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SUPPLEMENTARY ONLINE MATERIAL FOR

A new basal sphenacodontid synapsid from the Late Carboniferous of the Saar-Nahe Basin, Germany

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Files contained in the Supplementary Online Material:

1. List of European pelycosaur-grade synapsids.
2. Character list for phylogenetic analysis.
3. Data matrix for phylogenetic analysis.
4. Supplementary references.

1. List of European pelycosaur-grade synapsids

German pelycosaur-grade synapsids:

Döhlen Basin, Saxony (Döhlen Formation, Early Permian, Asselian)

Sphenacodontia

Pantelosaurus saxonicus von Huene, 1925

Thuringian Forest Basin, Thuringia (Manebach Formation, Early Permian, Asselian)

Sphenacodontia

? *Haptodus* sp. (Werneburg 1999)

Döhlen Basin, Saxony (Niederhäslich Formation, Early Permian, Sakmarian)

Sphenacodontia

Palaeohatteria longicaudata Credner, 1988

Edaphosauridae

Edaphosaurus (Naosaurus) credneri (Jaekel, 1910) Romer and Price, 1940

Bromacker Quarry near Tambach, Thuringia (Tambach Formation, Early Permian, Artinskian)

Sphenacodontia

Dimetrodon teutonis Berman, Reisz, Martens, and Henrici, 2001

Caseidae

Undescribed caseid (see Reisz 2005)

Varanopidae

Undescribed varanopid (see Berman et al. 2001)

Other European pelycosaur-grade synapsids:

Igornay near Autun, France (Early Permian, Asselian)

Ophiacodontidae

Stereorhachis dominans Gaudry, 1880

Les Télots near Autun, France (Early Permian, Asselian)

Sphenacodontia

Haptodus baylei Gaudry, 1886

Margenne near Autun, France (Early Permian, Asselian)

Sphenacodontia

Haptodus (Callibrachion) gaudryi (Boule and Glangeau, 1893) Romer and Price, 1940

Colline du Cayla near Valady, Aveyron, France (? Middle or Late Permian, "Saxonian")

Caseidae

"*Casea*" *rutena* Sigononeau-Russel and Russel, 1974

Undescribed caseid

Moissey, France (Early Permian, “Walchia beds”)

Sphenacodontia

Neosaurus (Geosaurus ?) cynodus (Gervais, 1869) Nopcsa, 1923

Kounova, Czech Republic (Late Carboniferous, Stephanian B, Gzhelian)

Sphenacodontia

Macromerion schwarzenbergii Fritsch, 1889

Edaphosauridae

Edaphosaurus (Naosaurus) mirabilis (Fritsch, 1895) Romer and Price, 1940

Nýřany, Czech Republic (Late Carboniferous, Westphalian D, Moscovian)

Opiacodontidae

Archeothyris sp. (see Reisz 1975)

Nowa Ruda (Neurode), Poland (Early Permian, “Lower Rotliegend”)

Sphenacodontia

Haptodus (Datheosaurus) macrourus (Schroeder, 1905) Romer and Price, 1940

Kenilworth, Warwickshire, England (Early Permian, Kenilworth Sandstone Formation)

Sphenacodontia

Sphenacodontidae incertae sedis (*Oxyodon britannicus* von Huene, 1908) (see Paton 1974, Eberth 1985)

Haptodus grandis Paton, 1974

Coventry, Warwickshire, England (Early Permian, Kenilworth Breccia Group)

Ophiacodontidae

Ophiacodon sp. (see Paton 1974)

2. Character list for phylogenetic analysis

Character list for the phylogenetic analysis performed in this study. The primary source of each character is listed behind the character definition. Abbreviations for authors are as follows: B, Berman et al. (1995); HB, Hopson and Barghusen (1986); L, Laurin (1993); M, Modetso (1995); RBS, Reisz et al. (1992); S, Sidor (2003); SH, Sidor and Hopson (1998).

