

1. Hypodigm for *Pappochelys rosinae*

Holotype: SMNS 91360, partially articulated incomplete postcranial skeleton (Fig. 1a,b; EDFig. 5).

Paratype: SMNS 90013, disarticulated skeleton with incomplete skull (Fig. 1c,d).

Referred Specimens: SMNS 91113 and 91115, two partial postcranial skeletons; SMNS 91120, partial skeleton; SMNS 91272, partial postcranial skeleton; SMNS 91356, partial skull and postcranial skeleton (Extended Data Fig. 1); SMNS 91357, partial postcranial skeleton of large individual; SMNS 91413, left maxilla; SMNS 91895, partial postcranial skeleton; SMNS 91961, partial postcranial skeleton; SMNS 91967–91968, two isolated trunk ribs; SMNS 92044, right scapula; SMNS 92063, partial skeleton of small individual (ribs, gastralia, maxilla); SMNS 92064, disarticulated pelvic girdle and vertebrae; SMNS 92065, disarticulated postcranial skeleton of small individual (ribs, gastralia, pelvis); SMNS 92066, disarticulated remains of very small individual (dentary, frontal, jugal, prefrontal, gastralia, femur and tibia; Extended Data Fig. 2); SMNS 92067–92069, three isolated trunk ribs. All material was collected from the type horizon and locality.

2. Type Horizon and Locality

The Schumann quarry is located east of the village Eschenau in the municipality of Vellberg in northern Baden-Württemberg (Germany). Muschelkalk limestones underlying the Lower Keuper strata are quarried for road metal and building material. Since 1985 collectors have recovered vertebrate fossils from a 5-15-cm-thick horizon of dark grey sapropelic claystone in the Lower Keuper (Erfurt Formation)¹⁷. Since 2000 teams from the Staatliches Museum für Naturkunde Stuttgart have conducted systematic excavations in the quarry with the cooperation of the quarry owners who leave areas of Keuper strata unattached until they can be prospected. The fossiliferous horizon has yielded the skeletal remains of numerous autochthonous aquatic or semi-aquatic vertebrates (13 taxa of fishes, 6 taxa of temnospondyl stem-amphibians, *Pappochelys rosinae*, and a choristoderan-like reptile) and a wide range of terrestrial reptiles (including a variety of archosauriforms and a rhynchocephalian). The strata were laid down in a shallow oligohaline or freshwater lake, deposits of which can be traced in neighbouring quarries and exposures for distances of up to 5 km. The age of the Lower Keuper (Erfurt Formation) is late Middle Triassic (Ladinian: Longobardian).

3. Phylogenetic analysis

In order to assess the phylogenetic position of *Pappochelys*, we coded character states for this taxon into a comprehensive character-taxon matrix published by Lyson et al.⁵. This matrix itself represents a revised and expanded version of previously published data sets^{2,4}.

1. Premaxilla small (0) or large, forming most of the snout (1).
2. Premaxilla-prefrontal contact absent (0) or present (1).
3. Premaxilla dentition present (0) or absent (1).
4. Premaxilla excluded from posterior border of external naris (0) or contributing to posterior border of external naris (1)
5. Septomaxilla, facial process: absent (0) or present (1).
6. External nares widely separated (0) or close to mid-line (1).
7. External nares separated by intranarial bar (0) or confluent (1).
8. Choana, palatal exposure: parallel medial border of maxilla (0), deflected posteromedially (1), or hidden in palatal view (2).
9. Nasals paired (0) or fused/absent (1).
10. Nasal equal in length or shorter than frontal (0) or nasal significantly longer than frontal (1).
11. Ascending process of maxilla absent (0) or between orbit and external naris (1).
12. Horn on maxilla behind external naris absent (0) or present (1).
13. Anterolateral maxillary foramen: absent or if present equal in size to all other maxillary foramina (0) or present and at least twice the diameter of all other foramina (1).
14. Length of maxilla: reaching posterior orbital margin (0) or not reaching it (1).
15. Maxilla excluded from orbital margin (0) or entering orbital margin (1).
16. Maxilla-quadratojugal contact absent (0) or present (1).
17. Lacrimal present, entering narial margin (0) present but excluded from narial margin (1), restricted to orbit or absent (2).
18. Lacrimal duct enclosed by lacrimal (0) or only partially bordered by maxilla.

