

JOURNAL OF VERTEBRATE PALEONTOLOGY

SUPPLEMENTARY DATA

The postcranial skeleton of *Galecyon*: evidence for morphological and locomotor diversity in early Hyaenodontidae (Mammalia: Creodonta)

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## APPENDIX S1. MATERIALS EXAMINED

List of materials used to construct the character taxon matrices. **Institutional abbreviations** (excluding those given in the main text)— **AMNH**, American Museum of Natural History, New York; **CM**, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania; **SMM**, Science Museum of Minnesota, St. Paul, Minnesota; **UALVP**, Laboratory for Vertebrate Paleontology, University of Alberta, Edmonton, Canada; **UCMP**, University of California, Museum of Paleontology, Berkeley, California; **UW**, University of Wyoming Geological Museum, University of Wyoming, Laramie, Wyoming; **YPM**, Yale Peabody Museum, Yale University, New Haven, Connecticut.

*Protungulatum donnae*: AMNH 118260, SMM 62-2028, UCMP 125961, Szalay and Decker (1974), Boyer et al. (2010)

*Mithrandir gillianus*: USNM 15439, 37229, 404944, Rigby (1981)

*Cimolestes magnus*: UALVP 3791, 3793, Lillegraven (1969)

*Didymictis* spp.

*D. proteus*: UM 73714

*D. protenus*: CM 34469, USGS 1721, 15941, 21835, 25039, 25040, 27585, USNM 487894, YPM-PU 17689, Heinrich and Rose (1997), Polly (1997)

*Viverravus* spp.

*V. acutus*: AMNH 16113, USGS 6733, 9193, USNM 493905, Polly (1997), Heinrich and Houde (2006)

*V. gracilis*: USNM 13322, Heinrich and Houde (2006)

*Arfia gingerichi*: Smith and Smith (2001)

*Arfia junnei*: UM 71767, 86135, Gingerich (1989)

*Arfia shoshoniensis*/*A. opisthotoma*

*A. shoshoniensis*: CM 39126, UM 63591, 66449, 69474, 77051, 82820, 83328, 87768, USGS 16473, UW 9915, YPM 36932

*A. opisthotoma*: UM 69131, 68899, 69949, Gingerich and Deutsch (1989)

*Prototomus minimus*: Smith and Smith (2001)

*Prototomus deimos*: UM 76469, 79612

*Prototomus phobos*: UCMP 43957, UM 68075, 74134, YPM-PU 13019

*Prototomus secundarius*: USGS 6666, 9066, 9095, USNM 495126

*Gazinocyon whitiae*: AMNH 15606, USGS 25296, USNM 19347, 510864, 510979, YPM 29839/29585, Polly (1996)

*Prototomus martis*: UM 94036, 69186, 87317, 67138, 76174, 79745, 85842, USNM 509700, USNM 511037, 511045, 511087, 511088, 511089, 525550, 527677

*Pyrocyon strenuus*: AMNH 4781, USGS 6111, 16474, 16475, 25076, 27236, USNM 491821

*Pyrocyon dioctetus*: UM 94757

*Prolimnocyon haematus*: UM 63885, 64806, 64984, 67511, 80039, 80232, Gingerich and Deutsch (1989)

*Prolimnocyon atavus*: DPC 5364, UM 97143, USGS 9330, 12784, USNM 510977

*Galecyon morloi*: Smith and Smith (2001)

*Galecyon peregrinus*: AMNH 56320, USNM 509676, UW 9864, YPM 32230

APPENDIX S1. (CONTINUED)

*Galecyon mordax*: AMNH 15168, 16157, UM 69794, 85887, 86399, USNM 1125, 490637, 521446

*Galecyon chronius*: USGS 9276, 10284, 15956, USNM 487920, 511004, 521860, YPM 23341

