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ARTICLE

The second mamenchisaurid dinosaur from the Middle Jurassic of Eastern China

Xin-Xin Ren[a,b,c,d], Jian-Dong Huang[d] and Hai-Lu You[a,b,c]

[a]Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; [b]CAS Center for Excellence in Life and Paleoenvironment, Beijing, China; [c]University of the Chinese Academy of Sciences, Beijing China; [d]Anhui Geological Museum, Hefei, China

ABSTRACT

A new mamenchisaurid dinosaur, *Anhuilong diboensis* gen. et sp. nov. from the Middle Jurassic of Eastern China is reported here. The holotype consists of complete left humerus, ulna and radius of an individual. Comparative study and cladistic analysis shows this new taxon belongs to Mamenchisauridae and bears a unique combination of characters, such as low ratios of the average of the greatest widths of the proximal end, mid-shaft and distal end of the humerus/length of the humerus, total length of ulna to humerus and total length of radius to humerus; the lateral edge of the deltopectoral crest directs caudolaterally, the lateral accessory condyle on the craniodistal edge of humerus is more robust than the medial one, and the cross-sectional shape of the ulna at mid-shaft is elliptical with highest ratio of transverse to craniocaudal diameter among mamenchisaurids. Phylogenetically, *Anhuilong* is the sister taxon of *Huangshanlong*, and with *Omeisaurus* they together form the sister clade to all other members of Mamenchisauridae. Including *Huangshanlong*, two mamenchisaurids have been found in eastern China, and indicates that Mamenchisauridae was already a diverse sauropod clade in China by the Middle Jurassic.

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KEYWORDS
Huangshan; Eastern China; Middle Jurassic; Hongqin Formation; Mamenchisauridae; *Anhuilong*

Introduction

Mamenchisauridae (Young and Chao 1972) is the dominant sauropod clade in the Middle and Late Jurassic of East Asia (Lü et al. 2008; Upchurch et al. 2004; Mannion et al. 2011; Suteethorn 2012; Xing et al. 2015b). It contains multiple genera, although many of them are based on fragmentary and undiagnosable materials (Young 1939, 1954, 1958; Young and Chao 1972; Hou et al. 1976; He et al. 1988, 1996; Zhao et al. 1993; Russell and Zheng 1993; Zhang et al. 1998; Tang et al. 2001; Li 1997; Fang et al. 2000, 2004; Ouyang et al. 2002; Lü et al. 2008; Jiang et al. 2011; Wu et al. 2013; Huang et al. 2014; Xing et al. 2015b). This clade has been referred to Diplodocidae, Bothrosauropodoidea, and 'Euhelopodidae', the current consensus regards the group as an early-diverging clade within Eusauropoda. Still, the relationships among the members of the clade are unstable, even the validity of Mamenchisauridae is debatable (Li and Cai 1997; Upchurch et al. 2004; McIntosh 1990; Wilson and Sereno 1998; Xing et al. 2015b). Additionally, Mamenchisauridae may not be endemic in East Asia (Suteethorn 2012; Mannion 2013). Sauropod fossil records are sparse in the Middle Jurassic (Upchurch et al. 2004; Barrett and Upchurch 2005; Remes et al. 2009), and mamenchisaurids from the Middle Jurassic of China provide valuable opportunity to understand sauropod diversity and phylogeny in this period.

Here we report a new mamenchisaurid sauropod, *Anhuilong diboensis* gen. et sp. nov., based on a left humerus, ulna and radius from the Middle Jurassic Hongqin Formation of Anhui Province, Eastern China (Figure 1). This formation has previously yielded the mamenchisaurid *Huangshanlong* (Huang et al. 2014). Comparative study and cladistic analysis shows the new taxon is different from *Huangshanlong*. *Anhuilong*, *Huangshanlong*, and *Omeisaurus* form the sister clade of all other known mamenchisaurids.

