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SUPPLEMENTARY DATA

Cranial anatomy, ontogeny and relationships of the Late Carboniferous tetrapod *Gephyrostegus bohemicus* Jaekel, 1902

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APPENDIX S1. List of characters used in phylogenetic analysis. All characters are unordered and of equal weight.

(1) Position of midpoint of maximum anteroposterior orbit diameter: closer to tip of snout than to posterior end of skull (0); at midlength of skull (1); closer to posterior end of skull than to tip of snout (2).

(2) Antorbital vacuities absent (0) or present (1).

(3) Skull longer than broad (0), as broad as long (1), or broader than long (2).

(4) Preorbital region of skull less than twice as wide as long (0) or at least twice as wide as long (1).

(5) Nasals much shorter than frontals (less than one-third as long as frontals) absent (0) or present (1).

(6) Total width of premaxillae more (0) or less (1) than two-thirds the width of the skull table.

(7) Distinct, triangular or digitiform, dorsal alary processes of premaxillae, widely separated by intervening nasals, absent (0) or present (1).

(8) Prefrontal-postfrontal suture present (0) or absent (1).

(9) Position of prefrontal-postfrontal suture relative to the mid-length of the frontal: posterior (0); at the same level (1); anterior (2).

(10) Prefrontal-postfrontal contact broad (0) or point-like (1).

(11) Postorbital medial margin straight for most of its length or very gently curved (1) or irregularly sinuous (0).

(12) Postorbital not broader than long (0) or broader than long (1).

(13) Postorbital without distinct ventrolateral (jugal) ramus (0), with incipient ramus (1), with well-developed and elongate ramus (2).

(14) Postorbital without distinct dorsomedial ramus for postfrontal (0), with incipient ramus (1), with elongate ramus (2).

(15) Absence of outgrowth from posterolateral ventral surface of tabular (0), presence of outgrowth in the form of spike-like unornamented component (1), elongate and recurved unornamented blade (2), rectangular, unornamented plate-like process (3), presence of conical extension of unornamented portion of posterolateral corner of tabular (4), small rectangular, ornamented plate-like process (5).

(16) Tabular buttons absent (0) or present (1).

(17) Prolonged posterolateral ornamented surface of tabular absent (0) or present (1).

(18) Septomaxilla absent (0) or present (1).

(19) Septomaxilla forming part of skull roof (0) or not (1).

(20) Septomaxilla touching nasal (0) or not (1).

(21) Nostrils slit-like (0), round (1), elliptical and wide (2), elliptical and elongate (3), keyhole-shaped and longer than premaxilla (4).

(22) Maximum diameter of nostril less wide than (0) or almost as wide as premaxilla (1).

(23) Intertemporal present (0) or absent (1).

(24) Intertemporal smaller than supratemporal (0) or larger than/comparable in size with supratemporal (1).

(25) Parietal-tabular contact absent (0) or present (1).

(26) In lateral view quadratojugal underlies jugal (0), jugal-quadratojugal suture is oriented approximately dorsoventrally (1), jugal underlies quadratojugal (2).

(27) Jugal not interposed between maxilla and quadratojugal (0) or interposed (1).

(28) Otic flange, a ventrolateral sheet of bone formed by supratemporal and tabular (crista arcuata of tabular), absent (0) or present (1).

- (29) Prefrontal-jugal suture absent (0) or present (lacrima not entering orbit) (1).
- (30) Dorsal-most part of quadratojugal above (0) or below (1) highest point of maxilla.
- (31) Posteromedial extensions of occipital flanges of postparietals projecting posteroventrally (a rearward process) absent (0) or present (1).
- (32) Suborbital ramus of lacrima present and long (more than one-third of ventral half of orbit rim) (0), present and short (less than one third of ventral half of orbit rim) (1), or absent (2).
- (33) Postorbital region of jugal longer (0) or shorter (1) than suborbital region.
- (34) Depth of suborbital region of jugal more (0) or less (1) than half of the length of anteroposterior orbit diameter.
- (35) Length of postorbital region of jugal more (0) or less (1) than one-third of the length of the postorbital cheek region.
- (36) Postorbital process of jugal rectangular, with bluntly terminated posterior end present (1) or absent (0).
- (37) Broad (0) or narrow (1) postorbital-jugal contact (length of suture less than three times the distance between dorsal-most and ventral-most point of orbital edge of postorbital).
- (38) Posterior apex of postorbital lying posterior to (0) or anterior to/at same level as rearmost part of postfrontal (1).
- (39) Paired parietals not broader than long (0) or broader (1).
- (40) Lateral margins of skull table irregular (0), straight or gently concave (1), convex at level of supratemporals (2).
- (41) Squamosal embayment absent (0), shallow (squamosal straight) (1), deep and dorsoventrally broad (squamosal semicircular) (2), deep and dorsoventrally narrow (oval in dorsal view) (3), shallow and dorsoventrally broad (4).

