) coded as “1” (absent or fused with the parietal)
- Character 53 (parietal-alisphenoid or fronto-squamosal contact) coded as “1” (fronto-squamosal contact)
- Character 228 (stylar cusp B) coded as “1” (small or forming and ectocingulum)
- Character 230 (stylar cusp D) coded as “?”, as Babot et al. (2002) suggest the posterolabial cingulum on the upper molars could represent a reduced stylar cusp D, a condition that is seen in some other sparassodonts (e.g., MPEF-PV 4345; Goin et al., 2010)

Comments: These characters coded based on Babot et al. (2002).

- Character 47 (position of lacrimal foramina) coded as “0&1” (two and one)

– Character 48 (number of lacrimal foramina) coded as “0&1” (two and one)

Comments: The number and position of the lacrimal foramina differ between different specimens of *C. vincei* (Forasiepi et al., 2015). Therefore, these characters are polymorphic, rather than uncertainties

– Character 242 (trigonid versus talonid length [m1-3]) coded as “2” (trigonid larger than talonid).

***Paraborhyaena boliviana***

– Character 23 (flaring of maxillary “cheeks”) coded as “1” (absent)

– Character 26 (length/width ratio of palatal process of maxilla in ventral view) coded as “1” (greater than 1.5)

Comments: Coded based on Petter and Hoffstetter (1983)

– Character 140 (ventral margin of dentary posterior to last molar in lateral view) changed from “1” (straight) to “?”

Comments: Changed based on the revised criteria for coding this character.

– Character 256 (precingulid) coded as “2” (absent)

Comments: Coded based on observations of UATF-V-000129

– Character 242 (trigonid versus talonid length [m1-3]) coded as “2” (trigonid larger than talonid)

***Thylacosmilus atrox***

– Character 6 (level of palate relative to basicranium) coded as “1” (palate and basicranium at same level)

– Character 23 (flaring of maxillary “cheeks”) coded as “1” (absent)

Comments: Coded based on observations of FMNH P14531

- Character 111 (height of first upper incisor [serially homologous I1]) changed from "-" to "?".

Comments: Although it is clear *Thylacosmilus* has a reduced compliment of incisors compared to other sparassodonts, the homologies of the retained incisors are uncertain. Upper incisors were clearly present based on wear facets (Churcher, 1985), but no specimen of *Thylacosmilus* preserves the upper incisors. It is possible that one of the lost upper incisors in *Thylacosmilus* corresponds to I1, based on arguments for incisor homology in borhyaenids (Forasiepi, 2009), but it is also possible that the lost upper incisors represent different loci, especially given the unusual upper incisor arcade of *Paraborhyaena* (Petter and Hoffstetter, 1983) where there are two pairs of incisors (possibly I1-2 and I3-4) that are mesiodistally aligned with one another. Until a specimen of *Thylacosmilus* with the upper incisors is discovered, their number and possible homologies remain uncertain.

LIST AND DESCRIPTION OF 400 CHARACTERS USED IN PHYLOGENETIC ANALYSIS.

* = Ordered character.

**1. Length of the skull:** Short (Less than twice width at level of zygomatic arch) (0); Long (Greater than twice width at level of zygomatic arch) (1)

**2. Length of rostrum*:** Less than 1/3 total length of skull (0); Between 1/3 and 1/2 total length of skull (1); More than 1/2 total length of skull (2)

**3. Expanded apex of rostrum:** Absent (0); Present (1)

**4. Width of braincase versus maximum postorbital width:** Braincase wider than maximum postorbital width(0); Braincase narrower than maximum postorbital width (1)

**5. Dimensions of braincase:** As wide as long, or slightly wider than long (0); Much longer than wide (1)

**6. Level of the palate relative to the basicranium:** Palate lower than basicranium (0); Palate and basicranium at the same level (1)

**7. Paracanine fossa:** Formed by premaxilla and maxilla (0); Formed by premaxilla only (1)

**8. Dimensions of paracanine fossa:** Longer than high (0); Higher than long (1)

**9. Precanine notch:** Absent (0); Present (1)

**10. Lateral palatal process of premaxilla:** Anterior to or just reaches anterior border of canine alveolus (0); Posterior to anterior border of canine alveolus (1)

**11. Posterior border of incisive foramen:** Anterior to or just reaches anterior border of canine alveolus (0); Posterior to anterior border of canine alveolus (1)

**12. Position of medial palatal process of premaxilla:** Horizontal (0); With posterior end more dorsal, forming an incisive fossa (1)

**13. Tubercle or internarial process on anterodorsomedial surface of premaxilla:** Absent (0); Present (1)

**14. Posteriormost point of premaxilla-nasal contact*:** Anterior or at the level of the canine (0); Posterior to the canine (1); Posterior to p2 (2)

**15. Anterior extent of nasals:** Protrude anteriorly, obscuring the nasal opening in dorsal view (0); Retracted posteriorly, exposing the narial opening in dorsal view (1)

**16. Shape of naso-frontal suture:** Open W-shape or posteriorly convex (0); Acute W or V-shaped (1)

**17. Median process of frontals wedged between nasals:** Absent (0); Present (1)

**18. Postorbital processes:** Absent or indistinct (0); Well-developed (1)

**19. Fronto-maxillary or naso-lacrimal contact:** Naso-lacrimal contact (0); Fronto-maxillary contact (1)

**20. Angle of maxillo-jugal contact:** More than 140 degrees (0); Between 95 and 140 degrees (1)

**21. Postorbital process of jugal:** Absent (0); Present (1)

**22. Location of the infraorbital foramen*:** Anterior or dorsal to the anterior root of P3 (0); Dorsal to the midpoint or posterior root of P3 (1); Dorsal to M1 (2); Posterior to M1 (3)

**23. Flaring of maxillary "cheeks" behind infraorbital foramen:** Present (0); Absent (1)

**24. Fossa for levator labii muscle:** Mainly on jugal (0); Mainly on maxilla (1)

**25. Large foramen at anteroventral end of maxilla medial to canines:** Absent (0); Present (1)

**26. Palatal length/width ratio:** Lesser than or equal to 1.5 (0); Greater than 1.5 (1)

**27. Shape of the palate:** Rectangular (molar rows near parallel) (0); Triangular (wider posteriorly) (1)

**28. Number of palatal pits*:** Absent (0); One (between M3-M4) (1); Two (between M2-M3 and M3-M4) (2); Three (one between each pair of molars) (3)

**29. Maxillopalatine fenestrae:** Absent (0); Present (1)

**30. Major palatine foramen:** One pair opening in maxilla, palatine, or maxillo-palatine suture (0); Many small foramina on the surface of the maxilla (1)

**31. Minor palatine foramen:** Complete (0); Incomplete or absent (1)

**32. Posterior extent of palatines:** Extend to the level of the last molar (0); Extend beyond the level of the last molar (1)

**33. Shape of posterior end of palate:** Concave posteriorly (0); Straight (1)

**34. Palatine torus:** Present and well-developed (0); Absent or only a slight thickening around choanae (1)

**35. Medial postpalatine spine:** Well-developed, making posterior edge of palate double-arched (0); Absent or poorly-developed (1)

**36. Palatine contributes to infraorbital canal:** Present (0); Absent (1)

**37. Postpalatine torus foramen:** Small (less than half size of minor palatine foramen) (0); Large (more than half size of minor palatine foramen) (1)

**38. Morphology of postpalatine torus foramen*:** Closed (0); Open (1); Absent (2)

**39. Posterolateral corners of the palate inflected ventrally forming prominent lateral corners:** Absent (0); Present (1)

**40. Position of sphenorbital foramen relative to lacrimal:** Posterior to the level of the posterior border of lacrimal (0); Anterior or at the level of the posterior border of lacrimal (1)

**41. Position of sphenorbital foramen relative to molars**: Anterior or dorsal to M3 (0); Posterior to or dorsal to M4 (1)

**42. Development of pterygoids*:** Well-developed and expanded on medial side, with midline contact (0); Well developed and expanded on medial side, but no midline contact (1); Reduced, not expanded on medial side (2)

