

First evidence of co-occurrence of multituberculate and eutherian mammals in the Cretaceous of Western Europe - paleobiogeographical implications

Supplementary Material

Supplementary Text 2 : Cladistic analysis of the relationships of cf. *Azilestes yvetteae* n. sp.

408 characters x 77 taxa, 16 states.

[illegible][illegible][illegible][illegible]

Montanalestes keeblerorum

00????????????????????1????????????????000110001110????????????????????????????????02000100111011111000
000\$3010021201100201010110001?021??
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Deltatheridium pretituberculare

00100011000000000?0?01010101210010?00000000000101?000000000010111010000022111001010111220120000000?01110021000001100101110?0
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?1??01100???1???10\$?0?20111?0202110000?0??0002?2000001000?0101???????1?0??012???01?0?0????????????????????????????
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Mayulestes ferox

00100000000000000000101010?2?0100?00000000000100???00000000010111010020122122101011111220121100000?0011000110101113011311000
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010011100?0001000101?1?201110011?10000011100002?2100001000?0111000??0?1000?0????????201100100?????1100111000110000??10001
10010?00000?0100110?0010001100000

Pucadelphis andinus

00100000000000000000101010?2?0100?00000000000101?000000000010111010020121122101101111220221101000?0011000010111113012312000
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10000?0000??0?0?11000010001100000

Eomaia scansoria

0000000000000?000?000001010?0?100101000????????010010010?00?100?10?1?0?002???100?00???1111012??00?0??001??0?0?010?01?02??01?00
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?????1????0????????????11??0????00?0?00???110?000??0???1
?0?111?0???????11?0??0??10?00????

Prokennalestes spp.

000?00?0?????????0?0???100?0?1?01010001110000000000010001010011001100*002111000000111110120000000?0010000000100110011111000
00011010011201100200010?100001010????011?1????????????????????????????????0?0????????????????????11\$????????????
????????????????10000?00111?0001110000??11000010000000?00?000????????1?00?02???11?0????????????????????????????
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Murtoilestes abramovi

00??0111021000002111000000111120120000000?0?1??000101?0111011111000
0??
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Bobolestes zenge

000?0?0?0?????0??00?00???110?0?1????????????00010000120000100110?20010022?11001001111221120000000?0010000000101111011111000
000\$201?01?01?????????010000?1????????0????????????????????????0000?0??0????????????????????????????????

[illegible]

Paranyctoides quadrans

000?0??0?????0?100?00??00?00????????????????00010???10100110011111100112211111100111112112111111000?1??00000100112112102000
010\$\$01??11?01??????????00?1?0???
??0100?11??????????
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Paranyctoides maleficus

00??1010??10011111100002211111100111112112111111000?1??00000100112112102000
00???0????????????????????????1??
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[illegible][illegible][illegible][illegible]

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00????????????????????????????????????????????10???0000?1100????????????????????????????????????????00000111112122312000
10???2010011201100200010020000?021????????????????????????????????????????????????????????????????????????????
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[illegible][illegible][illegible]

[illegible]

[illegible][illegible][illegible]

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[illegible]

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?00?11?0011001112100001010200?220
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[illegible]

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Kulbeckia kulbecke
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Zhangolestes jilinensis
 000?00?1?????1?1?211???111?0?????????????????????????00011???121??0100???000001?01131222??000
 0?*?101?????????????????????0?0??
 ???
 ???
Alymlestes kielanae
 00??0???001002210131223???00
 0??
 ???
 ???
Zalambdalestes lechei
 00\$00\$11110?21211211000111?\$?1000?21111120000000???00012100010022002021002121111102111100?220012000?0011000100221113122312100
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 000\$0111012103000101?00011110011?100000000101111\$00100211111\$0000001101000?102???1100101???00?11????11??100?0???0?????01???
 100??0?1\$2200?1?210\$01201??0112?0
Barunlestes butleri
 002\$00?1?????1211211011111?2?1????201111200?000???0??12100010022002021002121111102111100?220012000?0011000100221113122312100
 011?1010111200100200001010101?121???0?11000???0?100?110?0???0220101001?00???1?1\$01100??0???10?0?????011?1?11112001130??1
 000?0111012103000101?0?011110011?10000000?1?11???00100211111?000000???1?0??1?????????011100?0???0?0?1???100001110?0010001211
 1001?0?1????????????????????????????
Gypsonictops spp.
 00\$?00?????????????0?0???010?\$?1????2211222111000010*1\$121101100221010210022211111001111221220112220000100000002\$111312\$112000
 0002201???1200??020000?????1?021?????11??
 ???
 ???
Leptictis spp.
 0013003110000000000000001110?101001?11112221110010??000121201100220020210022211111021111221120112120000110000002\$1113122112000
 00012010111200100200001120?01?1211100112111011110101011001000002011100000010101100000000102??01100010010011111110201012120101
 10020110011001100100000011110011?10000001?10001?1001002100?111110000101100100211012??301?111???000201111000001110?0001010011
 1002?0010220001021020020101111210
Purgatorius spp.