- (42) Unornamented otic flange of squamosal absent (0), narrow (1), narrow dorsally and broad ventrally (2), narrow ventrally and broad dorsally (3).
- (43) Squamosal-tabular suture present (0) or absent (1).
- (44) Maxilla highest point in anterior third of its length (0) or at its midlength (1).
- (45) Palatal vacuities absent (0), present and narrow (1), or present and broad (2).
- (46) Shape of cultriform process biconvex (0), narrowly triangular (1), parallel-sided (2), or with proximal constriction followed by swelling (3).
- (47) Ventral surface of pterygoid palatal ramus covered with shagreen (0), with radiating, densely spaced low ridges with denticle rows (1), with radiating sharp ridges with denticle rows (2), with densely spaced denticle rows radiating from posterior midlength of palatal ramus (3), with tooth row(s) along medial margin (4), with multiple rows coursing mostly parallel to mesial and lateral margins of palatal ramus (5), smooth (6).
- (48) Transverse process of pterygoid absent (0) or present (1).
- (49) Teeth on transverse process of pterygoid absent (0) or present (1).
- (50) Pterygoids not visible in lateral aspect below ventral margin of jugal and quadratojugal (0) or visible (1).
- (51) Posterior plate of parasphenoid absent (0) or present (1).
- (52) Ventrolateral crests of parasphenoid absent (0) or present (1).
- (53) Median posterior process of parasphenoid absent (0), present and unpaired (1), present and paired (2).
- (54) Posterolateral processes of parasphenoid absent (0), present and short (1), or present, elongate, and wing-like (2).
- (55) Parasphenoid cultriform process with shagreen (0), with patch of denticles (1), with radiating ridges and denticle rows (2), smooth (3).

- (56) Posterior plate of parasphenoid behind cultriform process with shagreen (0), with denticulated field (1), sculptured with or without denticles (2), with light striations (3), smooth (4), smooth with denticles arranged in rows or scattered (5).
- (57) Ventral, exposed surface of vomers narrow, elongate and strip-like (1) or not (0).
- (58) Fangs on vomer present (0) or absent (1).
- (59) Shagreen on vomer absent (0) or present (1).
- (60) Presence (0) or absence (1) of subcentral tooth row (teeth comparable in size to marginal series, often aligned with fangs) on vomer, or presence of row along medial margin (2).
- (61) Denticle row (line of small teeth between tooth row and lateral margin of the bone) on vomer present (0) or absent (1).
- (62) Fangs on palatine present (0) or absent (1).
- (63) Shagreen on palatine absent (0) or present (1).
- (64) Tooth row on palatine present (0) or absent (1).
- (65) Denticle row on palatine present (0) or absent (1).
- (66) Fangs on ectopterygoid present (0) or absent (1).
- (67) Shagreen on ectopterygoid absent (0) or present (1).
- (68) Presence (0) or absence (1) of tooth row on ectopterygoid present (0) or absent (1).
- (69) Denticle row on ectopterygoid present (0) or absent (1).
- (70) Denticle rows on vomer (continuation of rows on pterygoid) absent (0) or present (1).
- (71) Denticle rows on palatine (continuation of rows on pterygoid) absent (0) or present (1).
- (72) Denticle rows on ectopterygoid (continuation of rows on pterygoid) absent (0) or present (1).
- (73) Row(s) of denticles lining the exochoanal margin absent (0) or present (1).
- (74) Ectopterygoid partly separated from cheek (1) or not (0).
- (75) Ectopterygoid longer than (0), as long as (1), shorter than (2) palatine.

- (76) Anterior, triangular, wedge-like, more or less distinct process of parasphenoidal plate immediately anterior to basipterygoid processes absent (0) or present (1).
- (77) Lateral margins of posterior plate of parasphenoid not sharp (0) or sharp (1).
- (78) Lateral margins of posterior plate of parasphenoid raised all around (1) or not (0).
- (79) Lateral margins of posterior plate of parasphenoid confluent with anterior wedge-like process (1) or not (0).
- (80) Jagged margins of posterior plate of parasphenoid behind basipterygoid processes present (1) or absent (0).
- (81) Posterolateral margins of parasphenoidal plate extend laterally from medioventral level of posterolateral processes (0) or not (forming acute angles with horizontal plane) (1).
- (82) Absence (0) or presence (1) of otic tubes.
- (83) Absence (0) or presence (1) of suborbital fenestra.
- (84) Posttemporal fossae large (dorsal surface of fossa occupying more than half of maximum width of tabular ornamented surface) (0), small (1), or absent (2).
- (85) Interclavicular stem absent (0), slightly elongated and subtriangular with blunt posterior end (1), elongate and rod-like and with broadened anterior portion (2), elongate and rod-like and with broadened posterior portion (3), elongate and rod-like and with midlength expansion along shaft (4), elongate and rod-like but without expansion along shaft and shaft with more or less posteromedially converging lateral margins (5), or elongate and rod-like but without expansion along shaft and shaft with parallel sided lateral margins (6).
- (86) Anterior margin of ventral plate of clavicle without (0) or with (1) fimbriate indentations.
- (87) Clavicle ventral plate with anterior expansion (0) or anteroposteriorly narrowed (1).
- (88) Scapula and coracoid not separate (0) or separate (1).
- (89) Cleithrum with (0) or without dorsal expansion (1).

