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A new sauropodomorph dinosaur from the Lower Jurassic Fengjiahe Formation of Dali of Yunnan Province, China

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Early-diverging sauropodomorph dinosaurs are abundant in the Lower Jurassic Lufeng Formation of Lufeng area of Yunnan Province, southwestern China. However, the fossil records of this group remain relatively scarce in other regions of China. Here we describe a new sauropodomorph, *Xiangyunloong fengming* gen. et sp. nov., based on recently collected material from the Lower Jurassic Fengjiahe Formation of Xiangyun County of Dali Bai Autonomous Prefecture of Yunnan Province, which is about 200 km west to the Lufeng dinosaur fossil sites. *Xiangyunloong* can be diagnosed by several unique features such as lateral expansion developed at the middle region of the dorsal end of cervical neural spines, heightened hyposphene of dorsal vertebrae, and ilium with anteroposteriorly reduced

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but laterally and ventrally flaring supracetabular crest. Phylogenetic analysis recovers *Xiangyunloong* at a position between Massospondylidae and Sauropodiformes, and within an unresolved clade together with *Xingxiulong chengi* and *Xingxiulong yueorum*. Nonetheless, *Xiangyunloong* exhibits significant morphological distinctions from *Xingxiulong* and other early-diverging sauropodomorphs, supporting its designation as a new genus. The discovery of *Xiangyunloong* not only further expands the known taxonomic composition of Early Jurassic sauropodomorphs in southwestern China, but also enhances our understanding of the diversity, distribution and evolutionary history of this group.

1. Introduction

The Early Jurassic epoch is a pivotal period in dinosaur evolution, witnessing the diversification and rise to dominance of sauropodomorph dinosaurs in the terrestrial ecosystem [1–3]. Within this group, non-sauropodan massopodan sauropodomorphs played a crucial role in the evolutionary pathways leading to the gigantic body plans characteristic of sauropods [4–6]. Understanding the anatomy, diversity and paleobiogeography of these early-diverging sauropodomorphs is therefore fundamental to deciphering the origins of sauropods, which represent one of the most successful dinosaurian clades [7,8].

East Asia, particularly southwestern China, has yielded abundant Early Jurassic sauropodomorph fossils, significantly contributing to our knowledge of the early radiation of this group. The Lower Jurassic of Yunnan Province, China, stands as one of the most important terrestrial sequences for studying the evolution of the non-sauropodan sauropodomorphs globally. Most of the fossils of this group were discovered from the Lower Jurassic Lufeng Formation of Lufeng area (e.g. *Lufengosaurus*, *Yunnanosaurus huangi*, *Jingshanosaurus*, *Xingxiulong*, *Yizhousaurus* and *Lishulong* [9–17]). By contrast, the fossil records remain relatively scarce in other regions of Yunnan and were mainly recovered from the Lower Jurassic Fengjiahe Formation (e.g. *Yimenosaurus*, *Yunnanosaurus youngi* and *Irisosaurus* [18–21]). The recently reported *Wudingloong*, discovered from the Lower Jurassic Yubacun Formation, is considered the earliest-diverging sauropodomorph in East Asia [22,23]. These taxa provide invaluable insights into the morphology and diversity of the early-diverging sauropodomorphs.

Here, we report on a recently discovered new specimen of non-sauropodan sauropodomorph from the Lower Jurassic Fengjiahe Formation in Luming Town, Xiangyun County, Dali Bai Autonomous Prefecture, Yunnan Province, China, which is a newly discovered dinosaur fossil site (figure 1). The new specimen is represented by partial cervical and dorsal vertebrae, anterior caudal vertebrae, partial left ilium and complete right ischium. The discovery of this new specimen significantly enriches the known Early Jurassic dinosaur fauna of southwestern China. It provides critical new anatomical features that enhance our understanding of morphological disparity and evolutionary patterns among the early-diverging sauropodomorphs.

2. Geological setting

In Yunnan Province, the dinosaur fossils were found in the central and east regions of the Chuxiong Basin, such as Yimen, Jiangyi, Shuangbai and Wuding (e.g. [18–22,24–26]), as well as the small eastern basins, including the Lufeng and Chuanjie Basins (e.g. [9,10,12,14–16,27,28]). The new specimen was found in the First Member of the Lower Jurassic Fengjiahe Formation of Luming area, Xiangyun County of Dali Bai Autonomous Prefecture of western Yunnan (figure 1). This fossil site is located in the western part of the Chuxiong Basin, and the dinosaur fossils founded from this area were recently mentioned by Hu *et al.* [29] but without detailed study. In the study area that yields the new specimen, the Fengjiahe Formation is subdivided into two members. The First Member is dominated by purplish-red and dark purple medium- to thick-bedded mudstones, argillaceous siltstones and siltstones, interbedded with greyish-green and yellowish-green lithic quartz sandstones and fine sandstones, which yields most of the dinosaur fossil remains. The Second Member consists primarily of greyish-yellow and yellowish-green lithic quartz sandstones and fine sandstones, with interbeds of wine-red siltstones, argillaceous siltstones and mudstones [29,30]. The Fengjiahe Formation is

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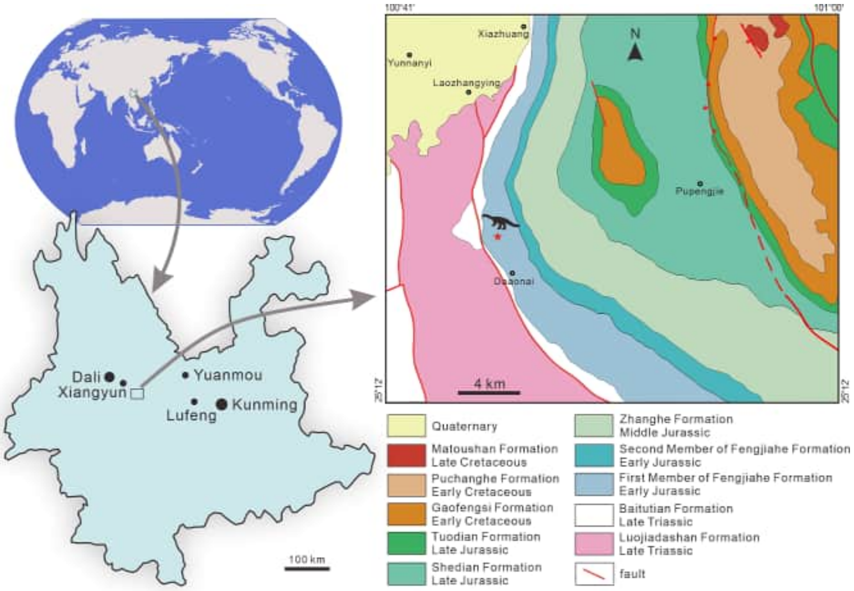

Figure 1. Geological map showing the location of *Xiangyunloong fengming* (indicated by the red star).

characterized as a continental-dominated red bed sequence, exhibiting sedimentary structures such as mud cracks and wave ripples. It underlies the Middle Jurassic Zhanghe Formation conformably and overlies the Upper Triassic Baitutian Formation, also in conformable contact. The depositional environment was interpreted as dominated by shallow lacustrine, shoreline and fluvial settings [29].

The stratigraphic sequence of the Fengjiahe Formation in the Luming area of Xiangyun can be well correlated with that of the Fengjiahe Formation in the Anlongbao area of Shuangbai County. The lithology hosting the fossils is relatively similar; however, the fossil-bearing horizon in the study area is lower than that in the Anlongbao region [25]. Compared with the Lufeng Formation of Lufeng City, the First Member of the Fengjiahe Formation bearing the dinosaur fossils are roughly equivalent to the Zhangjiaao Member [29].

3. Material and methods

3.1. Material

The new specimen YDDY 10001-10041 was discovered and excavated from Xiangyun County of Dali Bai Autonomous Prefecture, which is about 200 km west to the Lufeng dinosaur fossil sites, by the staff of Yunnan Institute of Geological Survey and the Bureau and Natural Resources of Lufeng County. It is now housed at the Yunnan Institute of Geological Survey. Some of the elements of YDDY 10001-10041, including the first caudal vertebra and the ilium, were reconstructed with plaster. The neurocentral suture of almost all the vertebrae is completely closed, with the exception of the last cervical and an anterior dorsal vertebra that only preserves their centrum and neural arch, respectively, which is probably due to crushing, indicating it was a skeletally mature individual. Based on the measurements of the preserved vertebral elements, *Xiangyunloong* is slightly larger than *Jingshanosaurus* and *Xingxiulong yueorum* in body size, with a length of about 9–10 m.

3.2. Terminology

The traditional ‘Romerian’ anatomical and orientational terms (e.g. anterior, posterior) are employed [31]. The anatomical terminology for vertebral laminae and fossae follows Wilson [32,33] and Wilson *et al.* [34].

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3.3. Phylogenetic analysis

To determine the phylogenetic position of the new specimen, it was added in the dataset of Wang *et al.* [22]. Recently reported *Lishulong* and *Xingxiulong yueorum* [17,35] were also incorporated into the dataset. Character 331 of *Yunnanosaurus* and *Jingshanosaurus* was modified from '1' to '0' due to the absence of the paramarginal ridge on the cnemial crest in these taxa, as observed by the authors. Characters 8, 13, 19, 23, 42, 60, 72, 104, 114, 131, 135, 145, 148, 159, 162, 164, 165, 172, 177, 182, 185, 191, 198, 220, 224, 227, 236, 247, 252, 262, 271, 279, 282, 296, 308, 329, 335, 344, 366, 380, 384, 386, 391 and 395 were ordered following Wang *et al.* [22].

The final data matrix, which includes 82 taxa and 398 characters, was analysed under equally weighted parsimony in TNT 1.5 [36] (electronic supplementary material). A heuristic search was performed using 1000 replicates of Wagner trees generated with random addition sequences, followed by tree bisection and reconnection (TBR) branch swapping, retaining 10 trees per replication. Branch support was calculated using Bremer support and bootstrap analysis with 1000 replicates. The resulting consensus tree was time-calibrated using R package paleotree [37] and visualized using R package strap [38].

4. Systematic palaeontology

Dinosauria Owen, 1842

Saurischia Seeley, 1887

Sauropodomorpha Huene, 1932

Massopoda Yates, 2007

Xiangyunloong fengming gen. et sp. nov.

4.1. Etymology

Xiangyun (auspicious clouds) is the name of the county where the specimen was found; *loong* is the Pinyin for the traditional 'Chinese dragon', symbolizing power and auspiciousness. The specific name *fengming* (phoenix singing) echoes Luming (deer calling), the name of the town where the fossil was discovered, reminding us that birds are living dinosaurs. Additionally, 'Fengming' was the original name of Lin Fengmian, the artistic master and founding president of China Academy of Art, whose staff participated extensively in this project.

4.2. Holotype

YDDY 10001-10041, a partial skeleton including three cervical, five dorsal and 15 caudal vertebrae, several dorsal rib fragments, nearly a dozen chevrons, an incomplete left ilium, and a right ischium.

4.3. Type locality and horizon

Daaonai, Luming Town, Xiangyun County, Dali Bai Autonomous Prefecture, Yunnan Province, China; the upper part of First Member of Fengjiahe Formation, Lower Jurassic.

4.4. Diagnosis

A large non-sauropodan massopodan sauropodomorph dinosaur diagnosed by the following unique combination of features and two potential autapomorphies (marked with an asterisk): lateral expansion developed at the middle region of the dorsal end of cervical neural spines*; hyposphene equal to the height of the neural canal in dorsal vertebrae; highly developed posterodorsal corner present at the neural spine of last dorsal vertebra; presence of prezygapophyseal centrodiapophyseal fossa in first

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caudal vertebra; ilium with anteroposteriorly reduced but laterally and ventrally flaring supracetabular crest*.

5. Description

5.1. Cervical vertebrae

There are three cervical vertebrae preserved in *Xiangyunloong*. Based on their relative length (table 1), the shape of the neural spines and the relative size of the articular surface of the centra, they are interpreted as one anterior, one middle-posterior and the last cervical vertebrae. The cervical centra are amphicoelous like other non-sauropodan sauropodomorphs. They are slightly shorter than those of *Jingshanosaurus* and *Lishulong*, but much longer than those of *Lufengosaurus*, *Yunnanosaurus*, *Xingxiulong* and *Wudingloong*.

5.1.1. Anterior cervical vertebra

The anterior cervical vertebra probably represents Cv3 or Cv4. Here it is numbered as Cv3 for convenience (figure 2). The length of the centrum is 3.2 times the height of the anterior articular facet. This ratio is fairly similar to that of *Plateosaurus* (Cv3: 3.1; Cv4: 3.2 [39]), *Xingxiulong chengi* (Cv3: 3.0, Cv4: 2.6 [14,40]), *Lufengosaurus* (Cv3: 3.3, Cv4: 2.5 [9]) and *Yunnanosaurus youngi* (Cv3: 3.0, Cv4: 2.9 [19]), but contrasts to the relatively longer cervical centrum of most non-sauropodan sauropodomorphs such as *Wudingloong* (Cv3: 3.5, Cv4: 3.6 [22]), *Massospondylus* (Cv3: 7.5, Cv4: 7.6 [41]), *Adeopapposaurus* (approx. 5.0 [42]), *Coloradisaurus* (approx. 3.8 [43]), *Leyesaurus* (Cv3: 4.0, Cv4: 3.8 [44]), *Yunnanosaurus huangi* (Cv3: 3.7, Cv4: 3.4 [10]), *Jingshanosaurus* (Cv3: 3.9 [12]), *Lishulong* (Cv3: 4.6, Cv4: 3.9 [17]) and *Yizhousaurus* (Cv3: 4.4, Cv4: 3.9 [15]). However, *Irisosaurus*, which was also discovered from the Early Jurassic Fengjiahe Formation, displays a much lower anterior cervical vertebral elongation ratio (1.7 [20]). The lateral surface of the centrum of Cv3 is slightly compressed. In lateral view, the ventral margin of the centrum is slightly concave. The ventral surface bears a faint longitudinal keel that extends almost the entire length of the centrum except for the anterior- and posterior-most ends (figure 2e). This weakly developed ventral keel of Cv3 of *Xiangyunloong* resembles that of *Xingxiulong chengi*, *Yunnanosaurus* and *Lishulong*, but contrasts to *Yimenosaurus*, *Wudingloong*, *Lufengosaurus* and *Jingshanosaurus* in which this keel is more pronounced. The anterior articular facet of the centrum is slightly concave, and the posterior articular facet is highly concave due to the posterior extension of the ventral margin. The parapophyses are developed as small tubercles and placed ventrolaterally at the anterior end of the centrum. The diapophysis is absent.

