Supplementary Material For

New palaeothentid marsupials (Paucituberculata) from the middle Miocene of Quebrada Honda, Bolivia, and their implications for the palaeoecology, decline, and extinction of the Palaeothentoidea

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Contents

Institutional Abbreviations.

AC, Beneski Museum of Natural History, Amherst, U.S.A.; **AMNH**, American Museum of Natural History, New York, U.S.A.; **FMNH**, Field Museum of Natural History, Chicago, Illinois, U.S.A.; **MACN-A**, Ameghino collection, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Buenos Aires, Argentina; **MACN-SC**, Santa Cruz collection, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Buenos Aires, Argentina; **MCNAM-PV**, Museo de Ciencias Naturales y Antropológicas 'J. C. Moyano', Mendoza Province, Argentina; **MLP,** Museo de La Plata, La Plata, Buenos Aires, Argentina; **MPEF-PV**, Museo Paleontológico Edigio Ferugulio, Trelew, Chubut, Argentina; **MPM-PV**, Museo Regional Provincial Padre M. Jesús M. Río Gallegos, Santa Cruz, Argentina; **UATF**, Universidad Autónoma Tomás Frías, Potosí, Bolivia; **UF**, Florida Museum of Natural History, University of Florida, Gainesville, Florida, U.S.A.; **USNM**, National Museum of Natural History, Washington D.C., U.S.A.; **YPM-VPPU**, Princeton University Collection of Yale Peabody Museum, New Haven, Connecticut, U.S.A.

Supplementary Methods

Methodology of Angular Measurements

The angle of the enlarged lower incisor (i2) or anterior border of the coronoid process was measured using Adobe Acrobat XI Pro on images in the previously published literature or photos of casts in the Larry Marshall Marsupial Dentition Collection in lateral view. These angles were measured relative to the horizontal long axis of the dentary, as shown in Figure S5. In cases where the horizontal long axis of the dentary was not clear, the angle was measured based on the alveolar border of the postcanine teeth, specifically the alveolar border of the anterior molar teeth (m1–2) in species with curvature of the molar row.

Determining the Relative Abundance of Palaeothentids at Quebrada Honda and Santa Cruz

Relative abundance of palaeothentids at Quebrada Honda was determined using two methods. In both cases, we compared the number of palaeothentid/palaeothentoid specimens (NISP) at each locality to the number of 'small rodent' (*i.e.*, acaremyids, echimyids, *Acarechimys* spp.) specimens from the same site. Small rodents were used as a point of comparison as these animals span a similar range of body sizes to palaeothentoid marsupials (~50-800 g, see Tab. S5), and therefore relative abundances of these groups are unlikely to be biased by differential preservation due to body size. NISP for Quebrada Honda specimens were drawn from the collections of the Florida Museum of Natural History and the Universidad Autónoma Tomás Frías (see Table S6) whereas those for Santa Cruz were drawn from the collections examined by Croft (2013). Only specimens identifiable to family level or below were used for each analysis, as only family-level NISP was available for specimens from Santa Cruz.

Differences between localities were examined using a chi-square test for significance. Degrees of freedom are not reported for each statistical analysis given that each analysis represented a 2x2 contingency table and therefore degrees of freedom = 1.

First, we performed a family-level analysis comparing the number of palaeothentid specimens at both localities to the number of specimens of echimyids. Basal octodontoids (i.e., *Acarechimys* spp.), the only other small rodent group shared between Quebrada Honda and Santa Cruz, could not be used as a point of comparison given the great disparity in NISP between these two localities compared to these other groups (8 specimens from the Santa Cruz collections examined by Croft (2013) versus 39 specimens from Quebrada Honda). No significant difference in abundance of palaeothentids relative to echimyids was observed between these two localities (X^2 = 2.524, P-value = 0.112), even though palaeothentid specimens were unusually more abundant (Tab. S5). This disparity is primarily due to the composition of the UF Quebrada Honda collection, in which palaeothentids are unusually abundant (n = 9) and small rodents are relatively rare (Echimyidae, n = 2; *Acarechimys*, n = 6). Therefore, the UATF collection, which comprises a much larger number of specimens than the UF collection (n = 854 versus n = 82), might be expected to provide a more accurate ratio of palaeothentid versus echimyid specimens. No significant difference was found between the relative abundance of palaeothentids at Santa Cruz and Quebrada Honda based on the UATF Quebrada Honda collection (X^2 = 0.001, P-value = 0.970).

For the second analysis, we compared the total number of small rodent specimens to the total number of palaeothentoid specimens at both localities. In addition to *Acarechimys* spp., this meant adding NISP for the Abderitidae and Acaremyidae, two groups which are not present at Quebrada Honda. Abderitids were included because these animals at least partially overlapped with palaeothentids in terms of their inferred ecological niches and may have competed for ecological niches with palaeothentids in areas where both groups were present (Dumont *et al.* 2000). However, because this method might be affected by taxonomic biases (i.e., abderitids and acaremyids are not present at Quebrada Honda), relative abundance was calculated both with and without these Santa Cruz-only groups. The difference in the relative abundance of palaeothentids or palaeothentoids was not considered significantly different regardless of whether these Santa Cruz-only taxa were (X^2 = 0.009, P-value = 0.924) or were not (X^2 = 0.695, P-value = 0.404) included.

TABLE S1. List of presently recognized paucituberculatan species. In addition to the references listed here for each species, Abello (2007) and Abello (2013) were used to evaluate occurrences and taxonomy of the Paucituberculata as a whole. Numbering for gen. et sp. nov. 1–5 follows Abello (2013).

Taxon	**Family**	**Age**	**References**
Bardalestes sp.	Basal Species	Itaboraian	Goin *et al.*, 2009
Bardalestes hunco	Basal Species	"Sapoan"	Goin *et al.*, 2009
Evolestes hadrommatos	Basal Species	Deseadan	Goin *et al.*, 2007
Evolestes sp.	Basal Species	"Canteran"	Goin *et al.*, 2010
Riolestes capricornus	Basal Species	Itaboraian	Goin *et al.*, 2009
Caenolestes caniventer	Caenolestidae	Modern	Patterson, 2008
Caenolestes condorensis	Caenolestidae	Modern	Patterson, 2008
Caenolestes convelatus	Caenolestidae	Modern	Patterson, 2008
Caenolestes fuliginosus	Caenolestidae	Modern	Patterson, 2008
Caenolestes sangay	Caenolestidae	Modern	Ojala-Barbour *et al.*, 2013
Gen. et sp. nov. 1	Caenolestidae	Colhuehuapian	Abello, 2007; Abello, 2013
Gen. et sp. nov. 2	Caenolestidae	Colhuehuapian	Abello, 2007; Abello, 2013
Gen. et sp. nov. 3	Caenolestidae	Colhuehuapian	Abello, 2007; Abello, 2013
Lestoros inca	Caenolestidae	Modern	Patterson, 2008
Pliolestes aff. *P. tripotamicus*	Caenolestidae	Chasicoan	Abello, 2007
Pliolestes venetus	Caenolestidae	Huayquerian	Goin *et al.*, 2000
Pliolestes tripotamicus	Caenolestidae	Chapadmalalan	Reig, 1955
Pseudhalmarhipus guaraniticus	?Caenolestidae	Deseadan	Patterson & Marshall, 1978
Rhyncholestes raphanurus	Caenolestidae	Modern	Patterson, 2008
Stilotherium dissimile	Caenolestidae	Santacrucian–Colloncuran	Marshall, 1980
Phonocdromus gracilis	Pichipilidae	Santacrucian	Ortiz-Jaureguizar, 1997
Gen. et sp. nov. 4	Pichipilidae	Colhuehuapian	Abello, 2007; Abello, 2013
Gen. et sp. nov. 5	Pichipilidae	Colhuehuapian	Abello, 2007; Abello, 2013