- (90) Cleithrum with (0) or without (1) branchial lamina.
- (91) Atlantal rib present (0) or absent (1).
- (92) Gastralium chevron-like and rectangular (0), gastralium round (1), absent (2) or round or elliptical (3).
- (93) In lateral aspect, angular extends to posterior margin of jaw (1) or not (0).
- (94) Adductor crest absent (0), formed only by surangular (1), formed by posterior coronoid and surangular (2), or formed by dentary (3).
- (95) Three (0) or one (1) coronoids.
- (96) Posterior coronoid not exposed in lateral view (0) or exposed (1).
- (97) Contact between anterior coronoid and mesial lamina of splenial absent (0) or present (1).
- (98) Contact between middle coronoid and mesial lamina of splenial absent (0) or present (1).
- (99) Mesial lamina of angular absent (0) or present (1).
- (100) Rearmost part of mesial lamina of splenial closer to adductor fossa (1) than to anterior margin of lower jaw (0).
- (101) Posterior coronoid without (0) or with (1) posterodorsal process.
- (102) Suture between prearticular and surangular absent (0) or present (1).
- (103) Suture between prearticular and splenial present (0) or absent (1).
- (104) Postsplenial present (0) or absent (1).
- (105) Mesial lamina of postsplenial absent (0) or present (1).
- (106) Denticles on prearticular absent (1) or present (0).
- (107) Adductor fossa faces dorsally (0) or mesially (1).
- (108) Fangs on anterior coronoid present (0) or absent (1).
- (109) Fangs on middle coronoid present (0) or absent (1).
- (110) Fangs on posterior coronoid present (0) or absent (1).

- (111) Mesially projecting flange on dorsal edge of prearticular absent (0) or present (1).
- (112) Relatively small posterior Meckelian fenestra between prearticular and angular absent (0), present and small (1), present and large (2) (depth comparable with size of adductor fossa; occasionally shifted slightly anteriorly to involve postsplenial).
- (113) Relatively small anterior Meckelian fenestra between splenial, postsplenial, and prearticular absent (0), present and small (1), present and large (2) (depth comparable with size of adductor fossa; occasionally shifted slightly anteriorly to involve postsplenial).
- (114) Single, large elongate Meckelian fenestra leaving narrow mesial exposure of splenial (diadectid pattern) absent (0) or present (1).
- (115) Anterior mandibular fenestra between anteromedial lamina of dentary and splenial absent (0) or present (1).
- (116) Parasymphysial plate present (0) or absent (1).
- (117) Tooth row of parasymphysial plate absent (0) or present (1).
- (118) Fang pair of parasymphysial plate absent (0) or present (1).
- (119) Denticle field on anterior coronoid absent (0) or present (1).
- (120) Denticle field on middle coronoid absent (0) or present (1).
- (121) Denticle field on posterior coronoid absent (0) or present (1).
- (122) Anterior fang pair on dentary present (0) or absent (1).
- (123) Number of presacral vertebrae: 30 (0), 30–38 (1), more than 38 (2), 30–28 (3), fewer than 28 (4).
- (124) Pleurocentra paired (0), fused ventrally but forming incomplete rings dorsally (1), forming complete rings (2), fused dorsally but not ventrally (3), with dorsal extremities in contact but not fused (4).