001?00?1??300?0?1?0?0???01??1?????????2\$10000010??00020010110022\$02021002222\$11102111112112112222000?1??001?0110111122111000
0003200??
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????????????????????????????????????
Protungulatum spp.
001??0?????????0?0?000?01010?1?2????10112\$11100010??10011000111022102021002222111102111211022102222000011000*001101111\$1312000
100\$010021200100201001020001?121??1?\$?????????????????
?????????????????00000?011?1?001?10???0??211?0\$?\$001002101011?????????1?00?0201112???0????????????????????????????????????
?????????022100?011000020101110120
Oxyprimus erikseni
001????????????????????????????1????????????????????????1001200011102210202100222211110211121102210222200001?0000001101111\$1212000
10*?1010021200100???00?2???1?131??
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????????????????????????????????
Vulpavus spp.
00\$000210000000000000001010?\$?0111?00011230000011??00000000?12022002021002222111102111100?22101111\$10011001100210111122131000
010\$0?0011?00?0000001112??01?1??11\$011001\$010110001111001?0?01\$?????01?0010\$?0?????????0000110?01?01001111??110?0???2120111
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1001???00220001021010020102011100
Miacis spp.
001000210000000000000?01010?1?0111?0000123000101???00010000012022002021002221011102111100?221001\$010011001100100111110231000
01*?10100?10000?0????1111???1?1\$1?????10012?10?10?????????????????20???0??????10?1000000110000?10?010010?111111?101011?21\$0111
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1?????000?????????1?1?0?????????1??
Hyopsodus spp.
001300210100000000000011110?102010?10012001100010??0\$0221100111120020210022221111021120220221012232*00110*0000210111222221000
100\$2010111010000\$01001110?01?1211110111000011110001011?012000\$00103?0000000000?00?000?02??011?0?111001111011101010021201?1
0002011000101100100000?0?1101011?100101002\$?002??00100200101\$101?10???1?00?00201?11???0???111?0?1?02001011100011111010101100?
100210000121001021120020101110100
Meniscotherium spp.
001100210040000400000011110?102001?20012201110011??0002211001121200201110222211112122020122101223210011000000110111222031?00
00002110121000000001001120011?121111011\$0100*011000101100121?0\$02000000?0000001?0001000??000001100?2100011110??101010?\$120111
00?2011000101300100000?011101011?10010000110002???0?00210101\$0?111????1?00?0???1??1???0?0111101110020111110010111110101011111
100210000121001021000020101111120
Phenacodus spp.
001000211040000400000001110?1?2010?21012201110?11??0*0221\$001\$112002011102222211112122022022102223210011000100210111222211000
100020100\$1000?00001001120?0?????111011\$0000?01100010110012100220?03?00000*0000?00000001012??011?0021??011110?????1010?2120111

00?2011000101300100\$?002?1101011?10010000?1??02??10?002100?1210*110???1?00?0??????100\$0?01111???10020111?10010111110101010111
10121000022?001021?00020101?112?0

Ptilocercus lowii

0020003110000021100010101100200000?10011020100?????00022100110012202021002212211100110100?22111122010010000010110213122312000
10031010011200000200001020001?13111200101120001110011010010000000113001000111111100100011000111010020111011101110101002120101
0000011001101100000010?111110211?1210100211100\$11100002000?120110010101100100211112??30101111?11*1010111100100011000000111000
100110000221011021020010112111100

Plesiadapis spp.

00\$1031013000101020?0\$12?0?\$?20\$0?2\$012\$011*0?????0000\$1\$0011122\$02021*02222\$1110211012202210222320001*001000210213122102000
10032100021200000200011021101?1311120112002011110100101000000000113?01000000010?0011001?02??010?01?120001111?1112?20011200?1
1002011000101100002000?211110011?121000031??\$02?211111200201\$1110011011000? ??????2??30?111? ???1?00101???000000110000???110*0
1?01???00220011011001020112111101

Northarctus spp.

0010003200400004000000010100102011?20002\$01100010??0\$02211001112210202100222211110211012212210122320001101?????10212222202000
100121*00\$1200000200001021\$11?13111101100011101100011011010000000013?0000001001?000??0??0001110?0?\$120001110?11110200?1200?1
100?011000001100002010?111110211?12101003111?0\$11?1111200201\$1110010011000? ?????11?2??30?11111???00010??0?00100011000010?10?00
1002100002210100210?1110112211221

Tribosphenomys spp.

0032114301221?121131?02?2???3?2???0002?????????????????0210?010122002021002222211122?101220221022031?001111?????21313122102010
001?2100?102100?02??0???10101?131?1???1110????????????????????????????????10?????1?????????????????????????????????????
???
??????0002210010110200201011111?0

Adapis spp.

0013003200400004000000011100102010?\$0002201100010??00022110011122\$02021002222\$1110211012002210122320001001?????10212222002?00
10012100011000000300101021\$11?13111101\$0021101100011011010000010113?00000*0001100011011?0001110?010120001110?1101020011210?1
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???2????0221010021011110112211121

Paramys spp.

0032114301221?121131?02?2???\$?2???00022201110?????????0211?0101\$33????11??222211?22?22?2202210222320001111?????21313222101010
00*32100110210000\$??010220101?1311120?1110200011000111110?0100002113?0200000001??3011001?02??01010000100011101110202002020111
0212001200001300010000?011110001?1010000012000011101002100?11111020?001000?0?????2???0?011110?00010??0?0000*011?10?00?11211
100210000220001011020020101111210

Rhombomylus turpanensis

0032114301221?121131?02?2???3?2???2\$012\$00200?????011220200111233????10??021211?22?20100?221022032?1?1111?????11013121112000
0003\$100011210000210000020101?1211120?1110200011000111110?0100002003?0100001011101011001000001101012120001111111202002120*01
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101210000221001011020021101110120

Gomphos elkema

00\$21132012110121131102?2???\$?2????21012100000????022021200101233????11?022211?22?201020221022032?0?1111?????11313122102010
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1?1?10000220001021020111101111100

Mimotona wana

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0003?1??????10????????????01??????1120?1110?????1?01?1?????1?????????000000?1?????????????????????????????????
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Blarina brevicaudata

00\$3002\$11200\$1110300011\$?1?0?0???10021200200????0000200001001100202110202221110100100?221101022?1111000100111213112332000
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100??10???111300001000?011110031?1200000011010001000002112012101000100100100?101012??00?01111001*0000100110000011000001110010
1001100102200011210000201011101?1