Geological setting

Many continental basins developed in Eastern China during the Mesozoic. Tunxi Basin is one of them located in the midland, pertaining to a small intermountain basin during the Mesozoic. In this basin, the red beds are well exposed, and the outcrops are generally continuous. It is a representative basin on stratigraphic research in the eastern part of China (Yu et al. 2001). The geotectonic position of Tunxi Basin belongs to the eastern segment of Jingnan intracontinental orogenic belt, southeast of Yangzi Block (Jiang et al. 2016). Since the Indosinian Movement, this area is exposed above the sea level as a result of the crustal rising. Different types of continental basins were chronologically overlapped during different tectonic phases. Tunxi Basin is dominated by fluvial deposits with volcanic deposits in Jurassic (Ren et al. 2015 and 2017).

The new genus comes from purple sandstones of the Hongqin Formation, interbedded with purple shales. The Hongqin Formation was originally regarded to be of Middle Jurassic age according to the study of invertebrate (Bureau of Geology and Mineral Resources of Anhui Province 332 Geological team 1971, unpublished).

Systematic paleontology

Dinosauria Owen (1842)
Saurischia Seeley (1887)

CONTACT Xin-Xin Ren laotourenxin@126.com

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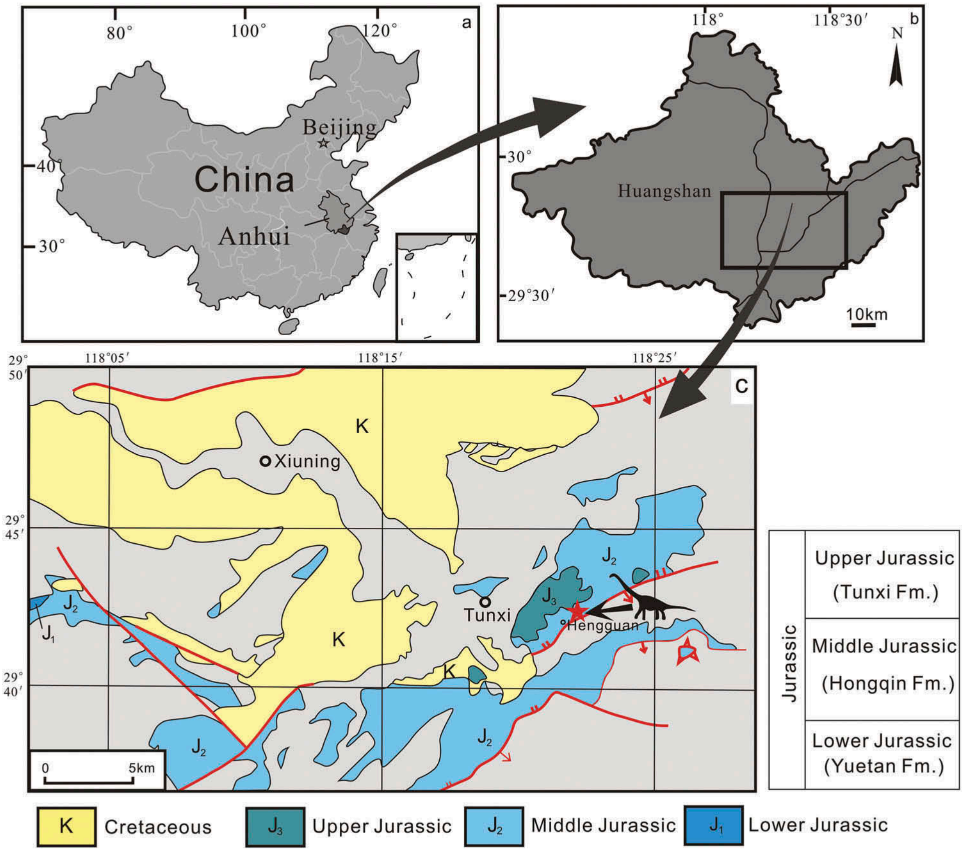

Figure 1. Geographic and geologic map showing the location of *Anhuilong diboensis* gen. et sp. nov. (indicated by the red star and dinosaur silhouette) and generalized stratigraphic section of Jurassic of Tunxi Basin, modified from Ren et al. (2017).