The neural arch is completely fused with the centrum (figure 2*a*). The prezygapophyses, although lacking their anterior ends, extend more anteriorly than the anterior surface of the centrum. They diverge from each other at an angle of 40° in dorsal view. In lateral view, the prezygapophyses are almost level with the postzygapophyses. The postzygapophyses are projected not beyond the posterior margin of the centrum due to the strong extension of the ventral margin of the posterior articular facet. This condition is similar to that of *Lishulong* [17]. In dorsal view, the postzygapophyses diverge at an angle of 60°. The articular facets expand medially to fuse with each other and forms the floor of a wide recess [41] with a small posterior notch to separate the two postzygapophyses, which is also present in other non-sauropodan sauropodomorphs (e.g. *Massospondylus*, *Adeopapposaurus*, *Jingshanosaurus*, *Xingxiulong* and *Lishulong* [17,41,42]). The epipophyses are developed as a moderately tall ridge on the dorsal surface of the postzygapophyses, extending from the neural spine posteriorly close to the posterior end of the postzygapophyses (figure 2*a*). The neural canal occupies the dorsal region of the centrum. The neural spine is long and low, with a lateral expansion developed at the middle region of the dorsal end (figure 2*d*). A similar expansion is developed in *Lishulong* [17] and *Yunnanosaurus youngi* [19]; however, this expansion of *Xiangyunloong* is anteroposteriorly more elongated and located more posterior than that of *Lishulong* and *Y. youngi*. Although these expansions are possibly synapomorphic of these taxa, the morphological difference indicates that this feature is a potential autapomorphy of *Xiangyunloong*. Furthermore, a spur-like expansion that is developed at the anterior end of the neural spines of the cervical vertebrae of *Lishulong* is absent in *Xiangyunloong*.

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Table 1. Measurements (in mm) of the vertebrae of *Xiangyunloong fengming*. *Estimated value.

element	total height	anteroposterior length of centrum	anterior height of centrum	anterior width of centrum	posterior height of centrum	posterior width of centrum	length of neural spine (at the bottom)
Cv3/4	131.6	197.0	61.8	56.7*	70.5	61.2	77.3
Cv8	184.1	219.0*	82.3*	99.8	103.6*	114.2	57.7
Cv10	—	172.9	123.5*	99.0*	140.1	124.7	—
D5	—	—	—	—	—	—	56.7
D7	233.3	140.0	117.7	96.8*	102.5*	88.0*	75.0
D9	264.7	145.7	123.6	103.0	148.2	116.4	118.9
D11	261.7	129.5	140.2	136.6	140.4	148.1	106.0
D14	320.0	150.4	161.0	148.0	162.7	159.3	80.1
Cd1	397.0*	141.4	—	—	—	165.0	102.6
Cd3	362.1	129.3	185.0	149.8	172.1	150.6	89.3
Cd5	353.3	151.3	149.5	116.0	143.0	121.6	69.5
Cd6	—	135.0	153.4	141.7	137.0*	133.0	—
Cd7	—	122.3	132.8	116.8	134.8	116.5	—
Cd8	231.9*	143.2	129.0	130.0	131.0	129.6	69.2
Cd9	265.1	157.3	121.9	113.8	124.3	126.3	60.5
Cd10	250.0	144.5	112.3	92.4	116.0	96.0	51.0
Cd12	233.2	127.6	106.1	102.2	114.0	93.9	52.0
Cd13	221.3	128.2	102.0*	129.2*	106.1*	130.9*	46.3
Cd14	214.8	133.7	101.4	100.6	106.5	94.8	44.1
Cd15	204.2	125.4	101.5	102.0	99.8*	99.1	44.6
Cd16	213.0	124.0	94.7	91.0	98.6	94.8	41.8
Cd17	205.1	121.7	95.6	102.5	97.4	106.2	40.1
Cd18	—	126.4	94.2	75.0	93.4	80.4	—

5.1.2. Middle cervical vertebra

This cervical vertebra is possibly assigned to Cv8 based on its larger size, the development of the diapophyses and the shorter neural spine with respect to those of Cv3 (figure 3*a–e*). The centrum is approximately 2.7 times longer than it is high anteriorly, which is higher than that of *Yizhouaurus* (2.3 [15]), *Lishulong* (2.2 [17]), *Irisosaurus* (1.65 [20]), *Lufengosaurus* (1.8 [9]) and *X. chengi* (1.8). However, this ratio of *Xiangyunloong* should be lower because the centrum is distinctly compressed dorsoventrally, leading to a reduction in its height and an elongation of its length. The lateral surface appears more compressed than that of *Jingshanosaurus*, *X. chengi* and *Lishulong*. As in Cv3, the posterior articular facet of the centrum is more concave than the anterior articular facet. The ventral margin of the posterior articular facet is projected more posteriorly than the dorsal margin but not as projected as that of Cv3 (figure 3*e*). A ventral keel is present along the entire length of the centrum and slightly more prominent than that of the anterior element. The parapophyses are more developed than that of Cv3. The diapophyses are well developed, tapering distally and lateroventrally directed.

The neural aches are strongly fused to the centra. The prezygapophyses extend far beyond the anterior margin of the centrum, with their articular surfaces facing dorsomedially. In dorsal view, the prezygapophyses are separated by a broad gap, and they diverge at an angle of approximately 70°. The postzygapophyses are short, extend posteriorly slightly beyond the posterior edge of the centrum, and their articular facets are oriented ventrolaterally. They diverge from each other at an angle of approximately 55° in dorsal view. In lateral view, the postzygapophyses are slightly elevated dorsally

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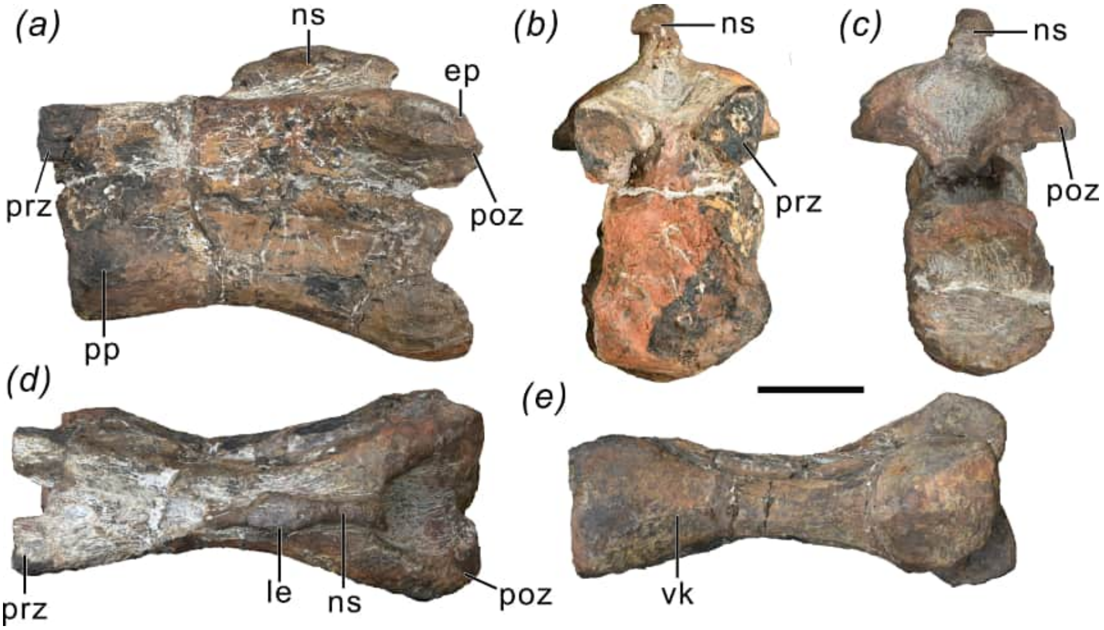

Figure 2. The anterior cervical vertebra (Cv3 or Cv4) of *Xiangyunloong fengming* in (*a*) lateral, (*b*) anterior, (*c*) posterior, (*d*) dorsal and (*e*) ventral views. Abbreviations: ep, epipophysis; le, lateral expansion; ns, neural spine; poz, postzygapophysis; pp, parapophysis; prz, prezygapophysis; vk, ventral keel. Scale bar equals 5 cm.

relative to the prezygapophyses at an angle of about 20°, as also occurs in most non-sauropodan sauropodomorphs. The floor formed by the articular facets of the postzygapophyses is broader and posteriorly extended than that of Cv3, with only a faint notch developed at its posterior margin. The epipophyses are less developed than those of the anterior elements and fused with postzygapophyses along their entire length. The neural spine is shorter and higher than the anterior element. A dorsal expansion is also developed at the same position as that of the anterior cervical, although it probably has been exaggerated by compression (figure 3*b*–*d*).

5.1.3. The last cervical vertebra

This cervical vertebra only preserves its centrum, which is significantly shorter than the previous cervical centra, and its parapophyses are located higher than those of Cv3 and Cv8 (figure 3*f*–*h*). Therefore, it is interpreted as Cv10. Cv10 remarkably decreases its length, with the centrum being 1.4 times longer than it is anteriorly high, similar to that of *Irisosaurus* (1.3 [20]), *Lishulong* (1.3) and *Lufengosaurus* (1.5), but still less than that of *Massospondylus* (4.1 [41]) and *Yizhousaurus* (1.7). The lateral surface of the centrum is compressed as that of Cv8. The posterior articular facet is not as excavated as that of the previous elements. The ventral keel, although being broken centrally, is well developed anteriorly (figure 3*h*). The parapophyses are enlarged, more laterally projected and situated higher than that of Cv3 and Cv8.

5.2. Dorsal vertebrae and ribs

Five dorsal vertebrae are preserved, representing each region of the dorsal axial column with the exception of the anterior elements. All the centra are amphicoelous and transversely constricted with shallow lateral depression. The neural arch is all lower than the articular facet of the respective centrum. There are some isolated fragments of the dorsal ribs. Their true position and articulation with the dorsal vertebrae are hard to determine. The dorsal centra are slightly longer than the corresponding elements of *Jingshanosaurus* and *Yizhousaurus* [12,15], and much longer than those of *Lufengosaurus*, *Yunnanosaurus* and *X. chengi*.

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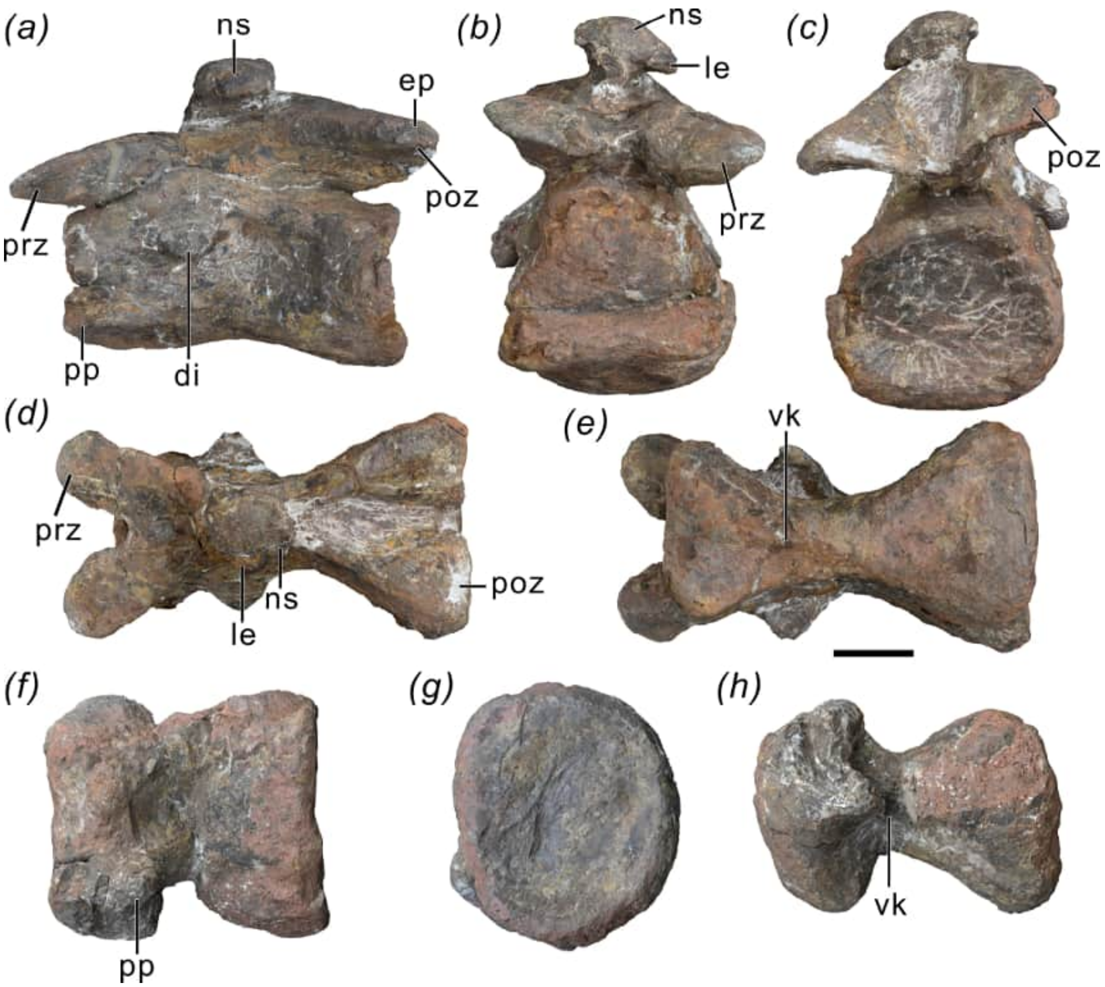

Figure 3. The middle and posterior cervical vertebrae of *Xiangyunloong fengming*. (*a–e*) Cv8? in (*a*) lateral, (*b*) anterior, (*c*) posterior, (*d*) dorsal and (*e*) ventral views. (*f–h*) Cv10 in (*f*) lateral, (*g*) posterior and (*h*) ventral views. Abbreviations: di, diapophysis; ep, epipophysis; le, lateral expansion; ns, neural spine; poz, postzygapophysis; pp, parapophysis; prz, prezygapophysis; vk, ventral keel. Scale bar equals 5 cm.