## APPENDIX S2. POSTCRANIAL CHARACTER LIST

- P1. (Scapula) glenoid shape: (0) ovoid, distinctly longer than wide; (1) subcircular, length and width more similar.
- P2. (Scapula) distal deflection of anterior glenoid fossa: (0) restricted to anterior 1/3 or less; (1) exceeds 1/2 of glenoid anteroposterior length.
- P3. (Scapula) lateral projection on glenoid border: (0) at anterolateral corner of glenoid, close to supraglenoid tubercle; (1) on lateral surface posterior to anterolateral corner, clearly separated from supraglenoid tubercle.
- P4. (Scapula) medial border of infraglenoid tubercle: (0) forms a distinct ridge that defines a fossa on the posterior scapular neck; (1) ridge absent, posteromedial scapular neck smoothly curved.
- P5. (Humerus) greater tuberosity height: (0) lower than humeral head; (1) even with humeral head; (2) higher than humeral head.
- P6. (Humerus) anteromedial projection of greater tuberosity: (0) weak, greater tuberosity closely appressed to humeral head; (1) strong, medial margin of tuberosity projects well anterior to humeral head.
- P7. (Humerus) tubercle for pectoralis profundus: (0) small and low, lateral wall of groove for biceps tendon poorly defined; (1) enlarged, lateral wall of groove for biceps tendon sharply defined.
- P8. (Humerus) medial projection of lesser tuberosity: (0) strong, lesser tuberosity projects well medial to humeral head, particularly posteriorly; (1) weak, lesser tuberosity appressed to humeral head.
- P9. (Humerus) teres tubercle: (0) present as a definable crest or ridge on the medial side of the proximal humeral shaft; (1) absent, no clear scar for teres major and latissimus dorsi present.
- P10. (Humerus) distal terminus of deltopectoral crest: (0) distal portion of crest elevated and termination relatively abrupt, a clear inflection is present between crest and shaft in lateral view; (1) crest tapers smoothly into shaft, no clear transition is present in lateral view.
- P11. (Humerus) primary orientation of facet on lateral side of posterodistal humerus: (0) posterior, flush with remainder of posterodistal humerus; (1) lateral, distinctly angled from remainder of posterodistal humerus.
- P12. (Humerus) projection of medial epicondyle: (0) strong, medial epicondyle projects well medial to humeral shaft, entepicondylar bar forms an angle of 45 degrees or more with the long axis of the humerus; (1) weaker, medial epicondyle more appressed to medial humeral shaft, angle between entepicondylar bar and long axis less than 45 degrees.
- P13. (Humerus) height of medial epicondyle: (0) low, proximodistal height approximately double anteroposterior depth; (1) tall, anteroproximal margin more proximally extensive, height more than double depth.
- P14. (Humerus) olecranon fossa shape: (0) broad and shallow, margins poorly defined; (1) narrow and deep, margins well defined.
- P15. (Humerus) pit on posteromedial distal humerus for ulnar collateral ligament: (0) deep but lateral margin flush with olecranon fossa; (1) deep and separated from olecranon fossa laterally by a ridge of bone; (2) shallow and indistinct.

## APPENDIX S2. (CONTINUED)

- P16. (Humerus) radial fossa: (0) shallow, margins poorly defined; (1) deep, margins well-defined, particularly lateral margin.
- P17. (Humerus) capitulum width: (0) much broader than deep; (1) moderately broader than deep.
- P18. (Humerus) capitular tail: (0) prominent; (1) very weak.
- P19. (Humerus) projection of trochlea on distal humerus: (0) Weak, trochlea does not project strongly, angle between distal margins of trochlea and capitulum large; (1) strong, trochlea projects well distal to capitulum, angle between distal margins of trochlea and capitulum reduced.
- P20. (Radius) ulnar facet curvature: (0) rounded; (1) flattened.
- P21. (Radius) trochlear facet on proximal radius: (0) very narrow or absent; (1) prominent.
- P22. (Radius) medial transition between radial head and shaft: (0) smooth, with a curved transition; (1) abrupt, with a sharp transition.
- P23. (Radius) brachioradialis crest: (0) forms a prominent, proximally extensive crest on anterior margin of distal radius; (1) weak, restricted to near distal end of bone.
- P24. (Radius) crest on lateral surface of distal radius: (0) weak, most of lateral surface occupied by anterior facet; (1) strong, sharply divides lateral surface into subequal anterior and posterior facets.
- P25. (Radius) styloid process: (0) does not project significantly beyond remainder of distal radius; (1) projects strongly beyond remainder of distal radius.
- P26. (Ulna) length of olecranon process: (0) short, only slightly longer than semilunar notch; (1) longer, substantially longer than semilunar notch.
- P27. (Ulna) medial deflection of olecranon process, relative to a line separating the trochlear facet from the radial and posterior humeral facets: (0) substantial, ~30 degrees; (1) small, ~10 degrees.
- P28. (Ulna) shelf at posteroproximal corner of medial olecranon: (0) weak, poorly differentiated from remainder of proximal border; (1) well-developed and projecting strongly medially.
- P29. (Ulna) shape and orientation of anconeal process: (0) wide and directed laterally; (1) narrow and directed laterally; (2) narrow and deflected proximolaterally.
- P30. (Ulna) trochlear facet width: (0) wide; (1) narrow.
- P31. (Ulna) orientation of radial facet: (0) anterolateral; (1) more lateral than anterolateral.
- P32. (Ulna) shape of radial facet: (0) semicircular, posterolateral and anteromedial portions subequal in size, distal border weakly concave; (1) comma-shaped, posterolateral portion much larger than anteromedial, distal border sharply concave.
- P33. (Ulna) position of strongest projection of anterolateral crest on ulnar shaft: (0) less than 1 semilunar notch length from distal edge of notch; (1) more than 1 semilunar notch length from distal edge of notch.
- P34. (Ulna) surface for attachment of m. pronator quadratus: (0) anteriorly oriented with a sharp distomedial border; (1) anteromedially oriented, distomedial border indistinct.
- P35. (Ulna) angulation of distal ulnar articular surfaces: (0) approximately 60 degrees to long axis of ulna; (1) nearly perpendicular to long axis of ulna, approximately 80 degrees.