Sauropodomorpha Huene (1932)
Sauropoda Marsh (1878)
Eusauropoda Upchurch (1995)
Mamenchisauridae Young and Chao (1972)
Anhuilong diboensis gen. et sp. nov. (Figures. 2–4)

Holotype

Anhui Geological Museum: AGB 5822. Associated and complete left humerus, ulna and radius. Reposited in Anhui Geological Museum, Hefei, Anhui Province, China.

Etymology

The generic name refers to Anhui Province, where the holotype was found; 'long' means dragon in Chinese Pinyin. The specific name refers to the locality where the holotype was reposited.

Diagnosis

A mamenchisaurid possessing the following unique combination of character states (autapomorphies are marked by *):

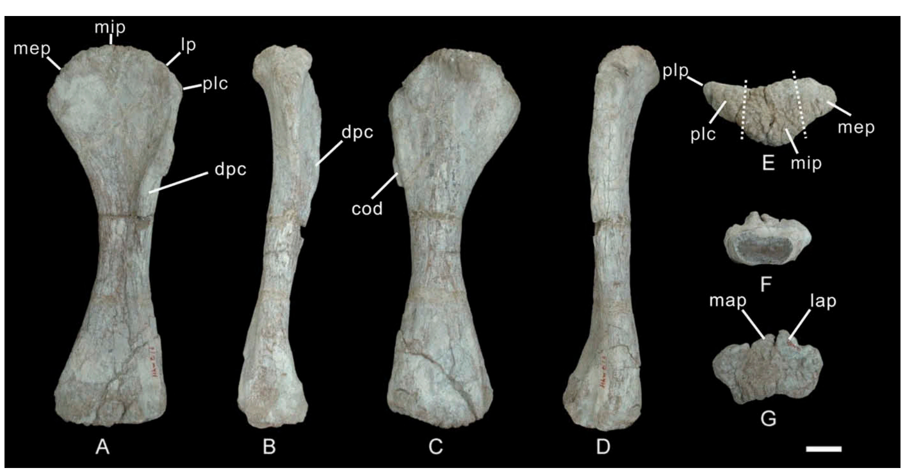

Figure 2. Left humerus of *Anhuilong diboensis* gen. et sp. nov. A, cranial; B, medial; C, caudal; D, lateral; E, proximal; F, cross section in proximal (the cross section near the narrowest area); G, distal views (the cranial is upward). Scale bar equals 10cm. Abbreviations: cod, caudolateral bulge of the deltopectoral crest; dpc, deltopectoral crest; map, medial accessary process; mep, medial part of proximal surface; mip, middle part of proximal surface; lap, lateral accessary process; lp, lateral part of proximal surface; plc, proximolateral corner; plp, proximolateral process.