1. Premaxilla: short (0); long, slender (1); wide (2); robust (3). (L2)
2. Premaxillary vomerine process: present (0); absent (1). (L3)
3. Septomaxilla facial exposure: absent (0); small (1); large (2). (L4)
4. Nasal: shorter than, or equal to frontal (0); longer than frontal (1). (L5)
5. Nasal posteroventral narial process: absent (0); present (1). (L6)
6. Frontal anterior process: equal in width to posterior process (0); narrow (1). (L7)
7. Frontal anterior process: short (0); long, forming at least 2/3 of length of bone (1). (L8)
8. Frontal orbital process: absent (0); poorly developed (1); extends far laterally (2). (L9)
9. Frontal posterolateral wings: present (0); absent (1). (L10)
10. Prefrontal pocket: absent (0); shallow (1); deep (2). (L11)
11. Postfrontal: straight postorbital suture (0); incised by postorbital (1). (L13)
12. Postorbital lateral surface: flat (0); slightly recessed (1); strongly recessed (2). (L14)
13. Postorbital: posterior process broad (0); narrow (1). (L15)
14. Postorbital-squamosal contact: short (0); absent (1); extensive (2). (L16)
15. Supratemporal notch of the parietal: shallow (0); deep (1). (L18)
16. Parietal: width/length ratio lower than 0.8 (0); width/length ratio higher than 0.8 (1). (L19)
The character coding for *Ianthodon schultzei* was corrected from “1” in Kissel and Reisz (2004) to “0”, as the specimen has a parietal width/length ration of 0.65.
17. Parietal foramen: at posterior end of skull table (0); well anterior of back of skull table (1). (L20)
18. Pineal rim: flush (0); ridged (1); on boss (2). (L21)
19. Supratemporal: contacts postorbital (0); separated from postorbital (1). (L25)
20. Maxillary-prefrontal contact: absent (0); present (1). (L27)
21. Maxilla supra canine buttress: absent (0); present (1); with ascending process (2). (L28)
22. Maxilla preorbital dorsal process: absent (0); present (1). (L29)
23. Lacrimal: enters naris (0); excluded from naris (1). (L30)
24. Lacrimal: longer than ½ preorbital length (0); shorter than ½ preorbital length (1). (L31)
25. Lacrimal orbital contribution: large (0); small (1). (L32)
26. Jugal posterior process: narrow (0); broad (1). (L33)
27. Jugal anterior process: narrow anteriorly (0); broad anteriorly (1). (L34)
28. Jugal-squamosal suture orientation: posteroventral (0); indented (1); anteroventral (2); jugal indented (3). (L35)
29. Squamosal external acoustic meatus: absent (0); present (1). (L37)
30. Quadratojugal: borders cheek ventrally (0); confined to rear corner of temporal fenestra (1). (L38)
31. Basipterygoid articulation: present (0); absent (1). (L39)