## APPENDIX S2. (CONTINUED)

- P36. (Ulna) distal radial facet: (0) extends onto lateral surface of distal ulna; (1) restricted to anterior surface.
- P37. (Ulna) orientation of facet for triquetrum: (0) distally and slightly medially; (1) medially and slightly distally.
- P38. (Pelvis) shape of rectus tubercle: (0) rounded; (1) ovoid, elongated anteroposteriorly.
- P39. (Pelvis) orientation of ventrolateral surface of iliac blade: (0) ventrolateral; (1) more ventral than lateral.
- P40. (Femur) fovea for ligamentum teres: (0) does not interrupt margin of articular surface of femoral head; (1) interrupts margin.
- P41. (Femur) posterolateral extension of femoral head: (0) absent; (1) present.
- P42. (Femur) height of greater trochanter: (0) subequal to than femoral head; (1) distinctly taller than femoral head.
- P43. (Femur) posterior projection of lesser trochanter: (0) projects posteromedially and does not extend far posterior to femoral shaft; (1) projects more posteriorly, well posterior to femoral shaft.
- P44. (Femur) patellar groove: (0) shallow and wide, does not extend proximally beyond epiphysis; (1) deeper and more narrow, extends onto diaphysis.
- P45. (Tibia) orientation of lateral condyle: (0) proximal, posterior end is not significantly curved posteriorly; (1) posteroproximal, posterior end curves posteriorly.
- P46. (Tibia) tibial tuberosity orientation: (0) anteroproximal; (1) proximal, with only a small anterior component.
- P47. (Tibia) angulation of distal tibia: (0) aligned with shaft, posterior border of distal tibial shaft flat; (1) curved posteriorly relative to shaft, posterior border of distal tibial shaft distinctly concave.
- P48. (Tibia) crest forming posterior border of groove for flexor digitorum medialis: (0) at posteromedial corner of distal tibia, forms a sharp ridge in distal view; (1) slightly anteriorly shifted, ridge poorly defined in distal view; (2) strongly shifted anteriorly, posteromedial corner smoothly rounded in distal view.
- P49. (Tibia) length of lateral portion of astragalar facet: (0) much less than medial portion; (1) slightly less than medial portion.
- P50. (Tibia) check facet, anterior view: (0) forms a prominent semicircle on the anterior surface of the distal tibia; (1) reduced to a narrow strip at the far distal margin of the anterior surface.
- P51. (Tibia) medial malleolar projection: (0) substantial, malleolus projects well distal to astragalar facet; (1) small, only projects modestly beyond astragalar facet.
- P52. (Tibia) orientation of distal malleolar facet: (0) distal; (1) distolateral.
- P53. (Tibia) facet on the anterior surface of the medial malleolus for articulation with the cotylar fossa: (0) prominent and anteriorly oriented; (1) prominent and anterolaterally oriented; (2) poorly defined.
- P54. (Astragalus) tibial facet shape: (0) tibial facet wider than long; (1) tibial facet length and width subequal; (2) tibial facet longer than wide.
- P55. (Astragalus) width of posteromedial extension of tibial facet: (0) narrow, less than half of total facet width; (1) broad, greater than half of total facet width.

## APPENDIX S2. (CONTINUED)

P56. (Astragalus) posterior extension of lateral margin of tibial facet: (0) absent, sharp corner at posteromedial corner of tibial facet; (1) present, extends medial to astragalar foramen.

P57. (Astragalus) proximomedial plantar tuberosity: (0) salient, medial margin of groove for flexor fibularis well defined; (1) low, medial margin of groove for flexor fibularis poorly defined.

P58. (Astragalus) ectal facet shape: (0) broad, particularly posteriorly, sides converge anteriorly; (1) narrow, not substantially broader anteriorly than posteriorly, sides subparallel.

P59. (Astragalus) lateral process formed by projection of ectal facet lateral to fibular facet: (0) absent; (1) present.

P60. (Astragalus) medial extension of sustentacular facet: (0) absent, sustentacular facet isolated from medial margin of astragalar neck by a gutter; (1) present but narrow; (2) present but broad.

P61. (Astragalus) lateral extension of sustentacular facet: (0) absent; (1) present but offset from both the sustentacular facet and navicular facets; (2) present and confluent with both the sustentacular and navicular facets.

P62. (Astragalus) malleolar facet on dorsomedial surface of astragalar neck: (0) absent or indistinct; (1) well-defined.

P63. (Astragalus) astragalar head orientation in distal view: (0) transverse, long axis parallels a line between medial and lateral trochlear rims; (1) oblique, long axis inclined relative to a line between medial and lateral trochlear rims, primary curvature remains more or less transverse; (2) oblique, long axis inclined relative to a line between medial and lateral trochlear rims, primary curvature dorsoventral.

P64. (Calcaneus) orientation of endplate of calcaneal tuber: (0) flat or nearly flat; (1) medial margin projects distinctly posterior to lateral margin.

P65. (Calcaneus) calcaneal tuber proportions: (0) short and broad; (1) longer and transversely compressed.

P66. (Calcaneus) orientation of ectal facet: (0) long axis oriented ~30 degrees from long axis of calcaneal tuber; (1) long axis oriented ~45 degrees from long axis of calcaneal tuber.

P67. (Calcaneus) width of ectal facet: (0) relatively constant from posterior to anterior, posterior end slightly narrowed; (1) posterior half much narrower than anterior half.

P68. (Calcaneus) width of dorsal fibular facet: (0) broad; (1) narrow.

P69. (Calcaneus) connection between sustentacular facet and distal sustentacular facet: (0) absent, facets isolated from one another; (1) present, an articular bridge extends from the lateral margin of the sustentacular facet to the medial margin of the distal sustentacular facet.