19. Skull proportions: preorbital portion equal to postorbital portion (0) preorbital region longer than postorbital region (1), or postorbital region longer than preorbital region (2).
20. Prefrontal-palatine contact narrow (0) or broad, approaching mid-line (1).
21. Bulbous medial process of prefrontal absent (0) or present (1).
22. Frontal contributing to orbital margin (0) or excluded from orbital margin (1).
23. Frontal, anterior margins: frontal-nasal suture transverse (0) or oblique, forming angle of at least 30° with long axis of skull (1).
24. Frontal, lateral lappet: absent (0) or present as distinct lateral process (1).
25. Frontal, posterolateral process: absent (0) or present (1).
26. Frontal proportions: length exceeding width by at least four times (0) or length no more than twice width (1).
27. Frontal parallelogram-shaped (0) or hourglass-shaped (1).
28. Orbit shape: generally circular (0) or oval, elongate (1).
29. Postfrontal not entering upper temporal fenestra (0) or entering it (1).
30. Postorbital and supratemporal in contact (0), not in contact (1), or supratemporal absent (2)
31. Postorbital-parietal contact present (0) or absent (1).
32. Postorbital: posterior extent not in line with posterior limit of parietal (0) or in line with posterior limit of parietal (1).
33. Jugal, posterior extent: extending to middle of cheek (0) or extending almost to back of skull (1).
34. Zygomatic arch configuration: squamosal excluded (0) or squamosal included (1).

35. Squamosal, lateral exposure: ventral process descending to orbital margin (0), ventral process terminating prior to reaching orbital margin (1), or rod-like with no ventral process (2).
36. Squamosal contribution to posttemporal fenestra absent (0) or present (1).
37. Occipital flange of squamosal poorly exposed occipitally (0) or well exposed occipitally (1).
38. Quadrate, posterior margin: straight (0), deeply excavated (1), or posterior exposure reduced (2).
39. Quadrate exposure: covered by squamosal and quadratojugal (0) or exposed laterally (1).
40. Quadrate, lateral conch: absent (0) or present (1).
41. Quadrate, anterior process: long, extending forward along its sutural contact with quadrate process of pterygoid, nearly reaching level of transverse flange (0) or short, not extending anteriorly beyond 55% of length of quadrate process of pterygoid (1).
42. Quadratojugal configuration: present and horizontal dimension exceeding vertical dimension by factor of at least three (0), present but vertical dimension exceeding horizontal one by factor of at least two (1), present, but greatly reduced and restricted to condylar region (2), or absent (3).
43. Quadratojugal ornamentation absent (0) or present (1).
44. Stapedial shaft rod-like (0) or blade-like (1).
45. Stapes robust (0) or slender without perforating foramen (1).
46. Stapes, dorsal process ossified (0) or unossified (1).
47. Parietal skull table broad (0) or strongly constricted and forming sagittal crest (1)

48. Parietal shelf for adductor musculature absent (0) or parietal dorsolaterally excavated (1).
49. Pineal foramen: in middle of skull table (0), displaced posteriorly (1), displaced anteriorly (2), or absent (3).
50. Upper temporal fossa: absent (0), present and larger than orbit (1), or present and smaller than orbit (2).
51. Lower temporal fossa: absent (0), present with quadratojugal included (1), present with quadratojugal excluded (2), or open ventrally (3).
52. Postparietal present and paired (0), present and fused (1), or absent (2).
53. Supratemporal present and large (0), present but small (1), or absent (2).
54. Intertemporal present (0) or absent (1).
55. Tabular present and short ventrally (0), present but long ventrally (1), or absent (2).
56. Supraoccipital, configuration: plate-like (0), broad or narrow (1), or very narrow, pillar-like (2).
57. Occiput, configuration: plate-like (0) or open (1).
58. Angle of occiput: vertically oriented (0) or tilted anteriorly (1).
59. Posttemporal fenestra: absent (0), small (1), or large (2).
60. Orientation of paroccipital process: extending laterally and forming angle of 90° with parasagittal plane (0), paroccipital process deflected posterolaterally at angle of about 20° from transverse width of skull (1); paroccipital process deflected dorsolaterally at angle of nearly 45° (2).
61. Paroccipital process slender (0) or heavy (1).