5.2.1. Middle dorsal vertebrae

There are two middle dorsal vertebrae preserved (figure 4). They possibly represent D5 and D7 due to the relatively low placement of their parapophyses (just on the neurocentral suture), the development of the diapophyseal laminae, and relative anteroposterior shortness of the neural spine (table 1). Here they are tentatively assigned to D5 and D7. D5 only preserves its neural arch (figure 4*a–c*), and D7 is almost complete (figure 4*d–f*).

In ventral view, the centrum of D7 is smooth without a keel, as in other non-sauropodan sauropodomorphs. The lateral surface of the centrum is shallowly depressed and lacks any pneumatic foramina or fossae. The anteroposterior length of the centrum is 1.2 times the dorsoventral height of the anterior articular facet, as also occurs in *Lufengosaurus*, *X. chengi* and *Jingshanosaurus*, but in contrast to the more elongated elements of *Adeopapposaurus*, *Seitaad* and *Massospondylus* [41,42,45].

The parapophysis of D5 appears situated centrally on the lateral surface of the dorsal according to its relative position with the diapophysis (figure 4*a*). It lacks the ventral region, which is probably located at the centrum. The dorsal part of the parapophysis is placed at the neural arch, with its dorsal margin positioned below the ventral margin of the prezygapophysis. The well-preserved parapophysis of D7 is large and oval in profile (figure 4*d*). It has migrated both anteriorly and dorsally compared with that of D5 but is still situated on the neurocentral junction, with its dorsal margin extended almost as dorsally as the ventral margin of the prezygapophysis.

The diapophyses of D5 and D7 are extended laterally and slightly dorsally possibly due to crushing. They are supported by the prezygodiapophyseal lamina (PRDL), paradiapophyseal lamina (PPDL),

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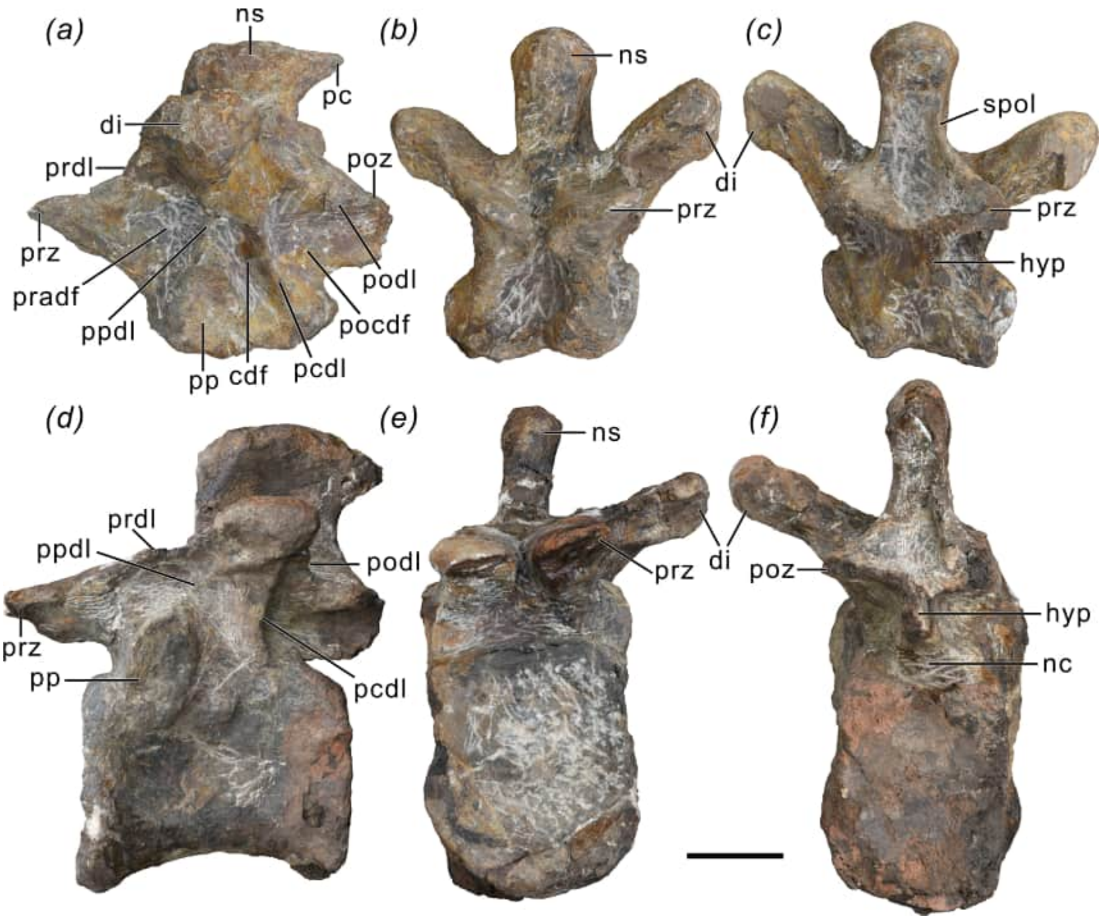

Figure 4. The middle dorsal vertebrae of *Xiangyunloong fengming*. (*a–e*) D5? in (*a*) lateral, (*b*) anterior and (*c*) posterior views. (*d–f*) D7? in (*d*) lateral, (*e*) anterior, and (*f*) posterior views. Abbreviations: cdf, the centrodiapophyseal fossa; di, diapophysis; hyp, hyposphene; nc, neural canal; ns, neural spine; pc, posterodorsal corner; pcdl, posterior centrodiapophyseal lamina; pocdf, postzygapophyseal centrodiapophyseal fossa; podl, postzygodiapophyseal lamina; poz, postzygapophysis; pp, parapophysis; ppdl, paradiapophyseal lamina; pradf, prezygapophyseal paradiapophyseal fossa; prdl, prezygodiapophyseal lamina; prz, prezygapophysis; spol, spinopostzygapophyseal lamina. Scale bar equals 5 cm.

posterior centrodiapophyseal lamina (PCDL) and postzygodiapophyseal lamina (PODL) in D5 (figure 4*a*). In D7, the PPDL is only weakly developed (figure 4*d*). The PRDL and PPDL delimit a large, deep prezygapophyseal paradiapophyseal fossa (PRPADF) in D5, which is also present in most non-sauropodan sauropodomorphs [41] but absent in *Coloradisaurus* [43]. PRPADF is considerably reduced but still present in D7. The centrodiapophyseal fossa (CDF) and postzygapophyseal centrodiapophyseal fossa (POCDF) are both well developed in D5 and D7.

The prezygapophyses of D5 and D7 are projected more anteriorly than the anterior surface of the centrum, with their articular facets facing almost horizontally and slightly medially. The postzygapophyses, although being broken, appear less extended than the prezygapophyses. The postzygapophysis supports a spinopostzygapophyseal lamina (SPOL) that merges into the neural spine at a position close to the dorsal top, as also occurs in *X. chengi*. By contrast, the SPOL is absent in the anterior dorsal vertebrae in *Massospondylus* [41]. The hyposphene of both D5 and D7 is well developed and appears dorsoventrally higher than the sub-circular neural canal that is infilled by matrix (figure 4*c,f*).

The neural spine of D5 is expanded laterally at its dorsal summit, and this dorsal expansion is much reduced in D7 (figure 4*a,d*). A prominent posterodorsal corner is developed in both D5 and D7. This corner is observed in most non-sauropodan sauropodomorphs (e.g. *Xingxiulong*, *Yunnanosaurus*, *Plateosaurus* [39], *Coloradisaurus* [43] and *Mussaurus* [46]). However, it appears particularly pronounced in *Xiangyunloong*, especially in D5.

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5.2.2. Posterior dorsal vertebrae

Three dorsal vertebrae are much larger than the anterior elements and are tentatively interpreted as D9, D11 and D14 due to higher location of the parapophysis and increase of the total height (figures 5 and 6).

The three posterior dorsal vertebrae are all nearly completely preserved. The centrum of D9 is elongated with respect to that of D11. The length of the centrum of D9 is 1.18 times the height of its anterior articular facet, resembling that of D7. By contrast, the centrum of D11 and D14 is shorter than it is high anteriorly, with a length/height ratio of 0.92 and 0.93, respectively. The decrease of this ratio of the centra along the dorsal series is typical for the non-sauropodan sauropodomorphs. The centrum of D14 is anteroposteriorly longer than those of other posterior dorsal centra, unlike the condition of most Chinese non-sauropodan sauropodomorphs (e.g. *Lufengosaurus*, *Y. huangi*, *Y. youngi*, *Jingshanosaurus*, *X. chengi* and *Yimenosaurus*), in which the last dorsal centrum is normally the shortest among the posterior dorsal centra. Both articular facets of the centrum of D9 are sub-oval and dorsoventrally higher than it is transversely wide (figure 5*c*,*d*). However, the articular facets of the centrum of D11 and D14 are more rounded, with their height being almost as same as the width (figure 6*c*,*d*,*g*,*h*). The articular facets of D11 are nearly flat and less concave than those of D9 and D14, which has potentially been exaggerated by crushing.

The parapophyses are large, oval in outline and positioned above the neurocentral junction at the anterior end of the neural arches. The diapophyses are mostly extended laterally. The PPDL, PCDL and PODL are developed in D9 and D11, and only PCDL and PODL are developed in D14, similar to that of other non-sauropodan sauropodomorphs. The PCDL of D11 and D14 is more robust than that of D9. The CDF of D9 is shallower, larger and more dorsally facing than that of D11 and D14.

The prezygapophyses of D9 and D14, which are more completely preserved than those of D11, are anteriorly less projected than those of the middle dorsal vertebrae. Furthermore, the articular facets of the prezygapophyses are more medially facing than those of D5 and D7. In lateral view, the postzygapophyses extend beyond the posterior margin of the centrum. The SPOLs of these posterior dorsal vertebrae merge into the neural spine at a more ventral position compared with those of the middle dorsal vertebrae. Although the hyposphenes of the posterior dorsal vertebrae are not completely preserved, they appear to be developed as simple, thin triangular structures with straight ventral margin and slightly concave posterior surface (figures 5*d* and 6*d*,*h*), as in most non-sauropodan sauropodomorphs, but unlike the more complex hyposphenes present in later-diverging sauropodiforms such as *Antetonitrus* and *Aardonyx*, and most sauropods [47–49]. The hyposphene is dorsoventrally slightly higher than the neural canal in D9 and D11 and nearly as high as the neural canal in D14 (see §7). The neural canals are oval and transversely wider than they are dorsoventrally high, and this condition appears to be their original morphology since no evidence of dorsoventral compression nor distortion could be observed.

The neural spine is compressed transversely and anteroposteriorly long in D9 and D11, and becomes transversely wider, anteroposteriorly shorter and dorsoventrally higher in D14, similar to that of most non-sauropodan sauropodomorphs (e.g. *Plateosaurus*, *X. chengi* and *Jingshanosaurus*). The posterodorsal corner of D9 and D11 is present but less extended than that of previous dorsal vertebrae but becomes more pronounced in D14 (figures 5*a* and 6*a*,*e*). This condition is atypical for other non-sauropodan sauropodomorphs (e.g. *Plateosaurus* [39], *Massospondylus* [41], *Adeopapposaurus* [42], *X. chengi*, *Jingshanosaurus* and *Yizhousaurus* [15]), in which the posterodorsal corner is absent or reduced.

The morphology of the dorsal ribs is alike those of other non-sauropodan sauropodomorphs. The ribs consist of a short tuberculum and a longer, much more medially expansive capitulum.

5.3. Caudal vertebrae

15 caudal vertebrae are preserved in *Xiangyunloong*. Although their precise position within the caudal sequence cannot be definitively determined, all the elements are probably located at the proximal region based on their morphology. The first two caudal vertebrae are assigned to Cd1 and Cd3 owing to their total height, low elongation and similar morphology to that of other non-sauropodan sauropodomorphs (e.g. *Lufengosaurus*, *Jingshanosaurus*, *Yizhousaurus* and *X. yueorum*). For convince, other caudal vertebrae are provisionally designated as Cd5–18. Cd1 is missing most of its centrum, and other caudal vertebrae are all almost completely preserved (figures 7 and 8). All the caudal vertebrae are relatively dorsoventally higher and anteroposteriorly longer than those of most Chinese Early Jurassic sauropodomorphs except for *Yunnanosaurus youngi* [19].

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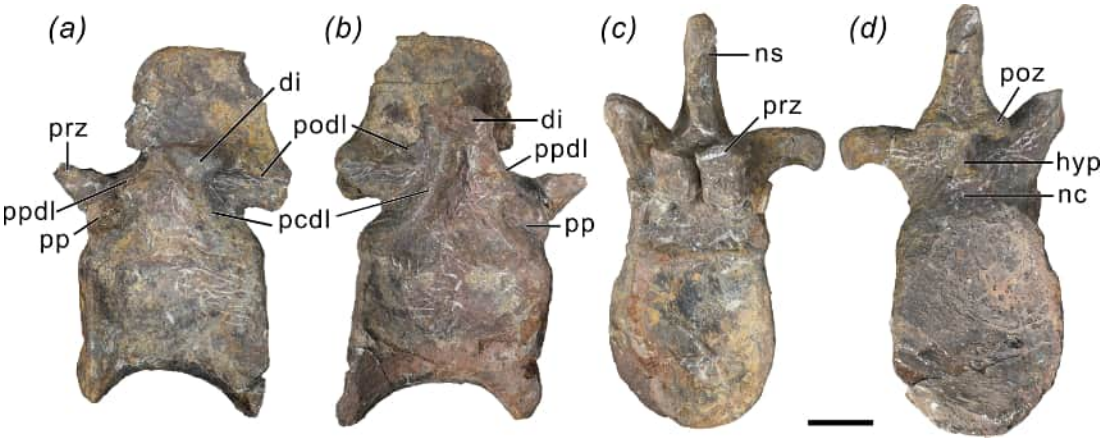

Figure 5. The posterior dorsal vertebra (D9?) of *Xiangyunloong fengming* in (*a*) left lateral, (*b*) right lateral, (*c*) anterior and (*d*) posterior views. Abbreviations: di, diapophysis; hyp, hyposphene; nc, neural canal; ns, neural spine; pcdl, posterior centrodiapophyseal lamina; podl, postzygodiapophyseal lamina; poz, postzygapophysis; pp, parapophysis; ppdl, paradiapophyseal lamina; prz, prezygapophysis. Scale bar equals 5 cm.