32. Parasphenoid ventral plate: broad, with shallow median groove (0); narrow, shallow median groove (1); narrow, deep median groove (2); no groove, median keel (3); narrow, shallow groove and median keel (4); wide, median keel (5). (L41)
33. Interpterygoid vacuity: long (0); short (1). (L42)
34. Jaw joint: posterior to occiput (0); even with occiput (1). (L46)
35. Paroccipital process: extends horizontally (0); ventrolaterally (1). (L48)
36. Paroccipital process: extends laterally (0); posterolaterally (1). (L49)
37. Paroccipital process: broad, blade-like (0); narrow, blade-like (1); narrow, rod-like (2). (L50)
38. Stapes shaft: massive, rod-like (0); blade-like (1); slender, rod-like (2). (L51)
39. Dentary-coronoid-surangular profile: horizontal (0); strongly arched dorsally (1). (L53)
40. Posterior end of dentary: well below dorsal edge of jaw (0); at dorsal edge of jaw (1). (L54)
41. Anterior coronoid: present (0); absent (1). (L55)
42. Angular reflected lamina: absent (0); not incised (1); moderately incised (2); deeply incised (3). (L56)
43. Angular reflected lamina: absent (0); shallow (1); deep (2). (L57)
44. Surangular contribution to notch of reflected lamina: absent (0); small (1); large (2). (L58)
45. Splenial overlaps angular: along complex suture (0); ventrally (1); dorsally (2); ventrally and dorsally (3). (L59)
46. Posterior end of surangular: straight (0); strongly curved ventrally (1). (L60)
47. Retroarticular process: absent (0); small (1); large (2). (L61)
48. Retroarticular process: horizontal (0); curved ventrally (1). (L62)
49. Shape of marginal teeth: slender, sharp (0); robust, peg-like, bulbous (1); robust, sharp (2); teardrop-shaped (3); spatulate or short, blunt and straight (4). (L63*)
50. Cutting edges: absent (0); present (1). (L64)
51. Marginal teeth serrations: absent (0); present (1). (L65)
52. Premaxillary teeth: in shallow sockets (0); in deep sockets (1). (L66)
53. Premaxillary tooth size: decreasing posteriorly (0); subequal size (1). (L67)
54. Premaxillary tooth number: five or more (0); less than five (1). (L68)
55. Greatly enlarged first premaxillary tooth: absent (0); present (1). (L69)
56. Caniniform root: not swollen (0); expanded into choana (1). (L70)
57. Number of maxillary precaniniform teeth: four or more (0); from one to three (1); none (2). (L71)
58. Caniniform tooth: no more than twice as high as postcaniniform teeth (0); at least three times as high (1). (L72)
59. Number of upper postcaniniform teeth: 13 or more (0); 12 or fewer (1). (L73)
60. Anterior dentary teeth: small (0); 2nd slightly enlarged (1); 2nd greatly enlarged (2); all large (3). (L75*; RBS61*)
61. Vomerine teeth: present (0); absent (1). (L77)
62. Ectopterygoid teeth: present (0); absent (1). (L79)
63. Posterior coronoid teeth: absent (0); present (1). (L81)
64. Neural spines: short (0); elongate (1); greatly elongate (2). (L82)
65. Neural spine shoulders: absent (0); present anteriorly and posteriorly (1). (L83)
66. Neural arch excavations: absent (0); shallow (1); deep (2). (L84)

67. Vertebral notochordal canal: present in adult (0); absent in adult (1). (L85)
68. Anterior dorsal intercentra: present (0); absent (1). (L86)
69. Cervical centra: ridged (0); keeled ventrally (1); rounded (2). (L92)
70. Length of cervical centra: shorter (0); equal (1); longer than dorsal vertebrae (2). (L93)
71. Cervical ribs anterior process: present (0); absent (1). (L95)
72. Sacral ribs: point ventrally (0); laterally (1). (L96)
73. Scapula: broad above glenoid (0); narrow above glenoid (1). (L97)
74. Scapula: does not flare (0); flares distally (1). (L98)
75. Supraglenoid buttress: present (0); absent (1). (L99)
76. Scapulocoracoid notch: absent (0); shallow (1); deep, low (2); deep, high (3). (L100)
77. Cleithrum and clavicle: in contact (0); separated (1). (L101)
78. Ossified sternum: absent (0); present (1). (L102)
79. Ectepicondylar groove: open (0); enclosed (1). (L103)
80. Manual intermedium: larger than medial centrale (0); smaller than medial centrale (1). (L104)
81. Ilium dorsal groove: present (0); absent (1). (L106)
82. Ilium: narrow and posterodorsally oriented (0); expanded anterodorsally, with horizontal dorsal margin (1). (L107)
83. Acetabulum outline: oval (0); circular (1). (L108)
84. Acetabulum: shallow (0); deep (1). (L109)
85. Supraacetabular buttress: absent (0); present (1). (L110)
86. Intertrochanteric fossa: prominent (0); absent (1). (L111)
87. Femoral head: terminal (0); inflected medially (1). (L112)
88. Femoral condyles: prominent (0); not projecting beyond shaft (1). (L113)
89. Femoral head: elongate (0); spherical (1). (L114)
90. Posterior condyle: extends further distally than anterior condyle (0); subequal to anterior condyle (1). (L115)
91. Femoral ventral ridge system: prominent (0); feeble (1). (L116)
92. Tibial articular surface of astragalus: mediodistal (0); anterodorsal (1). (L117)
93. Lateral centrale: no larger than second or third tarsals (0); larger than second or third tarsals (1). (119)
94. Pedal phalangeal formula: 2-3-4-5-4 (0); 2-3-4-4 or 3-3 (1). (L121)
95. Snout: short (0); elongate (1). (RBS2)
96. Premaxilla: ventral edge straight (0); sloping anteroventrally (1); sloping anterodorsally (2). (RBS3)
97. Nasal-maxillary suture: no contact (0); shorter than (1), longer than nasal lacrimal suture (2). (RBS10)
98. Parietal: narrow (0); broad posterolateral wing (1). (RBS15)
99. Parietal: lateral edge concave or straight (0); lateral edge convex (1). (RBS16)
100. Maxilla ventral margin: straight (0); gently convex (1); strongly convex (2). (RBS25)
101. Pterygoid anterior process: low dorsal flange (0); tall dorsal flange (1). (RBS36)
102. Pterygoid quadrate process: has medial shelf (0); lacks medial shelf (1). (RBS37)
103. Stapes dorsal process: slender (0); broad (1); absent (2). (RBS40)
104. Basicranial articulation: level with pterygoid transverse flange (0); posterior to pterygoid transverse flange (1). (RBS42)
105. Prearticular: nearly straight (0); twisted posteriorly (1). (RBS52)