- (125) Intercentra low (0), crescent (1), disc-like (2), with dorsal extremities in contact but not fused (3).
- (126) Swollen neural arches absent (0) or present (1).
- (127) Absence (0) or presence (1) of laterally compressed, rectangular to fan-shaped neural arches.
- (128) Absence (0) or presence (1) of condition: dorsal-most extremity of ossified part of neural spine aligned vertically with posterior level of pleurocentrum of the same vertebral segment.
- (129) Height of ossified portion of neural spine and arch less than the distance between pre- and postzygapophysis in lateral aspect, absent (0) or present (1).
- (130) Number of sacral ribs: one (0) or two (1).
- (131) Dorsal process of iliac blade high (0), low rounded (1), absent (2), with dorsal notch dividing the blade into small anterior and posterior processes (3).
- (132) Posterodorsal process of iliac blade elongate and slender (0), stout and abbreviated posteriorly (1), stout and broad posterodorsally (2).
- (133) Transverse line of ilium absent (0), present (1), presence of iliac shelf (2).
- (134) 'L'-shaped deltopectoral crest absent (0) or present (1).
- (135) Deltopectoral crest in the middle of humerus length (0), more or less halfway between caput humeri and radial condyle, or more proximal (1).
- (136) Ectepicondyle offset relative to latissimus dorsi process (0) or aligned with the latter (1).
- (137) Distal extremity of ectepicondyle aligned with ulnar facet (0), between ulnar and radial facets (1), aligned with radial facet (2).
- (138) Ectepicondylar foramen present (0) or absent (1).
- (139) Entepicondylar foramen present (0) or absent (1).

- (140) Distance from most proximal point of articular surface of caput humeri to radial condyle smaller (0) or greater than twice the width of caput humeri (1) in extensor view.
- (141) Entepicondyle about half as long as humeral shaft (0) or less (1).
- (142) Olecranon process absent (0) or present (1).
- (143) Tarsus without (0) or with (1) 'L'-shaped proximal element.
- (144) Manus with more than five (0), five (1), four (2), three (3) digits.
- (145) Stapedial foramen present (0) or absent (1).
- (146) Atlantal pleurocentrum paired (0) or fused (1) in mature individuals.
- (147) Anteriorly directed, mid-ventral process of axial intercentrum-atlantal pleurocentrum complex absent (0) or present (1).
- (148) Axial neural arch and pleurocentrum unfused (0) or fused (1).
- (149) Axial intercentrum and atlantal pleurocentrum unfused (0) or articulated/fused (1).
- (150) Longest mid-trunk ribs shorter than (0) or at least as long as (1) four mid-trunk vertebrae.
- (151) Suborbital process (or ramus) of lacrimal overlaps suborbital process of jugal (0) or vice versa (1) or vertical suture between both bones (2).
- (152) Triangular ornamented or denticulated field on ventral surface of posterior parasphenoidal plate bordered by distinct ridge posteriorly (0) or not (1).
- (153) Interpremaxillary fenestra absent (0) or present (1).
- (154) Elevated exochoanal portion of vomer absent (0) or present (1).
- (155) Narrow elliptical fenestra between anteromedial margins of pterygoids absent (0) or present (1).
- (156) Series of ridges running in anteromedial-posterolateral direction on posteroventral surface of vomer and anterior half of palatine or at least on one of these bones, present (0) or absent (1).

APPENDIX 2. Character-taxon data matrix used for phylogenetic analysis.

OUTGROUP

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0000000000 0000000000 0000000000 000000

Acanthostega gunnari

2000000000 00000000?? 00???00010 0?00000000 11001000?0 00000?0000
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Archeria crassidisca

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Ariekanerpeton sigalovi

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11420101?0 21?1012100 0??1?????1 110001

Balanerpeton woodi

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Baphetes kirkbyi

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Brukererpeton fiebigi

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Chroniosaurus dongusensis

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014220010? 200001?101 0?01???1?? ?11001

Crassigyrinus scoticus

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Dendrerpeton acadianum

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Diadectes absitus

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Discosauriscus austriacus

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D. pulcherrimus

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Ecolsonia cutlerensis

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Eocaptorhinus laticeps

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Eoherpeton watsoni

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Eryops megacephalus

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Gephyrostegus bohemicus

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Greererpeton burkemorani

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Ichthyostega stensioei

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Karpinskiosaurus secundus

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Lethiscus stocki

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Limnoscelis paludis

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Makowskia laticephala

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Megalocephalus pachycephalus

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Microbrachis pelikani

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Petrolacosaurus kansensis

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Pholiderpeton scutigerum

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Proterogyrinus scheelei

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Sauroplesura pectinata / scalaris

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Saxonerpeton geinitzi

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Seymouria baylorensis

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S. sanjuanensis

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Spinarerpeton brevicephalum

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Tseajaia campi

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Utegenia shpinari

1000010000 1012200101 2100101001 1111010012 1110111101 1122231001
1000110011 1111210000 01115?0111 001300??1? 1000111111 1???11???1
11320?0??0 21????????? ???1??????1 110001

Whatcheeria deltae

2000000000 1120??1??? 10000??0?0 1?00001000 0?10??0??? 1??133?0?0
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