Erinaceus europaeus

00\$0002211000\$10102010101110\$00????\$0011000100????00022000010012002021000222211?02100100?22110223201111000100211213122032?00
11*3\$010121000000300101020101?13111100100111111111?01101200100111100100101111?0101110*002??01001000100011111101010021200?1
04020111?1100111001000?011110011?1010100210000011001000111012101020100*000100201?1110\$010111110110010110110011011000011110201
100110010221011011120120101010110

Solenodon paradoxus

002300210130012000000010110?2?1000?10011020100????00012000010020002020012213???1120111100?120100011?0010000000201001000030?00
00013010021100000301111010101?131111011\$11111111101111001200001111100001???211101011100002???1001000000111110110100?02120111
100?0110?1211300000000?01111001021100000011000111001002112012110000110100110?????2???3010111010111020110101000011010100110010
1001100002210010211?0020101010211

Eoryctes melanus

002?00????????????0????01??2?1????10011220000????0001000?010022002021002210101102112000?120?01000?0?100000?02000110203?2000
0?0\$2????????????????????010?????????1001???0?10?11?110????0?2210100?0???2??????00?0??2???10?00?00?001111?11??0???2120111
100?0110?1\$0111101?010?1?1110????1210100211000\$1100100011101?1000?01?01????????????????0????????????????????????
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Potamogale velox

0023002101200023000010101100202000?20012210000????11012000110021102022102212001100111100?120001000?0010000000211111020032?00
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Chaetophractus villosus

011?0054????0????????1111??
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[illegible][illegible][illegible]

23 uninformative characters are made inactive

Characters active:

[illegible]

6 characters are additive :

[illegible]

77 terminal taxa are active:

- 0 Nanolestes_drescherae
- 1 Peramus_tenuirostris
- 2 Vincelestes_neuquenianus
- 3 Kielantherium_gobiense
- 4 Montanalestes_keeblersorum
- 5 Deltatheridium_pretituberculare
- 6 Mayulestes_ferox
- 7 Pucadelphis_andinus
- 8 Eomaia_scansoria
- 9 Prokennalestes_spp.
- 10 Murtoilestes_abramovi
- 11 Bobolestes_zenge
- 12 Paranyctoides_quadranis
- 13 Paranyctoides_maleficus
- 14 Paranyctoides_sternbergi
- 15 Paranyctoides_na
- 16 Eozhelestes_mangit
- 17 Sheikhdzheilia_rezvyii
- 18 Borisodon_kara
- 19 Zhalmouzia_bazhanovi
- 20 Lainodon_orueetxebarriai
- 21 Avitotherium_utahensis
- 22 Gallolestes_pachymandibularis
- 23 Parazhelestes_spp.
- 24 Aspanlestes_aptap
- 25 Zhelestes_temirkazyk
- 26 Eoungulatum_kudukensis
- 27 Cimolestes_spp.
- 28 Maelestes_gobiensis
- 29 Batodon_tenuis
- 30 Bulaklestes_kezbe
- 31 Daulestes_spp.
- 32 Uchkudukodon_nessovi
- 33 Kennalestes_gobiensis
- 34 Asioryctes_nemegtensis
- 35 Ukhaatherium_nessovi
- 36 Deccanolestes_spp.

37 Kulbeckia_kulbecke
38 Zhangolestes_jilinensis
39 Aymlestes_kielanae
40 Zalambdalestes_lechei
41 Barunlestes_butleri
42 Gypsonictops_spp.
43 Leptictis_spp.
44 Purgatorius_spp.
45 Protungulatum_spp.
46 Oxyprimus_erikseni
47 Vulpavus_spp.
48 Miacis_spp.
49 Hyopsodus_spp.
50 Meniscotherium_spp.
51 Phenacodus_spp.
52 Ptilocercus_lowii
53 Plesiadapis_spp.
54 Northarctus_spp.
55 Tribosphenomys_spp.
56 Adapis_spp.
57 Paramys_spp.
58 Rhombomylus_turpanensis
59 Gomphos_elkema
60 Mimotona_wana
61 Blarina_brevicaudata
62 Erinaceus_europaeus
63 Solenodon_paradoxus
64 Eoryctes_melanus
65 Potamogale_velox
66 Chaetophractus_villosus
67 Bradypus_variegatus
68 Tamandua_spp.
69 Orycteropus_afer
70 Rhynchocyon_spp.
71 Procavia_capensis
72 Moeritherium_trigodon
73 Azilestes_ragei
74 Mistralestes

75 *Valentinella*

76 **cf. *Azilestes yvetteae* n. sp.**

Memory for 10000 Trees. Collapsing Rule 3 : branches with no possible support (Max length = 0)

