Appendix

Character-taxon matrix. The following are scorings for 173 characters in 15 terminal taxa and two outgroups. Square brackets surrounding terminal taxa indicate they are ichnofossils. Characters 1–172 are morphological characters scored with state 0 (primitive), states 1–4 (derived), ? (missing information), and 9 (inapplicable). All morphological characters are binary except four (characters 40, 44, 53, 63), which are unordered. (Please note that several characters have multiple states in the analysis of Wilson [2002], but only two of those states are present in the taxa analyzed here. The full list of states is given in the ''Character List'' below.) Character 173 is the stratigraphic character (within parentheses), with ordered states 0–9 and A–B. Taxa that traverse stratigraphic boundaries are polymorphic (&); those whose age is not well established are uncertain (/).

	10	20	30	40	50	60	70	80	90	100
Theropoda	0000000000	0000000000	9000000000	0000000000	0000109000	0000000009	0000900000	0000900010	1009000000	0000000000
Prosauropoda	0000000000	0000000000	9000000000	0000000000	0001109000	0010000009	0000900000	0000900000	0009000000	0000000000
[Portozuelo]	??????????	??????????	??????????	??????????	??????????	??????????	??????????	???????1??	?????????1	0?????????
Blikanasaurus	??????????	??????????	??????????	??????????	??????????	??????????	??????????	??????????	??????????	??????????
Antenonitrus	??????????	??????????	??????????	??????????	?00??09?0?	?0?0000009	00?????000	???????100	??09001??0	00??????0?
[*Tetrasauropus*]	??????????	??????????	??????????	??????????	??????????	??????????	??????????	???????1??	?????????1	0?0????????
Isanosaurus	??????????	??????????	??????????	??????????	??0??1900?	???0???009	00????????	????????0?	??????????	??????????
Tazoudasaurus	?????????0	?????????0	9???????00	1??0?10110	0?0??19???	?0?10?11?0	00????????	???110????	??????????	????????0?
Vulcanodon	??????????	??????????	??????????	??????????	??0???9???	??????????	??1???00??	11???0?101	0?11111???	???????1?01
[Lavini di Marco]	??????????	??????????	??????????	??????????	??????????	??????????	??????????	???????1??	?????????1	0?1???????
Barapasaurus	??????????	??????????	??????????	?????11111	?00?019?01	00?1111111	01110?00??	10?1?0?111	011111????	?????01111
Gongxianosaurus	?????1????	??????????	??????????	???????11?	??0??0?00?	????0?????	???????0??	0??090?101	????1?1???	??????????
Shunosaurus	0110111100	01?0011111	0101100110	11?1111112	0003119101	002100?009	0010910000	1?01111101	011?111010	0110101111
Neosauropoda	1111111111	1111111111	1111111111	111111?112	1013011001	0031111111	1021110011	1011?11111	0111111111	1011111111
Patagosaurus	1?1011????	??????????	?????1????	???1?11111	?01?011001	00?11111??	012????0??	1?1??0?111	011111????	??????1111
Omeisaurus	1110111??	1110111111	11?111?110	1??1111111	1014011110	0031111111	0021110000	1?11100111	0110111010	00111?1111
Mamenchisaurus	111?11110?	?110111111	11?11??110	1111111111	0114010110	1131111101	002??11100	1?1110?111	0111111?11	11????1111

	110	120	130	140	150	160	170
Theropoda	0000000000	0000000009	9000000000	0000000000	0010000900	0000000000	0000000001	11(0&1&2&3&4&5&6&7&8&9&A&B)
Prosauropoda	0000000000	0000000000	0000000000	0000000000	0000000900	0000000000	0000001110	00(0&1&2&3&4&5&6)
[Portozuelo]	?????0????	???????1??	?????????0?	??????????	??????????	??????????	???001?0??	??(1)
Blikanasaurus	????????1?	0000000001	0100000000	000?0????0?	??????????	????????1?	????????1?	?0(1)
Antenonitrus	??0010??10	0??????001	010000??01	?00?0?????	???0?00900	0????????1	1?00001110	00(2)
[*Tetrasauropus*]	????0?????	??????1???	???????1??	??????????	??????????	??????????	???010?0??	??(2)
Isanosaurus	??1010????	??????????	??????????	??????????	?????????0	0?????????	??1?000???	?0(3)
Tazoudasaurus	??????????	???0101???	?????????0	100??1???0?	0?????0000?	????0001??	??????????	?0(7)