62. Exoccipitals meeting below foramen magnum (0) or not meeting below foramen magnum (1).
63. Basioccipital and basisphenoid separated by gap (0) or fused (1).
64. Basiparasphenoid ratio: narrowest transverse width no more than 60% of maximum length measured from basipterygoid process to posteriormost limit (0) or narrowest part (waist) exceeding 80% of length (1).
65. Ventral basicranial tubera: absent (0), present on basioccipital (1), very large on basisphenoid (2).
66. Opisthotic-cheek contact not sutured (0) or sutured (1).
67. Prootic-parietal contact absent (0) or present (1).
68. Medial wall of inner ear unossified (0) or ossified (1).
69. Occipital flange absent (0) or present (1).
70. Sphenethmoid present (0) or absent (1).
71. Pleurospenoid (ossified): absent (0), present (1), or present as alisphenoid (2).
72. Palate kinetic (0) or akinetic (1).
73. Interpterygoid vacuity: anterior border tapering sharply (0), anterior border crescentric (1), or absent (2).
74. Suborbital fenestra: absent (0), present with contribution from either maxilla or jugal forming lateral border (1), present with both maxilla and jugal excluded from lateral border (2).
75. Cultriform process long (0) or short (1).
76. Palatal process of pterygoid: extending anteriorly past anterior limit of palatine (0), ending before anterior limit of palatine (1), or sutural contact with palatine transverse (2).

77. Pterygoid flange: oriented mostly laterally and slightly posteriorly (0) or directed anterolaterally (2).
78. Transverse flange of pterygoid with denticles (0), single large tooth row (1), or edentulous (2).
79. Transverse flange of pterygoid extending below maxillary tooth row (0) or above or at level of maxillary tooth row (1).
80. Angle of transverse flange of pterygoid more than 70° from sagittal plane (0) or less than 45° from sagittal plane (1).
81. Ectopterygoid: present and edentulous (0), present and bearing teeth (1), replaced by medial process of jugal (2), or replaced by lateral process of pterygoid (3).
82. Mandibular joint: even with occiput (0), behind occiput (1), or anterior to occiput (2).
83. Distinct coronoid process: absent (0), present, formed by coronoid (1), or present, formed by dentary (2).
84. Number of coronoid bones: more than one (0) or only one (1).
85. Meckelian fossa facing mediodorsally (0) or facing dorsally, prearticular broad (1).
86. Surangular extending anteriorly to coronoid eminence (0) or terminates before reaching level of coronoid eminence (1).
87. Surangular, lateral shelf absent (0) or present (1).
88. Splenial: entering mandibular symphysis (0), excluded from mandibular symphysis (1), or absent (2).
89. Angular, lateral exposure: exposed along one third of lateral face of mandibular ramus (0), only small sliver of angular exposed (1), or not exposed laterally (2).

90. Ventral edge of angular: smooth, no ventral projection (0) or keeled (reflected lamina) (1).
91. Prearticular: extending beyond coronoid eminence (0) or stopping at coronoid eminence (1).
92. Retroarticular process absent (0) or present (1).
93. Labyrinthodont infolding present (0) or absent (1).
94. Tooth implantation: set in deep sockets (0), loosely attached to medial surface of jaw (1), or ankylosed to jaw (2).
95. Caniniform teeth present (0) or absent (1).
96. Single canine tooth absent (0) or present (1).
97. Presacral vertebral count more than 20 (0) or 20 or fewer (1).
98. Caudal vertebral count 25 or more (0) or 20 or fewer (1).
99. Vertebral centra notochordal (0) or non-notochordal (1).
100. Vertebral centra amphicoelous (0), platycoelous (1), or other (2).
101. Accessory vertebral articulations absent (0) or present (1).
102. Atlantal ribs ossified (0) or not ossified (1).
103. Cervical centra rounded and smooth ventrally (0) or keeled ventrally (1).
104. Cervical intercentra present (0) or absent (1).
105. Cervical ribs without anterior process (0) or with anterior process (1).
106. Trunk neural arches swollen with heavy zygapophyseal buttress (0), narrow, strongly excavated without heavy buttress (1), or swollen with narrow, tall zygapophyseal buttress (2).
107. Dorsal intercentra present (0) or absent (1).