1- Unconstrained and unweighted standard analysis

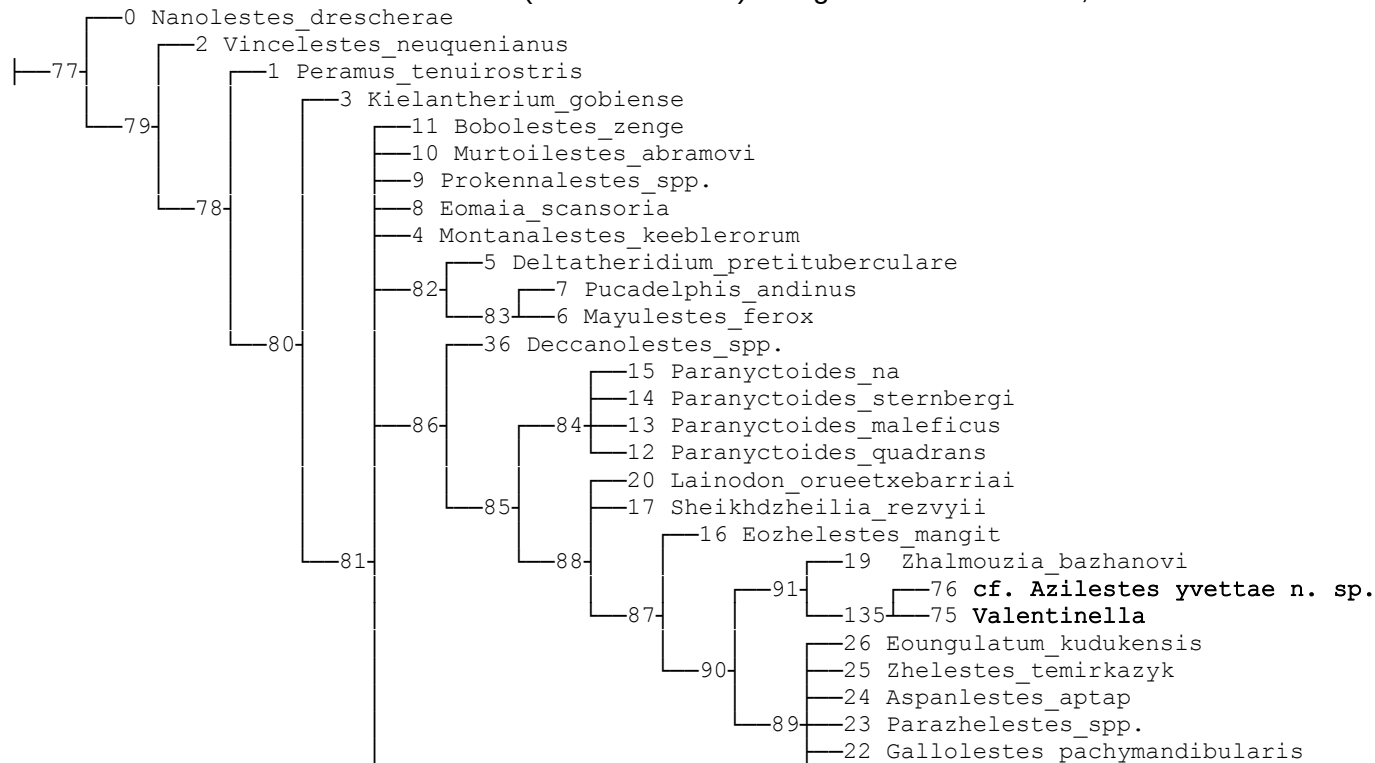
Two rounds of standard analyses, the first obtaining 60 MPTs, and the second obtaining 10000 MPT by overflow

Completed 100 random addition sequences. Total rearrangements examined: 137,434,227.

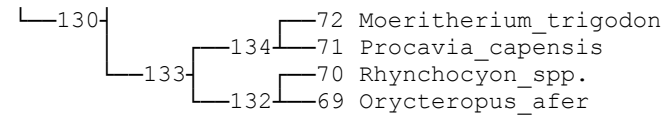
Best score hit 6 times out of 100 (some replications overflowed. Best score (TBR): 2246. 60 trees retained.

Completed TBR branch-swapping. Total rearrangements examined: 1,188,016,720. Best score (TBR): 2245. 10000 trees found (overflow).

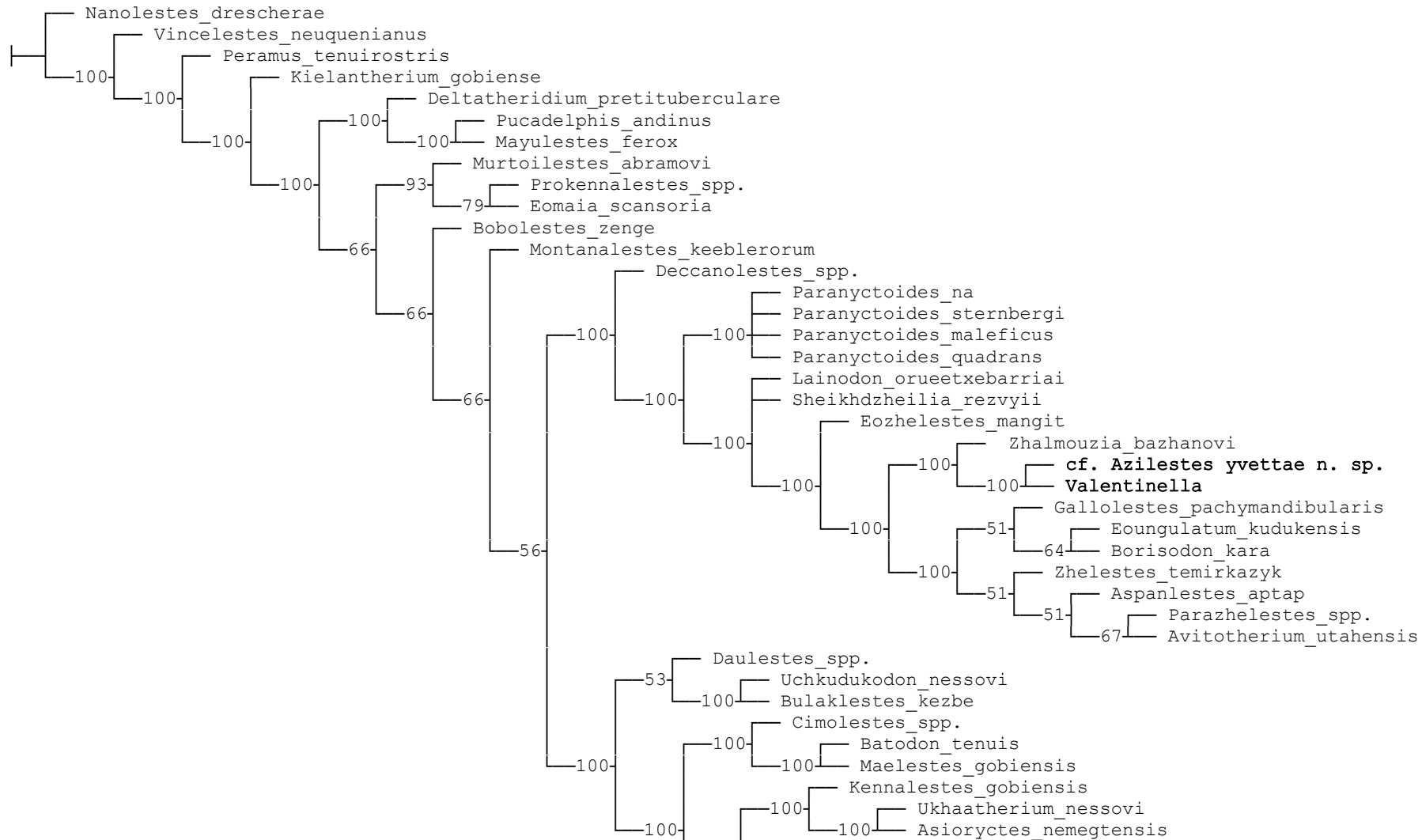
- Strict consensus of 10000 trees (0 taxa excluded). Length = 2245. RI= 57.7; CI= 25.3.