Pichipilidae gen. et sp. indet.	Pichipilidae	"Canteran"	Goin *et al.*, 2010
Pichipilus riggsi	Pichipilidae	Colhuehuapian	Ortiz-Jaureguizar, 1997
Pichipilus centinelus	Pichipilidae	Santacrucian	Ortiz-Jaureguizar, 1997
Pichipilus osborni	Pichipilidae	Santacrucian	Ortiz-Jaureguizar, 1997
Pichipilus halleuxi	Pichipilidae	Colloncuran	Marshall, 1990
Quirogalestes almagaucha	Pichipilidae	Barrancan	Goin & Candela, 1998
Perulestes cardichi	Basal Palaeothentoidea	Santa Rosa Local Fauna	Goin & Candela, 2004
Perulestes fraileyi	Basal Palaeothentoidea	Santa Rosa Local Fauna	Goin & Candela, 2004
Pilchenia antiqua	Basal Palaeothentoidea	Tinguiririran	Goin *et al.*, 2010
Pilchenia intermedia	Basal Palaeothentoidea	"Canteran"	Goin *et al.*, 2010
Pilchenia lucina	Basal Palaeothentoidea	Deseadan	Bown and Fleagle, 1993
Pilchenia boliviensis	Basal Palaeothentoidea	Deseadan	Patterson and Marshall, 1978
"Giant Palaeothentoid"	*incertae sedis*	Deseadan	Villarroel and Marshall, 1982
Sasawatsu mahaynaq	Basal Palaeothentoidea	Santa Rosa Local Fauna	Goin and Candela, 2004
Palaeothentidae gen. et sp. indet.	Palaeothentidae	"Canteran"	Goin *et al.*, 2010
Palaeothentidae gen. et sp. nov.	Palaeothentidae	Deseadan	Abello *et al.*, 2011
Antawallathentes illmani	Palaeothentidae	Deseadan	Rincón *et al.*, 2015
Antawallathentes quimsacruza	Palaeothentidae	Deseadan	Rincón *et al.*, 2015
Carlothentes chubutensis	Palaeothentidae	Deseadan	Bown and Fleagle, 1993
Hondathentes cazador	Palaeothentidae	Laventan	Dumont and Bown, 1997
Palaeothentes primus	Palaeothentidae	Colhuehuapian	Bown and Fleagle, 1993
Palaeothentes marshalli	Palaeothentidae	Colhuehuapian	Bown & Fleagle, 1993
Palaeothentes migueli	Palaeothentidae	Colhuehuapian	Bown & Fleagle, 1993
Palaeothentes aratae	Palaeothentidae	Santacrucian	Bown & Fleagle, 1993
Palaeothentes intermedius	Palaeothentidae	Santacrucian–Colloncuran	Marshall, 1990; Bown & Fleagle, 1993
Palaeothentes lemoinei	Palaeothentidae	Santacrucian–Colloncuran	Marshall, 1990; Bown & Fleagle, 1993
Palaeothentes minutus	Palaeothentidae	Santacrucian–Colloncuran	Marshall, 1990; Bown & Fleagle, 1993
Palaeothentes pascuali	Palaeothentidae	Santacrucian	Bown & Fleagle, 1993
Acdestis maddeni	Palaeothentidae	Laventan	Goin *et al.*, 2003

Acdestis owenii	Palaeothentidae	Santacrucian–Colloncuran	Bown & Fleagle; Rae *et al.*, 1996
Acdestodon bonapartei	Palaeothentidae	Colhuehuapian	Bown & Fleagle, 1993
Decastinae indet.	Palaeothentidae	Deseadan	Bown & Fleagle, 1993; Abello, 2007
Titanothentes simpsoni	Palaeothentidae	Santacrucian	Rae *et al.*, 1996
Titanothentes sp. nov.	Palaeothentidae	Santacrucian	Kramarz *et al.*, 2010
Trelewthentes rothi	Palaeothentidae	Colhuehuapian	Bown & Fleagle, 1993
Abderites crispus	Abderitidae	Colhuehuapian	Abello & Rubilar-Rogers, 2012
Abderites meridionalis	Abderitidae	Santacrucian	Abello & Rubilar-Rogers, 2012
Abderites aisenense	Abderitidae	Colloncuran	Abello & Rubilar-Rogers, 2012
Parabderites minisculus	Abderitidae	Deseadan	Marshall, 1980; Ortiz-Jaureguizar, 2003
Parabderites bicrispatus	Abderitidae	Colhuehuapian	Marshall, 1980; Ortiz-Jaureguizar, 2003
Pitheculites minimus	Abderitidae	Colhuehuapian–Santacrucian	Dumont *et al.*, 2000
Pitheculites rothi	Abderitidae	Colloncuran	Marshall, 1990
Pitheculites chenche	Abderitidae	Laventan	Dumont & Bown, 1997
cf. '*Pilchenia boliviensis*'	*incertae sedis*	Deseadan	Marshall *et al.*, 1984; Rincón *et al.*, 2015
'*Palaeothentes*' *smeti*	*incertae sedis*	Santacrucian	Flynn *et al.*,2002
Palaeothentes serratus	Palaeothentidae	Laventan	Present study
Palaeothentes relictus	Palaeothentidae	Laventan	Present study
Chimeralestes ambiguus	Palaeothentidae	Laventan	Present study

TABLE S2. Measurements of the lower dentition of Quebrada Honda paucituberculatans. Trigonid length was measured from the base of the proto- or metacone to the anterior end of the tooth. Talonid length was measured from the same point to the posterior end of the tooth. L - left, R - right, * - approximate measurement based on alveoli of the tooth.