**43. Posterior process of pterygoids covering alisphenoid-basisphenoid suture:** Absent (0); Present (1)

**44. Anterior extent of lacrimal (width of facial process relative to lacrimal dorsoventral height:** Restricted to orbit (less than half height) (0); Extending onto rostrum (more than half height) (1)

**45. Shape of facial process of lacrimal:** Rounded (0); Triangular with anterodorsal projection (1)

**46. Lacrimal tubercle:** Present (0); Absent (1)

**47. Position of lacrimal foramina:** Within orbit (0); Exposed on face (1)

**48. Number of lacrimal foramina:** Two (0); One (1)

**49. Glenoid process of jugal:** With articular facet (0); Without articular facet (1)

**50. Orbital crest:** Absent (0); Present (1)

**51. Interparietal:** Present (0); Absent (or fused with parietal) (1)

**52. Shape of fronto-parietal suture:** Formed by posterior wedge of frontals (0); Straight (1); Formed by anterior wedge of parietals (2)

**53. Parietal-alisphenoid or fronto-squamosal contact:** Parietal-alisphenoid (0); Fronto-squamosal (1)

**54. Width of glenoid cavity:** Less than twice anteroposterior length (0); More than twice anteroposterior length (1)

**55. Distinct preglenoid process of squamosal:** Absent (0); Present (1)

**56. Morphology of postglenoid process*:** Wider than high (half as tall as wide or less) (0); Wide and low (1); Height subequal or greater than width (2)

**57. Proportions of postglenoid process:** As wide as glenoid cavity (0); Narrower than glenoid cavity (1)

**58. Postglenoid foramen:** Absent (0); Present (1)

**59. Location of postglenoid foramen*:** Entirely medial to postglenoid process (0); Posterior to glenoid process, aligned with medial end of postglenoid process (1); Posterior to glenoid process, lateral to medial edge of postglenoid process (2)

**60. Anteroposterior position of postglenoid foramen relative to postglenoid process:** Close and in contact or nearly so (0); Well-separated (1)

**61. Suprameatal foramen:** Above suprameatal crest (0); Below suprameatal crest (1)

**62. Squamosal at external acoustic meatus*:** Not thickened at meatus (0); Thickened at meatus with mediolateral width shorter than anteroposterior width (1); Thickened at meatus with mediolateral width longer than anteroposterior width (2)

**63. Paracondylar process of occipital:** Low tubercle or absent (0); Long process with diameter at apex smaller than proximodistal length (1)

**64. Paracondylar process of exoccipital and post-tympanic process of squamosal:** Paracondylar process larger (0); Both processes similar in length (1)

**65. Orientation of the post-tympanic and/or paracondylar processes:** Ventrally projecting (0); Anteroventrally projecting (1)

**66. Alisphenoid glenoid process:** Absent (0); Present (1)

**67. Optic foramen and sphenorbital fissure:** Separate (0); Joined (1)

**68. Transverse foramen:** Absent (0); Present (1)

**69. Tympanic process of alisphenoid:** Absent (0); Present (1)

**70. Hypotympanic sinus:** Absent (0); Present (1)

**71. Petrosal contribution to hypotympanic sinus:** Absent (0); Present (1)

**72. Squamosal contribution to hypotympanic sinus:** Absent (0); Present (1)

**73. Medial process of the squamosal:** Absent (0); Present (1)

**74. Concave process of alisphenoid contributing to antero-dorsal portion of hypotympanic sinus:** Present (0); Absent (1)

**75. Squamosal epitympanic sinus excavated in the roof of the external auditory meatus:** Absent (0); Present (1)

**76. Intratympanic sinus excavated in the exoccipital:** Absent (0); Present (1)

**77. Intratympanic sinus in the pars mastoidea:** Absent (0); Present (1)

**78. Dorsal epitympanic expansion of hypotympanic sinus above glenoid fossa:** Absent (0); Present (1)

**79. Anterior expansion of middle ear sinus within the lateral wall of the braincase:** Absent (0); Present (1)

**80. Pneumatization of squamosal:** Absent (0); Present (1)

**81. Tensor tympani fossa:** Smooth and shallow area (0); Distinct circular pit or elongated fossa (1); Long and narrow groove bordering anterior edge of promontorium (2)

**82. Eustachian foramen*:** No impression (0); Notch on the alisphenoid (1); Foramen on petrosal (2)

**83. Composition of primary foramen ovale:** On petrosal (0); Between petrosal and alisphenoid (1); On alisphenoid (2)

**84. Location of foramen ovale:** On lateral wall of braincase (0); On ventral surface of skull (1)

**85. Secondary foramen ovale completely enclosed in alisphenoid:** Absent (0); Present (1)

**86. Foramen for the greater petrosal nerve:** Distinct notch or foramen (0); Without distinct notch or foramen (1)

**87. Position of carotid foramen:** Anterior to the basisphenoid-basoccipital suture (0); At the level of the basisphenoid-basoccipital suture (1)

**88. Hypoglossal foramina:** Two or more (0); One (1)

**89. Groove between hypoglossal foramina and foramen for inferior petrosal sinus:** Shallow or absent (0); Well-defined with prominent lateral borders (1)

**90. Size of jugular foramen relative to fenestra vestibuli:** Subequal (0); Larger (1)

**91. Jugular fossa:** Absent (0); Present (1)

**92. Jugular foramen and foramen for inferior petrosal sinus:** Separate (0); Confluent (1)

**93. Median keel in basioccipital:** Absent (0); Present (1)

**94. Median rod or crest of basisphenoid/presphenoid (sphenoid crest):** Absent (0); Present (1)

**95. Dorsal margin of the foramen magnum:** Formed only by exoccipitals (0); Formed by both exoccipitals and supraoccipital (1)

**96. Ascending canal:** Present (0); Absent (1)

**97. Contribution of squamosal to occiput:** Absent or small (0); Large (1)

**98. Mastoid foramen or other emissary foramina in the occiput:** Present (0); Absent (1)

**99. Connection between condylar articular facets in ventral view:** Absent (0); Present (1)

**100. Inclination of the major axis of the condyle in posterior view:** Inclined (less than 55 degrees) (0); Vertical to subvertical (between 90 and 55 degrees) (1)

**101. Supraoccipital in posterior view:** Concave (0); Convex or flat (1)

**102. Sagittal crest*:** Prominently developed (extending to frontals) (0); Weakly developed (not extending to frontals) (1); Absent (2)

**103. Position of nuchal crest:** At or posterior to the level of the condyles (0); Anterior to the condyles (1)

**104. Morphology of the stapes:** Columelliform (not perforated by stapedial foramen) (0); Bicrurate (perforated by stapedial foramen) (1)

**105. Ectotympanic shape:** Ring-shaped (0); Expanded (1)

**106. Ectotympanic attachment to skull*:** Ligamentous (0); Tight articulation with marked ridges and grooves (1); Fused to rostral tympanic process (2)

**107. Position of petrosal:** At the level of the ventral margin of the braincase (0); Dorsal to the ventral level of the braincase (1)

**108. Orientation of the pars cochlearis of the petrosal (plane defined by the apex of the promontorium-fenestra vestibuli-fenestra cochleae):** Subhorizontal or slightly oblique (0); Subvertical (1)

**109. Orientation of the major axis of the petrosal (as defined by subarcuate fossa-internal acoustic meatus)*:** Subhorizontal to slightly oblique (0); Oblique to subvertical (1); Vertical (2)

**110. Mastoid portion of the petrosal:** Contributes to the occipital shield (0); Excluded from the occipital shield (1)

**111. Petrosal-squamosal fusion:** Absent (0); Present (1)

**112. Cavum epiptericum*:** Floored by petrosal (0); Floored by petrosal and alisphenoid (1); Floored primarily or exclusively by alisphenoid (2)

**113. Internal acoustic meatus:** Deep with thick prefacial commissure (0); Shallow with thin prefacial commissure (1)

**114. Subarcuate fossa:** Deep (0); Shallow (1)

**115. Medial expansion of the crista petrosa that forms a thin and straight lamina covering the anterolateral part of the subarcuate fossa:** Absent (0); Present (1)