• Majority rule tree (from 10000 trees, cut 50)





2- Constrained analysis 1 : cf. *Azilestes yvetteae* n. sp. and *Azilestes ragei* constrained in the same clade (sister-groups)

Constrain command : Force + [73 76]; constrain =;

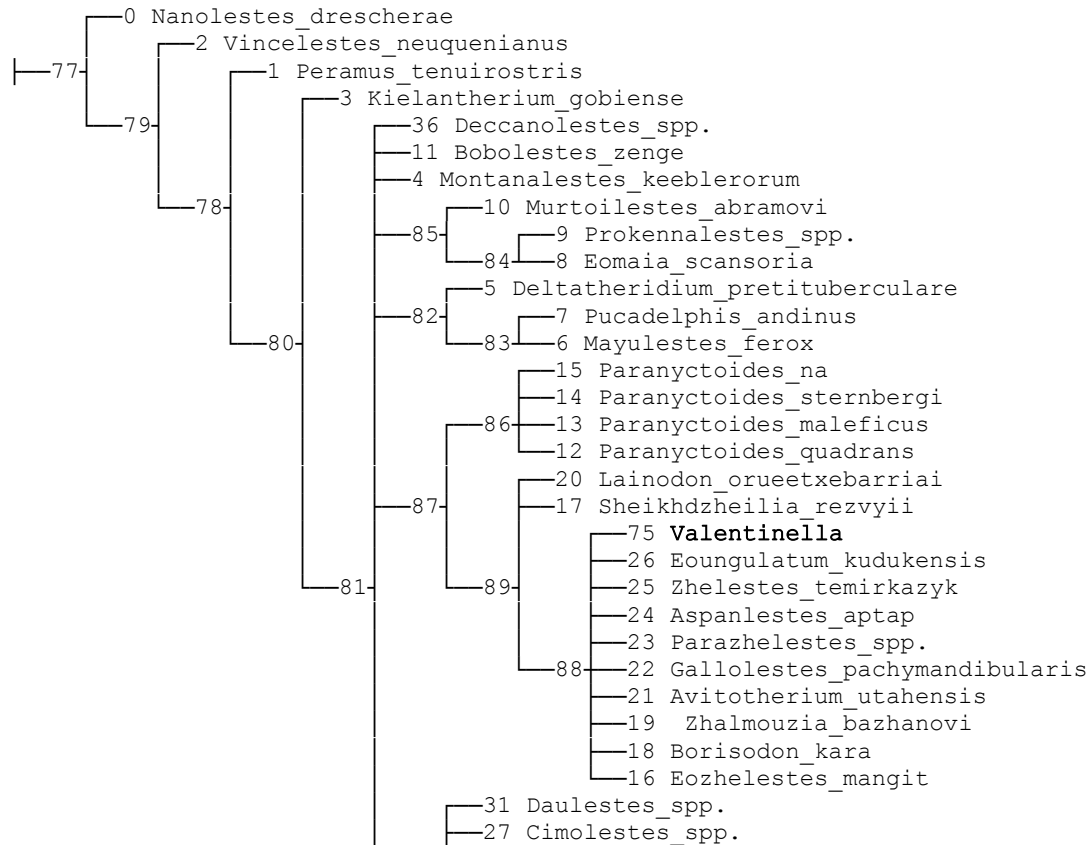
Two rounds of standard analysis, the first obtaining 120 MPTs, and the second obtaining by overflow 10000 MPTs with length of 2250 steps.

Repl. Algor.	Tree	Score	Best Score	Time	Rearrang.
100 TBR	999 of 1000	-----	2250	0:00:05	137,660,121

Completed 100 random addition sequences. Total rearrangements examined: 1, 040, 440, 824.

Constraints enforced during search. Best score hit 12 times out of 100 (some replications overflowed). Best score (TBR): 2250. 120 trees retained. Completed TBR branch-swapping. Total rearrangements examined: 1,188,016,720. Best score (TBR): 2250. 10000 trees found (overflow).

- Strict consensus of 10000 trees (0 taxa excluded). Length = 2250. RI= 57.6; CI= 25.3.