P70. (Calcaneus) position of peroneal tubercle: (0) does not reach anterior margin of calcaneus; (1) extends to anterior margin of calcaneus.

P71. (Calcaneus) projection at midline of distal calcaneal body: (0) strong, cuboid facet has a sharp dorsal corner in anterior view; (1) weak, dorsal margin of cuboid facet more gently rounded in distal view.

P72. (Calcaneus) plantar tubercle development: (0) flattened and non-projecting, anterior end confluent with ventral margin of cuboid facet; (1) bulbous and projecting, anterior end confluent with ventral margin of cuboid facet; (2) bulbous and projecting, anterior end separated from ventral margin of cuboid facet by a pit.

## APPENDIX S2. (CONTINUED)

P73. (Calcaneus) cuboid facet proportions: (0) cuboid facet deeper than wide; (1) dorsoventral and mediolateral dimensions subequal; (2) cuboid facet wider than deep.

P74. (Cuboid) proportions of cuboid calcaneal facet: (0) approximately twice as wide (mediolateral) as deep (dorsoplantar); (1) width only approximately 1.5 times length.

P75. (Cuboid) development of cuboid astragalar facet: (0) prominent and oriented proximomedially; (1) small and oriented directly medially.

P76. (Cuboid) anterior surface of cuboid: (0) strongly concave; (1) weakly concave; (2) flat or slightly convex.

P77. (Cuboid) orientation of long plantar tubercle: (0) distoplantad; (1) directly plantad.

P78. (Cuboid) shape of ectocuneiform facet: (0) depth uniform from dorsal to plantar; (1) plantar half shallower (proximodistal) than dorsal half.

P79. (Cuboid) accessory ectocuneiform facet: (0) absent; (1) present.

P80. (Cuboid) proportions of metatarsal facet: (0) width and depth subequal; (1) much wider (mediolateral) than deep (dorsoplantar).



# APPENDIX S3. POSTCRANIAL CHARACTER-TAXON MATRIX

Key: 'A' = (0&1); 'B' = (1&2).

<i>Protungulatum donnae</i>	?????????	000010000?	???????????	???????????
	???????????	???0001?00	2010000110	122?????????
<i>Mithrandir gillianus</i>		11???000?0	00001001?1	01?????????
	0111?1?011	1???????00	2010000010	02210100?1
<i>Didymictis</i> spp.		111?210101	1111111011	0011101000
	01110??101	0001011110	2120100001	10211100?0
<i>Viverravus</i> spp.		?????10?1??	0001111010	0010001?2?
	1011010011	???1010000	?01?????????	???????????
<i>Arfia shosh./opis.</i>		????211111	1111111111	10111?002?
	01?1011100	1001011100	002A001001	02B?????????
<i>Prolimnocyon atavus</i>		0101000000	0000000000	0000001000
	100010101?	001000000?	?1000000?0	1110110000
<i>Galecyon chronius</i>		101?111111	010121101?	?????00011
	???010111	0122101012	1010010100	1010021011
<i>Galecyon mordax</i>		1010???????	0??1?110??	???????????
	01?????????	???????????	?????10100	101?????????
<i>Pyrocyon strenuus</i>		0000110100	?0?0000?00	00???00?0A
	1?1?000010	00110?00?1	2001100110	0001000100
<i>Prototomus phobos</i>		????101101	???????????	???????????
	?0110000??	???100001?	?0000000?0	0011??0??0
<i>Gazinocyon whitiae</i>		00?????????	110120101?	???????????
	???????????	???100001?	?02000?0?0	1?1101000?

#### APPENDIX S4. DENTAL CHARACTER LIST

Key: '\*' = character modified from Zack (2011); '†' = new character not included in Zack (2011).