108. Dorsal transverse processes short (0) or long (1).
109. Number of sacrals two (0) or three or more (1).
110. Caudal lateral projections (transverse processes) absent beyond fifth caudal (0) or present beyond fifth caudal (1).
111. Caudal ribs (transverse processes) L-shaped and curved (0) or straight (1).
112. Chevron position intercentral (0) or located on anterior pedicel (1).
113. Cleithrum present (0) or absent (1).
114. Clavicles broad (0) or slender (1).
115. Interclavicle: rhomboidal (0), T-shaped with broad transverse bar (1), or T-shaped with gracile transverse bar (2).
116. Mineralized sternum absent (0) or present (1).
117. Scapula: short and broad with height not exceeding width (measured at level of glenoid) by more than three times (0), tall and blade-like with height exceeding width by at least factor of four (1), or tall and slender, nearly cylindrical in cross-section (2)
118. Acromion: absent (0), present and blade-like (1), or present and pointed cylindrical (2).
119. Supraglenoid buttress present (0) or absent (1).
120. Coracoid ossifications: one (0) or two (1).
121. Coracoid foramen enclosed by coracoid only (0) or between coracoid and scapula (1).
122. Humerus with large epicondyles (0) or reduced epicondyles (1).
123. Humeral torsion: proximal and distal ends at 45° (0) or opposing ends at less than 20° twist (1).

124. Humeral shaft-distal end ratio: shaft length less than one third maximum width of distal end of humerus (0); shaft long at least four times width of distal end (1).
125. Humeral distal articulation with distinct trochlea and capitellum (0) or low double condyle (1).
126. Supinator process large and angled from shaft (0), large and confluent with shaft (1), or small or absent (2).
127. Ectepicondylar groove: open, notched anteriorly (0), open without notch (1), or completely enclosed foramen without groove (2).
128. Entepicondylar foramen present (0) or absent (1).
129. Radius shorter than ulna (0), radius longer than ulna (1), or radius and ulna equal in length (2).
130. Olecranon process large, well developed (0) or small or absent (1).
131. Perforating foramen in manus present (0) or absent (1).
132. Ratio of metacarpals IV/III: mc. IV larger than mc. III (0) or IV equal or smaller than mc. III (1).
133. Thyroid fenestra absent (0) or present (1).
134. Iliac blade, posterior process: present (0) or fan-shaped distally (1).
135. Iliac blade not expanded anteriorly (0) or expanded anteriorly (1).
136. Pubic tubercle small and anteroventrally directed (0) or large and downturned in lateral view (1).
137. Acetabulum oval (0) or circular (1).
138. Acetabular buttress weak (0) or triangular process (1).
139. Femoral shaft stout and straight (0) or sigmoidally curved, slender (1).

140. Fourth trochanter of femur present (0) or absent (1).
141. Trochanter major of femur: absent (0), present, deflected distally from proximal head of femur (1), pyramidal process high on femoral shaft (2), or pyramidal process at mid-length on femoral shaft (3).
142. Intertrochanteric fossa well-defined (0), reduced (1), or absent (2).
143. Distal femoral condyles prominent, projecting from distal end of shaft (0) or not projecting beyond distal end of femur (1).
144. Anterior femoral condyle larger than posterior condyle (0) or smaller or equal (1).
145. Fibula bowed away from tibia (0) or straight and not bowed away (1).
146. Perforating artery in pes located between astragalus and calcaneum (0) or located between distal ends of tibia and fibula (1).
147. Tibia-astragalus articulation loosely defined (0) or tightly fitting with well developed articulation (1).
148. Discrete astragalus absent (0) or present (1).
149. Astragalus and calcaneum: not fused in adult (0), fused in adult (1), or specialized hinge (2).
150. Articulation between distal tarsal 4 and astragalus: poorly defined (0), well defined (1), or absent (2).
151. Calcaneal tuber absent (0) or present (1).
152. Distal tarsal 1 present (0) or absent (1).
153. Distal tarsal 5 present (0) or absent (1).
154. Metatarsal V long and slender (0) or short with broad base (1).
155. Metatarsal V straight (0) or hooked (1).