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3- Constrained analysis 2 : cf. *Azilestes yvetteae* n. sp., *Azilestes ragei*, *Valentinella* constrained in the same clade

Constrain command : Force + [73 75 76]; constrain =;

Two rounds of standard analysis, the first obtaining 30MPTs, and the second obtaining by overflow 10000 MPTs with length of 2251 steps.

Repl. Algor.	Tree	Score	Best Score	Time	Rearrang.
--------------	------	-------	------------	------	-----------

```
100 TBR 999 of 1000 ----- 2251 0:00:05 141,091,516
```

Completed 100 random addition sequences. Total rearrangements examined: 141,091,516.

Best score hit 3 times out of 100 (some replications overflowed). Best score (TBR): 2251. 30 trees retained.

Start swapping from 30 trees (score 2251)...

Repl. Algor.	Tree	Score	Best Score	Time	Rearrang.
--------------	------	-------	------------	------	-----------

```

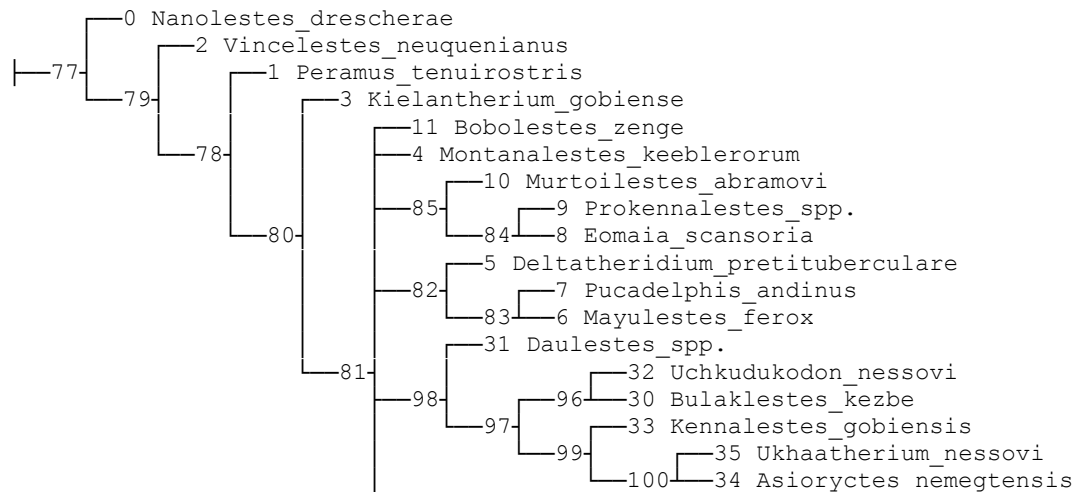
--- TBR 9999 of 10000 ----- 2251 0:00:39 1,059,133,336

```

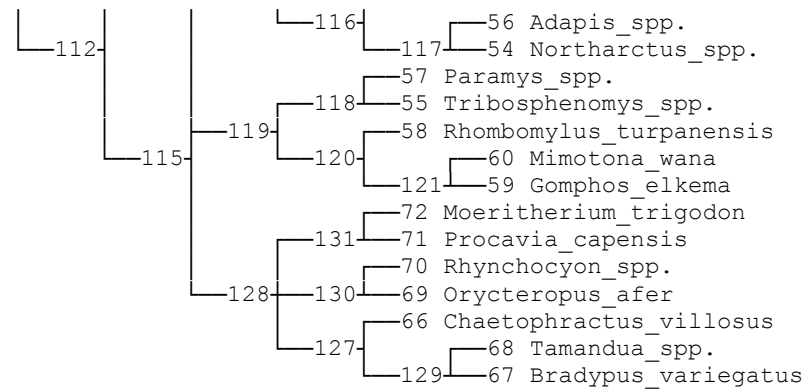
Completed TBR branch-swapping. Total rearrangements examined: 1,059,133,336.

Constraints enforced during search. Best score (TBR): 2251. 10000 trees found (overflow).

- Strict consensus of 10000 trees (0 taxa excluded). Length = 2251. RI= 57.6; CI= 25.3.







4- Constrained analysis 3 : cf. *Azilestes yvetteae* n. sp., *Azilestes ragei*, *Valentinella* constrained within Zhelestidae

```
Constrain command = Force + [16 17 18 19 20 21 22 23 24 25 26 73 75 76]; constrain =;
```

Two rounds of standard analysis the first obtaining 30MPTs, and the second obtaining by overflow 10000 MPTs with length of 2253 steps).

Repl. Algor.	Tree	Score	Best Score	Time	Rearrang.
100 TBR	999 of 1000	-----	2253	0:00:05	155,492,154