Vulcanodon	10101?00?0	0001001071	0010010000	11001?????	??00?0??00	??????0?0?	100000??0?	?0(7)
[Lavini di Marco]	?????0????	???????1??	??????1???	??????????	??????????	??????????	???100?0??	??(4)
Barapasaurus	1011110111	11?1?1??01	0????????1?	?11?0??0?1	0000?00000	0????000?0	000000????	00(5/6/7)
Gongxianosaurus	??1110??1?	?0????000?	01?0000001	00000?????	?????0?900	0????????0?	010000????	?0(6)
Shunosaurus	?01111?11?	10010?1111	0111011?1	1111011110	0000000000	0000001000	0000000000	00(8)
Neosauropoda	1111111111	1011111111	0111111111	1111000000	0000000000	0111111100	0000000000	00(8&9&A&B)
Patagosaurus	1011110001	????????1?1	011????????	?????????0?	11110?0900	0????00?00	0000000??0	00(A)
Omeisaurus	101?101111	?001011111	1111111111	1111000000	0000110000	0000000000	0000000000	00(B)
Mamenchisaurus	101111111?	1101111?1	01?1?11?1?	?1??000000	0000?01111	1000000?00	0000000000	00(B)

Character List

The following list of characters is derived from numerous sources. Characters 1–158 are from Wilson 2002 and references therein; character 159 is from Galton and van Heerden 1998; characters 160–161 are from Yates and Kitching 2003; character 162 is from He et al. 1998; character 163 is from Buffetaut et al. 2000; characters 167–172 are from Sereno 1999; the stratigraphic character (173) is new to this analysis.

1. Posterolateral processes of premaxilla and lateral processes of maxilla, shape: without midline contact (0); with midline contact forming marked narial depression, subnarial foramen not visible laterally (1).
2. Premaxillary anterior margin, shape: without step (0); with marked step, anterior portion of skull sharply demarcated (1).
3. Maxillary border of external naris, length: short, making up much less than one-fourth narial perimeter (0); long, making up more than one-third narial perimeter (1).
4. Preantorbital fenestra: absent (0); present (1).
5. Antorbital fossa: present (0); absent (1).
6. External nares, position: terminal (0); retracted to level of orbit (1); retracted to a position between orbits (2).
7. Orbital ventral margin, anteroposterior width: broad, with subcircular orbital margin (0); reduced, with acute orbital margin (1).
8. Lacrimal, anterior process: present (0); absent (1).
9. Jugal-ectopterygoid contact: present (0); absent (1).
10. Postorbital, ventral process shape: transversely narrow (0); broader transversely than anteroposteriorly (1).
11. Frontal contribution to supratemporal fossa: present (0); absent (1).
12. Frontal, anteroposterior length: approximately twice (0) or less than (1) minimum transverse breadth.
13. Parietal occipital process, dorsoventral height: short, less than the diameter of the foramen magnum (0); deep, nearly twice the diameter of the foramen magnum (1).
14. Parietal, distance separating supratemporal fenestrae: less than (0) or twice (1) the long axis of supratemporal fenestra.
15. Supratemporal fenestra, long axis orientation: anteroposterior (0); transverse (1).
16. Supratemporal region, anteroposterior width: temporal bar longer (0) or shorter (1) anteroposteriorly than transversely.
17. Supratemporal fossa, lateral exposure: not visible laterally, obscured by temporal bar (0); visible laterally, temporal bar shifted ventrally (1).
18. Laterotemporal fenestra, anterior extension: posterior to orbit (0); ventral to orbit (1).
19. Quadratojugal, anterior process length: short, anterior process shorter than dorsal process (0); long, anterior process more than twice as long as dorsal process (1).
20. Quadrate fossa: absent (0); present (1).
21. Quadrate fossa, depth: shallow (0); deeply invaginated (1).
22. Pterygoid, transverse flange (i.e., ectopterygoid process) position: posterior of orbit (0); between orbit and antorbital fenestra (1); anterior to antorbital fenestra (2).