- 106. Pterygoideus process: formed by articular and prearticular (0); mainly by articular, sheathed by prearticular (1). (RBS53)
- 107. Pterygoid teeth: arranged in three groups (0); two groups (1). (RBS66)
- 108. Axis: neural spine expanded anteroposteriorly (0); narrow dorsally (1). (RBS68)
- 109. Dorsal centra: ridged (0); keeled ventrally (1). (RBS71)
- 110. Neural spines: blade-like (0); rounded in cross-section (1). (RBS75)
- 111. Neural spines: anterior and posterior grooves absent (0); present (1). (RBS78)
- 112. Supraglenoid foramen: on posterior surface (0); on lateral surface of scapula (1); no foramen (2). (RBS82)
- 113. Posterior coracoid: triceps process small (0); large (1); absent (2). (RBS83*)
- 114. Limbs: short and stout (0); long and slender (1). (RBS84)
- 115. Ulna: broad olecranon (0); narrow, elongate olecranon (1); small (2). (RBS86)
- 116. Ischium: slender distally (0); expanded posterodorsally (1). (RBS91)
- 117. Fibula: distal head/shaft diameter less than 3/1 (0); equal or greater than 3/1 (1). (RBS94)
- 118. Astragalus: proximal neck region short (0); long (1); absent (2). (RBS95*)
- 119. Calcaneum: width and length subequal (0); length greater than width (1). (RBS96)
- 120. Shape of anterior portion of dentary: tapering continuation of posterior regions (0); dorsoventral deepened compared with posterior portions (1). (HB:2.21.1*; SH98*; S4*)
- 121. Splenial appearance: visible near symphysis in lateral view (0); or not visible in lateral view (1). (B59*; SH90*; S26*)
- 122. Level of jaw articulation: set below dentary tooth row (0); roughly at or slightly above level of dentary tooth row (1). (M15*; S52*)

3. Data matrix for phylogenetic analysis

Missing and inapplicable data are coded as “?”, polymorphisms for states 0 and 1 as “A”, polymorphisms for states 1 and 2 as “B”, polymorphisms for states 0 and 2 as “C”, polymorphisms for states 0 and 5 as “D”, polymorphisms for states 1 and 4 as “E”, polymorphisms for states 0, 1 and 2 as “F”, and polymorphisms for states 0, 2 and 3 as “G”.