156. Metatarsal V plantar tubercle absent (0) or present (1).
157. Metatarsal I/IV ratio: length of mt. I more than 50% that of mt. IV (0) or length of mt. I less than 50% that of mt. IV.
158. Number of pedal centralia: lateral and medial present (0), medial centrale absent (1), or both centralia absent (2).
159. Pedal digit V longer than pedal digit I (0) or slender, shorter than pedal digit I (1).
160. Metapodials not overlapping proximally (0) or overlapping (1).
161. Pedal phalangeal formula: 2-3-4-5(4)-4 (0), 2-3-4-4-3 (1), or 2-3-3-4-3(or fewer) (2).
162. Limbs short and stout (0) or long and slender (1).
163. Manus and pes short and broad (0) or long and slender (1).
164. Unguals shorter than phalanges (0) or unguals at least 50% longer than penultimate phalanges (1).
165. Body osteoderms: absent (0). present but few restricted to mid-line (1), or present and spread all over back (2).
166. Osteodermal ridges: absent (0), fine, regularly spaced ridges (1), or heavy, irregularly spaced ridges (2).
167. Appendicular osteoderms: absent (0) or present as conical studs (1).
168. Gastralia present (0) or absent (1).
169. Plastron absent (0) or present (1).
170. T-shaped ribs: absent, ribs circular or oval in cross-section (0); present, ribs distinctly T-shaped in cross-section and comprise an endochondral rib portion and a metaplastically ossified dermal portion (1).

171. Ribs not meeting or lying on top of each other (0) or touching one another and lying on top of each other (1).
172. Number of dorsal vertebrae more than 10 (0) or 10 or fewer (1).
173. Length of dorsal vertebrae not greatly exceeding width (0) or length more than twice centrum width (1).
174. Trunk length much greater than trunk width (0) or trunk length and trunk width approximating each other (1).
175. Sacral rib distal overlap: broad with narrow gaps between ribs (0) or small or absent with wide gaps between ribs (1).
176. Dermal skull ornamentation: absent (0), tuberosities present (1), tuberosities and pits present (2), or honeycomb texture present (3).
177. Number of dorsal ribs more than 10 (0) or 10 or fewer (1).
178. Distinctly broadened ribs: absent (0), 10 or more ribs distinctly broadened (1), or 9 or fewer ribs distinctly broadened (2).
179. Outgrowth of dermal bone from perichondral collar of dorsal ribs: absent (0), dorsal ribs have endochondral ossification (1), or present, dermal bone growing out of perichondral collar (2).
180. Dorsal ribs distinctly curved (0) or nearly straight (1).
181. Dorsal ribs ending bluntly, indicating presence of ventral ribs or sternum (0) or ending smoothly and tapered, indicating loss of ventral ribs or sternum (1).
182. Fan-shaped (flabellate) arrangement of dorsal ribs absent, with dorsal ribs roughly parallel to each other or their entire length (0) or present, with distal ends of dorsal ribs farther away from each other than proximal ends (1).

183. Sharpey's fibres on ventral portion of dorsal ribs: Sharpey's fibres present on lateral edges of ribs, but Sharpey's fibres do not extend onto the ventral portion of rib (0) or Sharpey's fibres present on ventral portion of ribs, often asymmetrically (1).
184. Dorsal neural spines distinctly broadened to form neurals: absent (0) or present (1).
185. Clavicle and interclavicle incorporated into plastron: not incorporated (0) or incorporated into immobile bony plastron (1).
186. Gastralia without lateral and medial segments (0), with lateral and medial segments (1), or paired gastralia lacking lateral and medial portions (2).
187. Gastralia not incorporated into bony plastron (0) or incorporated into bony plastron (1).
188. Dorsal osteoderms overlying ribcage not sutured together (0) or sutured together (1).
189. Peripheral bones (dermal ossifications offset from overlying scales) absent (0) or osteoderms lateral to ribcage, offset from overlying scales (1).
190. Number of ventral dermal ossifications (not including pectoral girdle elements): more than 10 ventral ossifications (0) or 10 or fewer dermal ventral ossifications (1).
191. Ventral osteoderms overlying gastralia absent (0) or present (1).