23. Pterygoid, palatine ramus shape: straight, at level of dorsal margin of quadrate ramus (0); stepped, raised above level of quadrate ramus (1).
24. Palatine, lateral ramus shape: plate-shaped (long maxillary contact) (0); rod-shaped (narrow maxillary contact) (1).
25. Epipterygoid: present (0); absent (1).
26. Vomer, anterior articulation: maxilla (0); premaxilla (1).
27. Basisphenoid/basipterygoid recess: present (0); absent (1).
28. Occipital region of skull, shape: anteroposteriorly deep, paroccipital processes oriented posterolaterally (0); flat, paroccipital processes oriented transversely (1).
29. Dentary, depth of anterior end of ramus: slightly less than that of dentary at midlength (0); 150% minimum depth (1).
30. External mandibular fenestra: present (0); absent (1).
31. Adductor fossa, medial wall depth: shallow (0); deep, prearticular expanded dorsoventrally (1).
32. Splenial posterodorsal process: present, approaching margin of adductor chamber (0); absent (1).
33. Coronoid, size: extending to dorsal margin of jaw (0); reduced, not extending dorsal to splenial (1); absent (2).
34. Tooth rows, shape of anterior portions: narrowly arched, anterior portion of tooth rows V-shaped (0); broadly arched, anterior portion of tooth rows U-shaped (1); rectangular, tooth-bearing portion of jaw perpendicular to jaw rami (2).
35. Tooth rows, length: extending to orbit (0); restricted anterior to orbit (1); restricted anterior to subnarial foramen (2).

36. Crown-to-crown occlusion: absent (0); present (1).
37. Tooth crowns, orientation: aligned along jaw axis, crowns do not overlap (0); aligned slightly anterolingually, tooth crowns overlap (1).
38. Tooth crowns, cross-sectional shape at mid-crown: elliptical (0); D-shaped (1); cylindrical (2).
39. Enamel surface texture: smooth (0); wrinkled (1).
40. Marginal tooth denticles: present (0); absent on posterior edge (1); absent on both anterior and posterior edges (2).
41. Dentary teeth, number: more than 20 (0); 17 or fewer (1).
42. Presacral bone texture: solid (0); spongy, with large, open internal cells, ''camellate'' (1).
43. Presacral centra, pneumatopores (pleurocoels): absent (0); present (1).
44. Cervical vertebrae, number: 9 or fewer (0); 10 (1); 12 (2); 13 (3); 15 or greater (4).
45. Cervical neural arch lamination: well developed, with well-defined laminae and coels (0); rudimentary; diapophyseal laminae only feebly developed if present (1).
46. Cervical centra, articular face morphology: amphicoelous (0); opisthocoelous (1).
47. Cervical pneumatopores (pleurocoels), shape: simple, undivided (0); complex, divided by bony septa (1).
48. Anterior cervical centra, height/width: less than 1 (0); approximately 1.25 (1).
49. Mid-cervical centra, anteroposterior length/height of posterior face: 2.5–3.0 (0); >4 (1).
50. Mid-cervical neural arches, height: less than that of posterior centrum face (0); greater than that of posterior centrum face (1).
51. Middle and posterior cervical neural arches, centroprezygapophyseal lamina (cprl), shape: single (0); divided (1).
52. Posterior cervical and anterior dorsal neural spines, shape: single (0); bifid (1).
53. Dorsal vertebrae, number: 15 (0); 14 (1); 13 (2); 12 (3); 11 (4); 10 or fewer (5).
54. Dorsal neural spines, breadth: narrower (0) or much broader (1) transversely than anteroposteriorly.
55. Anterior dorsal centra, articular face shape: amphicoelous (0); opisthocoelous (1).
56. Middle and posterior dorsal neural arches, anterior centroparapophyseal lamina (acpl): absent (0); present (1).
57. Middle and posterior dorsal neural arches, prezygoparapophyseal lamina (prpl): absent (0); present (1).
58. Middle and posterior dorsal neural arches, spinodiapophyseal lamina (spdl): absent (0); present (1).
59. Middle and posterior dorsal neural arches spinopostzygapophyseal lamina (spol) shape: single (0); divided (1).
60. Middle and posterior dorsal neural arches, spinodiapophyseal lamina (spdl) and spinopostzygapophyseal lamina (spol) contact: absent (0); present (1).