**116. Deep sulcus for carotid artery on anterior end of promontorium:** Absent (0); Present (1)

**117. Epitympanic wing of petrosal:** Present (0); Absent (1)

**118. Prootic canal:** Present (0); Absent (1)

**119. Prootic canal morphology:** Large with endocranial opening (0); Reduced with intramural opening (1)

**120. Rostral tympanic process of petrosal*:** Absent (0); Low crest (1); Raised process (2)

**121. Anterior extent of rostral tympanic process of petrosal:** Restricted to posterior half (0); Extends anteriorly and contacts alisphenoid (1)

**122. Caudal tympanic process completely floors postpromontorial sinus:** Absent (0); Present (1)

**123. Petrosal plate:** Absent (0); Present (1)

**124. Paroccipital process of petrosal:** Distinct process (0); Indistinct or absent (1)

**125. Position of hiatus fallopii*:** On dorsal (cerebellar) face of petrosal (1); Intermediate (1); On ventral (tympanic) face of petrosal (2)

**126. Stylomastoid foramen:** Absent (0); Present (1)

**127. Floor of cavum supracochleare:** Absent (0); Present (1)

**128. Stapedial ratio:** Rounded, less than 1.8 (0); Elliptical, more than 1.8 (1)

**129. Contribution of squamosal to epitympanic recess*:** Squamosal contribution much smaller than petrosal (0); Squamosal contribution roughly as large as petrosal (1); Squamosal contribution much larger than petrosal (2)

**130. Fossa incudis:** Continuous with epitympanic recess (0); Separated from the epitympanic recess (1)

**131. Tympanic petrosal crest:** Present (0); Absent (1)

**132. Tuberculum tympani:** Weakly developed (0); Large (1)

**133. Stapedial fossa:** Twice the size of fenestra vestibuli (0); Small and shallow (1)

**134. Foramina for temporal ramus with well-developed internal branch of stapedial artery:** Present (0); Absent (1)

**135. Location of foramina for temporal rami:** On petrosal (0); On parietal or squamosal (1)

**136. Foramina for veinous drainage of the temporal cavity on parietal or squama of squamosal:** Present (0); Absent (1)

**137. Post-temporal canal or notch:** Present (0); Absent (1)

**138. Post-temporal sulcus on squamosal surface of petrosal:** Present (0); Absent (1)

**139. Shape of dentary (depth below m3/m4 embrasure/length m1-4)*:** Shallow (less than 0.6) (0); Intermediate (between 0.6 and 0.8) (1); Deep (greater than 0.8) (2)

**140. Ventral margin of dentary posterior to last molar in lateral view:** Straight (0); Curved (1)

**141. Mandibular symphysis:** Unfused (0); Fused (1)

**142. Anteroventral angle of symphysis relative to tooth row:** Little to no angle (< 25 degrees) (0); Pronounced angle (> 25 degrees) (1)

**143. Number of mental foramina:** One to two (0); Three or more (1)

**144. Enlarged anterior mental foramen:** Absent (0); Present (1)

**145. Posteriormost mental foramen*:** Below p3 (0); At p3/m1 embrasure (1); Below m1 (2); Posterior to m1 (3)

**146. Retromolar space:** Absent (0); Present (1)

**147. Labial mandibular foramen inside masseteric fossa:** Absent (0); Present (1)

**148. Masseteric fossa:** Restricted dorsally by crest reaching condyle (0); Extends ventrally to lower margin of dentary (1)

**149. Posterior shelf of masseteric fossa:** Absent (0); Present (1)

**150. Medially inflected angular process:** Absent (0); Present (1)

**151. Shape of the angular process*:** Shelf-like (ASL/AL > 0.81) (0); Intermediate (0.72 < ASL/AL < 0.81) (1); Rod-like (ASL/AL < 0.72) (2)

**152. Angle between anterior border of coronoid process and tooth row*:** Between 95 and 105 degrees (0); Between 106 and 125 degrees (1); Greater than 126 degrees (2)

**153. Position of the mandibular foramen*:** Posterior to the mid-point of the coronoid process (0); At the mid-point of the coronoid process (1); Anterior to the mid-point of the coronoid process (2)

**154. Morphology of mandibular condyle:** Subspherical (0); Cylindrical (1)

**155. Position of mandibular condyle relative to tooth row*:** Completely above tooth row (0); Above alveolar border of tooth row but not completely above dentition (1); Aligned with or below alveolar border of tooth row (2)

**156. Number of upper incisors*:** Five (0); Four (1); Three (2); Two or fewer (3)

**157. Height of first upper incisor (serially homologous I1):** Taller than other incisors (0); Subequal to or smaller than remaining incisors (1)

**158. Roots of I1 in anterior view:** Parallel (0); Diverging dorsally (1)

**159. Diastema between I1-2:** Present (0); Absent (1)

**160. Size of I3 versus I2*:** I3 smaller (0); I3 subequal to I2 (1); I3 larger (2)

**161. Size of I4 versus I3:** I4 subequal to I3 (0); I4 larger (1)

**162. Size of I5 versus I4:** I5 subequal to I4 (0); I5 smaller than I4 (1)

**163. Shape of upper incisors (I2-5):** Peg-shaped (0); Spatulate (1)

**164. Shape of upper incisor arcade*:** Parabolic (0); Slightly anteriorly convex (1); Transverse (2)

**165. Number of lower incisors*:** Four (0); Three (1); Two or less (2)

**166. Staggered lower incisor (serially homologous i3):** Absent (0); Present (1)

**167. Procumbent lower incisors:** Procumbent (0); Not procumbent (1)

**168. Size of canines:** Relatively small (0); Enlarged (0)

**169. Number of roots on upper canine:** Two (0); One (1)

**170. Shape of upper canines:** Not saber-like (0); Saber-like (1)

**171. Roots of upper canines:** Closed in adults (0); Open (1)

**172. Roots of lower canines:** Closed in adults (0); Open (1)

**173. Surface of the roots of the canines:** Smooth (0); With small grooves and ridges (1)

**174. Prominent median sulci on labial faces of canines:** Absent (0); Present (1)

**175. Prominent median sulci on lingual faces of canines:** Absent (0); Present (1)

**176. Procumbent lower canine:** Absent (0); Present (1)

**177. Number of premolars*:** Four or more (0); Three (1); Two or less (2)

**178. Orientation of P/p1 relative to tooth row*:** Parallel to tooth row (less than 19 degrees) (0); Obliquely oriented to tooth row (20 degrees or more) (1); Transversely oriented to tooth row (2)

**179. Orientation of P/p2 relative to tooth row:** Parallel to tooth row (0); Oblique (1)

**180. Diastema between C-P1*:** Absent (alveolar margins in contact) (0); Small (less than one tooth root in length) (1); Long (greater than one tooth root in length) (2)

**181. Diastema between P1-2*:** Absent (alveolar margins in contact) (0); Small (less than one tooth root in length) (1); Long (greater than one tooth root in length) (2)

**182. Diastema between c-p1*:** Absent (alveolar margins in contact) (0); Small (less than one tooth root in length) (1); Long (greater than one tooth root in length) (2)

**183. Diastema between p1-2*:** Absent (alveolar margins in contact) (0); Small (less than one tooth root in length) (1); Long (greater than one tooth root in length) (2)

**184. Shape of premolars:** Uninflated (0); Inflated, with apical wear strongly developed (1)

**185. Shape and position of main cusp of P1:** Asymmetrical and aligned with anterior root (0); Posterior to anterior root (1)

**186. Shape and position of main cusp of p1:** Anteroposteriorly aligned with or anterior to anterior root (0); Posterior to anterior root (1)

**187. Cusp on the posterior heel of P3:** Absent or vestigial (0); Well-developed (1)

**188. Posterolingual cingulum on P3*:** Absent (0); Small cingulum (1); With a small posterolingual cusp (2)

**189. Posterolabial cingulum on P3:** Present (0); Absent (1)

**190. Size of p2:** Smaller than p3 (0); Larger than p3 (1)

**191. Change in height of lower premolars:** Increase gradually in height (0); Abrupt change in size between p1 and p2-3 (1); Abrupt change in size between p1-2 and p3 (2)