- D1. P<sub>1</sub> size: (0) large; (1) small; (2) absent.
- D2. P<sub>1</sub> roots: (0) one; (1) two.
- D3. Diastema between P<sub>1</sub> and P<sub>2</sub>: (0) less than length of P<sub>2</sub>; (1) greater than length of P<sub>2</sub>.
- D4. Diastema between P<sub>2</sub> and P<sub>3</sub>: (0) absent; (1) small.
- \*D5. P<sub>3</sub> proportions: (0) elongate and low, protoconid apex lower than P<sub>2</sub>; (1) short and high, protoconid apex taller than P<sub>2</sub>; (2) elongate and low, protoconid apex taller than P<sub>2</sub>.
- D6. P<sub>3</sub> talonid cusps: (0) hypoconid only; (1) second cusp present distal to the hypoconid.
- D7. P<sub>4</sub> mesial cusp: (0) absent or very weak; (1) strong.
- \*D8. P<sub>4</sub> protoconid height: (0) tall:  $\geq$  M<sub>1</sub> protoconid; (1) low:  $<$  M<sub>1</sub> protoconid.
- D9. P<sub>4</sub> protoconid cross-section: (0) circular; (1) lenticular.
- †D10. P<sub>4</sub> talonid height: (0) tall; (1) low.
- D11. P<sub>4</sub> talonid buccal cusps: (0) hypoconid only; (1) second cusp present distal to hypoconid.
- D12. Lingual margin of P<sub>4</sub> talonid: (0) no rim present; (1) weak rim present; (2) well-developed entocristid present.
- D13. P<sub>4</sub> width: (0) narrow (gracile); (1) broad (robust).
- †D14. Basal distention of M<sub>2</sub> buccal enamel (modified from Solé, 2013, C37): (0) weak or absent; (1) strong.
- D15. M<sub>2</sub> buccal cingulid at mesial margin of crown: (0) weak and crestiform, restricted to paraconid mid-height; (1) weak and denticulate, restricted to paraconid mid-height; (2) strong and shelf-like, extends to base of paraconid.
- D16. M<sub>2</sub> buccal cingulid: (0) absent or restricted to hypoflexid; (1) continuous around protoconid and/or hypoconid.
- D17. Protoconid height on M<sub>1-2</sub>: (0) much taller than metaconid and paraconid, trigonid  $\gg$  talonid; (1) slightly taller than metaconid and paraconid, trigonid  $>$  talonid.
- D18. M<sub>2</sub> paraconid and metaconid relative heights: (0) paraconid substantially lower than metaconid; (1) paraconid moderately lower than metaconid; (2) paraconid subequal to metaconid; (3) paraconid taller than metaconid
- D19. M<sub>2</sub> paraconid orientation: (0) slightly oblique, trigonid relatively closed; (1) strongly oblique, trigonid relatively open.
- D20. Length of paraconid portion of M<sub>2</sub> paracristid: (0) short; (1) elongate.
- D21. M<sub>1-2</sub> paraconid keel: (0) weak; (1) strong.
- D22. M<sub>2</sub> metaconid position: (0) metaconid apex immediately lingual to protoconid apex; (1) metaconid apex distolingual to protoconid apex.
- \*D23. Width of M<sub>1</sub> talonid: (0) substantially narrower than trigonid; (1) Subequal to trigonid width.
- D24. M<sub>1-2</sub> hypoconid size: (0) small, apex at distobuccal corner of crown, postcristid absent; (1) enlarged, apex mesial to distobuccal corner, postcristid present.

#### APPENDIX S4. (CONTINUED)

- D25. M<sub>1-2</sub> entoconid size: (0) very small, much lower than hypoconulid, talonid semitrenchant; (1) small, subequal to hypoconulid, low rim on lingual margin; (2) enlarged, subequal to hypoconulid, well separated, distinct wall.
- D26. M<sub>1-2</sub> entoconulid morphology: (0) absent or very small, becomes indistinct with light wear; (1) forming a series of denticulations on lingual entocristid; (2) mesially displaced and well-separated from remainder of entocristid.
- D27. M<sub>1-2</sub> talonid basin depth: (0) shallow, cusp relief low; (1) deep, cusp relief substantial.
- D28. M<sub>1-2</sub> size: (0) M<sub>2</sub> much larger than M<sub>1</sub>; (1) size subequal.
- D29. M<sub>3</sub> roots: (0) two; (1) one.
- D30. M<sub>3</sub> trigonid height: (0) much taller than talonid, differential comparable to M<sub>1-2</sub>; (1) low, height differential reduced compared to M<sub>1-2</sub>.
- D31. M<sub>3</sub> morphology: (0) comparable to M<sub>1-2</sub> with minor distinctions; (1) disjunct from M<sub>1-2</sub>, paraconid and paracristid greatly enlarged.
- D32. M<sub>3</sub> size: (0) larger than M<sub>1-2</sub>; (1) subequal to M<sub>1-2</sub>; (2) slightly reduced; (3) strongly reduced
- D33. Orientation of P<sup>3</sup>: (0) aligned with P<sup>4</sup>; (1) set at an angle to P<sup>4</sup>.
- D34. Protocone lobe on P<sup>3</sup>: (0) absent; (1) present.
- D35. P<sup>4</sup> buccal cingulum: (0) complete; (1) incomplete mesially.
- D36. P<sup>4</sup> parastyle: (0) weak or absent; (1) forming a strong, conical cusp.
- D37. P<sup>4</sup> metastyle: (0) long, subequal to length of paracone; (1) short, much shorter than paracone.
- D38. P<sup>4</sup> protocone position: (0) lingual to paracone; (1) mesiolingual to paracone.
- D39. P<sup>4</sup> protocone size: (0) prominent, extending as far lingually as M<sup>1</sup> protocone; (1) reduced, lingual extent less than on M<sup>1</sup>.
- D40. P<sup>4</sup> preprotocrista: (0) continuous onto parastyle; (1) ending at base of paracone.
- †D41. P<sup>4</sup> metastylar orientation: (0) long axis inclined relative to long axis of paracone; (1) long axis parallel to long axis of paracone.
- D42. M<sup>1</sup> parastyle development: (0) poorly developed, slight thickening at mesiobuccal corner; (1) prominent, well-developed cusp and lobe mesial to paracone.
- D43. M<sup>1</sup> paracone and metacone: (0) separate almost to base; (1) fused to midway from base.
- D44. M<sup>1</sup> paracone and metacone size: (0) paracone much larger and taller than metacone; (1) paracone slightly larger than metacone, heights subequal.
- D45. Separation of M<sup>1</sup> metacone and metastyle: (0) linear crests separated by a carnassial notch; (1) a single unbroken arcuate crest connects metacone and metastyle.
- \*D46. Elongation of molar carnassial metastyles (M<sup>1</sup> and M<sup>2</sup> if applicable): (0) short, much less than combined length of paracone and metacone; (1) moderate, subequal to combined length of paracone and metacone; (2) elongate, greater than combined length of paracone and metacone.
- D47. Orientation of M<sup>1</sup> metastyle: (0) subparallel to a line between paracone and metacone apices; (1) sharply oblique to a line between paracone and metacone apices.
- D48. Development of M<sup>1</sup> conules: (0) paraconule larger and more elevated than metaconule; (1) paraconule and metaconule subequal in size and height.