61. Middle and posterior dorsal neural spines, shape: tapering or not flaring distally (0); flared distally, with pendant, triangular lateral processes (1).
62. Middle and posterior dorsal neural arches, ''infradiapophyseal'' pneumatopore between acdl and pcdl: absent (0); present (1).
63. Sacral vertebrae, number: three or fewer (0); four (1); five (2); six (3).
64. Sacrum, sacricostal yoke: absent (0); present (1).
65. Sacral vertebrae contributing to acetabulum: numbers 1–3 (0); numbers 2–4 (1).
66. Caudal transverse processes: persist through caudal 20 or more posteriorly (0); disappear by caudal 15 (1); disappear by caudal 10 (2).
67. First caudal centrum, articular face shape: flat (0); procoelous (1); opisthocoelous (2); biconvex (3).
68. Anterior caudal centra (excluding the first), articular face shape: amphiplatyan or platycoelous (0); procoelous (1); opisthocoelous (2).
69. Anterior caudal neural arches, prespinal lamina (prsl): absent (0); present (1).
70. Anterior caudal neural arches, postspinal lamina (posl): absent (0); present (1).
71. Anterior caudal transverse processes, proximal depth: shallow, on centrum only (0); deep, extending from centrum to neural arch (1).
72. Anterior and middle caudal centra, ventral longitudinal hollow: absent (0); present (1).
73. Cervical rib, tuberculum-capitulum angle: greater than 90° (0); less than 90°, rib ventrolateral to centrum (1).
74. ''Forked'' chevrons with anterior and posterior projections: absent (0); present (1).
75. ''Forked'' chevrons, distribution: distal tail only (0); throughout middle and posterior caudal vertebrae (1).
76. Chevrons, ''crus'' bridging dorsal margin of haemal canal: present (0); absent (1).
77. Chevrons: persisting throughout at least 80% of tail (0); disappearing by caudal 30 (1).
78. Posture: bipedal (0); columnar, obligately quadrupedal posture (1).
79. Scapular acromion process, size: narrow (0); broad, width more than 150% minimum width of blade (1).
80. Humeral deltopectoral attachment, development: prominent (0); reduced to a low crest or ridge (1).
81. Humeral distal condyles, articular surface shape: restricted to distal portion of humerus (0); exposed on anterior portion of humeral shaft (1).

82. Humeral distal condyle, shape: divided (0); flat (1).
83. Ulnar proximal condyle, shape: subtriangular (0); triradiate, with deep radial fossa (1).
84. Ulnar proximal condylar processes, relative lengths: subequal (0); unequal, anterior arm longer (1).
85. Ulnar olecranon process, development: prominent, projecting above proximal articulation (0); rudimentary, level with proximal articulation (1).
86. Radial distal condyle, shape: round (0); subrectangular, flattened posteriorly and articulating in front of ulna (1).
87. Humerus-to-femur ratio: less than 0.60 (0); 0.60 or more (1).
88. Carpal bones, number: three or more (0); two or fewer (1).
89. Carpal bones, shape: round (0); block-shaped, with flattened proximal and distal surfaces (1).
90. Metacarpus, shape: spreading (0); bound, with subparallel shafts and articular surfaces that extend half their length (1).
91. Metacarpals, shape of proximal surface in articulation: gently curving, forming a 90° arc (0); U-shaped, subtending a 270° arc (1).
92. Metacarpal I distal condyle, transverse axis orientation: beveled approximately 20° proximodistally (0) or perpendicular (1) with respect to axis of shaft.
93. Manual digits II and III, phalangeal number: 2-3-4-3-2 or more (0); reduced, 2-2-2-2-2 or less (1); absent or unossified (2).
94. Manual phalanx I.1, shape: rectangular (0); wedge-shaped (1).
95. Manual nonungual phalanges, shape: longer proximodistally than broad transversely (0); broader transversely than long proximodistally (1).
96. Pelvis, anterior breadth: narrow, ilia longer anteroposteriorly than distance separating preacetabular processes (0); broad, distance between preacetabular processes exceeds anteroposterior length of ilia (1).