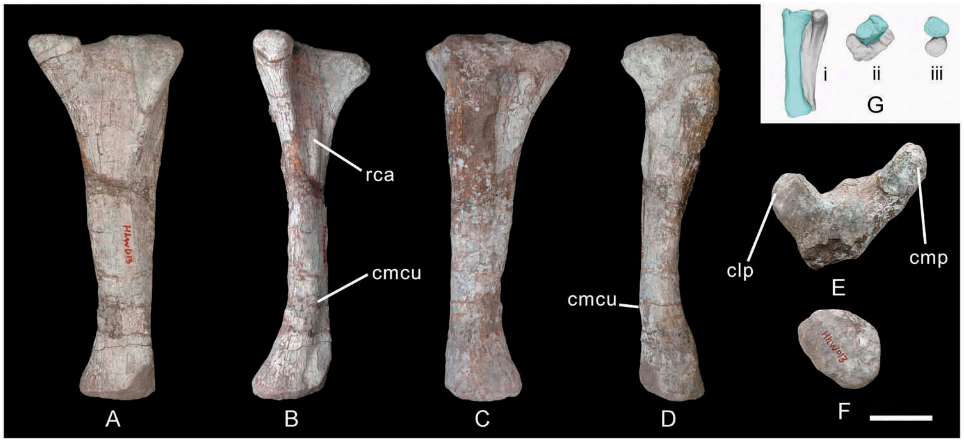

Figure 3. Left ulna of *Anhuilong diboensis* gen. et sp. nov. A, cranial; B, medial; C, caudal; D, lateral; E, proximal (the cranial is upward); F, distal views (the cranial is upward); G, reconstruction of left ulna and radius (gray represents ulna, blue represents radius; i, craniolateral; ii, proximal; iii, distal views). Scale bar equals 10cm. Abbreviations: clp, craniolateral process; cmcu, craniomedial convex of lower part of ulna; cmp, craniomedial process.

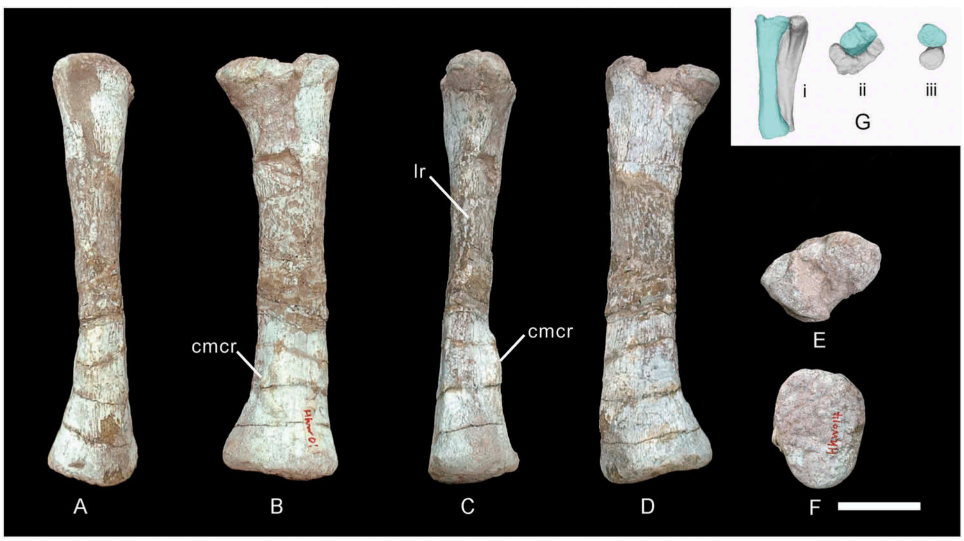

Figure 4. Left radius of *Anhuilong diboensis* gen. et sp. nov. A, cranial; B, medial; C, caudal; D, lateral; E, proximal (the cranial is upward); F, the distal views (the cranial is upward); G, reconstruction of left ulna and radius (gray represents ulna, blue represents radius; i, craniolateral; ii, proximal; iii, distal views). Scale bar equals 10cm. Abbreviations: cmcr, caudomedial convex of lower part of radius; lr, longitudinal ridge.

lateral edge of deltopectoral crest turning caudolaterally; lateral accessory process of humerus more robust than medial one; ratio of total length of radius to humerus is 0.50 (the lowest value among mamenchisaurids; *Huangshanlong*: 0.58) *; ratio of total length of ulna to humerus is 0.56 (the lowest value among mamenchisaurids; *Huangshanlong*: 0.67)*; elliptical cross-sectional shape of ulna at mid-shaft (*Huangshanlong* is circular), nearly perpendicular orientation of proximal end of ulna relative to long axis of ulnar shaft.