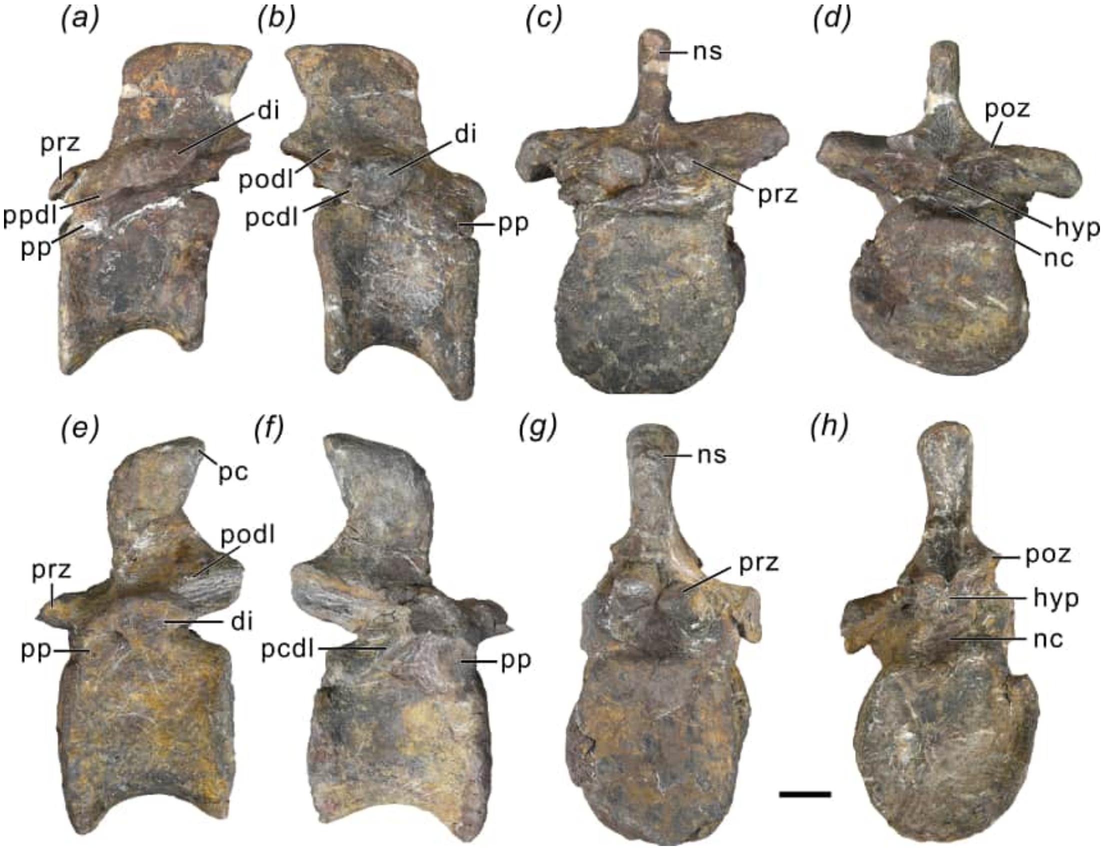

Figure 6. The posterior dorsal vertebrae of *Xiangyunloong fengming*. (*a–d*) D11? in (*a*) left lateral, (*b*) right lateral, (*c*) anterior and (*d*) posterior views. (*e–h*) D14 in (*e*) left lateral, (*f*) right lateral, (*g*) anterior and (*h*) posterior views. Abbreviations: di, diapophysis; hyp, hyposphene; nc, neural canal; ns, neural spine; pc, posterodorsal corner; pcdl, posterior centrodiapophyseal lamina; podl, postzygodiapophyseal lamina; poz, postzygapophysis; pp, parapophysis; ppdl, paradiapophyseal lamina; prz, prezygapophysis. Scale bar equals 5 cm.

The caudal centra are amphicoelous and transversely compressed with concave lateral surface, like those of the dorsal vertebrae. The ventral sulcus is present in all the centra, as also occurs in the majority of non-sauropodan sauropodomorphs (e.g. *Plateosaurus*, *Lufengosaurus* and *Jingshanosaurus*). By contrast, *X. chengi* (LFGT-D0001), *Yizhousaurus* and *Eucnemesaurus entaxonis*, display a ventral ridge that is present in the anterior caudal vertebrae [15,40,50], or *Mussaurus* in which the ventral surface

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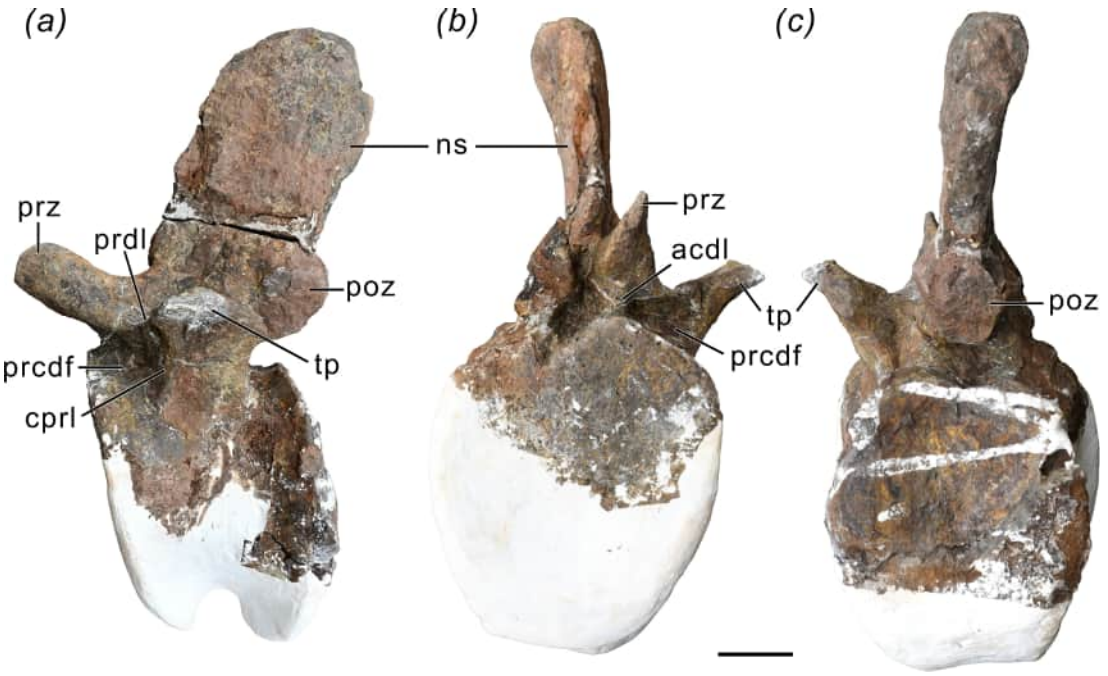

Figure 7. The first caudal vertebra of *Xiangyunloong fengming* in (*a*) lateral, (*b*) anterior and (*c*) posterior views. Abbreviations: acdl, anterior centrodiapophyseal lamina; cprl, centroprezygapophyseal lamina; ns, neural spine; poz, postzygapophysis; prcdf, prezygapophyseal centrodiapophyseal fossa; prdl, prezygodiapophyseal lamina; prz, prezygapophysis; tp, transverse process. Scale bar equals 5 cm.

is flat [46]. The ventral end of the caudal centra is constricted anteroposteriorly to form the articular facet for the chevrons. The centrum of Cd3 is anteroposteriorly shorter than it is dorsoventrally high anteriorly (figure 8*a,b*), with a length/height ratio of 0.70, similar to that of other non-sauropodan sauropodomorphs. The centrum of Cd5, however, is almost as long as it is anteriorly high. From Cd5, the centrum becomes proportionally longer and lower along the caudal series (figure 8*e,f*; table 1).

The neural arch is dorsoventrally much lower than the centrum. The transverse processes are dorsolaterally directed and restricted to the neural arches. The prezygapophyses of Cd1 are extremely long, with a length of 8.4 cm. It is more than half the total length of the centrum, which is rare in sauropodomorphs. Notably, the PRDL is developed in Cd1 and is much reduced in Cd3 (figures 7*a* and 8*a*). Furthermore, an incipient anterior centrodiapophyseal lamina (ACDL) and a centroprezygapophyseal lamina (CPRL) are present in Cd1 (figure 7*a,b*). The ACDL, CPRL and PRDL frame a deep prezygapophyseal centrodiapophyseal fossa (PRCDF). This condition is unusual for non-sauropodan sauropodomorphs (see §7). From Cd5 onwards, the three laminae are absent (figure 8*e*).

The postzygapophyses are much shorter and located higher than the prezygapophyses. The postzygapophyses are separated by an interpostzygapophyseal notch, in contrast to *Coloradisaurus* and *X. chengi* in which the postzygapophyses are placed on either side of the neural spine [43]. The hyposphene is absent in all the caudal vertebrae. The SPOL is only weakly developed in the anterior-most caudal vertebrae. The neural spines are dorsoventrally high, anteroposteriorly short, and extend dorsoposteriorly. The neural spine of Cd1 is higher than that of D14 and appears higher than that of *X. yueorum*. Along the caudal series, the neural spines become lower and shorter. The dorsal summit of the neural spine of Cd1 is widened, although in a degree less than that of D14.

5.4. Chevron

There are 12 chevrons preserved, possibly representing the anterior elements, although the true positions of most elements are difficult to ascertain (figure 9). Based on the relative length between the chevrons and caudal centra, as well as the comparison with other sauropodomorphs, they are tentatively assigned as the second to 13th elements, including the longest chevron that probably represents the fifth element, although they may not form a continuous series (table 2). The longest chevron is longer than twice the length of all the preserved anterior caudal centra. Furthermore, this

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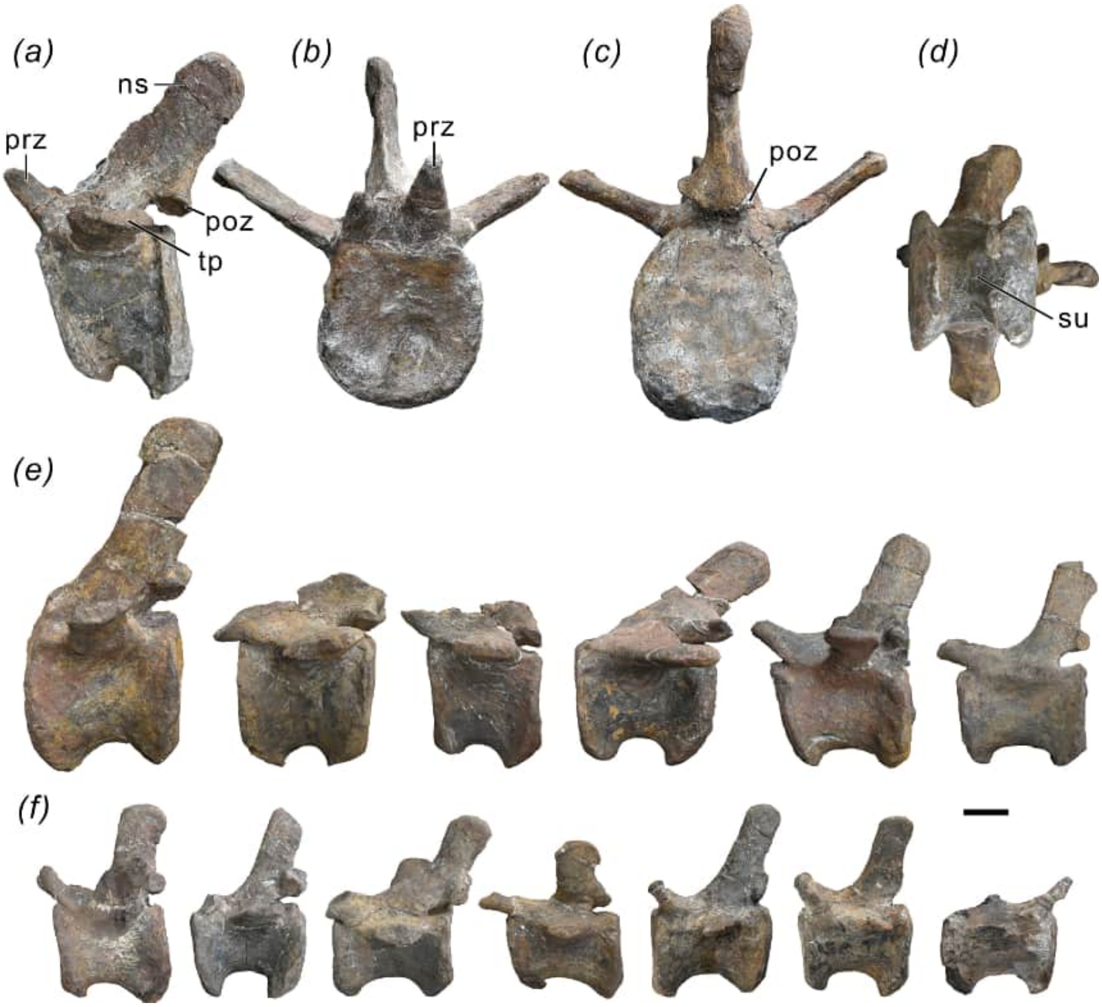

Figure 8. The caudal vertebrae of *Xiangyunloong fengming*. (*a–d*) Cd3 in (*a*) lateral, (*b*) anterior, (*c*) posterior and (*d*) ventral views. (*e*) Cd5–10? in lateral view. (*f*) Cd12–18? in lateral view. Abbreviations: ns, neural spine; poz, postzygapophysis; prz, prezygapophysis; su, sulcus; tp, transverse process. Scale bar equals 5 cm.

chevron, which is 35.4 cm in measurement, appears longer that of most non-sauropodan sauropodomorphs, including the large-bodied *Plateosaurus* [39], *Jingshanosaurus*, *X. yueorum* and *Aardonyx* [47]. However, it is shorter than that of *Y. youngi* whose longest chevron is 55 cm [19], which possibly represents the longest chevrons so far among the Chinese non-sauropodan sauropodomorphs.