97. Ilium, ischial peduncle size: large, prominent (0); low, rounded (1).
98. Iliac blade dorsal margin, shape: flat (0); semicircular (1).
99. Pubic apron, shape: flat (straight symphysis) (0); canted anteromedially (gentle S-shaped symphysis) (1).
100. Ischial blade, length: much shorter than (0) or equal to or longer than (1) pubic blade.
101. Ischial distal shaft, shape: triangular, depth of ischial shaft increases medially (0); bladelike, medial and lateral depths subequal (1).
102. Ischial distal shafts, cross-sectional shape: V-shaped, forming an angle of nearly 50° with each other (0); flat, nearly coplanar (1).
103. Femoral fourth trochanter, development: prominent (0); reduced to crest or ridge (1).
104. Femoral lesser trochanter: present (0); absent (1).
105. Femoral midshaft, transverse diameter: subequal to (0), 125–150%, or (1) at least 185% (2) anteroposterior diameter.
106. Femoral distal condyles, relative transverse breadth: subequal (0); tibial much broader than fibular (1).
107. Tibial proximal condyle, shape: narrow, long axis anteroposterior (0); expanded transversely, condyle subcircular (1).
108. Tibial cnemial crest, orientation: projecting anteriorly (0) or laterally (1).
109. Tibial distal posteroventral process, size: broad transversely, covering posterior fossa of astragalus (0); shortened transversely, posterior fossa of astragalus visible posteriorly (1).
110. Fibula, proximal tibial scar, development: not well marked (0); well marked and deepening anteriorly (1).
111. Fibula, lateral trochanter: absent (0); present (1).
112. Fibular distal condyle, size: subequal to shaft (0); expanded transversely, more than twice midshaft breadth (1).
113. Astragalus, shape: rectangular (0); wedge-shaped, with reduced anteromedial corner (1).
114. Astragalus, foramina at base of ascending process: present (0); absent (1).
115. Astragalus, ascending process length: limited to anterior two-thirds of astragalus (0); extending to posterior margin of astragalus (1).
116. Astragalus, posterior fossa shape: undivided (0); divided by vertical crest (1).
117. Distal tarsals 3 and 4: present (0); absent or unossified (1).
118. Metatarsus, posture: bound (0); spreading (1).
119. Metatarsal I proximal condyle, transverse axis orientation: perpendicular to (0) or angled ventromedially approximately 15° to (1) axis of shaft.
120. Metatarsal I distal condyle, transverse axis orientation: perpendicular to (0) or angled dorsomedially to (1) axis of shaft.
121. Metatarsal I distal condyle, posterolateral projection: absent (0); present (1).
122. Metatarsal I, minimum shaft width: less than (0) or greater than (1) that of metatarsals II–IV.
123. Metatarsal I and V proximal condyle, size: smaller than (0) or subequal to (1) those of metatarsals II and IV.
124. Metatarsal III length: more than 30% (0) or less than 25% (1) that of tibia.
125. Metatarsals III and IV, minimum transverse shaft diameters: subequal to (0) or less than 65% (1) that of metatarsals I or II (1).
126. Metatarsal V, length: shorter than (0) or at least 70% (1) length of metatarsal IV.

127. Pedal nonungual phalanges, shape: longer proximodistally than broad transversely (0); broader transversely than long proximodistally (1).
128. Pedal digits II–IV, penultimate phalanges, development: subequal in size to more proximal phalanges (0); rudimentary or absent (1).
129. Pedal unguals, orientation: aligned with (0) or deflected lateral to (1) digit axis.
130. Pedal digit I ungual, length relative to pedal digit II ungual: subequal (0); 25% larger than that of digit II (1).
131. Pedal digit I ungual, length: shorter (0) or longer (1) than metatarsal I.
132. Pedal ungual I, shape: broader transversely than dorsoventrally (0); sickle shaped, much deeper dorsoventrally than broad transversely (1).
133. Pedal ungual II–III, shape: broader transversely than dorsoventrally (0); sickle shaped, much deeper dorsoventrally than broad transversely (1).
134. Pedal digit IV ungual, development: subequal in size to unguals of pedal digits II and III (0); rudimentary or absent (1).
135. [*Vulcanodon* autapomorphy: marked dorsoventral flattening of the unguals of pedal digits II and III.]