We added the following seven characters to the data set:

192. Squamosal plate-like (0) or with four distinct processes (1).
193. Premaxilla straight (0) or deflected anteroventrally (1).
194. Femur without (0) or with deep groove on the posterior face of the distal end (1).

195. Ilium with short dorsal blade of variable shape and height (0) or with posteriorly extended and straight dorsal blade (1).
196. Dorsal process of maxilla absent or if present rounded (0) or tall with pointed apex (1).
197. Median part of gastralia throughout facing anteriorly (0) or anterior gastralia with posteriorly facing median parts, intermediate ones straight medially, and posterior ones with anteriorly facing median parts (1).
198. Pubis without (0) or with lateral process (1).

The parsimony analysis was undertaken with TNT (<http://www.cladistics.org/tnt.html>), using the New Technology Search (Ratchet, 100 iterations, 100 times minimal length option). It generated a single most parsimonious tree (TL=759 steps; CI=0.32; RCI=0.21) (Fig. 4, Extended Data Fig. 5).

When the original data set (with only 191 characters) by Lyson et al.⁵ was analysed using TNT, with scores for *Pappochelys* included, it yielded three MPTs that differed in the positions of Archosauriformes, *Prolacerta*, and rhynchosaurs, as well as of kuehneosaurids, lepidosaurs, and the turtle-sauropterygian clade. In that analysis, *Pappochelys* is found to nest below *Eunotosaurus* but still within a clade with turtles.

Robustness of nodes was assessed by bootstrap, resulting in collapse of many nodes, including Diapsida and the placement of *Eunotosaurus* at the base of the turtle clade. However, the position of *Pappochelys* at the base of the turtle clade was retained, with a bootstrap value of 59%, and the placement of *Odontochelys* with 80%.

The individual nodes (Extended Data Fig. 5) are supported by derived states of the following characters:

Node 1: None.

Node 2: 22, 37, 78, 106, 148.

Node 3: 24, 32, 58, 90, 117.

Node 4: 19, 34, 44, 53, 92.

Node 5: 14, 30, 42, 55, 62, 65, 76, 103, 109.

Node 6: 11, 17, 67.

Node 7: 30, 32, 38, 41, 53, 61, 64, 68, 70, 72, 73, 75, 76, 78, 83, 84, 99, 107, 110, 111, 115, 116, 127, 131, 133, 137, 140, 141, 142, 144, 146, 149, 151.

Node 8: 57, 74, 84, 126, 158.

Node 9: 13, 20, 82, 92, 134, 153, 175.

Node 10: 6, 11, 16, 17, 49, 83, 86, 91, 106, 115.

Node 11: 23, 24, 32, 42, 60, 72.

Node 12: 55, 117.

Node 13: 14, 56, 75, 77, 95, 130, 137, 149, 158, 164.

Node 14: 16, 21, 35, 42, 65, 69, 78, 87.

Node 15: 8, 17, 22, 26, 43, 61, 63, 68, 72, 74, 79, 83, 97, 111, 112, 118, 127, 159, 165, 168.

Node 16: 64, 141, 167.

Node 17: 36, 41, 53.

Node 18: 62, 103, 124, 162, 163.

Node 19: 19, 25, 50, 88, 116, 160, 194.

Node 20: 17, 32, 48, 55, 79, 95, 102, 111, 113, 114, 115, 119, 120, 125, 130, 132, 137, 142, 144, 192, 195.

Node 21: 38, 39, 92, 110, 154.

Node 22: 18, 52, 53, 66, 70, 75, 99, 128, 129, 131, 153.

Node 23: 1, 4, 10, 25, 60, 105, 151.

Node 24: 27, 136, 149, 193.

Node 25: 61, 129.