The chevrons are closed 'Y-shaped' with a transversely wide proximal bony bridge that is articulated with the caudal vertebrae and two proximal rami ventrolaterally enclosing the haemal canal [51], as in other non-sauropodan sauropodomorphs. The haemal canals for the caudal blood vessels [52] are filled with matrix (figure 9*a*). In anterior or posterior view, the haemal canals are positioned dorsally in a dorsoventrally elongated groove and appear transversely narrow and slit-shaped, similar to that of *Jingshanosaurus* and *Massospondylus*, but different from *Plateosaurus*, *Lufengosaurus* and *X. chengi* in which the canals are wider and more oval in outline [39]. In lateral view, the distal blade of proximal-most chevron tapers distally, whereas the blade of the distal chevrons is slender at the midpoint and becomes expanded distally (figure 9*b*).

5.5. Ilium

A partial left ilium, which lacks its posterior part of the main body, is preserved (figure 10). In terms of general morphology, the ilium is robust and dorsoventrally low (table 3), although it has suffered a dorsoventral deformation at the preacetabular process. The preacetabular process is long and sub-triangular in shape, almost reaching the anterior end of the pubic peduncle, as also occurs in *Adeopapposaurus* [42]. By contrast, the preacetabular process of other Chinese early-diverging

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Figure 9. The anterior to middle chevrons of *Xiangyunloong fengming* in (*a*) anterior and (*b*) lateral views. Abbreviation: hc, haemal canal. Scale bar equals 10 cm.

Table 2. Measurements (in mm) of the representative chevrons of *Xiangyunloong fengming*.

element	dimension	value
chevron 2	length	282.4
	transverse width of proximal end	—
	maximum anteroposterior width of distal blade	27.0
chevron 3	transverse width of proximal end	109.0
chevron 4	length	333.1
chevron 5 (longest)	length	354.3
	transverse width of proximal end	123.9
	maximum anteroposterior width of distal blade	62.1
chevron 6?	length	318.4
	transverse width of proximal end	98.0
	maximum anteroposterior width of distal blade	70.6

sauropodomorphs, such as *Lufengosaurus*, *X. chengi*, *X. yueorum*, *Jingshanosaurus*, *Yunnanosaurus* and *Yizhousaurus*, is relatively shorter and only reaches the around the anteroposterior midpoint of the pubic penduncle. The preacetabular process of *Xiangyunloong*, however, is not as long as that of *Anchisaurus* [53], *Leonerasaurus* [54] and NMQR 4125 [55] which extends anteriorly beyond the pubic penduncle. The preacetabular process appears projected at an angle of about 20° relative to the long axis of the pubic peduncle, contrasting to an angle of approximately 50–60° in other non-sauropodan sauropodomorphs (e.g. *Macrocollum* [56], *Plateosaurus* [39], *Jingshanosaurus*, *Xingxiulong*, *Sarahsaurus* [57], *Leonerasaurus* [54] and *Antetonitrus* [48]). The reduction of this angle is probably formed by compression. The lateral surface of the preacetabular process is slightly convex, and the medial surface is concave.

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The acetabulum is completely open and bears a supracetabular crest along its anterior margin. The supracetabular crest appears extends posteriorly in a short distance (i.e. anteriorly to the midpoint between the iliac peduncles; figure 10*a*). This condition resembles that of *Yizhousaurus* [15] and *Leonerasaurus* [54], but differs from most non-sauropodan sauropodomorphs, in which the supracetabular crest projects posteriorly behind the midpoint (e.g. *Lufengosaurus*, *Massospondylus*, *Adeopapposaurus*, *X. chengi*, *X. yueorum*, *Jingshanosaurus*) and the 'hyper-robust' ilium (NMQR 4125) described by McPhee & Choiniere [55]. Despite the shortness, the supracetabular crest is flaring at an extent more laterally and ventrally (which can be observed in medial view) than that of other Chinese non-sauropodan sauropodomorphs, including *Lufengosaurus*, *Y. huangi*, *Y. youngi*, *Jingshanosaurus*, *X. chengi*, *X. yueorum* and *Yizhousaurus*, and forms the transversely widest portion of the acetabulum in ventral view. The anterior and dorsal internal surface of the acetabulum is slightly concave, and the posterior surface (i.e. the anterior surface of the ischial peduncle) is convex. In ventral view, the acetabulum is remarkably wide transversely. The maximum transverse width of the acetabulum is 0.6 times the anteroposterior length of the acetabulum, resembling but slightly lower than that of NMQR 4125 [55].

The pubic peduncle is directed anteroventraly, with its dorsal margin convex dorsally. The distal end of the pubic peduncle is expanded anteroposteriorly, similar to that of other sauropodomorphs. The ventral surface of the pubic peduncle is drop-shaped (figure 10*c*). The transverse width of the ventral surface is 1.6 times its anteroposterior length, displaying a more robust morphology than that of *Lufengosaurus* (1.3), *Jingshanosaurus* (1.2) and NMQR 4125 (1.35 [55]).

The ischial peduncle is slightly shorter than the pubic peduncle, with their distal end almost level with each other, as is typical for non-sauropodan sauropodomorphs. A posteroventral 'heel' is present at the distal end of the ischial peduncle, resembling that of most non-sauropodan sauropodomorphs such as *Plateosaurus* [39], *Coloradisaurus* [43], *Lufengosaurus*, *Xingxiulong* and *Yizhousaurus* [15]. The ventral surface of the ischial peduncle is semi-circular in outline (figure 10*c*). Like that of the pubic peduncle, the ischial peduncle is also robust, with its transverse width at the ventral surface being 1.4 times the anteroposterior length.

5.6. Ischium

The right ischium is nearly completely preserved. It is a robust and stout element, composed of a proximal plate and the ischial shaft (figure 11). The total length of the ischium is 2.3 times the dorsoventral height of the proximal plate, as also occurs in *Massospondylus*, *Eucnemesaurus* and *Pulanesaura* [49]. The proximal plate extends distally at almost the midpoint of the ischial shaft, resembling that of *Plateosaurus* [39], *Yunnanosaurus*, *Jingshanosaurus* and *Sarahsaurus* [57], but unlike *Coloradisaurus* [43], *Lufengosaurus* and *Mussaurus* [46] in which the proximal plate only occupies the proximal third of the ischium. The proximal end of the proximal plate consists of the pubic and iliac pedicels, which are separated by a broad notch. In dorsal view, the surface of this notch is smooth and concave. The pubic pedicel is dorsally higher than the iliac pedicel. The articular facet of the pubic pedicel is sub-crescent in profile, and the articular facet of the iliac pedicel is transversely wider and sub-oval in outline. The lateral surface of the proximal plate is concave proximally and convex distally. The medial surface of this plate is concave. There is no sign of the presence of a notch that separates the proximal plate and the shaft.

The ischial shaft is robust, sub-triangular in cross-section and mediolaterally narrower than it is dorsoventrally deep. The dorsoventral depth of the shaft is 0.15 times the total maximum length of ischium, resembling that of *Jingshanosaurus*. By contrast, this metric appears lower in *Lufengosaurus*, *Adeopapposaurus* [42] and *Coloradisaurus* [43], all of which have a slenderer ischia shaft. The dorsal surface of the ischial shaft bears to a shallow longitudinal dorsolateral sulcus (figure 11*c*). The distal end of the ischium has experienced erosion, so that the shape of its distal surface cannot be determined, although it appears expanded with respect to the shaft as in other early-diverging sauropodomorphs.

6. Phylogenetic results

The phylogenetic analysis resulted in 168 most parsimonious trees (MPTs) with lengths of 1650 steps (CI = 0.285; RI = 0.659). The strict consensus tree is largely well resolved, with small polytomies present within the earliest-diverging sauropodomorphs and the sauropodiforms, similar to the result depicted by Wang *et al.* [22]. *Xiangyunloong* is recovered in an unresolved clade together with *X. chengi* and

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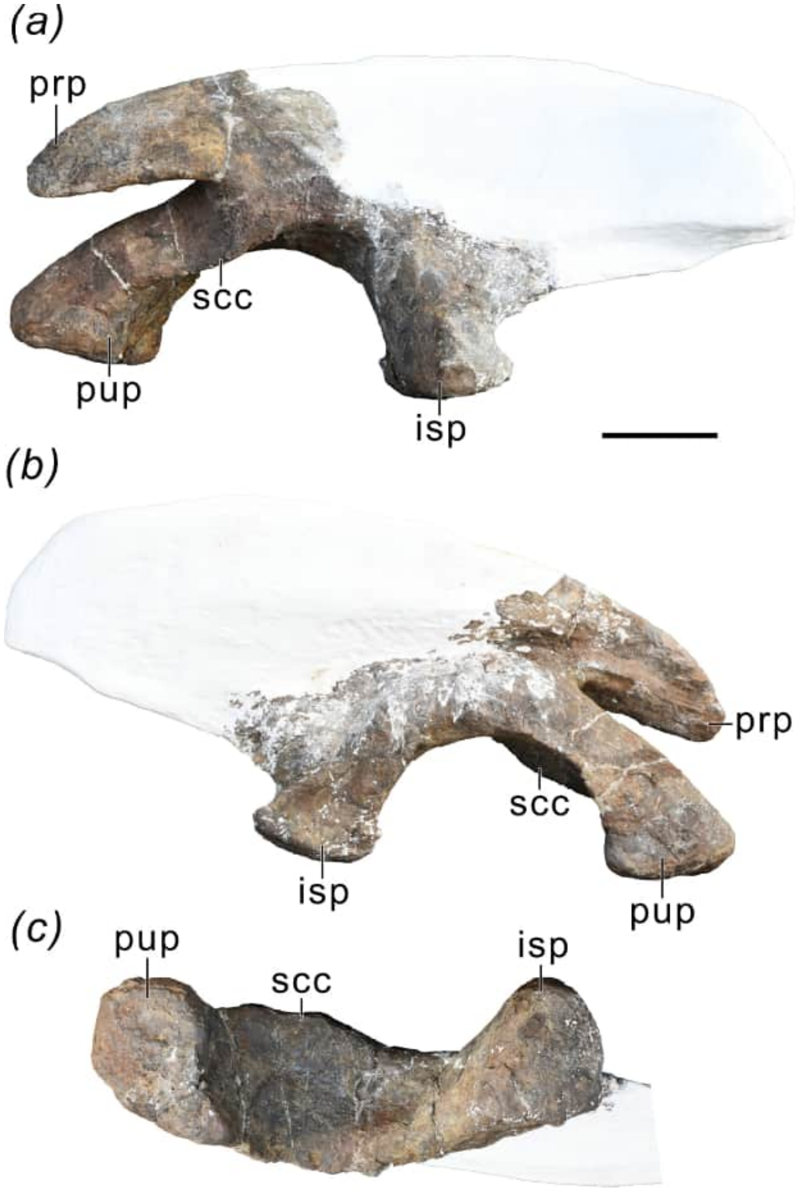

Figure 10. The left ilium of *Xiangyunloong fengming* in (*a*) lateral, (*b*) medial and (*c*) ventral views. Abbreviations: isp, ischial peduncle; prp, preacetabular process; pup, pubic peduncle; scc, supracetabular crest. Scale bar equals 10 cm.

Table 3. Measurements (in mm) of the ilium and ischium of *Xiangyunloong fengming*. *Estimated value.

element	dimension	value
left ilium	maximum transverse width of acetabulum	136.5
	length of pubic peduncle	209.0
	length of preacetabular process	160.4
	height of preacetabular process	115.3
right ischium	total length	517.2
	length of proximal obturator plate	224.0
	height of proximal obturator plate	315.4
	minimum width of mid-shaft	67.3
	minimum height of mid-shaft	76.7
	height of distal end	171.0*

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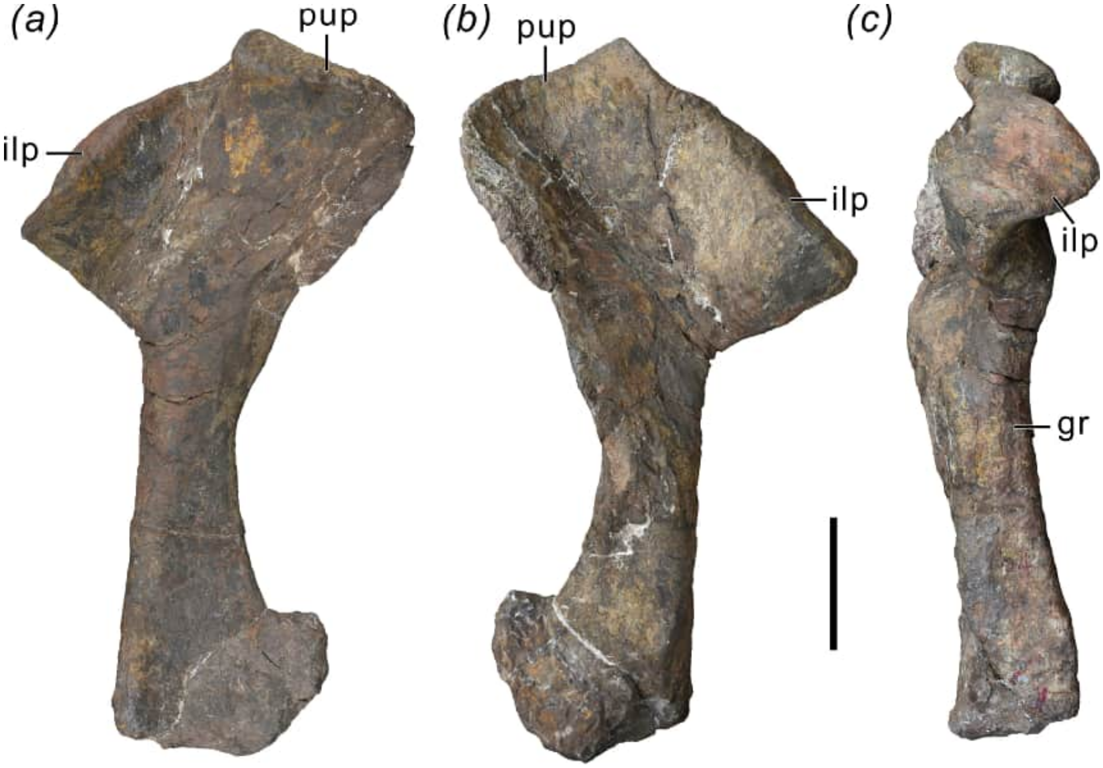

Figure 11. The right ischium of *Xiangyunloong fengming* in (*a*) lateral, (*b*) medial and (*c*) dorsal views. Abbreviations: ilp, iliac peduncle; gr, groove; pup, pubic peduncle. Scale bar equals 10 cm.