	p3		**m1**						**m2**						**m3**						**m4**	
Specimen	**L**	**W**	**L**	**L_{trig}**	**L_{tal}**	**W**	**W_{trig}**	**W_{tal}**	**L**	**L_{trig}**	**L_{tal}**	**W**	**W_{trig}**	**W_{tal}**	**L**	**L_{trig}**	**L_{tal}**	**W**	**W_{trig}**	**W_{tal}**	**L**	**W**
Acdestis maddeni																						
UATF-V-000925 (L)	-	-	6.42	4.58	1.84	2.72	2.32	2.72	3.52	1.71	1.81	2.44	2.40	2.44	-	-	-	-	-	-	-	-
UATF-V-000925 (R)	-	-	-	-	-	-	-	-	3.58	1.73	1.85	2.41	2.34	2.41	-	-	-	-	-	-	-	-
UATF-V-001519	-	-	-	-	-	-	-	-	3.61	-	-	2.42	-	-	2.49	-	-	1.78	-	-	1.27	1.13
UATF-V-001563	-	-	-	-	-	-	-	-	3.64	1.99	1.65	2.40	2.40	2.38	2.34	1.44	0.90	1.80	1.80	1.75	1.34	1.15
UF 27883	2.19	1.27	5.60*	3.74*	1.87	2.52	-	2.52	3.64	1.98	1.66	2.40	2.40	2.35	-	-	-	-	-	-	-	-
UF 27884	-	-	6.47	4.57	1.90	2.69	2.69	2.78	3.84	1.92	1.92	2.45	2.45	2.40	-	-	-	-	-	-	-	-
UF 99684	-	-	6.42	-	-	2.70	-	-	3.58	1.97	1.61	2.41	2.41	2.19	2.39*	-	-	-	-	-	-	-
UF 99685	-	-	-	-	-	-	-	-	3.71	1.94	1.77	2.34	2.34	2.10	-	-	-	-	-	-	-	-
***Palaeothentes serratus* sp. nov.**																						
UF 27882	1.49	0.88	2.58	1.46	1.12	1.55	1.35	1.55	2.13	1.10	1.03	1.53	1.53	1.49	-	-	-	-	-	-	-	-
***Palaeothentes relictus* sp. nov.**																						
UATF-V-001774	-	-	3.15	1.51	1.64	1.75	1.44	1.76	2.82	1.34	1.48	1.70	1.70	1.56*	-	-	-	-	-	-	-	-
***Chimeralestes ambiguus* gen. et sp. nov.**																						
UATF-V-001360	-	-	-	-	-	-	-	-	-	-	1.41	1.58	-	1.58	1.96	1	0.96	1.28	1.28	1.20	1.13	0.84

TABLE S3. Angle between the horizontal ramus of the dentary and the anterior border of the coronoid process in various species of paucituberculatans. See Supplementary Methods section for how this measurement was calculated.

Taxon	**Specimen**	**Angle**	**Reference**
Abderites crispus	MPEF-PV 5847	124°	Abello and Rubilar-Rogers (2012, fig. 6.5)
Abderites meridionalis	MACN-A 2037	132.01°	Engelman, pers. obs.
Abderites meridionalis	YPM-VPPU 15079	131.60°	Engelman, pers. obs.
Abderites meridionalis	YPM-VPPU 15425	126°	Sinclair (1906, fig. 9)
Acdestis maddeni	UATF-V-001519	124°	Present Study
Acdestis maddeni	UATF-V-001563	119°	Present Study
Acdestis owenii	FMNH P13160	107°	Engelman, pers. obs.
Acdestis owenii	MACN-A 5561	118°	Marshall (1980, fig. 33a)
Acdestis owenii	YPM-VPPU 15710	108.48	Engelman, pers. obs.
Acdestis owenii	YPM-VPPU 15710	124°	Sinclair (1906, pl. 65.6)
Carlothentes chubutensis	MACN 52-378	115°	Engelman, pers. obs.
Chimeralestes ambiguus	UATF-V-001360	136°	Present Study
Gen. et sp. nov. 1	MPEF-PV 4849	116°	Abello (2007, pl. 5a)
Gen. et sp. nov. 3	MLP 82-V-2-113	125.12°	Abello (2007, pl. 7d)
Gen. et sp. nov. 3	MPEF-PV 5684	131°	Abello (2007, pl. 7e)
Lestoros inca	-	90°	Martin (2013, fig. 4a)
Palaeothentes aratae	MACN-A 14	129°	Marshall (1980, fig. 29a)
Palaeothentes aratae	MACN-A 14	125.42°	Engelman, pers. obs.
Palaeothentes aratae	MACN-SC 1302	128°	Rae *et al.* (1996, fig. 7b)
Palaeothentes intermedius	AMNH 9598	103°	Engelman, pers. obs.
Palaeothentes lemoinei	MPM-PV 3566	110°	Forasiepi *et al.* (2014b, fig. 8a)
‘*Palaeothentes*’ *primus*	MACN-A 52-377	128.52°	Engelman, pers. obs.
Parabderites bicrispatus	MACN-A 52-45	129.00°	Engelman, pers. obs.
Phonocdromus gracilis	AMNH 9593	123°	Engelman, pers. obs.
Pilchenia lucina	AC 3110	130.50	Engelman, pers. obs.
Pichipilus riggsi	MPEF-PV 4705	115°	Abello (2007, pl. 6p)
Rhyncholestes raphanurus	-	107°	Martin (2013, fig. 4b)
Stilotherium dissimile	YPM-VPPU 15238	110.72°	Engelman, pers. obs.
Stilotherium dissimile	YPM-VPPU 15238	119°	Sinclair (1906, pl. 63.8)

TABLE S4. Angle between the enlarged second incisor (i2) at the point of implantation in the dentary and the long axis of the horizontal ramus of the dentary (measured from the base of the cheek tooth series) in species of paucituberculatans. See Supplementary Methods section for how this measurement was calculated.

Taxon	**Specimen**	**Angle**	**Reference**
Abderites crispus	-	30.72°	Abello (2007, fig. 11c)
Acdestis maddeni	UF 27883*	~34°	Present Study
Acdestis owenii	AMNH 9594	31.52°	Sinclair (1906, pl. 64.4)
Acdestis owenii	MACN-SC 3649	31.18°	Engelman, pers. obs.
Acdestis owenii	YPM-VPPU 15066	30.47°	Sinclair (1906, pl. 64.5)
Antawallalestes quimsacruza	UATF-V-7005	~13°	Rincón *et al.* (2015, fig. 5)
Caenolestes condorensis	FMNH 152134	7.48°	Albuja and Patterson (1996, fig. 3)
Caenolestes fuliginosus	AMNH 10559	7.85°	Sinclair (1906, pl. 63.14)
Caenolestes sp.	USNM 513429	7.05°	Engelman, pers. obs.
Fieratherium sorex	MCNAM-PV 3958	27.78°	Forasiepi *et al.* (2014a, fig. 3b)
Lestoros inca	-	8.25°	Martin (2013, fig. 4a)
Palaeothentes lemoinei	MACN-A 8293	31.47°	Marshall (1980, fig. 25c)
Palaeothentes lemoinei	MPM-PV 3566	31.00°	Forasiepi *et al.* (2014b, fig. 8a)
Palaeothentes minutus	YPM-VPPU 15706	6.84°	Sinclair (1906, pl. 63.5)
Palaeothentes minutus	YPM-VPPU 15708	5.26°	Sinclair (1906, pl. 63.4)
'Palaeothentes' primus	-	16.38°	Abello (2007, fig. 11e)
Palaeothentes serratus	UF 27882	3.78°	Present Study
Parabderites bicrispatus	-	17.76°	Abello (2007, fig. 11g)
Pitheculites minimus	-	34.00°	Abello (2007, fig. 11a–b)
Phonocdromus gracilis	AMNH 9593	8.88°	Sinclair (1906, pl. 63.9)
Pliolestes tripotamicus	MLP 57-VII-23-49	18.04°	Pascual and Herrera (1973, pl. 2.3)
Rhyncholestes raphanurus	-	0.32°	Martin (2013, fig. 4b)
Stilotherium dissimile	YPM-VPPU 15238	22.74°	Sinclair (1906, pl. 63.8)

* – The anteriormost part of the dentary in UF 27883, including the point of implantation of i2 in the dentary, was lost prior to our study. This measurement was taken from a cast of the specimen that was made prior to this part of the dentary being lost.