Node 26: 3, 10, 47, 56, 94, 132.

Node 27: 20, 51, 133, 146.

Node 28: 15, 19, 27, 40, 89.

Node 29: 17, 83, 94, 129, 149, 156.

Node 30: 112, 116, 143, 162, 163.

Node 31: 1, 17, 72, 80, 105, 109, 121, 154, 157, 194.

Node 32: 35, 108, 165, 191.

Node 33: 19, 76, 83, 88.

Node 34: 18, 19, 42, 48, 50, 61, 114, 127, 170, 172, 175, 177, 178, 179, 190.

Node 35: 142, 164, 180, 181, 187, 196, 197.

Node 36: 50, 169, 184, 185, 192.

Node 37: 118, 129, 175, 189.

In addition to the traditional parsimony analysis, a Bayesian analysis was conducted on the dataset in order to assess its robustness to different methods of phylogeny estimation. The Bayesian analysis of the character-taxon matrix was

undertaken using MRBAYES v. 3.1.2. In order to allow for rates of change to vary across characters we employed the Mk model (datatype 1/4 standard) with the addition of a gamma shape parameter (rates 1/4 variable). The analysis was run for 3,000,000 generations (Markov Chain Monte Carlo (MCMC): four chains, two simultaneous independent runs), with a tree sampled every 100 generations and with the first 10 per cent of the sampled trees being discarded as the 'burn-in'. The majority-rule consensus tree with posterior probability values for each is presented in Extended Data Fig. 6. An unexpected result was the (albeit weakly supported) traditional placement of *Eunotosaurus* among Parareptilia and completely separate from *Pappochelys*, *Odontochelys* and Testudines, all of which were recovered as the sister-group of Sauropterygia among Diapsida. *Pappochelys* was firmly recovered as the sister-taxon to *Odontochelys* + (*Proganochelys* + Testudines). This analysis underscores the urgent need for a comprehensive review of the structure of the skull and postcranial skeleton *Eunotosaurus*, which is now in progress by a research group led by G. S. Bever (New York Institute of Technology, College of Osteopathic Medicine) and T. R. Lyson (Denver Museum of Nature and Science).

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Sphenacodontidae

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Gorgonopsia

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Cynodontia

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Captorhinidae

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Bradysaurus

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Scutosaurus

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Anthodon

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Procolophon

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Owenetta

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Araeoscelidia

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Claudiosaurus

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Younginiformes

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Kuehneosauridae

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Rhynchocephalia

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?0010?0001011200

Squamata

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110001[02][01]1100110011[01]1[01]210010001111[02]10[01]111000101[01]0101[01]1
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Choristodera

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Rhynchosauria

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Prolacertiformes

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Trilophosaurus

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Archosauriformes

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01]11[01]101101111[01]010[01][01]01[01]1110111000110103[12][01]11011201[01]11
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Eunotosaurus

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Sinosaurosphargis

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112?1020????1???010100?100?01?1111????1?000101???????11?0?????????????????
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Placodus

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111?01000110000?01000010?000000100000000?001010011001000

Cyamodus

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0110101201212012111101000?110100?10??1111111?1111?000101111110121??1?0010
110?111??1??0?????????000200000000100000000?001010011000000

Eosauropterygia

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Odontochelys

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Proganochelys

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1111100111010012001101011111011211111121?1100011111

Testudines

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11020101111101[01][01]0211[01]2113[02]11111101[01]1???11[01][02]011[01]0?10
0111101022?01[01]1111[02]1011[01]110001011111111110[01]11100211200[01]00[0
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Pappochelys

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?????????01100?0010?0110??1111?001100?01011111

5. Rib structure

Thin-sections were made from two trunk ribs of *Pappochelys*⁵. The shaft of the larger and better preserved rib has an asymmetrically T-shaped outline in transverse section, with a dorsal (horizontal) blade and a rounded ventral (visceral) ‘bulge’, much as in *Eunotosaurus*⁵ (Extended Data Fig. 4). There are no traces of Sharpey’s fibres on the ventral bulge. Presumably the ontogenetic development of the trunk ribs was similar to that reconstructed for *Eunotosaurus*⁵.