136. [*Shunosaurus* autapomorphy: strap-shaped pterygoid.]
137. [*Shunosaurus* autapomorphy: anterior portion of the axial neural spine prominent.]
138. [*Shunosaurus* autapomorphy: ''postparapophyses'' on posterior dorsal vertebrae.]
139. [*Shunosaurus* autapomorphy: terminal tail club composed of at least three enlarged, co-ossified caudal vertebrae with two dermal spines.]
140. [*Barapasaurus* autapomorphy: posterior dorsal vertebrae with slit-shaped neural canal.]
141. [*Patagosaurus* autapomorphy: cervical vertebrae with elongate centroprezygapophyseal laminae and ''hooded'' infra-prezygapophyseal coels.]
142. [*Patagosaurus* autapomorphy: anterior dorsal vertebrae with elongate centropostzygapophyseal and postzygodiapophyseal laminae.]
143. [*Patagosaurus* autapomorphy: transversely narrow third sacral vertebra.]
144. [*Patagosaurus* autapomorphy: proximal humerus with median ridge on posterior aspect.]
145. [*Omeisaurus* autapomorphy: maxillary ascending ramus with dorsoventrally expanded distal end.]
146. [*Omeisaurus* autapomorphy: distalmost caudal chevrons fused to anteriormost portion of ventral centrum.]
147. [*Mamenchisaurus* autapomorphy: accessory prezygodiapophyseal lamina in anterior dorsal vertebrae.]
148. [*Mamenchisaurus* autapomorphy: ''forked'' chevrons in mid-caudal region with anterior and posterior projections oriented less than 45° to each other.]
149. [*Mamenchisaurus* autapomorphy: ulna with anterior arm of proximal condyle nearly one-half the length of shaft.]
150. [*Mamenchisaurus* autapomorphy: femur with medially expanded tibial condyle.]
151. [*Mamenchisaurus* autapomorphy: proximal half of femoral shaft broader than distal half.]
152. [Neosauropoda autapomorphy: supratemporal fenestrae separated by twice longest diameter of one supratemporal fenestra.]
153. [Neosauropoda autapomorphy: pterygoid palatine ramus with stepped dorsal margin.]
154. [Neosauropoda autapomorphy: basisphenoid/basipterygoid recess.]
155. [Neosauropoda autapomorphy: external mandibular fenestra closed.]
156. [Neosauropoda autapomorphy: marginal tooth denticles absent on both anterior and posterior margins of crown.]
157. [Neosauropoda autapomorphy: chevrons lack ''crus'' bridging dorsal margin of haemal canal.]
158. [Neosauropoda autapomorphy: carpal bones number two or fewer.]
159. [*Blikanasaurus* autapomorphy: fibula with enlarged, ovoid, ventromedially oriented distal articular surface.]
160. [*Antenonitrus* autapomorphy: ventral ridge on hyposphenes of dorsal vertebrae.]
161. [*Antenonitrus* autapomorphy: humerus deep sulcus adjacent the laterodistal margin of the deltopectoral crest.]
162. [*Gongxianosaurus* autapomorphy: coracoid foramen absent.]
163. [*Isanosaurus* autapomorphy: femur with sigmoid fourth trochanter.]
164. [Lavini di Marco autapomorphy.]
165. [*Tetrasauropus* autapomorphy.]
166. [Portozuelo autapomorphy.]
167. [Prosauropoda autapomorphy: dentary tooth 1 inset.]
168. [Prosauropoda autapomorphy: manual digit I-phalanx 1, axis through distal condyles rotated 60° ventrolaterally.]
169. [Prosauropoda autapomorphy: metatarsal II proximal articular surface hourglass-shaped.]
170. [Theropoda autapomorphy: intramandibular joint present.]
171. [Theropoda autapomorphy: cervical epipophyses prong-shaped.]
172. [Theropoda autapomorphy: internal cavitation of centra and long bones well developed.]
173. Stratigraphic character: Anisian (0); Carnian (1); Norian (2); Rhaetian (3); Hettangian (4); Sinemurian (5); Pliensbachian (6); Toarcian (7); Bajocian (8); Bathonian (9); Callovian (A); Oxfordian (B).