X. yueorum (figure 12). This clade is supported by four unambiguous synapomorphies: presence of caudosacral vertebra (Char. 192: 1; unknown in *Xiangyunloong*); length of the longest chevron greater than twice the length of the preceding centrum (Char. 211: 1); presence of posteriorly projecting 'heel' at the distal end of the ischial peduncle (Char. 281: 1); proximal tip of lesser trochanter distal to the femoral head (Char. 314: 1; unknown in *Xiangyunloong*).

Characters that unite *Xiangyunloong* with the sister group formed by *Jingshanosaurus* and *Seitaad*, and Sauropodiformes to the exclusion of *Yunnanosaurus* and *Qianlong* include: length of jugal ramus of quadratojugal longer than the squamosal ramus (Char. 68: 1; unknown in *Xiangyunloong*); convex posterior margin of astragalus (Char. 356: 1; unknown in *Xiangyunloong*); simple lateral surface of calcaneum (Char. 359: 0; unknown in *Xiangyunloong*). The Sauropodiformes clade is supported by five unambiguous synapomorphies: presence of longitudinal ventral sulcus on proximal and middle caudal vertebrae (Char. 205: 1); minimum transverse shaft width of first metacarpal less than twice the minimum transverse shaft width of second metacarpal (Char. 250: 1; unknown in *Xiangyunloong*); length of manual digit one greater than the length of manual digit two (Char. 261: 1; unknown in *Xiangyunloong*); proximal end of the tibia with a transverse/anteroposterior length ratio less than 0.7 (Char. 336: 0; unknown in *Xiangyunloong*); absence of fossa or foramina at anterior base of ascending process of astragalus (Char. 354: 1; unknown in *Xiangyunloong*).

Alternative phylogenetic placements of *Xiangyunloong* within Massopoda but outside of Sauropodiformes require at least two to three extra steps; and at least three to five extra steps are required to place *Xiangyunloong* within Sauropodiformes.

7. Discussion

7.1. Phylogenetic implications and comparisons

Although *Xiangyunloong* is placed within a small polytomy that also includes *X. chengi* and *X. yueorum*, which may result from the limited information of this new specimen, it exhibits marked distinctions from the two species of *Xingxiulong* [14,35]. First, the cervical neural spine of *Xiangyunloong* bears a lateral expansion at the middle region of the dorsal end, whereas this expansion is absent in *X. chengi*.

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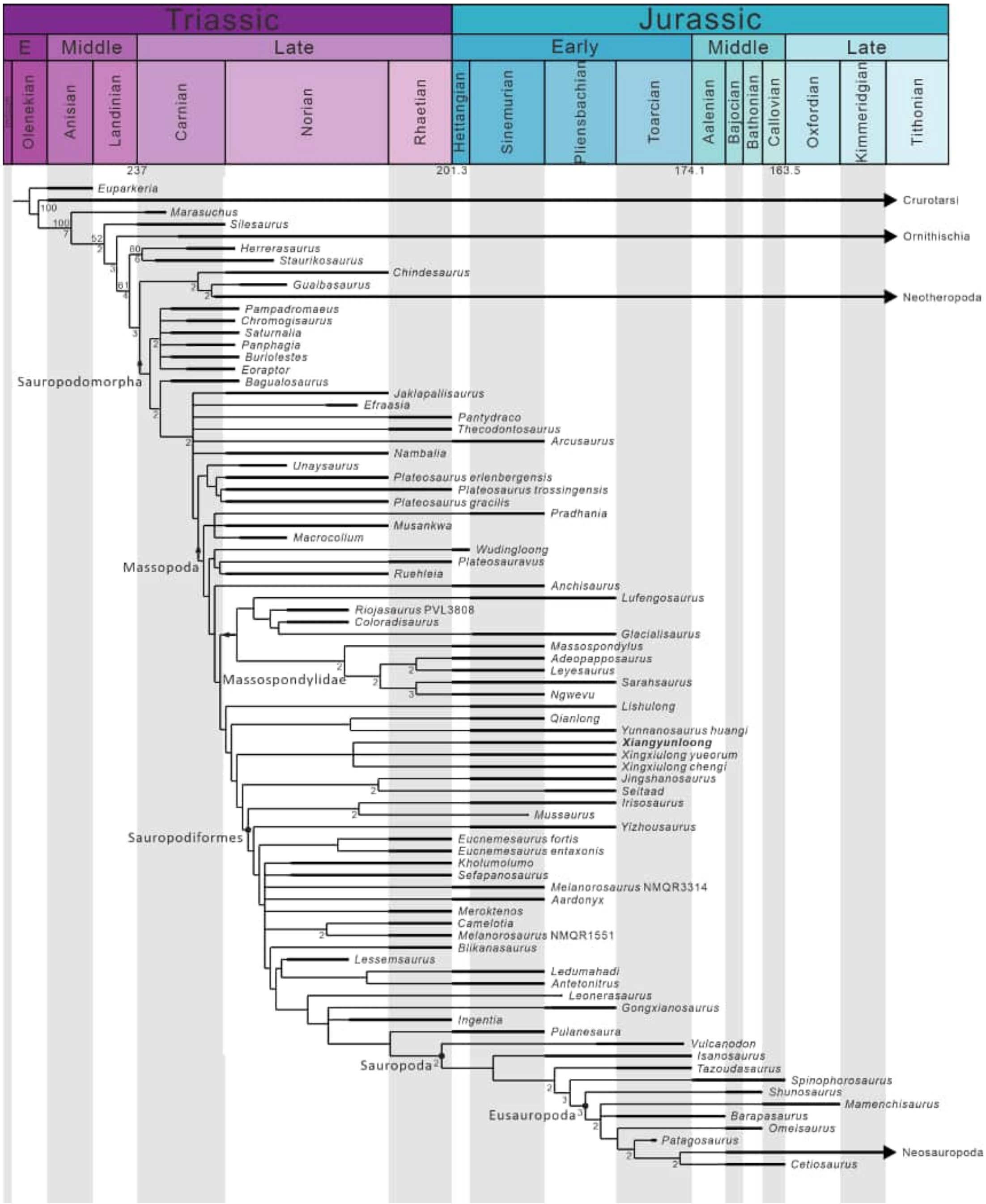

Figure 12. Time-scaled strict consensus of 168 MPTs showing the phylogenetic position of *Xiangyunloong fengming*. Numbers above the nodes represent bootstrap frequencies >50%, and numbers below the nodes represent Bremer support values >1. The age of each record was taken from Wang *et al.* [22].

Second, the posterodorsal corner present in the last dorsal vertebra of *Xiangyunloong* is absent in *X. chengi* and appears absent in *X. yueorum*; meanwhile, the dorsal summit of the last dorsal neural spine is not as widened as that of *X. chengi*. Third, the first caudal vertebra of *X. chengi* and *X. yueorum* lacks the laminar system and its corresponding PRCDF, which are developed in *Xiangyunloong*. Furthermore, the prezygapophyses of the anterior caudal vertebrae, especially Cd1 and Cd3, of *Xiangyunloong* are more anteriorly elongated than those of *X. yueorum*. Fourth, the supracetabular crest of the ilium of *Xiangyunloong* is anteroposteriorly reduced but laterally and ventrally flaring, unlike the posteriorly extended and less laterally developed crest in *X. chengi* and *X. yueorum*. Therefore, *Xiangyunloong* is significantly different from the two species of *Xingxiulong*. Combined with its distinct geographic locality and stratigraphic horizon, here it is assigned as a new genus. Due to the high degree of morphological similarity and limited diagnostic differences between *X. chengi* and *X. yueorum* [35],

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which will be addressed in further elsewhere, they are retained as separate species within the same genus.

Xiangyunloong represents one of the largest-bodied early-diverging sauropodomorphs from China. Other taxa that are similar in overall body size to *Xiangyunloong*, or slightly larger than it, are *Yimenosaurus*, *Jingshanosaurus* and *Yunnanosaurus youngi*. *Yimenosaurus* was reported in 1990 based on more than ten skeletons, and it was discovered from the Lower Jurassic Fengjiahe Formation of Yimen County, Yuxi City of Yunnan Province [18]. However, due to lack of enough illustrations provided by Bai *et al.* [18] and lack of access to the *Yimenosaurus* specimens for first-hand observation for now, a direct morphological comparison between *Xiangyunloong* and *Yimenosaurus* is currently impossible. Based on the descriptions provided in the original publication [18], two morphological distinctions between *Xiangyunloong* and *Yimenosaurus* could be identified. The ventral keel of the cervical vertebrae of *Xiangyunloong* is faint and only weakly developed, contrasting with the prominent ventral keel of *Yimenosaurus* as described by Bai *et al.* [18]. The centrum of the axis of *Yimenosaurus* is elongated based on the figure present in Bai *et al.* [18], similar to that of *Jingshanosaurus* [12], *Lishulong* [17] and *Yizhousaurus* [15], but more elongated than that of *Lufengosaurus* [9] and *Xingxiulong* [40], both of which possess short cervical centra similar to those of *Xiangyunloong*. In these taxa, Cv3 and Cv4 have a more elongated centrum than that of the axis, indicating that a same condition is also present in *Yimenosaurus*. Therefore, *Yimenosaurus* probably represents a long-necked taxon and has more elongated cervical centra than those of *Xiangyunloong*. Given the presence of unambiguous autapomorphies in *Xiangyunloong*, the lack of evidence in the publication of *Yimenosaurus* to support its possession of the diagnostic features of *Xiangyunloong*, and the differences between these two taxa mentioned above, we therefore suggest that *Xiangyunloong* and *Yimenosaurus* belong to two distinct genera under the current state of knowledge. However, a comprehensive re-examination and detailed re-description of the holotype of *Yimenosaurus* should be warranted in future, which would be critical to determine its taxonomic position and its relationships with other taxa.

Although the cranium of *Jingshanosaurus* was restudied with an emended diagnosis [58], the postcranial skeleton lacks detailed re-examination, especially the comparison with other non-sauropodan sauropodomorphs considering that most of the diagnostic characters listed in the original literature are not substantially distinct from those of other taxa. *Yunnanosaurus youngi* was described by Lü *et al.* [19] based on a partial complete postcranial skeleton, which was recovered from the Lower Jurassic Fengjiahe Formation of Yuanmou County of Yunnan Province [19,21]. Due to the current inability to directly observe the specimen of *Y. youngi*, it was not yet included in the phylogenetic analysis. However, given that it may represent one of the largest non-sauropodan sauropodomorph discovered from China to date, the further redescription and phylogenetic analysis on *Y. youngi* is warranted in future. Nonetheless, the diagnostic features of *Xiangyunloong* can differ it from *Jingshanosaurus* and *Y. youngi* based on the original descriptions of the two taxa [12,19]. The lateral expansion at the middle region of the dorsal end of the cervical neural spines of *Xiangyunloong* is absent in *Jingshanosaurus* or more anteriorly located in *Y. youngi*. Furthermore, *Jingshanosaurus* and *Y. youngi* lack the deep PRCDF in the first caudal vertebra, as well as the anteroposteriorly reduced but laterally and ventrally flaring supracetabular crest, which are both developed in *Xiangyunloong*.

Moreover, it is noteworthy that the specimen of *Xiangyunloong* was recovered from Xiangyun area, which is a locality from which no dinosaur fossils had ever been documented prior to this discovery and geographically remote from the discovery sites of previously reported taxa. In light of the morphological differentiations presented above, it is therefore reasonable to conclude that this specimen is clearly diagnostic at a genus level.

7.2. Morphological implications

There are two striking morphological features present in *Xiangyunloong*, including the heightened hyposphene of the dorsal vertebrae and the development of the laminar system on the first caudal vertebra, both of which links *Xiangyunloong* with the sauropodiforms and sauropods. In *Xiangyunloong*, except for D14 in which the hyposphene of the dorsal vertebrae is slightly lower than the neural canal, D7, D9 and D11 all have their hyposphene higher than the neural canal (figures 4 and 5). This is an unusual feature for the non-sauropodiform massopodans, but is fairly typical for the sauropodiforms and sauropods (e.g. *Yizhousaurus* [15], *Kholumolumo* [59], *Leonerasaurus* [54], *Melanosaurus* [60] and *Pulanesaura* [49]), although the hyposphene of *Xiangyunloong* remains simple, unlike that of the later-diverging sauropodiforms and sauropods. Given the relatively 'basal' phylogenetic position of *Xiangyunloong*, this 'derived' morphological feature may be linked to the initial stages of gigantism.

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The development of the hyposphene of *Xiangyunloong* may have increased spinal stability, which facilitated the evolution of a larger body size [61,62].