Table S5. Body mass estimates of small rodents at Quebrada Honda and Santa Cruz. Body masses of all species were estimated using the regression equation for lower toothrow length (dp4-m3 in octodontoids) for Hystricomorpha from Hopkins (2008b)

Taxon	Est. Mass (g)	dp4-m3 (mm)	Reference
Quebrada Honda			
Acarechimys sp.	100-155	7.1-8.3	Croft *et al.* (2011, appendix 2)
Quebradahondomys potosiensis	432	12*	Croft *et al.* (2011, fig. 10)
Santa Cruz			
Acarechimys constans	177	8.7	Arnal (2011, tab. 4.2)
Acarechimys minutissimus	49	5.5	Arnal (2011, tab. 4.3b)
Acarechimys minutus	68	6.2	Arnal (2011, tab. 4.1b)
Acaremys murinus	108	7.3	Arnal (2011, tab. 4.5b)
Adelphomys candidus	673	14	Scott (1905, p. 409)
Sciamys principalis	165	8.5	Scott (1905, p. 426)
Spaniomys modestus	194	9	Scott (1905, p. 412)
Spaniomys riparius	300-547	10.5-13	Scott (1905, p. 411)
Stichomys sp.	547-818	13-15	Scott (1905, p. 407)

* – This measurement is based on the alveolar length of the holotype and only described specimen of *Q. potosiensis* (UATF-V-01030), which lacks dp4.

TABLE S6. Specimen counts of palaeothentids/palaeothentoids and small rodents at Quebrada Honda and Santa Cruz.

Comparison	Locality	Small Rodents	Palaeothentids/oids
Palaeothentidae versus Echimyidae	Santa Cruz	30	16
	Quebrada Honda Fauna (UATF+UF)	13	15
	Quebrada Honda Fauna (UATF only)	11	6
Palaeothentids/oids versus small rodents	Quebrada Honda Fauna (UATF+UF)	53	15
	Santa Cruz (including abderitids and acaremyids)	66	18
	Santa Cruz (no abderitids or acaremyids)	40	16

Supplementary Figure Captions

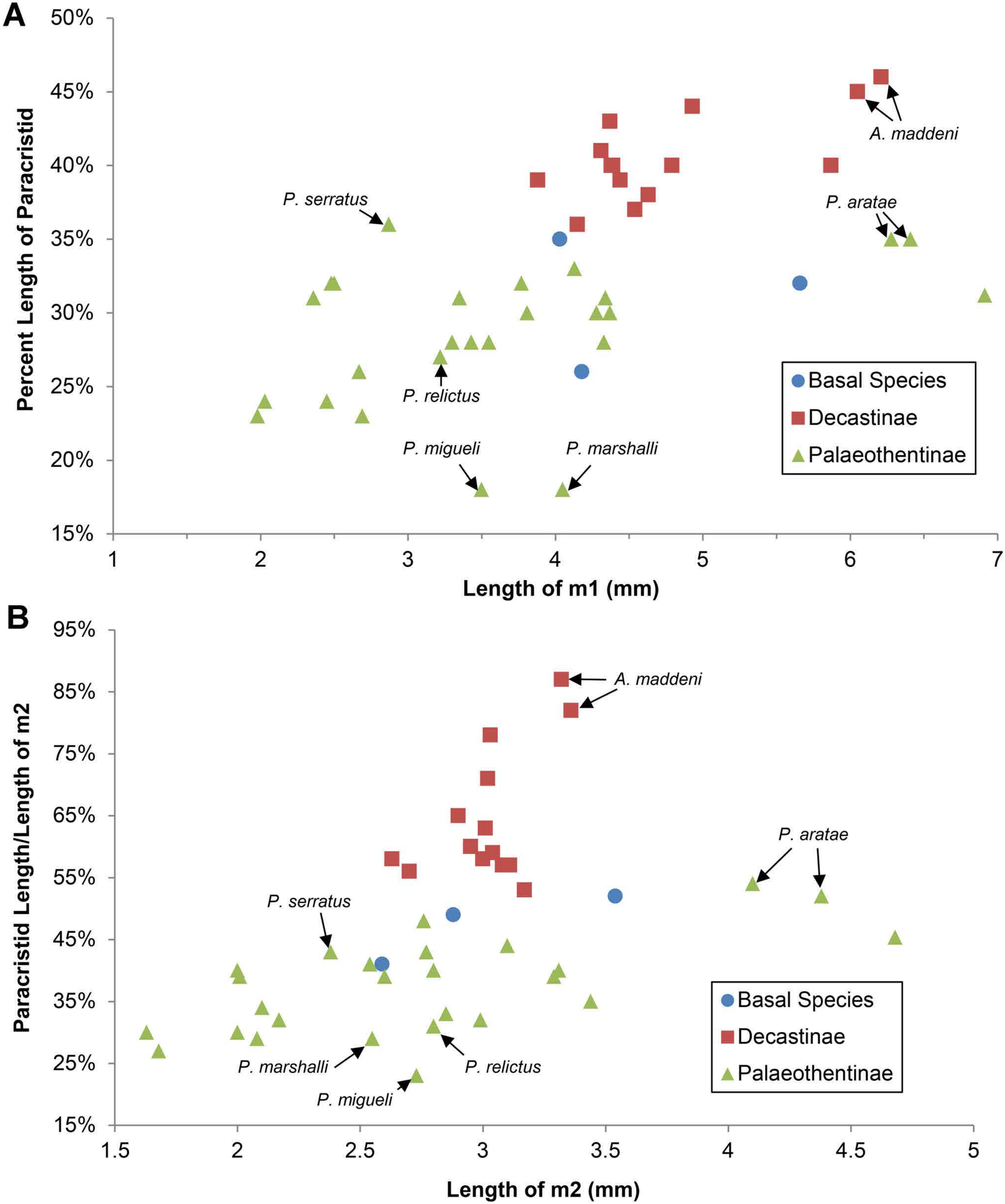
Figure S1. Close-up of second lower incisor (i2) of UF 99687 showing the transverse striations in the enamel of this tooth.