Locality and horizon

The specimen was excavated at Jimushan of Hengguan Village, Wangcun Town, Shexian County, Huangshan City, Anhui Province, Eastern China. The quarry is from the lower part of the Middle Jurassic Hongqin Formation. The bones were isolatedly found in a small area with a massive to finely laminated red siltstone containing some carbonate in its matrix. The siltstone layer is several meters thick and yielded the sauropod remains in its upper half. The sedimentological and petrologic researches indicate that the fossils were deposited in the floodplain environment (Wang et al. 2006).

Description

The left humerus is well preserved (Figure 2; see Table 1 for measurement). The outline is similar to other mamenchisaurids, but it looks a little more slender than other taxa of Mamenchisauridae with the lowest RI value (RI, the average of the greatest widths of the proximal end, mid-shaft and distal end of humerus/length of humerus). In cranial view, the proximal and distal portions expand gradually towards both ends, giving the proximal end a fan-like shape in cranial view. The proximal width is 36% of the total length of the humerus, resembling that in *Shunosaurus lii*, *Barapasaurus*, *Patagosaurus*, *Camarasaurus*, *Alamosaurus* and *Turiasaurus*

Table 1. Measurements of the left humerus (in cm).

Total length	105
Transverse width of proximal end	38
Craniocaudal width of proximal end (across articular head)	17
Distance from the proximal end to the lateral margin of the deltopectoral crest	30
Transverse width of mid-shaft	14
Craniocaudal width of mid-shaft	10
Transverse width of distal end	30
Maximum craniocaudal width of the distal end (across the two condyles)	20
RI	0.26

RI: the average of the greatest widths of the proximal end, mid-shaft and distal end of humerus/length of humerus (after Wilson and Upchurch 2003)

(Dong et al. 1983; Bonaparte 1986; McIntosh et al. 1996; Lehman and Coulson 2002; Royo-Torres et al. 2006; Bandyopadhyay et al. 2010). By contrast, the ratio in *Huangshanlong* and other mamenchisaurids is approximately 41% (He et al. 1998; Fang et al. 2000; Tang et al. 2001; Ouyang and Ye 2002; Huang et al. 2014). A cranial projection overhangs on the middle of the proximal end, which is 2 cm in height, 28 cm in width. This cranial projection is weak in early-diverging sauropods and *Omeisaurus* app. (Cooper 1981; Dong et al. 1983; He et al. 1988; Tang et al. 2001). The humeral head is located at the middle of the proximal end, and extends caudally in lateral view. The shape of the humeral head is close to an isosceles triangle, the base of which is 1.9 cm and the height is 0.9 cm. In proximal view, the proximal surface of humerus is divided into three planes, the lateral, middle, and medial (Figure 2, lp; mip; mep). The presence of these 'three planes' is common in mamenchisaurids, *Turiasaurus*, and some derived neosauropods forms such as *Tornieria* and *Saltasaurus* (He et al. 1988; Fang at al. 2000; Tang et al. 2001; Ouyang and Ye 2002; Remes 2006; Royo-Torres et al. 2006). Supracoracoideus tuberculum is lacking on the proximolateral portion of the humerus as in some neosauropods such as *Suuwassea*, *Opisthocoelicaudia*, *Isisaurus* and *Saltasaurus* (Royo-Torres et al. 2006; Harris 2006a; Whitlock and Harris 2010).

The length of the deltopectoral crest/total length of humerus is about 0.44 (*Huangshanlong* is 0.43; *Omeisaurus tianfuensis* is 0.44). It is oriented craniolaterally, which differs from the conditions in other early diverging eusauropods (e.g. *Shunosaurus lii*, *Omeisaurus tianfuensis*, *Mamenchisaurus youngi*, *Chuanjiesaurus*, *Barapasaurus* and *Patagosarus*). The distal half of the deltopectoral crest is 9 cm in length and the width is 2 cm. The caudolateral bulging of the deltopectoral crest is elliptical, the length of the major axis 10 cm and the minor axis 4 cm (Figure 2, cod). The cross section of the mid-shaft is ovoid, similar to those in *Vulcanodon*, *Shunosaurus lii*, *Omeisaurus tianfuensis* and *Huangshanlong*. The ratio of the width of the cross section to the total length of the humerus is 0.13, and this makes the morphology of *Anhuilong* particularly gracile considering the total length of the shaft (*Huangshanlong* is 0.16; *Omeisaurus tianfuensis* is 0.17). Despite the ovoid morphology of the cross section. The distal articular surface is deflected to the lateral and the angle between the axis of the distal articular surface and the proximal one is 25 degrees.