The PRDL of the first caudal vertebra is only reported to be present in sauropods and *Pulanesaura* that is closely related to sauropods [49,63], although it may be also weakly developed in *Lufengosaurus* and *X. yueorum* (Y.-M.W. 2026, personal observation). However, among all the non-sauropodan sauropodomorphs that preserves the caudal vertebrae discovered from China (e.g. *Lufengosaurus*, *Yunnanosaurus*, *Jingshanosaurus*, *Xingxiulong* and *Yizhousaurus*) so far, both ACDL and CPRL are only observed to be developed in *Xiangyunloong* (figure 7). Furthermore, the deep PRCDF of the first caudal vertebra of *Xiangyunloong* is the first occurrence within non-sauropodan sauropodomorphs, possibly representing the initial development of the laminar system observed in sauropods. Although intraspecific variability of the vertebral laminae has been documented in the cervical and dorsal vertebrae of *Plateosaurus* [64], the pronounced PRCDF in *Xiangyunloong* distinguishes it from other taxa in which the PRCDF is either absent or shallowly developed (e.g. *Massospondylus* [41]). Therefore, this deep PRCDF remains a potentially diagnostic feature of *Xiangyunloong*. In fact, this would be attributed to the heightening of the neural arch and the dorsally elevation of the transverse process. The neural canal of the first caudal vertebra of *Xiangyunloong* appears higher than it is transversely wide, although the taphonomic compression cannot be ruled out, if natural, this morphology would be similar to that of later-diverging sauropodiforms such as *Pulanesaura* [49,63] and sauropods like *Tazoudaasaurus* [65,66], but different from most non-sauropodan sauropodomorphs in which the neural canal is wider than its height (e.g. *Lufengosaurus*, *Massospondylus*, *Jingshanosaurus* and *Yizhousaurus*).

7.3. Functional implications

The low cervical vertebral elongation ratio of *Xiangyunloong*, *Lufengosaurus* [9], *Y. huangi* [10] and *X. chengi* [14] provides evidence for a shorter neck in these taxa, contrasting with the longer neck of *Jingshanosaurus* [12], *Y. youngi* [19], *Lishulong* [17] and *Yizhousaurus* [15]. It is possible that this discrepancy led to the differentiation of long-necked and short-necked morphotypes within these Chinese taxa. Furthermore, compared with *Jingshanosaurus* and *Yizhousaurus*, the dorsal vertebrae of *Xiangyunloong* are only slightly longer. By contrast to the short neck, *Xiangyunloong* has much longer and higher caudal vertebrae with extremely long prezygapophyses, as well as longer chevrons, than the large-bodied taxa such as *Jingshanosaurus* and *Yizhousaurus*. This morphology implies that the tail of *Xiangyunloong* is proportionally more robust and could have acted as an effective counterbalance to the heavy anterior body, facilitating bipedal postures for feeding, despite the short neck [67–69].

The ilium of *Xiangyunloong* has a similar robustness to that of NMQR 4125 [55], especially at the iliac peduncles, but bears a shorter and less flaring supracetabular crest (figure 10). The markedly hypertrophied supracetabular crest, as suggested by McPhee & Choiniere [55], may reflect enhanced abduction capability of *M. iliofemoralis*, which is functionally linked to bipedal locomotion, as increased stance-phase abduction offers limited adaptive advantage in a quadrupedal gait. The reduced supracetabular crest in *Xiangyunloong* could signal a decreased functional emphasis on powerful hip. Instead, as a possible biped, the robust tail of *Xiangyunloong* could provide strong posterior power, which may have supported a more upright gait [70]. This contrasts with other non-sauropodan sauropodomorphs from China, including the obligate bipeds with a more horizontal posture such as *Lufengosaurus* and *Yunnanosaurus*, as well as facultative quadrupeds such as short-necked *Xingxiulong* and long-necked taxa such as *Jingshanosaurus* and *Yizhousaurus* [6].

Overall, *Xiangyunloong* is characterized by a short neck and a proportionally robust and elongated tail, suggesting an alternative evolutionary pathway among the early-diverging sauropodomorphs (i.e. the elongation and robustness into the tail rather than the neck). However, the verification of this speculation will necessitate not only future discoveries of more complete material but also further morphofunctional investigations.

7.4. Implications for sauropodomorph diversity in the Early Jurassic of southwestern China

The discovery of *Xiangyunloong* adds another type of sauropodomorphs to the four associations of sauropodomorph assemblages from the Early Jurassic of southwestern China proposed by Wang *et al.* [22]. *Wudingloong* represents the first and most 'basal' group, which was characterized by the small, gracile body and remarkably robust first manual ungual. The second group is represented by the massospondylid members including *Lufengosaurus* and putative *Xixiposaurus* [71,72], which

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were figured by the medium-sized body and obligately bipedal locomotion [6]. The third group is exemplified by *Xingxiulong* and *Jingshanosaurus* which had medium to large body size and were at least facultative quadrupeds [6,12,14]. The fourth group is represented by *Xiangyunloong* (and probably *Y. huangi* and *Y. youngi*, as the former was a potential immature individual and may have had a large body when it was fully mature [17]) that had a large-sized body and were probably obligately bipeds. The fifth group consists of the sauropodiform members such as *Yizhousaurus* and *Gongxiansaurus* [15,73], which represents the most 'derived' taxa in the assemblages.

Xiangyunloong exemplifies a previously underappreciated ecomorphotype within the early-diverging sauropodomorphs (i.e. a large-bodied, short-necked form with a powerfully constructed tail). It provides further evidence for the diverse adaptive strategies employed by these dinosaurs prior to the dominance of the long-necked, gigantic sauropods.

8. Conclusions

Herein, we describe *Xiangyunloong fengming*, a new genus and species of sauropodomorph dinosaur from a newly discovered fossil site in the Lower Jurassic Fengjiahe Formation in Luming Town, Xiangyun County, Dali Bai Autonomous Prefecture, Yunnan Province, China. *Xiangyunloong* is distinguished from all other known non-sauropodan sauropodomorphs by a unique combination of features. Phylogenetic analysis recovers *Xiangyunloong* as a non-sauropodiform massopodan sauropodomorph, closely related to most of the Early Jurassic sauropodomorphs from China despite its distinctive morphology. The intriguing morphological features observed in *Xiangyunloong*, including its large body size, proportionally short cervical vertebrae, dorsal vertebrae with heightened hyposphenes, and elongate, robust caudal vertebrae with development of the laminar system, indicating an initial stage of gigantism and a potential bipedal locomotion, which may represent an alternative evolutionary pathway to the neck elongation seen in other early-diverging sauropodomorphs. The discovery of *Xiangyunloong* significantly enriches the morphological and ecological diversity of the early-diverging sauropodomorphs in southwestern China.

Ethics. This work did not require ethical approval from a human subject or animal welfare committee.

Data accessibility. The phylogenetic dataset used in this study has been uploaded to Dryad [74]. The dataset is also provided in electronic supplementary material [75].

Declaration of AI use. We have not used AI-assisted technologies in creating this article.

Authors' contributions. S.-B.H.: conceptualization, data curation, investigation, project administration, resources, validation, writing—original draft, writing—review and editing; Y.-C.W.: data curation, formal analysis, investigation, methodology, software, validation, visualization, writing—original draft, writing—review and editing; X.M.: conceptualization, data curation, investigation, project administration, resources, writing—original draft, writing—review and editing; X.-Q.Z.: data curation, formal analysis, investigation, software, visualization, writing—original draft, writing—review and editing; W.-T.Z.: investigation, project administration, resources, writing—review and editing; T.W.: data curation, investigation, project administration, resources, writing—review and editing; Z.-B.S.: investigation, project administration, resources, writing—review and editing; Q.-X.D.: data curation, investigation, resources, writing—review and editing; Q.G.: investigation, project administration, software, writing—review and editing; Y.-H.L.: data curation, software, visualization, writing—review and editing; Y.-S.Z.: data curation, software, visualization, writing—review and editing; Y.B.: data curation, software, visualization, writing—review and editing; Y.-M.W.: conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, validation, visualization, writing—original draft, writing—review and editing; H.-L.Y.: conceptualization, data curation, investigation, methodology, project administration, resources, software, validation, visualization, writing—original draft, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

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References

1. Brusatte SL, Nesbitt SJ, Irmis RB, Butler RJ, Benton MJ, Norell MA. 2010 The origin and early radiation of dinosaurs. *Earth Sci. Rev*. **101**, 68–100. (doi:10.1016/j.earscirev.2010.04.001)
2. Galton P, Upchurch P. 2004 Prosauropoda. In *The dinosauria* (eds DB Weishampel, P Dodson, H Osmólska), pp. 232–258, 2nd edn. Berkeley, CA: University of California Press. (doi:10.1525/california/9780520242098.003.0014)
3. Apaldetti C, Pol D, Ezcurra MD, Martínez RN. 2021 Sauropodomorph evolution across the Triassic–Jurassic boundary: body size, locomotion, and their influence on morphological disparity. *Sci. Rep*. **11**, 22534. (doi:10.1038/s41598-021-01120-w)
4. Apaldetti C, Martínez RN, Cerda IA, Pol D, Alcober O. 2018 An early trend towards gigantism in Triassic sauropodomorph dinosaurs. *Nat. Ecol. Evol*. **2**, 1227–1232. (doi:10.1038/s41559-018-0599-y)
5. Benson RBJ, Hunt G, Carrano MT, Campione N. 2018 Cope's rule and the adaptive landscape of dinosaur body size evolution. *Palaeontology* **61**, 13–48. (doi:10.1111/pala.12329)
6. McPhee BW, Benson RBJ, Botha-Brink J, Bordy EM, Choiniere JN. 2018 A giant dinosaur from the earliest jurassic of south africa and the transition to quadrupedality in early sauropodomorphs. *Curr. Biol*. **28**, 3143–3151. (doi:10.1016/j.cub.2018.07.063)
7. Upchurch P, Barrett PM, Dodson P. 2004 Sauropoda. In *The dinosauria* (eds DB Weishampel, P Dodson, H Osmólska), 2nd edn. Berkeley, CA: University of California Press. (doi:10.1525/california/9780520242098.003.0015)
8. Sander PM *et al*. 2011 Biology of the sauropod dinosaurs: the evolution of gigantism. *Biol. Rev*. **86**, 117–155. (doi:10.1111/j.1469-185x.2010.00137.x)
9. Young CC. 1941 A complete osteology of *Lufengosaurus huenei* Young (gen. et sp. nov.) from lufeng Yunnan, China. *Palaeontol. Sin*. **7**, 1–53.
10. Young CC. 1942 *Yunnanosaurus huangi* Young (gen. et sp. nov.), a new Prosauropoda from the Red Beds at Lufeng, Yunnan. *Bull. Geol. Soc. China* **22**, 63–104.
11. Barrett PM, Upchurch P, Xiao-Lin W. 2005 Cranial osteology of *Lufengosaurus huenei* Young (Dinosauria: Prosauropoda) from the Lower Jurassic of Yunnan, People's Republic of China. *J. Vertebr. Paleontol*. **25**, 806–822. (doi:10.1671/0272-4634(2005)025[0806:COOLHY]2.0.CO;2)
12. Zhang Y, Yang ZL. 1995 *A new complete osteology of Prosauropoda in the Lufeng Basin, Yunnan, China: Jingshanosaurus*. Kunming, People's Republic of China: Yunnan Publishing House of Science and Technology.
13. Barrett PM, Upchurch P, Zhou XD, Wang XL. 2007 The skull of *Yunnanosaurus huangi* Young, 1942 (Dinosauria: Prosauropoda) from the Lower Lufeng Formation (Lower Jurassic) of Yunnan, China. *Zool. J. Linn. Soc*. **150**, 319–341. (doi:10.1111/j.1096-3642.2007.00290.x)
14. Wang YM, You HL, Wang T. 2017 A new basal sauropodiform dinosaur from the Lower Jurassic of Yunnan Province, China. *Sci. Rep*. **7**, 41881. (doi:10.1038/srep41881)
15. Zhang QN, You HL, Wang T, Chatterjee S. 2018 A new sauropodiform dinosaur with a 'sauropodan' skull from the Lower Jurassic Lufeng Formation of Yunnan Province, China. *Sci. Rep*. **8**, 13464. (doi:10.1038/s41598-018-31874-9)
16. Wang YM, Zhao Q, You HL. 2024 Reassessment of ' *Gyposaurus* ' *sinensis* Young, 1941 (Dinosauria: Sauropodomorpha) from the Early Jurassic Lufeng Basin, Yunnan Province, China. *Zool. J. Linn. Soc*. **203**. (doi:10.1093/zoolinnean/zlae032)
17. Zhang QN, Jia L, Wang T, Zhang YG, You HL. 2024 The largest sauropodomorph skull from the Lower Jurassic Lufeng Formation of China. *PeerJ* **12**, e18629. (doi:10.7717/peerj.18629)
18. Bai Z, Yang J, Wang GF. 1990 *Yimenosaurus*, a new genus of Prosauropoda from Yimen County, Yunnan Province. *Yuxi Cult Scholarship* **1**, 14–23.
19. Lü J, Li T, Zhong S, Azuma Y, Fujita M, Dong Z, Ji Q. 2007 New yunnanosaurid dinosaur (Dinosauria, Prosauropoda) from the Middle Jurassic Zhanghe Formation of Yuanmou, Yunnan Province of China. *Mem. Fukui Prefect. Dinosaur Mus* **6**, 1–15.
20. Peyre de Fabrègues C, Bi S, Li H, Li G, Yang L, Xu X. 2020 A new species of early-diverging Sauropodiformes from the Lower Jurassic Fengjiahe Formation of Yunnan Province, China. *Sci. Rep*. **10**, 10961. (doi:10.1038/s41598-020-67754-4)
21. Ren XX, Su X, Wang GF, You HL. 2022 Sedimentological evidence suggests an Early Jurassic age for *Yunnanosaurus youngi* (Dinosauria: Sauropodomorpha) in Yunnan Province of China. *Hist. Biol*. **34**, 1827–1833. (doi:10.1080/08912963.2021.1984445)
22. Wang YM, Zhang QN, Wang YC, Xu H, Chen J, Feng Z, Xu X, Wang T, You HL. 2025 A new Early Jurassic dinosaur represents the earliest-diverging and oldest sauropodomorph of East Asia. *Sci. Rep*. **15**, 26749. (doi:10.1038/s41598-025-12185-2)
23. Chen J *et al*. 2026 Triassic–Jurassic environmental instability on the subtropical eastern Tethyan margin linked to low-latitude dinosaur dispersal. *Commun. Earth Environ*. **7**, 91. (doi:10.1038/s43247-025-03083-6)
24. Fu L, Zhang J. 2004 On the Middle Jurassic Sauropoda of Jiangyi, Yuanmou. *Yunnan. Geol.* **23**, 73–76.
25. Wang GF, Pan SG, Li J, Ren XX, You HL. 2019 Revision of the Lower Jurassic dinosaur-bearing horizons in Anlongbao of southeastern Chuxiong Basin Yunnan Province, China. *J. Stratigr* **43**, 432–441.
26. Zou Y, Chen L, Wang T, Wang GF, Zhang WG, Zhang XQ, Wang ZJ, Wu XC, You HL. 2025 A new metriacanthosaurid theropod dinosaur from the Middle Jurassic of Yunnan Province, China. *PeerJ* **13**, e19218. (doi:10.7717/peerj.19218)
27. Young CC. 1951 The Lufeng saurischian fauna. *Palaeontol Sin* **13**, 1–96.
28. Sekiya T. 2011 Re-examination of *Chuanjiesaurus anaensis* (Dinosauria: Sauropoda) from the Middle Jurassic Chuanjie Formation, Lufeng County, Yunnan Province, southwest China. *Mem. Fukui Prefect. Dinosaur Mus* **10**, 1–54.
29. Hu S, Liu J, Zeng W, Wang W, Mo X, Xia C, Guan Q. 2024 Discovery of a new dinosaur cemetery in Early Jurassic strata in Xiangyun area of western Yunnan. *Geol. Rev* **70**, 759–768. (doi:10.16509/j.georeview.2023.10.012)