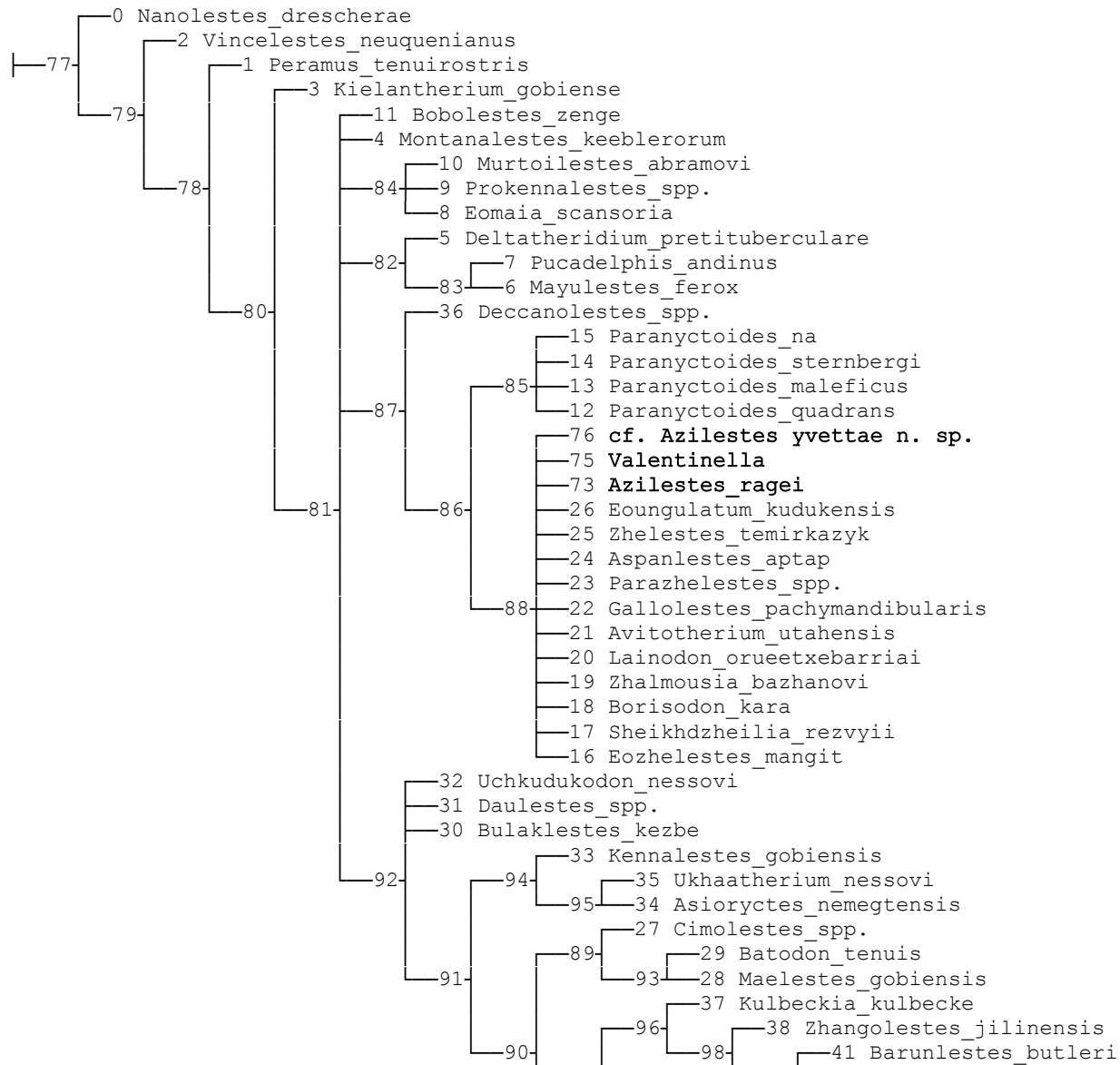
Completed 100 random addition sequences. Total rearrangements examined: 155,492,154.

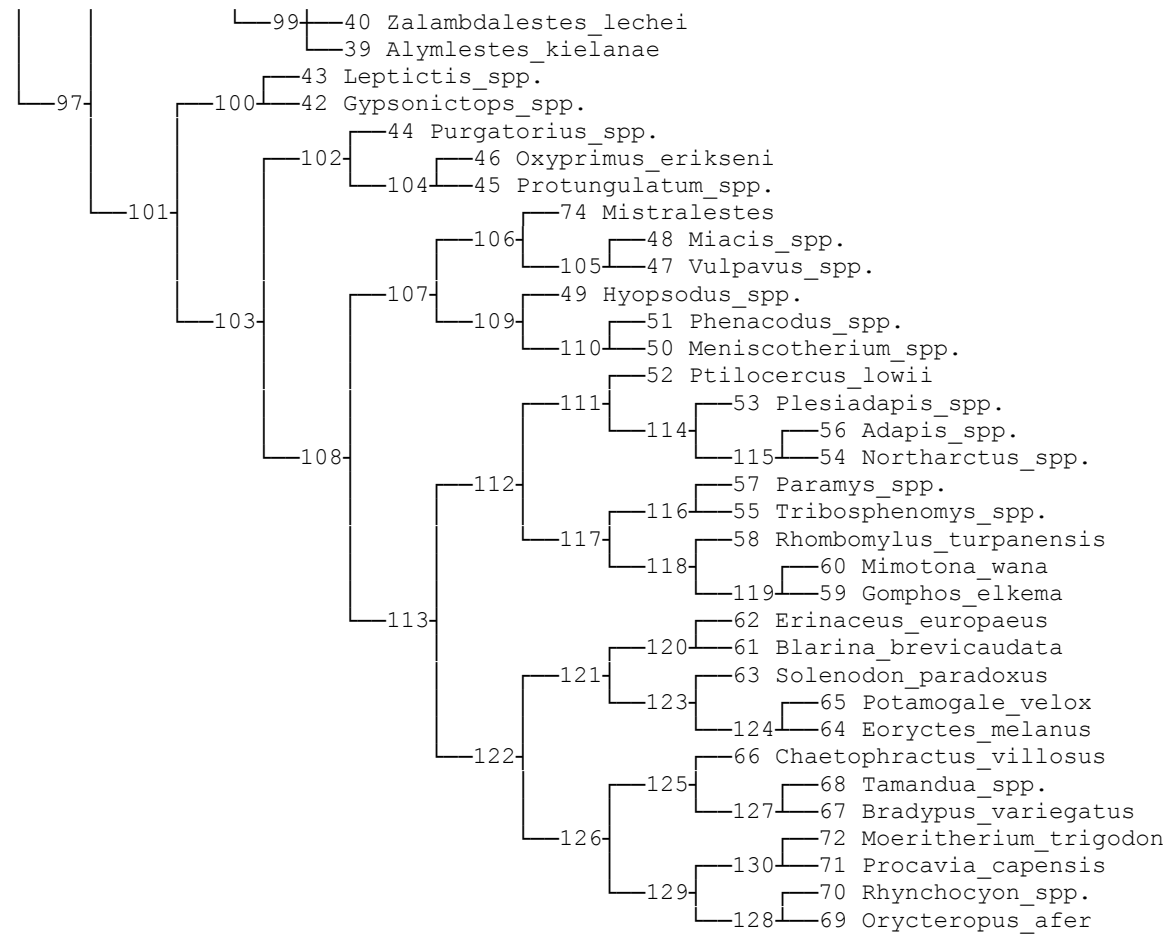
Constraints enforced during search. Best score hit 3 times out of 100 (some replications overflowed).