	1	111111112	222222223	333333334	444444445
Taxon	1234567890	1234567890	1234567890	1234567890	1234567890
Varanopidae	000000000	0000000A0	010000000	0D000000A	000?002001
Ophiacodontidae	1001001001	010000000	2000010000	0E0000000	000?B00000
Edaphosauridae	0000000B00	011A001010	0000000001	0000000111	000?1A10A0
<i>Haptodus</i>	0010000101	0110001110	1000000001	0000000111	000?311020
<i>Palaeohatteria</i>	0??0000100	1110A01000	1000000?01	040?????11	011020??20
<i>Pantelosaurus</i>	???0?0011?	1110011?10	1000011?01	0?00????10	0110?11?20
<i>Ianthodon</i>	01?0000102	1?101011?0	00000??01	0?????????	????????2?
<i>Cutleria</i>	0??1?01110	111C110?10	?0?011101	???0????11	?121????21
<i>Sphenacodon</i>	3101111212	1212110100	1010111001	0200111111	0122311131
<i>Ctenospondylus</i>	31011112?2	1212????00	1010111001	?2?0111111	?1?????131
<i>Dimetrodon</i>	3101111212	1212110100	1010111001	0200111111	0122B11131
<i>Secodontosaurus</i>	3101111101	1210101110	1011001201	0210112111	012??01121
<i>Cryptovenator</i>	???????????	???????????	???????????	?????????1?	?????????31
<i>Biarmosuchus</i>	2?210??202	0210?102?1	?111001211	1311002111	1220??1141
Dinocephalia	CA2A000B0C	A2A0?AAB11	?111A11G11	1311A00111	122A112141

	1	111111112	222222223	333333334	444444445
Taxon	1234567890	1234567890	1234567890	1234567890	1234567890
Varanopidae	A000000000	0000010000	?0000F?000	0000000000	0000000000
Ophiacodontidae	A000000001	0000000000	00010A0?00	0000000000	0000100001
Edaphosauridae	0010000??0	0?12110000	?0000A0010	1100000000	00?0000001
<i>Haptodus</i>	0100A00001	0010010000	000002??00	?100000000	0000010111
<i>Palaeohatteria</i>	010110000?	00000100?0	100000?000	11?0000000	0000010111
<i>Pantelosaurus</i>	01????000?	00?001000?	1000000000	1100000000	00??010111
<i>Ianthodon</i>	010110000?	???????????	???????????	???????????	????000111
<i>Cutleria</i>	010110?001	?0?00100?0	1?010??0?0	???????????	????0??1?1
<i>Sphenacodon</i>	1101111002	1001020012	?0010?0000	1100000000	0010011112
<i>Ctenospondylus</i>	0?011?1002	10?2120012	1??????0?0	1?000?????	????011112
<i>Dimetrodon</i>	1101111002	1002120012	?0010A0000	1100000000	0010012112
<i>Secodontosaurus</i>	0?00000000	1102120?12	?010??????	1100000000	0????112111
<i>Cryptovenator</i>	0?????????1	???????????	???????????	???????????	???????????
<i>Biarmosuchus</i>	1110002113	110002110?	1111131101	1111111111	1111022001
Dinocephalia	11A0002113	110002110?	?111131111	1111111111	111102200B

	1111111111	1111111111	11
	0000000001	1111111112	22
Taxon	1234567890	1234567890	12
<i>Varanopidae</i>	0000000000	0101001100	A1
<i>Ophiacodontidae</i>	1000000000	0000000000	11
<i>Edaphosauridae</i>	?1101??001	00000000?0	0A
<i>Haptodus</i>	1110101000	0111100110	01
<i>Palaeohatteria</i>	11111?1000	0??1?00??0	01
<i>Pantelosaurus</i>	??????10?0	0??1010??0	01
<i>Ianthodon</i>	???????????	???????????	??
<i>Cutleria</i>	???????0?0	0111?????0	11
<i>Sphenacodon</i>	1111111110	0111111111	01
<i>Ctenospondylus</i>	1111111110	011111??11	??
<i>Dimetrodon</i>	1111111111	1111111111	00
<i>Secodontosaurus</i>	0110111111	111111?10	01
<i>Cryptovenator</i>	???????????	??????????1	0?
<i>Biarmosuchus</i>	?1211010?0	0221?0?211	10
<i>Dinocephalia</i>	11?1101000	0221C0021A	A0

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