**192. Roots of lower premolars*:** Flat (as wide as crown) (0); Bulbous on only one premolar (1); Bulbous on all premolars and some molars (2)

**193. Precingulid or cingulid cusp on p2:** Absent (0); Present (1)

**194. Symmetry of main cusp on p3:** Anterior edge of cusp more convex than posterior edge (0); Both edges similar in curvature (1)

**195. Replacement of dP3:** dP3 is replaced (0); dP3 is not replaced (1)

**196. Timing of eruption between dP/p3 and M/m3-4*:** p3 erupts before m3 (0); p3 and m3 erupt almost simultaneously (1); p3 erupts almost simultaneously with or after m4 (2)

**197. Timing of eruption between M3-4 and m4:** M3 and m4 erupt simultaneously (0); M/m4 erupt simultaneously (1)

**198. Morphology of dp3:** With trigonid and talonid (0); With a main cusp and smaller accessory cusps (1)

**199. Size of molars increasing posteriorly:** Moderate posterior increase in size (0); Marked posterior increase in size (1)

**200. Shape of upper molar row:** Straight (0); Bowed (1)

**201. Width of M4 relative to M3:** Narrower than M3 (0); Subequal to wider than M3 (1)

**202. Size of metacone relative to paracone (based on M2 when possible)*:** Paracone slightly larger or subequal to metacone (0); Paracone slightly smaller (ca. 10%) than metacone (1); Paracone distinctly smaller (ca. 30%) than metacone (2); Paracone much smaller (ca. 50%) than metacone (3)

**203. Position of the metacone relative to paracone (based on M2 when possible):** Approximately at the same level (0); Lingual (1)

**204. Shape of paracone and metacone:** Conical (0); Subtriangular with a flat labial face (1)

**205. Bases of paracone and metacone*:** Separate (0); Partially adjoined (1); Almost completely connate (only tips separate) (2)

**206. Centrocrista:** Straight (0); V-shaped (1)

**207. Metacone on M4:** Distinct cusp (0); Present but adjoined to paracone or poorly distinct from crista (1); Absent (2)

**208. Number of roots on M4:** Three (0); Two or less (1)

**209. Size of protocone*:** Vestigial or absent (0); Small (narrower than bases of paracone and metacone) (1); Somewhat expanded anteroposteriorly (as wide as bases of paracone and metacone) (2); Greatly expanded anteroposteriorly (wider than bases of paracone and metacone) (3)

**210. Eccentric/procumbent protocone:** Absent (0); Present (1)

**211. Trigon basin:** Present (0); Absent (1)

**212. Height of protocone*:** Less than 60% of para/metacone height (0); Between 60 to 80% para/metacone height (1); Greater than or equal to 80% of para/metacone height (2)

**213. Paraconule and metaconule:** Present (0); Absent (1)

**214. Wing-like cristae associated with para- and metaconules:** Absent (0); Present (1)

**215. Relative position of para- and metaconule (based on M2 when possible):** At or lingual to the midpoint between protocone and para/metacone (0); Closer to the paracone or metacone (1)

**216. Extent of postprotocrista:** Ends lingual to apex of metacone (0); Extends labially beyond apex of metacone (1)

**217. Orientation of the preparacrista (based on M2 when possible):** Nearly perpendicular to long axis of tooth (0); Oriented anterobucally to long axis of tooth (1); Absent (2)

**218. Lengths of preparacrista on M3 and M4:** M4 preparacrista shorter (0); M4 preparacrista subequal or longer than M3 preparacrista (1)

**219. Postmetacrista (based on M3 if possible):** Strongly developed (longer than preparacrista) (0); Weakly developed (shorter than preparacrista) (1)

**220. Orientation of postmetacrista (based on M3 if possible):** Nearly perpendicular to tooth row (0); Oblique to tooth row (1)

**221. Carnassial notch in postmetacrista:** Absent (0); Present (1)

**222. Anterolabial cingulum (based on M3 if possible)*:** Expanded (0); Short (1); Vestigial to absent (2)

**223. Postcingulum:** Absent or weakly developed (0); Present (1)

**224. Width of parastylar lobe relative to metastylar lobe (on M3)*:** Metastylar lobe narrower (0); Parastylar and metastylar lobes uniform in width (1); Parastylar lobe slightly narrower (2); Parastylar lobe significantly narrower (stylar shelf small or absent on M2-3) (3)

**225. Width of stylar shelf (widest lobe on M3)*:** More than 50% total width (0); Less than 50% total width (1); Vestigial or absent (2)

**226. Deep ectoflexus (>10% tooth width) on upper molars*:** On M2 and M3 (0); On M3 only (1); Strongly reduced or absent (2)

**227. Stylar cusp A*:** Absent (0); Smaller than StB (1); Large, subequal to StB (2)

**228. Stylar cusp B*:** Large (0); Small or forming an ectocingulum (1); Vestigial or absent (2)

**229. Stylar cusp C:** Absent (0); Present (1)

**230. Stylar cusp D*:** Absent (0); Present, smaller than stylar cusp B (1); Present, larger than stylar cusp B (2)

**231. Stylar cusp E:** Present and distinct (0); Indistinct or absent (1)

**232. Size of m4:** m4 subequal or smaller than m3 (0); m4 larger than m3 (1)

**233. Posterior lobe of the crown lower than anterior lobe*:** Absent (0); Present only on m1-2 and slightly developed (1); Present on m1-3 and strongly developed (2)

**234. Roots of lower molars (based on m3 when possible):** Anterior root much larger than posterior root (0); Both roots similar in size (1)

**235. Talonid of m4 relative to m3:** Talonid of m4 reduced and narrower than m3 (0); Talonid of m4 similar to m3 (1)

**236. Alignment of the main cusps of m1:** Reverse triangle acute (0); Single longitudinal row (1)

**237. Trigonid configuration posterior to m1*:** Open, with paraconid anterolingual (0); Acute, with paraconid more posteriorly placed (1); Anteroposteriorly compressed (2)

**238. Relative positions of paraconid and metaconid (considered based on the apices of both cusps):** Paraconid and metaconid aligned labiolingually (0); Metaconid located more lingual (1)

**239. Orientation of postprotocristid/metacristid:** Transverse to lower jaw (0); Parallel or oblique to lower jaw (1)

**240. Relative lengths of paracristid and metacristid*:** Paracristid longer (0); Paracristid and metacristid subequal (1); Metacristid longer (2)

**241. Morphology of talonid:** Small basinless heel (0); Multicuspidate and basined (1)

**242. Trigonid versus talonid length (m1-m3)*:** Trigonid smaller than talonid (0); Trigonid subequal to talonid (1); Trigonid larger than talonid (2)

**243. Dimensions of trigonid*:** Longer than wide (0); Subequal (1); Wider than long (2)

**244. Width of talonid relative to trigonid (m1-3)*:** Narrower than trigonid (0); Subequal to trigonid (1); Wider than trigonid (2)

**245. Hypoconid versus protoconid height (based on m2-3)*:** hypoconid/protoconid height radio less than 20% (0); hypoconid/protoconid height radio between 25-35% (1); hypoconid/protoconid height radio between 40-60% (2)

**246. Metaconid on m1:** Present (0); Absent (1)

**247. Metaconid on m2-4*:** Present on m2-4 (0); Absent on m4 (1); Absent on m2-4 (2)

**248. Paraconid height relative to metaconid (m2-4)*:** Taller (0); Subequal (1); Lower (2)

**249. Volume of metaconid relative to paraconid in occlusal view*:** Larger (0); Subequal (1); Smaller (2)

**250. Height of protoconid:** Tallest cusp of the trigonid (0); Subequal to metaconid or paraconid (1)

**251. Location of protoconid relative to midline of tooth (on m2-4):** Slightly lingual to midline of tooth (0); Protoconid at midline of tooth (1)

**252. Labial extension of protoconid:** Protoconid subequal or narrower at mid-height than base (0); Protoconid wider at mid-height than base (1)