#### APPENDIX S4. (CONTINUED)

D49. Termination of M<sup>1</sup> postmetaconule crista: (0) joins metastylar crest at distolingual corner of crown; (1) terminates beneath metastylar crest.

D50. M<sup>1</sup> protocone transverse width: (0) short, apex of protocone close to apices of buccal cusps; (1) elongate, apex well lingual to apices of buccal cusps.

D51. M<sup>1</sup> protocone length: (0) broad; (1) compressed.

D52. M<sup>1</sup> protocone height: (0) much lower than buccal cusps; (1) slightly lower than buccal cusps.

D53. Elongation of M<sup>1</sup> distal cingulum: (0) distal cingulum terminates beneath, does not contact, metaconule; (1) distal cingulum extends buccal to metaconule.

†D54. Central M<sup>2</sup> width (excluding stylar regions): (0) subequal or slightly greater than M<sup>1</sup> width; (1) much greater than M<sup>1</sup> width.

†D55. M<sup>2</sup> stylocone: (0) absent; (1) present.

\*D56. Orientation of M<sup>2</sup> parastylar lobe: (0) oriented mesially or mesiobuccally; (1) oriented buccally.

\*D57. Distal portion of M<sup>2</sup>: (0) well-developed, metastylar elongation comparable to M<sup>1</sup>; (1) reduced, metacone much smaller than paracone, metastyle absent.

D58. M<sup>3</sup>: (0) slightly smaller than M<sup>1-2</sup>; (1) much reduced in size; (2) absent.

D59. Enamel texture on cheek teeth: (0) smooth; (1) crenulate.

# APPENDIX S5. DENTAL CHARACTER-TAXON MATRIX

Key: 'A' = (0&1).

<i>Protungulatum donnae</i>	0000101001	0010001000	0111101100	01??011000
0100101101	011010000			
<i>Mithrandir gillianus</i>	0001101000	0210001010	0111201100	0101101000
100110?1?0	011000000			
<i>Didymictis</i> spp.	0001211111	110020A200	01012011??	?31001010?
0100?0?1?1	01A0??121			
<i>Viverravus acutus</i>	0000111110	010020A100	A0011001??	?300110100
0100?0?0?1	011000120			
<i>Cimolestes magnus</i>	1100100000	0200200000	0001101100	01?1001000
01000010?1	01?010000			
<i>Arfia gingerichi</i>	??????0011	0200201100	001120?000	10?0011000
1001100111	0???00001			
<i>Arfia junnei</i>	??????????	???0?11?00	?01120?000	10?0001000
1001101101	011?????1			
<i>Arfia shosh./opis.</i>	0000000011	A2100A1100	AA11201000	101A0A1000
10011001A1	011100001			
<i>Prototomus minimus</i>	10A1??0011	1001200201	100010?000	0?????10010
0110011011	1?0?100?0			
<i>Prototomus deimos</i>	1001??0?0?	0101200?01	10001?1000	01?????????
???????????	?????????0			
<i>Prototomus phobos</i>	10A1000000	0101200201	0000101000	0100101010
1?10011011	1100A0000			
<i>Prototomus secundarius</i>	???1??000A	0101200201	00101010??	?????1A1010
1010011011	11001A000			
<i>Gazinocyon whitiae</i>	1011000001	0101200201	0010101000	01001000A0
10100110?1	110010000			
<i>Prototomus martis</i>	100A000010	0001200201	1000AA0000	01???0100?
0010021011	11001000A			
<i>Pyrocyon strenuus</i>	110A00A010	AA01200211	10001A0000	01?10A1000
0011021011	110011001			
<i>Pyrocyon diocetus</i>	1100000010	0101200211	1000100000	01?????????
?????2?????	?????11??1			
<i>Prolimnocyon haematus</i>	100000A010	AA0?000?01	1000101101	0300001100
?110011?01	1??011110			
<i>Prolimnocyon atavus</i>	1100000010	0A010002A1	1000101A11	030?001100
01100210A1	110011111			
<i>Galecyon morloi</i>	??????????	???1000210	100010??00	02???11010?
0110000000	0?0?????0			
<i>Galecyon peregrinus</i>	0??A0001A0	1001A00310	100010A101	02?????????
???????????	?????????1			

APPENDIX S5. (CONTINUED)

<i>Galecyon mordax</i>	A00001A100	1101100?10	1A00101101	02????????
?110000000	000?????1			
<i>Galecyon chronius</i>	A000111100	1111100310	1A00120101	021A111101
01A0000000	0000001?1			

## APPENDIX S6. COMBINED ANALYSIS SYNAPOMORPHIES

Characters supporting nodes in the tree derived from analysis of the combined dental and postcranial matrix (Fig. 13). Dental characters are indicated by the prefix “D”; postcranial characters are indicated by the prefix “P”. Key: “\*” = ACCTRAN optimization only; “\$” = DELTRAN optimization only; “+” = ACCTRAN and DELTRAN optimizations but not unambiguous.