Best score (TBR): 2253. 30 trees retained. Completed TBR branch-swapping. Total rearrangements examined: 1,110,789,808.

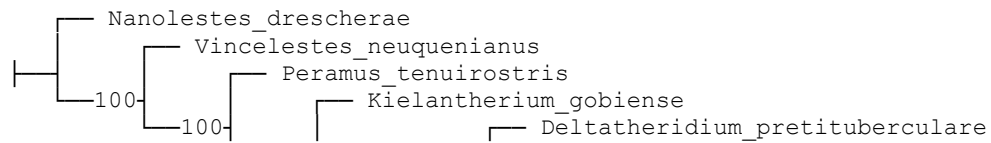
Constraints enforced during search. Best score (TBR): 2253. 10000 trees found (overflow).

- Strict consensus of 10000 trees (0 taxa excluded). Length = 2253. RI= 57.5; CI= 25.3.

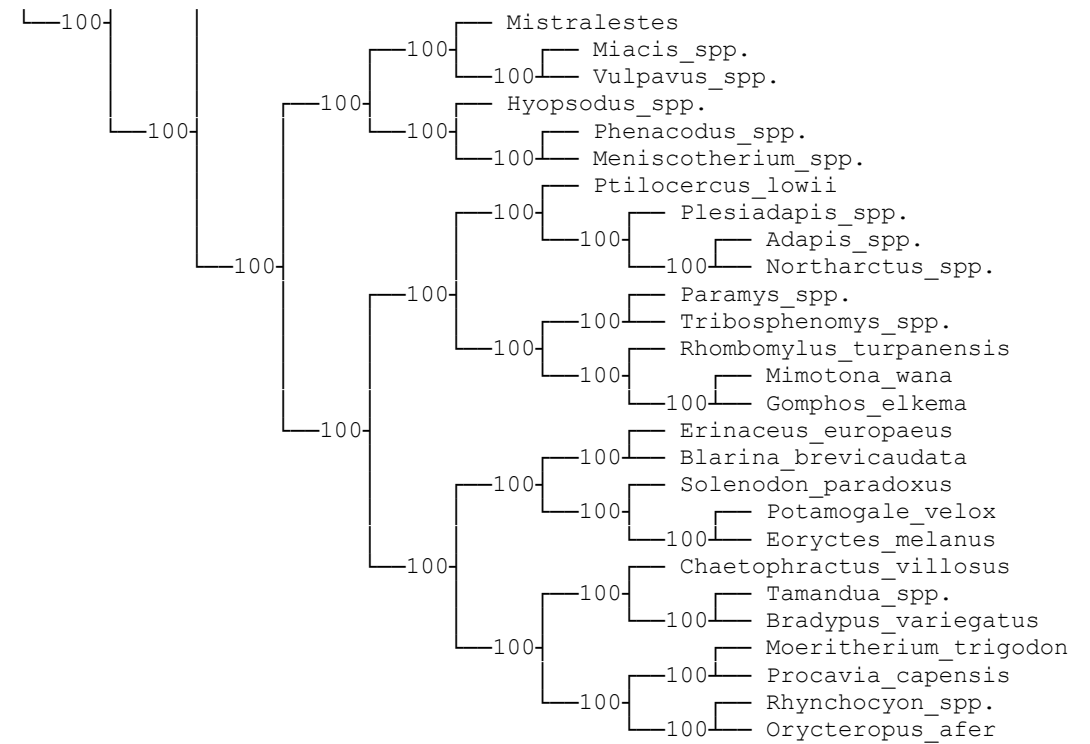




Majority rule tree (from 10000 trees, cut 50)







5- Constrained analysis 4 of *Azilestes ragei* and cf. *Azilestes yvettae* n. sp., within the clade Zhelestidae to the exclusion of *Valentinella*

Constrain command = Force + [16 17 18 19 20 21 22 23 24 25 26 73 76]; constrain =;

Two rounds of standard analysis, the first obtaining 30MPTs, and the second obtaining by overflow 10000 MPTs with length of 2254 steps

Repl.	Algor.	Tree	Score	Best Score	Time	Rearrang.
100	TBR	999 of 1000	-----	2278	0:00:05	151,543,694

Completed 100 random addition sequences. Total rearrangements examined: 151,543,694. Constraints enforced during search.

Best score hit 3 times out of 100 (some replications overflowed). Best score (TBR): 2278. 30 trees retained.

Start swapping from 30 trees (score 2278)...

Repl. Algor.	Tree	Score	Best Score	Time	Rearrang.	
---	TBR	9999 of 10000	-----	2278	0:00:42	1,090,629,584

Completed TBR branch-swapping. Total rearrangements examined: 1,090,629,584.
Constraints enforced during search. Best score (TBR): 2254. 10000 trees found (overflow).

- Strict consensus of 10000 trees (0 taxa excluded). Length = 2254. RI= 57.5; CI= 25.2.





Note: for consensus calculation, trees will be temporarily collapsed (when max. branch length = 0)

Majority rule tree (from 10000 trees, cut 50)