**253. Protoconid height/length of m3 or m4:** less than 0.9 (0); 0.9 or greater (1)

**254. Anterior keel at anterolingual angle of paraconid with hypoconulid notch:** Rounded (0); Forming a keel (1)

**255. Paraconid elongated with anteroventral projection of the paraconid keel:** Absent (0); Present (1)

**256. Anterolabial cingulid*:** Well-developed, extending from the protoconid to paraconid basins (0); Reduced, extended only on the base of the paraconid (1); Absent (2)

**257. Paraconid of m1:** Distinct (0); Low and confluent with cingulum (1)

**258. Length versus width of talonid basin (based on m2 when possible)*:** Longer than wide (0); Subequal (1); Wider than long (2)

**259. Presence of hypoconid (on m2-4):** Present (0); Absent (1)

**260. Location of hypoconid (on m2-4):** Approximately at the middle of the buccal margin of the talonid (0); At the posterobuccal corner of the tooth (1)

**261. Presence of the entoconid:** Present (0); Vestigial or absent (1)

**262. Shape of the entoconid:** Conical (0); Labio-lingually compressed (1)

**263. Height of entoconid:** Smaller than the hypoconid (0); Subequal to larger than the hypoconid (1)

**264. Location of entoconid:** At the posterolingual corner of the tooth (0); Between the metaconid and posterior tooth margin (1)

**265. Position of hypoconulid:** In posteromedial position (0); Lingually placed and twinned with entoconid (1)

**266. Hypoconulid of m4*:** Taller than other talonid cusps (0); Subequal to other talonid cusps (1); Absent (2)

**267. Pre-entocristid:** Present (0); Absent (1)

**268. Direction of the pre-entocristid:** To the base of the trigonid (0); Lingual to the trigonid (1)

**269. Cristid obliqua*:** Lingual to the carnassial notch (0); To the carnassial notch (1); Labial to the carnassial notch (2)

**270. Posthypocristid:** Oblique to long axis of tooth (0); Transverse to long axis of tooth (1)

**271. Lower molar hypoflexid:** Deep (40-50% of talonid width) (0); Shallow or absent (1)

**272. Carnassial notch in cristid obliqua:** Absent (0); Present (1)

**273. Labial postcingulid on m1-3:** Absent (0); Present (1)

**274. Labial postcingulid on m4:** Absent (0); Present (1)

**275. Atlas intervertebral foramen:** Absent (0); Present (1)

**276. Atlas transverse foramen:** Absent (0); Present (1)

**277. Ventral foramen on transverse process of axis:** Absent (0); Present (1)

**278. Posterior extent of transverse processes of atlas*:** Anterior or just reaches caudal facets for axis (0); Extend caudally just beyond level of caudal facets for axis (1); Extend caudally far beyond caudal facets for axis and processes much longer than wide (2)

**279. Anterior extent of transverse processes of atlas:** Does not reach level of atlantal foramen or groove (0); Extends anterior beyond atlantal foramen or groove (1)

**280. Shape of cranial facets:** Only concave (0); Dorsal edge curved (1)

**281. Atlas and intercentrum:** Unfused (0); Fused (1)

**282. Axis transverse foramen:** Absent, represented by a notch (0); Present, enclosed (1)

**283. Axis posterior spinous process extension:** Extends beyond the level of the postzygapophyses (0); Extends to the level of the postzygapophyses (1)

**284. Ventral sagittal crest of axis:** Roughly straight (0); Distinctly concave because of the development of a prominent ventral process posteriorly

**285. C3-C4 ventral sagittal process:** Absent (0); Present (1)

**286. C5 transverse process heads overlap transversally:** Present (0); Absent (1)

**287. C5 and T1 body length:** C5 subequal or longer than T1 (0); C5 shorter than T1 (1)

**288. C6 spinous process:** Protuberance (0); Lamina (1)

**289. C7 transverse foramen:** Absent (0); Represented by a notch (1); Complete foramen (2)

**290. Shape of anterior face of C7 centrum:** Circular to ovoid (0); Rectangular to trapezoidal (1)

**291. Position of tallest spinous process of thoracic vertebrae:** On T1 (0); On T2 (1); On T3 (2)

**292. Anticlinal vertebra:** On lumbar (0); On thoracic (1); No anticlinal vertebra (2)

**293. Foramen on dorsal arch of last lumbar vertebra:** Present (0); Absent (1)

**294. Metapophyses in third lumbar vertebra anterior to last:** Absent or weak (0); Present (1)

**295. Ventral median keel on lumbar vertebra:** Absent (0); Present (1)

**296. Auricular process of sacrum:** Developed on two sacral vertebrae (0); Developed on one sacral vertebra (1)

**297. Size of sacral spinous process:** Shorter than last lumbar (0); Taller than last lumbar (1)

**298. Length of the tail:** Shorter than twice the length of the precaudal vertebral column (0); Greater than twice the length of the precaudal vertebral column (1)

**299. Angle between scapular spine and dorsal border of scapula:** Acute or almost straight (between 80 and 95 degrees) (0); Obtuse (between 100 and 110 degrees) (1)

**300. Coracoid process:** Large (extends beyond medial border of glenoid cavity) (0); Small (just reaches medial border of glenoid cavity) (1)

**301. Ventral extension of acromion process:** Extends ventrally below glenoid cavity (0); Does not extend ventrally below glenoid cavity (1)

**302. Anterior extension of acromion process:** Posterior to anterior edge of glenoid cavity (0); Anterior to or just lateral to anterior edge of glenoid cavity (1)

**303. Width of infraspinous fossa:** Less than 1/4 its length (0); More than 1/4 its length (1)

**304. Width of the acromion process at the level of the neck*:** Wider than infraspinous fossa (0); Subequal (1); Narrower than infraspinous fossa (2)

**305. Infraspinous/supraspinous fossa width at the level of the neck:** Supraspinous fossa subequal or wider (0); Supraspinous fossa narrower (1)

**306. Scapular notch:** More than 130 degrees (0); Between 90 and 130 degrees (1)

**307. Clavicle:** Present (0); Absent (1)

**308. Medial process for teres major:** Absent (0); Present (1)

**309. Tricipital line of humerus*:** Absent (0); Ridge or crest (1); Massive crest continuous with deltopectoral crest (2)

**310. Capitulum for radius on humerus:** Spherical (0); Cylindrical (1)

**311. Entepicondylar foramen:** Present (0); Absent (1)

**312. Olecranon fossa or foramen:** Large fossa (0); Foramen (1)

**313. Laminar supinator crest/ectepicondylar crest*:** Large (0); Intermediate (1); Absent (2)

**314. Greater tuberosity height relative to humeral head height:**

0 Greater tuberosity subequal or lower in height to humeral head

1 Greater tuberosity is higher

**315. Development of greater tuberosity in proximal view:**

0 Small (less than half the anteroposterior length of head)

1 Large (greater than or equal to half the anteroposterior length of head)

**316. Extension of the deltoid crest:** Restricted to proximal half of humerus (0); Reaches distal half of humerus (1)

**317. End of deltoid crest:** Merging with diaphysis (0); Forming a distinct angle or process (1)

**318. Relative heights of trochlea and capitulum in anterior view*:** Longer proximal extension of capitulum (0); Subequal (1); Longer proximal extension of trochlea (2)

**319. Humerus medial epicondyle size:** Large (0); Small (1)

**320. Humerus distal end size:** Large (0); Small (1)

**321. Lateral extension of capitulum:** Rounded (0); Straight (1)

**322. Depth of intercondylar notch in posterior view:** Wide and relatively shallow concave (0); Narrower and concave posteriorly (1)

**323. Curvature of the posterior border of the humeral shaft:** Curved (0); Straight (1)

**324. Medial development of the ulnar anconeal process:** Does not protrude beyond medial border of olecranon process (0); Medially protruding (1)

**325. Medial curvature of the ulna:** Present (0); Absent (1)

**326. Posterior border of the ulna:** Convex (0); Straight or concave (1)

**327. Shape of articular facet for humerus:** Anteroposteriorly compressed (0); Circular (1)

**328. Distal shaft of radius:** Oval (wider than long) (0); Rounded (almost as wide as long) (1)

**329. Prepollex:** Absent (0); Present (1)

**330. Distolateral process of scaphoid*:** Absent (0); Present, does not separate lunate from magnum (1); Present, separates lunate from magnum (2)