*Protungulatum donnae* + *Mithrandir gillianus*: D7(1)†, D13(1)†, D17(1)†, D22(1)†, D23(1)†, D45(1)†, D48(1)†, P22(1)†, P40(1)†, P51(1)†, P69(1)†, P72(2)†, P80(1)†, P84(1)†  
*Protungulatum donnae*: D10(1), D12(0), D36(1)†, D55(1)†, P68(1)  
*Mithrandir gillianus*: D4(1), D19(1), D25(2), D35(1), D41(1), D42(0), D44(1), D50(0), P18(1), P71(0)  
*Cimolestes magnus* + Viverravidae + Ingroup: D15(2)†, D33(1)\*, P6(1)\*, P8(1)\*, P10(1)\*, P12(1)\*, P14(1)\*, P16(1)\*, P17(1)\*, P19(1)\*, P48(1)\*, P54(1)\*, P56(1)\*, P70(1)\*, P83(1)†  
*Cimolestes magnus*: D1(1), D2(1), D55(1)†  
Viverravidae + Ingroup: D9(1), D12(1)\*, D18(1/2), D34(0), D36(1)\*, D59(1)\*, P8(1)\$, P10(1)\$, P14(1)\$, P16(1)\$, P17(1)\$, P19(1)\$, P54(1)\$  
Viverravidae: D6(1), D7(1)†, D8(1), D12(1)\$, D32(3), D36(1)\$, D37(0), D38(1), D57(1), D58(2), P27(1)†, P56(1)\$, P65(1)\*, P75(1)\*, P85(1)†  
*Didymictis* spp.: D4(1), D5(1), D10(1), D11(1), D18(2)†, D22(1), D25(2), D33(1)\$, D48(1)†, D59(1)\$, P5(2)†, P11(1), P12(1)\$, P13(1), P24(1)†, P25(1)†, P48(1)\$, P49(0), P58(1)†, P59(1), P62(1), P63(2), P65(1)\$, P70(1)\$, P75(1)\$  
*Viverravus* spp.: D27(0), D33(0)\*, D35(1), D59(0)\*, P6(0)\*, P12(0)\*, P20(0), P29(2)†, P41(1), P42(0), P48(0)\*, P57(0)  
Ingroup: D5(0), D28(0)\*, P2(0)\*, P7(1), P9(1)\*, P12(1)\$, P39(1)†, P50(0)\*, P73(1)\*, P81(1)†  
*Arfia*: D10(1)\*, D12(2)\*, D17(1)†, D23(1), D25(2), D28(0)\$, D31(1), D32(0), D41(1), D42(0), D44(1), D45(1)†, D48(1)†, D54(1)\*, D59(1)\$, P5(2)\*, P11(1)\*, P13(1)\*, P18(1)\*, P21(1)\*, P24(1)\*, P25(1)\*, P29(2)\*, P32(1)\*, P38(1)\*, P47(1)\*, P49(0)\*, P51(1)\*, P58(1)\*, P61(0)\*, P63(2)\*, P67(1)\*, P71(0)\*, P72(2)X  
*Arfia junnei*: D16(1), D36(0)\*  
*Arfia gingerichi* + *A. shoshoniensis/opisthotoma*: D10(1)\$, D47(0), D49(1)\*  
*Arfia gingerichi*: D36(1)\$, D49(1)\$  
*Arfia shoshoniensis/opisthotoma*: D13(1), D15(0), D33(1)\$, D54(1)\$, P5(2)\$, P11(1)\$, P13(1)\$, P18(1)\$, P21(1)\$, P24(1)\$, P25(1)\$, P29(2)\$, P32(1)\$, P38(1)\$, P47(1)\$, P48(1)\$, P49(0)\$, P50(0)\$, P51(1)\$, P56(1)\$, P58(1)\$, P61(0)\$, P63(2)\$, P67(1)\$, P70(1)\$, P71(0)\$, P72(2)\$  
*Galecyon* + *Prototomus* + *Gazinocyon* + *Prolimnocyon* + *Pyrocyon*: D12(0)\$, D14(1), D18(2)†, D21(1), D24(0), D35(1)\*, D43(1), D53(0), P2(0)\$, P15(2), P20(0)\*, P23(0)\*, P33(0)\*, P53(1)\*, P56(0)\*, P59(1)\*, P60(1)\*, P70(0)\*, P73(1)\$  
*Galecyon*: D8(1)\*, D9(0)\*, D11(1)\*, D15(0)\*, D19(1), D28(1)\*, D32(2), D35(1)\$, D36(1)\$, D38(1), D40(1)\*, D47(0), D50(0), D52(0)\*, D57(1)\*, P29(1)\*, P30(1)\*, P34(1)\*, P50(1)\*, P52(1)\*, P53(2)\*, P54(2)\*, P55(1)\*, P60(2)\*, P61(1)\*, P66(1)\*, P68(1)\*, P74(0)\*, P76(2)\*, P77(1)\*, P79(1)\*, P80(1)\*  
*Galecyon morloi*: D15(0)\$, D37(0), D59(0)\*