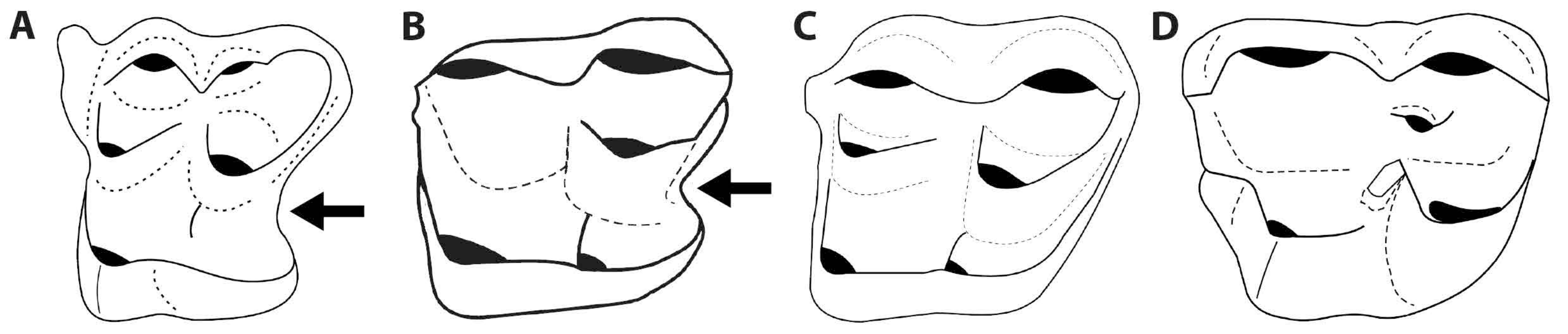
Figure S2. Close-up of the posterior molar row of *Acdestis maddeni* (UATF-V-001519), showing the single-rooted m4 of this taxon. Scale bar equals 1 mm.

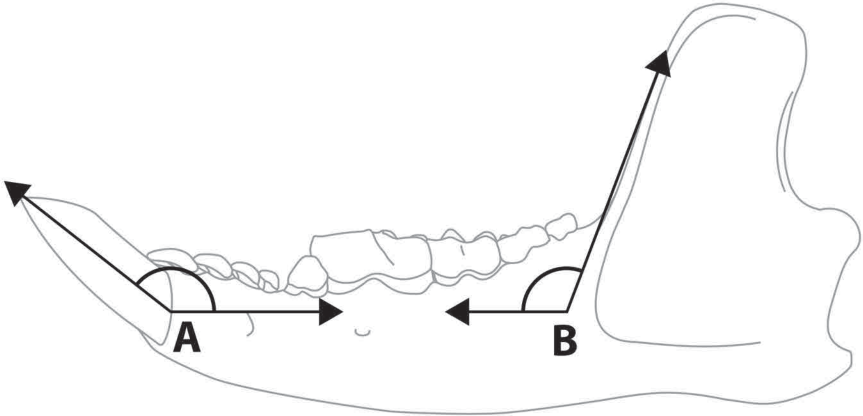
Figure S3. Plot of paracristid length (measured as the line between the tips of the paraconid and protoconid) in palaeothentids, abderitids, and the palaeothentoid *Pilchenia* spp. scaled by (**A**) length of m1 or (**B**) length of m2.

Figure S4. Upper molars of paucituberculatans, showing the presence of the posterior flexus in the postmetaconular crista (denoted by an arrow) in (**A**) *Evolestes hadrommatos* and (**B**) *Stilotherium dissimile* and the absence of this flexus in (**C**) Pichipilidae and (**D**) *Palaeothentes minutus*. Anterior is to the left in all images. All figures are from Abello (2013). Teeth not to scale.

Figure S5. Reconstruction of the dentary of *A. maddeni*, showing how angular measurements were determined in Tables S3–4. **A**, angle of implantation of i2; **B**, angle of the anterior border of the coronoid process. Note that this dentary is a reconstruction based on several species (see Fig. 10).


A
50%
45%
40%
35%
30%
25%
20%
15%
Percent Length of Paracristid
1
2
3
4
5
6
7
Length of m1 (mm)
A. maddeni
P. serratus
P. aratae
P. relictus
P. migueli
P. marshalli
Basal Species
Decastinae
Palaeothentinae
B
95%
85%
75%
65%
55%
45%
35%
25%
15%
Paracristid Length/Length of m2
1.5
2
2.5
3
3.5
4
4.5
5
Length of m2 (mm)
A. maddeni
P. aratae
P. serratus
P. marshalli
P. relictus
P. migueli
Basal Species
Decastinae
Palaeothentinae


A
B
C
D


A
B

Appendix S1. Changes to Data Matrix of Abello (2013)

New Characters

- Character 2 – Position of the infraorbital foramen: dorsal or anterior to anterior root of P3 (0); dorsal to posterior root of p3 (1); posterior to P3/M1 embrasure (2).

Although most paucituberculatan specimens do not preserve non-dental features of the skull, one feature that is present in many specimens is the infraorbital foramen. The exact position of this foramen varies among taxa. In most species it is located over the posterior root of P3, whereas in *Acdestis* it is more anteriorly located, and in the caenolestids *Lestoros* and *Rhyncholestes* it is located posterior to the P3/M1 embrasure and is over the molar row.

- Character 7 – Shape of lower unicuspids: not 'bent' (0); 'bent' (1).

The unicuspid teeth of palaeothentids and abderitids can be differentiated from most other paucituberculatans in being extended anteriorly, giving them a 'bent' appearance in lateral or medial view. By contrast, while the lower unicuspids of caenolestids are procumbent, they do not appear 'bent'.

- Character 8 – Morphology of p2: premolariform and distinct from other antemolar teeth (0); no morphologically distinct p2 (1).

In caenolestids and pichipilids, the p2 is premolariform and has a well-developed, non-procumbent protoconid and additionally anterior and posterior cusps. By contrast, in palaeothentids and abderitids, there is no morphologically distinct p2 . There are two possible explanations for this difference; either p2 was lost entirely or this tooth was evolutionarily reduced to the point that it was indistinguishable from the anterior unicuspid teeth. The posteriormost unicuspid in a few specimens of *Palaeothentes minutus* (MACN 8318 and MACN 8347-8354c) and *Abderites crispus* (MPEF-PV 5847) have fused roots, indicating that this tooth locus represents a premolar (see Abello 2013), but it is not possible at this time to determine whether this tooth represents p1 or p2. Either way, the absence of a premolariform p2 is a distinct feature uniting palaeothentids and abderitids.

- Character 19 – Length of paracristid: short (< 20% length of m1) (0); long (> 20% length of m1) (1).

In *Palaeothentes marshalli* and *P. migueli*, the paraconid appears to be positioned more posteriorly on m1 than in other palaeothentids, such that the paracristid is proportionally shorter and the anterior trigonid crest is proportionally longer than in other members of this group. This feature is only seen in *P. marshalli* and *P. migueli* and differentiates them from all other non-pichipilid palaeothentoids. The codings for this character were formulated by determining the proportional length of the m1 paracristid relative to the total length of m1, given that this metric most clearly shows the difference between *P. marshalli* and *P. migueli* and other palaeothentid taxa (see Fig. S3). Other ways of formulating this character (i.e., by comparing anterior trigonid crest length versus paracristid length) are possible but could not be used in this analysis as the length of the anterior trigonid crest was uncertain for many species. Given that the codings of this character are dependent on the presence of an anterior trigonid crest, this character could not be coded for taxa that lack an anterior trigonid crest (i.e., pichipilids and non-palaeothentoid paucituberculatans).

- Character 40 – Widths of m2 trigonid and talonid: talonid wider than trigonid (0); trigonid and talonid subequal in width (1).