**331. Number of plantar tubercles (distal heads) on trapezium:** Two (0); One (1)

**332. Angle between transverse axis of proximal and distal epiphyses of metacarpal I:** Absent (0); Present (1)

**333. Orientation of ilium relative to ischium:** Prominent dorsally (0); Aligned with ischium (1)

**334. Tuberosity for rectus femoris muscle:** Absent (0); Protuberance (1); Depression (2)

**335. Length of iliac neck*:** Longer than 15% total pelvis length (0); Between 6 and 15% total pelvis length (1); Less than 6% total pelvis length (2)

**336. Greater sciatic notch:** Greater than 120 degrees (0); Between 90 and 115 degrees (1)

**337. Iliac and gluteous fossa:** No fossa (0); Two fossa subequal in size (1); Gluteous fossa larger (2)

**338. Epipubic bones:** Present (0); Absent (1)

**339. Proximal size of epipubic bones:** Short (0); Long (1)

**340. Torsion between proximal and distal epiphyses of femur:** Present (0); Absent (1)

**341. Relative heights of greater trochanter and femoral head:**Greater trochanter lower or equal in height to femoral head (0); Greater trochanter higher than femoral head (1)

**342. Lesser trochanter of femur:** Present (0); Vestigial or absent (1)

**343. Femoral condyles*:** Lateral condyle wider than medial condyle (0); Subequal (1); Medial condyle wider than lateral condyle (2)

**344. Ossified patella:** Absent (0); Present (1)

**345. Parafibula:** Present (0); Absent (1)

**346. Femoro-fibular articulation:** Present (0); Absent (1)

**347. Tibia length relative to femur length:** Tibia subequal to or longer than femur (0); Tibia shorter than femur (1)

**348. Proximal dimensions of tibia*:** Larger mediolaterally than anteroposteriorly (0); Subequal (1); Larger anteroposteriorly than mediolaterally (2)

**349. Tibia shape:** Sigmoid (0); Straight (1)

**350. Torsion between proximal and distal epiphyses of tibia:** Present (0); Absent (1)

**351. Type of distal articulation of tibia:** Spiral (0); Sagittal (1)

**352. Posterior shelf of tibia:** Present but does not extend posteriorly beyond the medial astragalotibial facet (0); Present and extends posteriorly beyond the medial astragalotibial facet (1)

**353. Orientation of the lateral edge of the astragalus-tibia articular facet:** Parallel to epiphyseal suture of tibia (0); Oblique to epiphyseal suture of tibia (1)

**354. Anteroposterior length of medial malleolus relative to distal epiphysis:** Subequal (0); Medial malleolus much shorter (1)

**355. Distal malleolus of tibia:** Indistinct or absent (0); Distinct (1)

**356. Angle between medial and lateral astragalotibial facets*:** 90 degrees (0); Intermediate (1);180 degrees (2)

**357. Astragalonavicular facet extends onto ventromedial side of head:** Absent (0); Present (1)

**358. Width and height of navicular facet in distal view:** Transversely wider (0); Dorsoventrally wider (1)

**359. Visibility of medial plantar tuberosity in dorsal view:** Not visible (0); Visible (1)

**360. Angle between lateral tibial and fibular facets:** No angle (0); With angle (1)

**361. Medial extent of sustentacular facet:** Does not reach the medial edge of neck (0); Reaches the medial edge of neck (1)

**362. Astragalar canal:** Present (0); Absent (1)

**363. Width of astragalar neck:** Neck wider than head (0); Neck narrower or as wide as head (1)

**364. Major orientation of posterior astragalocalcaneal facet:** Anteromedial-posterolateral (0); Posteromedial-anterolateral (1)

**365. Malleolar shelf of astragalus:** Absent (0); Present (1)

**366. Astragalo-distal tuber:** Absent (0); Present (1)

**367. Astragalo-cuboid facet on astragalar head:** Absent (0); Present (1)

**368. Connection between astragalonavicular facet and sustentacular facet:** Present (0); Absent (1)

**369. Longest dimension of sustentacular facet:** Anteromedial-posterolateral (0); Sagittally longer (1); Transversely longer (2)

**370. Orientation of the calcaneoastragalar facet*:** Medial (0); Intermediate (1); Dorsal (2)

**371. Calcaneal peroneal tubercle:** Protuberance (0); Crest-like (1); Poorly developed or absent (2)

**372. Position of peroneal tubercle:** Anterior, non-protruding (0); At a distance from the anterior end of the calcaneus (1)

**373. Calcaneal peroneal groove for the peroneous longus:** Indistinct or weakly developed (0); Distinct, deep separation (1)

**374. Position of sustentaculum:** Reaches anterior end of calcaneus (0); Subterminal (1)

**375. Outline of sustentacular process:** Triangular or rounded (0); Rectangular (1)

**376. Mesiolateral orientation of sustentacular facet:** Medial (0); Dorsal (1)

**377. Anteroposterior orientation of sustentacular facet:** Dorsal (0); 45 degrees dorsoanteriorly (1)

**378. Sustentacular facet morphology:** Slightly concave or flat (0); Posteriorly convex (1)

**379. Secondary distal calcaneoastragalar facet:** Absent (0); Present (1)

**380. Sustentacular and posterior calcaneoastragalar facets:** Separate (0); Merged (1)

**381. Calcaneal facet for fibula:** Present (0); Absent (1)

**382. Orientation of calcaneal facet for fibula:** Dorsal (0); Lateral (1)

**383. Length of the tuber calci:** Longer than the body (0); Shorter than the body (1)

**384. Medial curvature of the tuber calci:** Present (0); Absent (1)

**385. Ventral curvature of the tuber calci:** Present (0); Absent (1)

**386. Proximal calcaneocuboid facet:** Absent (0); Present (1)

**387. Angle between proximal and distal areas of calcaneocuboid facet:** No angle (0); Oblique calcaneocuboid facet (1)

**388. Spatial relationship between navicular and entocuneiform:** Entocuneiform anterior to navicular (0); Entocuneiform extends proximally medial to the distal area of the navicular (1)

**389. Angle between navicular and distal metatarsal facets of ectocuneiform:** Oblique (0); Parallel to the distal facet (1)

**390. Prehallux:** Absent (0); Present (1)

**391. Mt I length relative to Mt III:** Greater than or equal to than 50% the length of Mt III (0); Less than 50% the length of Mt III or Mt I absent (1)

**392. Metatarsal V proximal process:** Does not extend ventral to cuboid (0); Extends ventral to cuboid (1)

**393. Proximal ends of metatarsal II and III:** Subequal in length (0); Mt II extends more proximally than Mt III (1)

**394. Ridge on proximal articular facet of metatarsal I:** Absent (0); Present (1)

**395. Mt III thickness relative to that of Mt IV:** Mt III thicker or subequal to Mt IV (0); Mt III thinner (1)

**396. Mt III thickness relative to that of Mt I:** Mt I thicker than Mt III (0); Mt III thicker than Mt I (1)

**397. Median keel on palmar/plantar surface of metapodials:** Sharp (0); Blunt (1)

**398. Foot ungual phalanx of digit IV in proximal view:** Larger dorsoventrally than mediolaterally (0); Larger mediolaterally than dorsoventrally (1)

**399. Groove on dorsal surface of tip of ungual phalanges:** Absent (0); Present (1)

**400. Dorsal border of ungual phalanges:** Forming a crest-like border (0); Rounded (1)

## CHARACTER-STATE MATRIX

? = unknown, - = inapplicable. Polymorphisms: a = 0 &1, b = 1 & 2, c = 2 &3, d = 0&2, e = 1&3, f= 0&1&2. Uncertainties: g = 0/1, h = 1/2.

*Vincelestes neuquenianus*

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0g00000110 0?00101000 0?0?000000 000110??00 101100000?
1100?--0-- -???01000 --0-?????? ??00??00?0 ?111000001
?00??????0 0000001000 -000200000 1-000?0110 0???01100
-120001?11 0-00200100 00???02??? ???0?????? ????????00
000010?110 1?1??0??11 ?201020101 000???0111 00001?0010
?000?2???? 1---01---? ?00010?0?1 ??0?00?021 ?000???00
0?100??100 00?000?100 1?01101??? ??10?0?0?? 000???00??
00???20000 -0-1???00? 10?00??000 00101????? ??????????
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*Prokennalestes* spp.