APPENDIX S6. (CONTINUED)

*Galecyon peregrinus* + *G. mordax* + *G. chronius*: D8(1)\$, D11(1)\$, D15(1)†, D18(3), D30(1), D59(1)\$

*Galecyon peregrinus*: D12(0)\*

*Galecyon mordax* + *G. chronius*: D6(1), D7(1)\*, D9(0)\$, D12(1)\$, D52(0)\$, P66(1)\$, P68(1)\$

*Galecyon mordax*: none

*Galecyon chronius*: D5(1), D7(1)\$, D13(1), D26(2), D27(0), D33(1)\$, D40(1)\$, D57(1)\$, P6(1)\$, P9(1)\$, P29(1)\$, P30(1)\$, P33(0)\$, P34(1)\$, P48(1)\$, P52(1)\$, P53(2)\$, P54(2)\$, P55(1)\$, P59(1)\$, P60(2)\$, P61(1)\$, P74(0)\$, P76(2)\$, P77(1)\$, P79(1)\$, P80(1)\$

*Prototomus* + *Gazinocyon* + *Prolimnocyon* + *Pyrocyon*: D1(1), D20(1), D33(0)\*, D36(0)\*, D46(1)\*, D49(1)\*, D51(1), D55(1), P1(0), P3(0)\*, P6(0)\*, P9(0)\*, P10(0)\*, P16(0), P35(0)\*, P36(0)\*, P41(1)\*, P42(0), P46(0), P48(0)\*, P57(0), P63(0), P69(1)\*

*Prototomus* (ex *P. martis*) + *Gazinocyon*: D4(1), D10(1)\*, D28(0)\$, D39(1), D46(1)\$, D49(1)\$, D59(0)\*, P11(1)\*, P38(1)\*

*Prototomus minimus*: D10(1)\$, D11(1), D12(0)\*, D36(1)†, D37(0)

*Prototomus deimos* + *P. phobos* + *P. secundarius* + *Gazinocyon whitiae*: D9(0), D12(1)\$, D41(1)\*, D42(0)\*

*Prototomus deimos*: none

*Prototomus phobos* + *P. secundarius* + *Gazinocyon whitiae*: D3(1)\*, D21(0), D35(1)\$, D41(1)\$, P59(1)\$

*Prototomus phobos*: D10(0)\*, P10(1)\*, P71(0)

*Prototomus secundarius* + *Gazinocyon whitiae*: D23(1), D42(0)\$, P63(2)\*

*Prototomus secundarius*: none

*Gazinocyon whitiae*: D3(1)\$, D10(1)\$, D37(0), P10(0)\$, P11(1)\$, P38(1)\$, P63(2)\$

*Prolimnocyon* + *Prototomus martis* + *Pyrocyon*: D35(0)\*, D46(2)†, D56(1)\*, P3(0)\$, P7(0), P10(0)\$, P12(0), P14(0), P15(0), P17(0), P19(0), P20(0)\$, P39(0)\*, P41(1)\$, P44(0)\*, P53(1)\$, P59(0)\*

*Prolimnocyon*: D15(0), D28(1)\*, D30(1), D32(3), D38(1), D49(0)\*, D56(1)\$, D57(1), D58(1), P2(1)\*, P4(1)\*, P5(0)\*, P8(0)\*, P27(1)\*, P31(1)\*, P43(0)\*, P45(1)\*, P47(1)\*, P54(0)\*, P62(1)\*, P72(1)\*, P74(0)\*, P75(1)\*

*Prolimnocyon haematus*: D46(1)†, D59(0)\*

*Prolimnocyon atavus*: D2(1), D29(1), D59(1)\$, P2(1)\$, P4(1)\$, P5(0)\$, P8(0)\$, P23(0)\$, P27(1)\$, P31(1)\$, P35(0)\$, P36(0)\$, P39(0)\$, P43(0)\$, P44(0)\$, P45(1)\$, P47(1)\$, P54(0)\$, P62(1)\$, P72(1)\$, P74(0)\$, P75(1)\$

*Prototomus martis* + *Pyrocyon*: D27(0), D28(0)\$, D34(1)\*, D42(0), D49(1)\$, P6(1)\*, P40(1)\*, P64(1)\*, P65(1)\*, P68(1)\*, P71(0)\*, P73(0)\*, P76(0)\*, P78(1)\*

*Prototomus martis*: D12(0)\*, D56(0)\*

*Pyrocyon*: D2(1), D19(1), D44(1)\*, D56(1)\$, D59(1)\$

*Pyrocyon strenuus*: D34(1)\$, D44(1)\$, P6(1)\$, P40(1)\$, P50(0)\$, P60(1)\$, P64(1)\$, P65(1)\$, P68(1)\$, P69(1)\$, P71(0)\$, P73(0)\$, P76(0)\$, P78(1)\$

*Pyrocyon diocetus*: D12(1)\$



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