Rincón *et al.* (2015) included a character in their analysis (character 75) comparing the occlusal areas of the trigonid and talonid in paucituberculatans. However, the definitions for how this character was coded are ambiguous, and in many cases we were not able to replicate their codings. Nevertheless, we did observe a related morphological feature whose coding was easier to replicate. In many paucituberculatans, including caenolestids and pichipilids, the trigonid of m2 is much narrower than the talonid, making this tooth appear strongly triangular in occlusal view. By contrast, in palaeothentids and their close relatives, the trigonid and talonid of m2 are generally subequal in width. The only exceptions to this among non-pichipilid palaeothentoids are *Perulestes cardichi* and *Pilchenia antiqua*, in which the trigonid is significantly narrower than the talonid.

- Character 50 – Entocristid continuous between entoconid and metaconid: present (0); absent (1).

In many marsupials, including caenolestids and almost all basal paucituberculatans (except *Fieratherium*, where there is no entocristid), the entocristid is continuous between the entoconid and the posterior face of the metaconid. However, in palaeothentoids (pichipilids, palaeothentids, abderitids, and their relatives), the entocristid does not reach the posterior face of the metaconid, even if the entocristid is straight.

- Character 88 – Flexus in postmetaconular crest: absent (0); present (1).

In several paucituberculatans, including *Evolestes hadrommatos* and *Stilotherium dissimile* (Figure S4), there is a distinct posterior flexus in the postmetaconular crest. However, in the extant caenolestids *Rhyncholestes* and *Caenolestes* and all known palaeothentoids, this crest is absent. Non-paucituberculatan marsupials and *Bardalestes* spp. were coded as inapplicable for this character, as these species all have a plesiomorphic tritubercular molar. The morphology of the upper molars assigned to *Evolestes* sp. from La Cantera was unclear, so this character was coded as unknown for this taxon. Some pichipilids (*e.g.*, *Pichipilus riggsi*, gen. et sp. nov. 3) seem to show a slight flex at the base of the crown that could be a vestige of the larger flexus seen in more basal paucituberculatans, though this is not certain as the specimens could not be observed firsthand.

All characters listed above were coded based on Sinclair (1906), Marshall (1980), Rae *et al.* (1996), Abello (2007), and Forasiepi *et al.* (2014b)

Character State Changes

- Character 2 of Abello (2013) (size and orientation of first incisor) refers to two distinct characters, the size of i1 and its procumbency. Therefore, this character was split into two distinct characters (Characters 2 and 3, respectively)
- Abello (2013) condensed several characters of the m1 trigonid used by previous authors (Marshall 1980; Bown & Fleagle 1993), including the positions of the para- and metaconid and the length of the paracristid, into a single character (character 13; structure of m1 trigonid). However, changes in the morphology of the m1 trigonid are not always correlated with each other, with changes in the position of the metaconid not being mirrored by the paraconid and vice versa. Therefore, this character was split into two separate characters, so as not to obscure phylogenetically significant information. The length of the paracristid, on the other hand, does seem to be correlated to the position of the paraconid and was not considered separately here.
- Character 15 of Abello (2013) (size of m1 paraconid) represents a morphocline and was therefore reordered and considered ordered in this analysis
- Based on the description of Abello (2013), character 18 of this study (morphology of the anterior crest of m1 trigonid) includes information on two distinct characters, the width of

this crest (wide and robust versus narrow) and its anteroposterior length (long versus reduced). Therefore, this character was split into two distinct characters (Characters 23 and 24 here, respectively).

- Character 18 of Abello (2013) (notch in protocristid of m1) represents a morphocline and has been reordered and is considered ordered in this analysis
- Character 19 of Abello (2013) (length of m1 protocristid) represents a morphocline and is considered ordered in this analysis
- Character 22 of Abello (2013) (position of metaconid relative to protoconid on m2-3) refers to two distinct traits and was therefore split into two different characters, Character 28 (position of metaconid relative to protoconid on m2) and Character 29 (position of metaconid relative to protoconid on m3)
- Character 23 of Abello (2013) (size of m2 paraconid) represents a morphocline and is considered ordered in this analysis. Additionally, character 23 of Abello (2013) (presence or absence of paraconid on m2) is related to character 24 of the same study (m2 paraconid size) and so the two have been combined into a single character in this analysis.
- Character 24 of Abello (2013) (relative positions of para- and metaconids on m2-3) represents a morphocline and is considered ordered in this analysis
- Character 25 of Abello (2013) (orientation of m2 postparacristid) represents a morphocline and is considered ordered in this analysis
- Character 32 of Abello (2013) (anterobasal cingulum on m2-3) refers to two distinct traits and was therefore split into two characters, Character 31 (anterobasal cingulum on m2)

and Character 32 (anterobasal cingulum on m3). Both of these characters have been coded as ordered.

- Character 34 of Abello (2013) (shape and size of hypoconid on m2-3) refers to two distinct traits and was therefore split into two characters, Character 44 (size of hypoconid on m2-3) and Character 45 (shape of hypoconid on m2-3). The wording of character 44 was changed slightly to clarify the different character states were diagnosed. As the hypoconid of all taxa are salient, this feature was not considered in this analysis.
- Character 37 of Abello (2013) (entocristid shape on m2-3 in occlusal view) refers to two distinct traits and was therefore split into two characters, Character 48 (entocristid shape on m2 in occlusal view) and Character 49 (entocristid shape on m3 in occlusal view).

Observations of several paucituberculatan specimens also indicate that there is a significant amount of variation in the shape of the entocristid for taxa coded as "labially concave" for this character. In some taxa, such as *Acdestis*, the entocristid is only slightly curved and approaches the posterior border of the talonid. By contrast, in other species, primarily members of *Palaeothentes*, the entocristid is curved much more sharply such that the anterior end of the crest is almost perpendicular to the long axis of the tooth and it does not approach the trigonid (compare figs. 3H and 3I in Abello, 2013). As a result, the "labially concave" state has been split into two states, "slightly labially concave" (referring to *Acdestis*-like species) and "strongly labially concave" (referring to *Palaeothentes*-like ones). Although these characters probably represent morphoclines, it is unclear if their morphologies are related to one another (i.e., whether the presence of a labially curved entocristid on m2 affects the curvature of the entocristid on m3), and so these characters are provisionally left unordered.

- Character 58 of Abello (2013) (size of metaconule on M1) represents a morphocline and is considered ordered in this analysis
- Character 59 of Abello (2013) (metaconule height relative to protoconule in M1-2) represents a morphocline and has been reordered and is considered ordered in this analysis
- Character 62 of Abello (2013) (relative size of StB and StC+D on M1) represents a morphocline and has been reordered and is considered ordered in this analysis
- Character 63 of Abello (2013) (relative size and proximity of paracone and StB on M1-2) represents a morphocline and is considered ordered in this analysis
- Character 64 of Abello (2013) (relative size and proximity of metacone and StC+D on M1-2) refers to two distinct traits and therefore was split into two characters, Character 77 (size of metacone relative to StC+D on M1–2) and Character 78 (proximity of metacone and StC+D on M1–2). Character 66 has been coded as ordered.
- Character 66 of Abello (2013) (shape of centrocrista) represents a morphocline and was considered ordered in this analysis
- Character 67 of Abello (2013) (relative positions of StB and StC+D, protocone and metaconule on M1-2) refers to two distinct traits and was therefore split into two characters, Character 81 (position of protocone relative to StB) and Character 82 (position of metaconule relative to StC+D). These characters were both coded as ordered.
- Character 69 of Abello (2013) (StA on M2) was redefined as follows: StA on M2 forming a distinct cusp (0); absent or coalescent with StB (1). This takes into account the fact that this cusp is present but greatly reduced and coalescent with StB in some

individuals of taxa where StA is normally absent (*e.g*, MACN-A 5568; *Palaeothentes lemoinei*).