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-21??????? ????00100? ?????00000 2??0???10? ?01?0???00
1000100021 0100-10110 1001111011 000?0?1102 10202?0200
000000?000 0000000000 0011?????? ?????????? ??????????
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*Asiorcytes nemegtensis*

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0000000?0? 0??????010 0?11???000 10????-2?0 101?001?11
??0002110? 1001000000 --0-000--? 00200?0100 ?101100?0?
?10?100000 0-??0001-0 -00?201101 1-001?1-01 0000?10000
-100001012 000000000? ??0??100?? ???01????? ?0??0???0?
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1000100002? 0?00-11111 1000112001 000?0?2102 1020??0200

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1???111??1 101?00???? 0110??0??? ?????0?1?? 0?0?00????

*Maelestes gobiensis*

01000?0?0? 0??????0?1 0010010010 000110-200 00??0?00?1

?0???21?00 100?000000 --0-000--? 002?010100 ?111100?0?

1???100000 ?-10000010 -000101100 1-001?0101 00?0011?00

-1?00????? ???01?001? ??0??10001 1010??02?? ?0000???00

1000100021 0?0??11111 0111112000 10010?2102 10212?0201

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*Holoclemensia texana*

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*Deltatheroides cretacicus*

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00001-0010 0100000001 1000001002 ?0????00?0 1??0???020

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*Deltatheridium pretrituberculare*

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?1??????0? 0100000010 -000?000?0 ??01-10001 0100200101

0110111??? 0-?0110110 0000001000 0000100100 000001??10

00001-0110 0100000001 1000001000 000?000000 1110000020

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*Kokopellia juddi*

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*Eodelphis browni*

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a02?1????? ???1110110 ??00011100 0001?01200 01??0???0?

1210000021 0201100100 10a2101000 110?102001 1122200021

0001000100 01001100a0 1011?????? ?????????? ??????????

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?????2??1? 1001?0110? ????001000 00???????? ??????????

*Didelphodon vorax*

0000000100 11111?0??0 021?010010 01101?0?0? ????????0?

0?01110110 -0??00??11 100?0?0??? 0??11????0 0011?100??

?0????0000 1200000011 0?00101011 ??11-10011 01a021011?

?01111?011 0-011?1110 0000001110 0001101210 a1100??000

1210000021 0201100100 10a2101001 010?102001 1122200021

0001000100 0100110020 1011?????? ?????????? ??????????

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Pediomyidae

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111a000031 0201011100 00131122a2 000?001a01 1a21200200

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*Alphadon* spp.

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a11?0????? ???????010 ??0000100? ?0a0?00100 00000???0?

110a000021 0201010110 00a1101011 0001001a01 1121200210

0?0100010a 0a001100a1 0011?????? ?????????? ??????????

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*Asiatherium reshetovi*

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???0010??? ?001?0?111 ?0?00?0??? ????1????? ??????????

?20??????? ????0?0??2 1000???0?? ???????01 0???21g101

?1200????? ???????010 ??000?1001 1?00100100 00000???00

1000001020 0201011111 0011112201 010?001101 1121200100

0001000101 0010100020 0011?????? ?????????? ???1??????

0?????0??0 000??00??0 0000?00?00 ???00000?? 0000000?0?

????0????? ?????????? ?????????? 0????????? ??????????

*Herpetotherium fugax*

1100000000 1??a?a1110 0b10010010 01???0???0 ?b?11001?0

1000110111 ?00-01?111 0000000??? 0?11010001 0?011101?1

120???0000 02100001-1 0101001010 011???1101 0000210111

1211000??2 ??00000010 0000011001 2120100?00 10000???00

1211010021 01aa000101 000211101f 1101001000 1b11200210

0001000201 0a10110021 1010?????? ?????????? ??????????

???00??011 0000?0110a 0011??1??? ???10????? 000??000??

1101?01000 010100?0?? 100010-000 0011101??? 1?????????

*Mimoperadectes* spp.

1000000000 0??0011a10 ?01001?1?? 01???0???0 ???a01a0?1

?20??????? ?0????1101 100?0?0??? 0?11??0??? ??????0???

?10????0?? ?210000012 1000201 0?0 1-?1-00001 0???f1????

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11010a0021 02a?100110 00011110a1 aa0?001101 1211200210

0001000201 0100110020 1010?????? ?????????? ??????????

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*Didelphis albiventris*

110100000a 100a011110 1010010010 01101a0010 1200011001

0a00021110 1010011111 1000000000 2a111a0a01 0001010a0a

0001000000 0210000012 0001b01010 0111-00011 0000210111

1a01000102 0010010110 0000011000 2220100101 -0a0020000

1211010021 021--00101 010211101a 0001001000 11122002b0

0001a00101 0111110021 00001a11a1 11100101b0 a210001001

0?11000ab1 00000a1aa0 1100000111 0110001011 0000100000

0111121000 0101000a00 1101011000 1-11a11101 00011010a1

*Metachirus nudicaudatus*

1100000000 100a011010 1110?10010 0110110010 120?011001

0010021110 10100111?1 100?000000 2?11100000 ?010010?01

?101000000 0210000012 000?101010 01?1-?0001 0000210111

1001000102 1010010110 0000011000 211010?101 -0a00???00

1211010021 021--00101 0102111011 ?00?001000 1112200210

0001000101 0111110021 00001a10?1 11?001012? 1211100000

1?10010110 0?a0011010 1101001111 0000002011 1000100000

1111111011 010?000a01 1101011000 1-11111101 0001101001

*Monodelphis* spp.

0100000001 a00a011110 1110010010 0110110010 0200011001

0a00021101 1000011111 1000000000 2a110a0001 0001110a00

0a01000000 0210000012 0001101110 0111-1a001 0000b10111

20a1000102 0010010010 0000011000 000010010a 11a0020000

121101a011 011--00101 010210101a 0001001000 1b11200210

0001000201 0101110021 00001a100a 1100010000 12100a0001

0?00100a10 0a00010100 0100001111 0110001011 a000100000

0111111000 0101000000 0001011000 1-11010101 0001001001

*Dromiciops gliroides*

0000000000 0000010011 1210000210 0110010000 1b01011000

01100211?1 00-0-11a11 0000111000 0221010000 0110110101

1211020000 02101001-2 1111111110 0?11-11101 0000210111

2221001111 0110000010 0000011001 1000100?10 0000020?00

0111001131 021--01011 0001202200 100100110a 1011200210

0001011101 0010110021 1000a01000 -1?00110b? 0a10101111

0110100120 0010000010 0010001002 1?02001010 0000?00001

0111121000 0101000102 2100010001 1-11101100 0000101001

*Dasyurus* spp.