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30. Fang XS, Pang QQ, Lu LW, Zhang ZX, Pan SG, Wang YM, Li XK, Cheng ZW. 2000 Lower, Middle, and Upper Jurassic subdivision in the Lufeng region, Yunnan Province. In *Proceedings of the Third National Stratigraphical Conference of China*. Beijing, People's Republic of China: Geological Publishing House.
31. Wilson JA. 2006 Anatomical nomenclature of fossil vertebrates: standardized terms or 'lingua franca'? *J. Vertebr. Paleontol*. **26**, 511–518. (doi:10.1671/0272-4634(2006)26[511:anofvs]2.0.co;2)
32. Wilson JA. 1999 A nomenclature for vertebral laminae in sauropods and other saurischian dinosaurs. *J. Vertebr. Paleontol*. **19**, 639–653. (doi:10.1080/02724634.1999.10011178)
33. Wilson JA. 2012 New vertebral laminae and patterns of serial variation in vertebral laminae of sauropod dinosaurs. *Contrib. Museum of Paleontol. Univ. Michigan* **32**, 91–110.
34. Wilson JA, D'Emic MD, Ikejiri T, Moacdieh EM, Whitlock JA. 2011 A nomenclature for vertebral fossae in sauropods and other saurischian dinosaurs. *PLoS One* **6**, e17114. (doi:10.1371/journal.pone.0017114)
35. Chen XY, Wang YM, Zhang QN, Wang T, You HL. 2025 A new species of *Xingxiulong* (Dinosauria, Sauropodomorpha) from the lower Jurassic Lufeng formation of Yunnan Province, China. *Hist. Biol*. **37**, 2800–2809. (doi:10.1080/08912963.2025.2458130)
36. Goloboff PA, Catalano SA. 2016 TNT version 1.5, including a full implementation of phylogenetic morphometrics. *Cladistics* **32**, 221–238. (doi:10.1111/cla.12160)
37. Bapst DW. 2012 paleotree: an R package for paleontological and phylogenetic analyses of evolution. *Methods Ecol. Evol*. **3**, 803–807. (doi:10.1111/j.2041-210x.2012.00223.x)
38. Bell MA, Lloyd GT. 2015 strap: an R package for plotting phylogenies against stratigraphy and assessing their stratigraphic congruence. *Palaeontology* **58**, 379–389. (doi:10.1111/pala.12142)
39. Schaeffer J. 2024 Osteological redescription of the holotype of *Plateosaurus trossingensis* (Dinosauria: Sauropodomorpha) from the Upper Triassic of SW Germany and its phylogenetic implications. *J. Syst. Palaeontol*. **22**, 2335387. (doi:10.1080/14772019.2024.2335387)
40. Wang Y, Wang T, Yang Z, You H. 2020 Cranium and Vertebral Column of *Xingxiulong chengi* (Dinosauria: Sauropodomorpha) from the Early Jurassic of China. *Anat. Rec*. **303**, 772–789. (doi:10.1002/ar.24305)
41. Barrett PM, Chapelle KEJ, Staunton CA, Botha J, Choiniere JN. 2019 Postcranial osteology of the neotype specimen of *Massospondylus carinatus* Owen, 1854 (Dinosauria: Sauropodomorpha) from the upper Elliot formation of South Africa. *Palaeontol. Afr.* **53**, 114–178.
42. Martínez RN. 2009 *Adeopapposaurus mognai*, gen. et sp. nov. (Dinosauria: Sauropodomorpha), with comments on adaptations of basal Sauropodomorpha. *J. Vertebr. Paleontol*. **29**, 142–164. (doi:10.1671/039.029.0102)
43. Apaldetti C, Pol D, Yates AM. 2013 The postcranial anatomy of *Coloradisaurus brevis* (Dinosauria: Sauropodomorpha) from the Late Triassic of Argentina and its phylogenetic implications. *Palaeontology* **56**, 277–301. (doi:10.1111/j.1475-4983.2012.01198.x)
44. Apaldetti C, Martinez RN, Alcober OA, Pol D. 2011 A new basal sauropodomorph (Dinosauria: Saurischia) from Quebrada del Barro Formation (Marayes-El Carrizal Basin), Northwestern Argentina. *PLoS One* **6**, e26964. (doi:10.1371/journal.pone.0026964)
45. Sertich JJW, Loewen MA. 2010 A new Basal sauropodomorph dinosaur from the Lower Jurassic Navajo Sandstone of Southern Utah. *PLoS One* **5**, e9789. (doi:10.1371/journal.pone.0009789)
46. Otero A, Pol D. 2013 Postcranial anatomy and phylogenetic relationships of *Mussaurus patagonicus* (Dinosauria, Sauropodomorpha). *J. Vertebr. Paleontol*. **33**, 1138–1168. (doi:10.1080/02724634.2013.769444)
47. Yates AM, Bonnan MF, Neveling J, Chinsamy A, Blackbeard MG. 2010 A new transitional sauropodomorph dinosaur from the Early Jurassic of South Africa and the evolution of sauropod feeding and quadrupedalism. *Proc. R. Soc. B* **277**, 787–794. (doi:10.1098/rspb.2009.1440)
48. McPhee BW, Yates AM, Choiniere JN, Abdala F. 2014 The complete anatomy and phylogenetic relationships of *Antetonitrus ingenipes* (Sauropodiformes, Dinosauria): implications for the origins of Sauropoda. *Zool. J. Linn. Soc*. **171**, 151–205. (doi:10.1111/zoj.12127)
49. McPhee BW, Choiniere JN. 2018 The osteology of *Pulanesaura eocollum*: implications for the inclusivity of Sauropoda (Dinosauria). *Zool. J. Linn. Soc*. **182**, 830–861. (doi:10.1093/zoolinnean/zlx074)
50. McPhee BW, Choiniere JN, Yates AM, Viglietti PA. 2015 A second species of *Eucnemesaurus* Van Hoepen, 1920 (Dinosauria, Sauropodomorpha): new information on the diversity and evolution of the sauropodomorph fauna of South Africa's lower Elliot Formation (latest Triassic). *J. Vertebr. Paleontol*. **35**, e980504. (doi:10.1080/02724634.2015.980504)
51. Otero A, Gallina PA, Canale JI, Haluza A. 2012 Sauropod haemal arches: morphotypes, new classification and phylogenetic aspects. *Hist. Biol* **24**, 243–256. (doi:10.1080/08912963.2011.618269)
52. Cooper MR. 1984 A reassessment of *Vulcanodon karibaensis* Raath (Dinosauria: Saurischia) and the origin of the Sauropoda. *Palaeontol. Afr.* **25**, 203–231.
53. Galton PM. 1976 Prosauropod dinosaurs (Reptilia, Saurischia) of North America. *Postilla* **169**, 1–98.
54. Pol D, Garrido A, Cerda IA. 2011 A new sauropodomorph dinosaur from the Early Jurassic of Patagonia and the origin and evolution of the sauropod-type sacrum. *PLoS One* **6**, e14572. (doi:10.1371/journal.pone.0014572)
55. McPhee BW, Choiniere JN. 2016 A hyper-robust sauropodomorph dinosaur ilium from the Upper Triassic–Lower Jurassic Elliot Formation of South Africa: Implications for the functional diversity of basal Sauropodomorpha. *J. Afr. Earth Sci*. **123**, 177–184. (doi:10.1016/j.jafrearsci.2016.08.004)
56. Müller RT, Langer MC, Dias-da-Silva S. 2018 An exceptionally preserved association of complete dinosaur skeletons reveals the oldest long-necked sauropodomorphs. *Biol. Lett*. **14**, 20180633. (doi:10.1098/rsbl.2018.0633)
57. Marsh AD, Rowe TB. 2018 Anatomy and systematics of the sauropodomorph *Sarahsaurus aurifontanalis* from the Early Jurassic Kayenta Formation. *PLoS One* **13**, e0204007. (doi:10.1371/journal.pone.0204007)

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58. Zhang QN, Wang T, Yang ZW, You HL. 2020 Redescription of the Cranium of *Jingshanosaurus xinwaensis* (Dinosauria: Sauropodomorpha) from the Lower Jurassic Lufeng Formation of Yunnan Province, China. *Anat. Rec.* **303**, 759–771. (doi:10.1002/ar.24113)
59. Peyre de Fabrègues C, Allain R. 2019 *Kholumolumo ellenbergerorum*, gen. et sp. nov., a new early sauropodomorph from the lower Elliot Formation (Upper Triassic) of Maphutseng, Lesotho. *J. Vertebr. Paleontol*. **39**, e1732996. (doi:10.1080/02724634.2019.1732996)
60. Barrett PM, Choiniere JN. 2024 Melanorosaurus readi Haughton, 1924 (Dinosauria, Sauropodomorpha) from the Late Triassic of South Africa: osteology and designation of a lectotype. *J. Vertebr. Paleontol* **44**, e2337802. (doi:10.1080/02724634.2024.2337802)
61. Apesteguía S. 2005 Evolution of the hyposphene-hypantrum complex within Sauropoda. In *Thunder-lizards: the sauropodomorph dinosaurs* (eds V Tidwell, K Carpenter), pp. 248–267. Bloomington, IN: Indiana University Press.
62. Stefanic CM, Nesbitt SJ. 2019 The evolution and role of the hyposphene-hypantrum articulation in Archosauria: phylogeny, size and/or mechanics? *R. Soc. Open Sci*. **6**, 190258. (doi:10.1098/rsos.190258)
63. McPhee BW, Bonnan MF, Yates AM, Neveling J, Choiniere JN. 2015 A new basal sauropod from the pre-Toarcian Jurassic of South Africa: evidence of niche-partitioning at the sauropodomorph–sauropod boundary? *Sci. Rep* **5**, 13224. (doi:10.1038/srep13224)
64. Regalado Fernández OR. 2024 Variability of vertebral laminae in eight specimens of *Plateosaurus* (Saurischia, Sauropodomorpha). *Revue de Paleobiologie* **43**, 85–100. (doi:10.581/zenodo.10732345)
65. Allain R *et al*. 2004 A basal sauropod dinosaur from the Early Jurassic of Morocco. *Comptes Rendus Palevol.* **3**, 199–208. (doi:10.1016/j.crpv.2004.03.001)
66. Allain R, Aquesbi NJG. 2008 Anatomy and phylogenetic relationships of *Tazoudasaurus naimi* (Dinosauria, Sauropoda) from the late Early Jurassic of Morocco. *Geodiversitas* **30**, 345–424.
67. Mallison H. 2010 The digital *Plateosaurus* I: body mass, mass distribution and posture assessed using CAD and CAE on a digitally mounted complete skeleton. *Palaeontol. Electron* **13**, 1–26.
68. Mallison H. 2010 The digital *Plateosaurus* II: an assessment of the range of motion of the limbs and vertebral column and of previous reconstructions using a digital skeletal mount. *Acta Palaeontol. Pol*. **55**, 433–458. (doi:10.4202/app.2009.0075)
69. Díez Díaz V, Demuth OE, Schwarz D, Mallison H. 2020 The tail of the Late Jurassic sauropod *Giraffatitan brancai*: Digital reconstruction of its epaxial and hypaxial musculature, and implications for tail biomechanics. *Front. Earth Sci*. **8**, 160. (doi:10.3389/feart.2020.00160)
70. Preuschoft H, Klein N. 2013 Torsion and bending in the neck and tail of sauropod dinosaurs and the function of cervical ribs: insights from functional morphology and biomechanics. *PLoS One* **8**, e78574. (doi:10.1371/journal.pone.0078574)
71. Sekiya T. 2010 A new prosauropod dinosaur from Lower Jurassic in Lufeng of Yunnan. *Global Geol.* **29**, 6–15.
72. Pol D, Mancuso AC, Smith RMH, Marsicano CA, Ramezani J, Cerda IA, Otero A, Fernandez V. 2021 Earliest evidence of herd-living and age segregation amongst dinosaurs. *Sci. Rep*. **11**, 20023. (doi:10.1038/s41598-021-99176-1)
73. He X, Wang C, Liu S, Zhou F, Liu T, Cai K, Dai B. 1998 A new sauropod dinosaur from the Early Jurassic in Gongxian County, south Sichuan. *Acta Geologica Sichuan* **18**, 1–7.
74. Hu SB *et al*. 2025 A new sauropodomorph dinosaur from the Lower Jurassic Fengjiahe Formation of Dali of Yunnan Province, China. [Dataset]. Dryad Digital Repository. (doi:10.5061/dryad.vdncjsz8k)
75. Hu SB *et al*. 2026 Supplementary material from: A new sauropodomorph dinosaur from the Lower Jurassic Fengjiahe Formation of Dali of Yunnan Province, China. Figshare. (doi:10.6084/m9.figshare.c.8375220)

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