- Character 75 of Rincón *et al.* (2015) (occlusal surface of m2 trigonid) has been greatly modified from how it was used in the analysis of these authors, and a variant form is listed here as Character 40 (widths of m2 trigonid and talonid).
- Character 76 of Rincón *et al.* (2015) (shape of entoconid notch in m1) was excluded from this analysis. The shape of the entoconid notch was observed to be quite variable among individuals of the same species. Additionally, this character seems to be strongly correlated with the presence of two other characters, the shape of the entocristid on this tooth and the presence of a crest-like structure posterior to the metaconid (character 36).
- Character 77 of Rincón *et al.* (2015) (hypoflexid of m1) was excluded from this analysis, as the coding of this character was highly correlated with and almost identical to that of character 28 (orientation of cristid obliqua on m1).

Taxon-Specific Changes

- Character 1 (antorbital vacuities) was coded as “0” (absent) for *Palaeothentes lemoinei* following Forasiepi *et al.* (2014b).
- Character 48 (shape of m2 entocristid) and character 49 (shape of entocristid on m3) coded as “1” (straight) for *Pilchenia lucina* based on Abello (2007) and personal observation of AC 3110.
- Character 17 (position of metaconid relative to protoconid of m1), 27 (length of m1 protocristid), 29 (position of metaconid relative to protoconid on m2), and 48 (shape of m2 entocristid in occlusal view) were coded for *Acdestodon bonapartei* based on Bown and Fleagle (1993)

- Character 36 (crest-like expansion posterior to metaconid in m1–3) was coded as "0 & 1" (absent and present) for *Acdestodon bonapartei*. Observations of this taxon show that there is a distinct crest-like structure posterior to the metaconid of m1 but that this structure is absent on m2.
- Character 48 (shape of entocristid on m2) was coded as "1" (straight) for "*Palaeothentes*" *primus* based on personal observation of MACN 52-377
- Characters 41 and 42 (anterobasal cingula of m2–3) were coded as "?" for *Evolestes hadrommatos*, as the lower dentition of this taxon is unknown.
- Character 71 (paracone on M1-2) was coded as "0" (present) in *Lestoros inca* following the observation by Martin (2013) that the paracone is present in this taxon but is rapidly obliterated by wear.
- Codings for *Acdestis spegazzinii* and *A. owenii* were merged following the argument of Engelman and Croft (2016) that these two taxa represent sexual dimorphs of the same species. The only character that was affected by this change was character 1 (presence of antorbital vacuities), which was not scored for *A. spegazzinii*.

Appendix S2. List of characters

Ordered characters are marked by an asterisk (*)

1. Antorbital vacuities
    - 0: absent
    - 1: present

2. Position of infraorbital foramen*
    - 0: dorsal or anterior to anterior root of P3
    - 1: dorsal to posterior root of P3
    - 2: posterior to P3/M1 embrasure

3. Size of i1
    - 0: small
    - 1: enlarged

4. Orientation of i1
    - 0: not procumbent
    - 1: procumbent

5. Orientation of anterior end of dentary
    - 0: horizontal to subhorizontal
    - 1: dorsally projecting

6. Number of antemolar teeth
    - 0: eight
    - 1: less than eight

7. Shape of lower unicuspids
    - 0: not "bent"
    - 1: "bent"

8. Morphology of p2
    - 0: larger than unicuspid teeth
    - 1: similar in size and shape to unicuspid teeth

9. Size of lower third premolar
    - 0: moderately to well-developed
    - 1: reduced

10. Roots of p3
    0: two
    1: one

11. Anterobasal cuspule on p3
    0: absent
    1: present

12. Talonid on p3
    0: present
    1: absent

13. Anterior lingual crests on p3
    0: absent
    1: present

14. Main cusp on p3
    0: straight
    1: lingually bent

15. p3-m1 contact
    0: mostly contiguous
    1: p3 supports most or all of the trigonid

16. Molar enamel thickness
    0: uniform
    1: markedly different thickness between lateral and occlusal faces

17. Position of metaconid relative to protoconid on m1*
    0: metaconid transversely aligned with protoconid
    1: metaconid posteriorly placed with respect to protoconid
    2: metaconid very posteriorly placed with respect to protoconid
    3: metaconid and protoconid aligned anteroposteriorly

18. Position of paraconid relative to protoconid on m1*
    0: para- and protoconid relatively close
    1: paraconid distant from protoconid
    2: paraconid very distant from protoconid
    3: paraconid and protoconid aligned anteroposteriorly

19. Length of paracristid
    0: short (< 20% length of m1)
    1: long (> 20% length of m1)

20. Shape of m1 paracristid
    0: notched
    1: not notched, forming a continuous blade between proto- and paraconid

21. Size of m1 paraconid
    0: moderately sized
    1: reduced
    2: very reduced

22. Height of paraconid relative to protoconid on m1
    0: shorter than protoconid
    1: subequal in height

23. Anterior crest of m1 trigonid
    0: absent
    1: present

24. Length of anterior crest of m1 trigonid
    0: long
    1: reduced

25. Width of anterior crest of m1 trigonid
    0: narrow
    1: wide

26. Notch in protocristid of m1*
    0: notch poorly developed or absent
    1: moderately developed
    2: strongly developed

27. Length of m1 protocristid*
    0: long
    1: relatively short
    2: very short

28. Orientation of cristid obliqua on m1

0: towards protoconid or slightly labial to protocristid notch
1: towards notch or midpoint between protoconid and metaconid
2: in contact with the metaconid

29. Position of metaconid relative to protoconid on m2
0: not anteriorly placed
1: anteriorly placed

30. Position of metaconid relative to protoconid on m3
0: not anteriorly placed
1: anteriorly placed

31. m2 paraconid size
0: paraconid and metaconid subequal in size
1: paraconid very reduced compared to metaconid
2: paraconid highly reduced compared to metaconid
3: paraconid absent

32. Relative positions of para- and metaconid on m2-3*
0: distant
1: close but not coalescent
2: coalescent

33. Orientation of m2 postparacristid*
0: anterolingual-posterolabially oblique
1: transverse
2: anterolabial-posterolingually oblique

34. Anterolabial trigonid cusp on m2-3
0: absent
1: present

35. Depth of protocristid in m2-3
0: deep
1: shallow

36. Crest-like expansion posterior to metaconid in m1-3
0: absent
1: present

37. Crest posterior to protoconid in m1-3

0: absent
1: present

38. Crown shape of lower molars

0: not basally wide
1: basally wide

39. Anterobasal cingulum of m1

0: present and follows the contour of the trigonid border
1: strongly developed and projects anterolabially