0000010a00 01011a0111 1210001a10 a110001101 a20101a001

0100021110 1010011111 000010010? 0211011001 00001101a1

0100100000 02101001-2 1111111000 0?11-1a101 0000b10111

201111a111 0-1111a110 00000020?0 10101?-??- -0-0000?00

0311011020 0200000101 0102101d02 1a01001010 1211200220

001100-201 0110110020 1aa0110a01 1100010aa0 a100011011

0010110a01 1011001b11 1101011002 1011002010 000a000001

0111121110 0001001001 2001011111 01a1101010 1110010000

*Sminthopsis crassicaudata*

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0110021111 0010011111 000011110? ?211110001 00a1110101

1200100000 02101001-2 1111111001 0?11-11101 0000110111

2121010101 0-10110010 0000011000 000010010a 1010020?00

0311011020 02a1000101 0002101d02 1111001000 1121200210

0001000201 0010100021 1010100000 1101011010 2110010001

0112000020 0110000011 000010000? ?010002010 1020000100

0100121111 0101001000 2011011111 1-11000010 1?1?010000

*Thylacinus cynocephalus*

1211011001 1a02111110 1310011a10 110100-201 011001a011

0110010100 1010001111 100010000? 10211a1001 0000010a01

0000100100 02001001-2 1001201100 0111-11101 0100e10111

1211111112 1-11111110 0000001001 2020110010 0000000?10

03011-1010 001--01101 010-211202 110101--10 120-1120-0

1001111200 1-00121--0 1110101101 0101110120 01011?0001

0010010020 0021100211 11010111?2 11020121-0 a010010211

0?1?111111 0101000122 200100-111 0001001000 111-0-0100

*Pucadelphys andinus*

0100000000 0000011a10 0001010000 0110000a00 1011a00000

0100021110 1001011001 111-000-00 1011000001 0011110001

010?000000 0b10010010 -000001010 0011-01101 0000210111

0aa1000112 0100010110 0000001a00 f010000100 1010021?00

1111010031 0201000110 0001112011 010?001101 112a200201

0001000101 0010100020 0011000001 000000002? 1001110000

000010001a 000001aa00 10000010?? ?1a1002000 0000100111

0a01100010 0100111010 0010101000 0010101??? 1???0?a110

*Andinodelphys cochabambensis*

1100000000 0010010110 0001010000 0110000000 1010001001

0000020110 1001011101 111-000000 1011000001 ?011110?0?

010??00000 0b10010010 -000001010 0011-01101 0000210111

0111000102 0100010110 0000001000 201000?100 10?00???00

1111010021 0201000110 000b111011 010?001001 1120200201

0001000101 0000100020 0111000001 000000002? ?000110100

0a0010011a 0?00011a00 100a00a000 ?111002000 0000100111

??01100010 010?1110?1 0010101000 0110101?0 101?01?110

*Mayulestes ferox*

0110000110 0001111000 0101010200 0101101100 0011101001

1001010110 1001011001 1110000000 1011000001 0011110000

000??00000 0110010010 -000001010 0011-0110? 010021011?

????00102 0100011110 0000001100 000000010? 10?00??00

1210101011 0101000100 0002101001 010?001100 1200200120

0111100001 0101100020 011000?001 00010???2? ?0011???10

010011?111 0000011000 10010000?? ?1011021-1 1000?00000

0000100000 100?111011 0010101000 0101001??? ????0?0???

*Allqokirus australis*

01100?0110 0?00?11000 0001011?00 0100101100 01?0?110??

??00020110 1001011001 111?0?0?00 1?11000??1 ???1110???

?00??0???0 ?110010010 -000001?10 0111-1110? 0100210111

000100???2 0100011110 0001101100 100000?100 1000021?00

1210100011 0101000101 0002111001 0101001100 1200200120

0111100000 ?101110110 0110?????? ?????????? ??????????

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*Patene simpsoni*

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1200100011 0101001101 0002111010 1101001010 1200100120
0111100000 0111110010 10a0?????? ?????????? ??????????
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*Hondadelphys fieldsi*

01??1?1??? ???????1?1 ?11?1?01?1 ?1???????? ???11001??
0?00010110 010110?011 11?00100?? ??111?0101 0010??00?0
000???0111 02100?1??0 -0?1001??? ??11-11101 01?1?10111
0???g????? ????11?110 ??00001001 2010?1010? 001002??00
1211000021 0101101101 0003111200 11111?0010 11022?0020
010111?101 0110110121 1000101??1 1???1????0 ?????????1
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*Stylocynus paranensis*

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?21000??21 01???01?01 ?1031??210 1101010010 1202100020
1101111100 0101110021 1000?????? ?????????? ??????????
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UF 27881

?01???1??? ??00?01000 ?a0?111301 010??01100 0??11001??
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0?0?????10 1?1--????? ??0??????? ?????????? ??????????

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*Sallacyon hoffstetteri*

???101???? ?????01101 1?01??100? 010?0111?0 0???1001??

?000?10?10 01??10?0?1 11100?0001 1?111??0?? 0????10???

?0????0111 0?1001?010 -00?10101? 01?1-111?? ????c?????

?????????? ?????????? ????????0? ?????????? ????????10

020010101? 000110?101 0103100100 100???--10 12001?20-0

1??111?101 01011100-0 1010?????? ?????????? ??????????

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*Notogale mitis*

??1?1??a01 10?h?????? ??1?1??h?1 ?????????? ??????????

0?0??????? 01011??111 1110000001 1?11100011 0000?10???

?0??010111 0210010010 -00?20101? 0111-111?? ????3??1??

????11?11 ?-?1111?110 0?00001002 2210?????0 ?0????????

??0010??11 001--?1?01 01031?0100 1?010?--10 12001120-0

111111?100 0?01?1??-0 101??????? ?????????? ??????????

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*Sipalocyon* spp.

0110111a01 1001101000 1a01111e01 0101a01100 011010010a

0000010110 0101101111 1110000001 1111100111 0000?10110

000?010111 0210010010 -001201010 0111-11001 0111210111

0001011011 1-11111110 000000100b 2bd0110000 00110???10

02001-b011 0001101001 0102110100 110101--10 12001120-0

1111111100 01011100-0 1000101101 0??11????0 ??011????1

1???0???1? 0010???2?? ?0???00?0? ?0?1???1-? ??11?1????

?100101100 1011110020 0110110000 0010101070 ??0001?000

*Acyon myctoderos*

1111111111 1??1101000 111?111b01 ?101????0? ???01001??

???0010110 010110?011 11???????? ??111??111 ??0????01?

000?0????1 0??0??0??? ???1?????? ???1-11?01 0111310111

1111111?11 1-?2111110 0000001002 2220110010 0011020110

0200102011 000a101101 0103111b00 110101--10 12001120-0

1111111100 a1011100-0 100010???1 a??1?????1 ??????????

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*Cladosictis patagonica*

11111111a1 11011aa100 1a01111b01 0101001100 0110100101

0200010110 0101101a11 1110000001 ?111110111 0?a10?0a10

000?010111 02?0?101-? ?00??0???? 01?1-111a1 01a1310111

aa11111011 1-12111110 0000001001 2220110000 00110??110

02001-2111 0001101101 0103111b00 110101--10 12001120-0

1111111100 a10111a0-0 10a0101?01 110110?12? ?101a00?01

1?1?111011 00a??102a? 101010000? ?1111121-1 001??11?11

11?010?100 ?1111???20 1000110000 0000001?10 ??0?0??000

*Lycopsis longirostrus*

11?1111??? ???????10? 1011????01 ?1????11?0 ?????001??

1??0010120 010110?101 11?1000000 ?011110101 1?0???001?

000???11a1 02?10111-0 -??1a0?0?? 1-11-11101 011?310111

a1110????? ????11?110 00100?1001 h?10110010 0010021?10

03001-2011 0001101101 0103111b00 110101--10 12001120-0
1111111100 01010200-0 110?10???? ??01?????? ?1??????0?
10????1?10 001011021? 1100010O?1 001?1121-0 001???0?10
1?0?10??1? ??????0??1 ?????110?? 1?10????1? ??????1?01

*Lycopsis padillai*

?????????? ?????????- ??1????2?? ?????????? ??????00??
?????????? ?????????? ?????????? ?????????? ??????????
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13001-101? 0001101101 0203110100 1????????? ??????????
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*Lycopsis torresi*

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?????????? ?????????? ?????????? ?????????? ??????????
?????????? ?????????? ?????????? ?????????1 01???10??1
a1???????? ???????1?0 00100?1?0? ???0?1???0 ga100???1?
13001-1011 0001101101 0203110100 110??1--10 120?1120-0
1??1?11200 01010200-? 1?0??????? ?????????? ??????????
?????????? ?????????? ?????????? ?????????? ??????????
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*Lycopsis viverensis*

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*Prothylacynus patagonicus*

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*Pharsophorus lacerans*

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*Borhyaena tuberata*

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*Arctodictis munizi*

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*Arctodictis sinclairi*

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*Australohyaena antiquua*

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*Callistoe vincei*

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Paraborhyaena boliviana

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*Patagosmilus goini*

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*Thylacosmilus atrox*

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*Proborhyaena gigantea*

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*Eomakhaira molossus*

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