40. Widths of m2 trigonid and talonid

0: talonid wider than trigonid
1: trigonid and talonid subequal in width

41. Anterobasal cingulum on m2*

0: long
1: short
2: vestigial

42. Anterobasal cingulum on m3*

0: long
1: short
2: vestigial

43. Ridge along anterior surface of m2-3 trigonid

0: absent
1: present

44. Size of hypoconid on m2-3

0: not fully distinct from the cristid
1: distinct from the cristid

45. Shape of hypoconid on m2-3

0: not anteroposteriorly compressed
1: anteroposteriorly compressed

46. Shape of entoconids on m1-3

0: conical

1: laterally compressed

47. Postentocristid on m1-3
    0: absent
    1: present

48. Shape of m2 entocristid in occlusal view
    0: lingually concave
    1: straight
    2: slightly labially concave
    3: strongly labially concave

49. Shape of m3 entocristid in occlusal view
    0: lingually concave
    1: straight
    2: slightly labially concave
    3: strongly labially concave

50. Entocristid continuous between entoconid and metaconid
    0: present
    1: absent

51. Relative heights of distal ends of cristid obliqua and entocristid on m1
    0: roughly equal in height
    1: cristid obliqua higher

52. Relative heights of distal ends of cristid obliqua and entocristid on m2-3
    0: roughly equal in height
    1: cristid obliqua higher

53. Shelf lingual to entocristid on m1
    0: absent
    1: present

54. Shelf lingual to entocristid on m2-3
    0: absent
    1: present

55. Orientation of cristid obliqua on m2
    0: towards notch or midpoint between protoconid and metacone

1: towards the protoconid or slightly labial to the protoconid notch

56. Morphology of cristid obliqua on m2-3
    0: long and sharp
    1: short and rounded

57. Position of entoconid on m2-3
    0: located opposite to hypoconid at lingual edge of talonid
    1: more posteriorly located

58. Hypoconulid shape in m1-3
    0: well to moderately-developed and not compressed
    1: reduced and anteroposteriorly compressed
    2: very broad, with dorsoventral compression and occupying most of the molar wall

59. Number of roots on m4
    0: two
    1: one

60. P3 width
    0: uniform width
    1: broader posteriorly
    2: broader medially

61. Size of upper third premolar
    0: not hypertrophied
    1: hypertrophied

62. Relative height of posterior and anterior ends of P3
    0: roughly equal
    1: posterior end higher

63. P3 lingual cingulum
    0: present
    1: absent

64. P3 labial cingulum
    0: present
    1: absent

65. P3 labial ridges
 0: absent
 1: present

66. P3 lingual ridges
 0: absent
 1: present

67. Paraconule
 0: present
 1: absent

68. Metaconule extension on M1-2
 0: not lingually salient
 1: lingually salient

69. Size of metaconule on M1*
 0: small
 1; moderately sized
 2: large

70. Metaconule height relative to protoconule in M1-2*
 0: much lower than protocone
 1: slightly lower than protocone
 2: subequal in height
 3: higher than protocone

71. Paracone on M1-2
 0: present
 1: absent

72. StC and StD
 0: unfused
 1: fused

73. Relative size of StB and StC+D on M1*
 0: StB larger than StC+D
 1: subequal
 2: StC+D larger than StB

74. Relative size and proximity of paracone and StB on M1-2*

0: paracone larger than and distant from StB

1: StB larger than and distant from paracone

2: paracone reduced and coalescent with StB

3: paracone greatly reduced and coalescent with StB

75. Labiolingual compression of StB and StC+D

0: not compressed

1: compressed

76. Metacone on M1-2

0: present

1: absent

77. Size of metacone relative to StC+D on M1-2*

0: larger than StC+D

1: slightly reduced compared to StC+D

2: greatly reduced compared to StC+D

78. Proximity of metacone and StC+D on M1-2

0: distant

1: coalescent

79. Relative position of metacone and StC+D

0: paired

1: metacone more anteriorly positioned

80. Shape of centrocrista*

0: straight

1: slightly V-shaped

2: deeply V-shaped

3: open, with premetacrista and postparacrista basally fused to lingual slopes of StC+StD and StB respectively

81. Position of protocone relative to StB*

0: protocone anteriorly placed relative to StB

1: protocone paired with StB

2: protocone posteriorly placed relative to StB

82. Position of metaconule relative to StC+D*

0: metaconule anteriorly placed relative to StC+D
1: metaconule paired with StC+D
2: metaconule posteriorly placed relative to StC+D

83. Transverse lophs
0: absent
1: present

84. StA on M2
0 forming a distinct cusp
1: absent or coalescent with StB

85. Anterior cingulum on M1
0: present
1: absent

86. Morphology of anterior cingulum of M1
0: short and narrow
1: short and broad
2: long and broad with lingual end on the crown base
3: long and broad with lingual end on the occlusal surface

87. Postmetaconular crest on M1-2
0: slightly extended labially
1: not extended labially
2: quite extended labially

88. Flexus in postmetaconular crest
0: absent
1: present

89. Premetaconular cusp on M1
0: absent
1: present

90. Compression of anterolabial root of M1
0: absent
1: present

Appendix S3. Character-State Matrix

? = missing data; - inapplicable character; a = polymorphism (0&1); b = uncertainty (0/1). No other types of polymorphisms (*e.g.*, “1&2”) were observed in this analysis.

Alphadon clemensi

????????0000000010?0100--10100000000000111000001100000000000???????000100?0
00???0??00??0-??

Pucadelphys andinus

000000000000000000?0100--10000000000000111000001100000100000000000000100
?000???1??00001-00

Didelphis albiventris

010000000000000000?0100--10000100000000?1100000110000010000000000001???00?
000???1??0000?-?0

Derorhynchus singularis

??1000???0?????0????????????0000000000?11100000110?0?010000???????000100?00
0???2??00001-00

Fieratherium sorex

??110?01???????000?0200--b100?1000000?0?1????00??1-??????-????????1?--0101000
013?-0001-10?

Riolestes capricornicus

??????????????021?0100--021???????0000????1010??01?0????0????????????????????
????0???????

Bardalestes sp.

???????????????0??????????????????000?????101?110?0?0100?????????00?10??100??
?2??00??1-??

Bardalestes hunco

???????????????0??00?101?10000?
20200??1-??

Evolestes hadrommatos

01?????????????0????????????0000100000????0101011??0?01001?00?????1110010200
00030100012100

Evolestes sp.

??????????????000???0???0000000100000??1101010110?0?010010???????111001020
001030100012?00

Lestoros inca

a21101000010001010?1200--0000001101000000001010000111110111001000011 2001
0?10211311011?2?00

Caenolestes fuliginosus

11110a00000000001010?1200--000000110100000000010100001111101110010000112011
1?10211311011?2000

Rhyncholestes raphanurus

121101000000001010?1200--000000010100000000010100001111101110010000112001
2310211311011?2000

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Pliolestes tripotamicus

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Perulestes cardichi

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Chimeralestes ambiguus

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Palaeothentes serratus

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