The distal end is quadrilateral, and the two condyles are convex slightly with coarse surfaces. There are two small accessary processes on the craniodistal edge of the humerus, as in other mamenchisaurids, *Patagosaurus*, *Apatosaurus*, and *Suuwassea*. Moreover, the lateral accessory process of *Anhuilong* is more robust than the medial one, which is different from other members of Mamenchisauridae (Figure 5). Both of the processes are nearly triangular. There is a shallow groove on the caudodistal portion of the humerus. The two condyles are semi-round in caudal view.

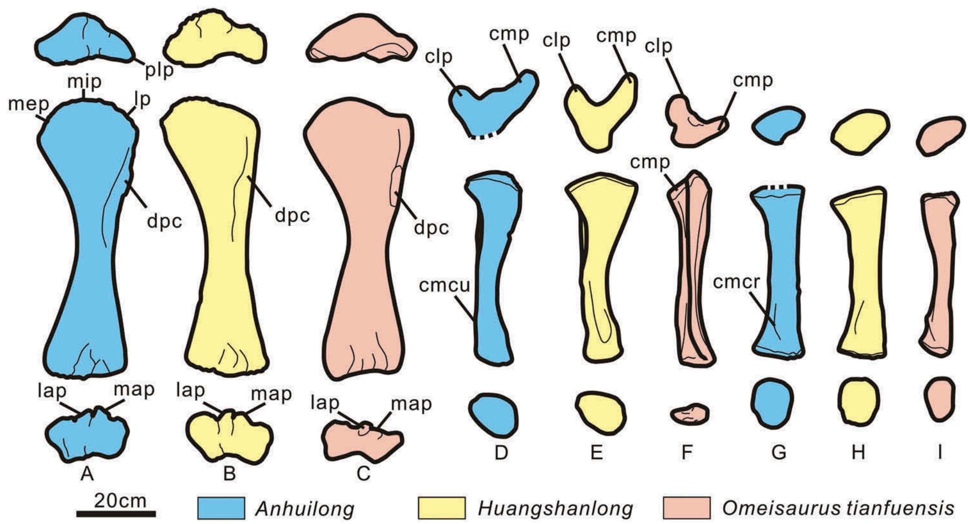

Figure 5. Comparation of forelimb of *Anhuilong, Huangshanlong* and *Omeisaurus tianfuensis*. A, left humerus of *Anhuilong* (from top to bottom: proximal; cranial; ventral views); B, right (left in reverse) humerus of *Huangshanlong* (from top to bottom: proximal; cranial; ventral views); C, left humerus of *Omeisaurus tianfuensis* (from top to bottom: proximal; cranial; ventral views); D, left ulna of *Anhuilong* (from top to bottom: proximal; lateral; ventral views); E, right (left in reverse) ulna of *Huangshanlong* (from top to bottom: proximal; lateral; ventral views); F, left ulna of *Omeisaurus tianfuensis* (from top to bottom: proximal; cranial; ventral views); G, left radius of *Anhuilong* (from top to bottom: proximal view; medial view; ventral view); H, right (left in reverse) radius of *Huangshanlong* (from top to bottom: proximal view; medial view; ventral view); I, left radius of *Omeisaurus tianfuensis* (from top to bottom: proximal view; medial view; ventral view); Abbreviation: cap, caudal process; clp, craniolateral process; cmcr, caudomedial convex of lower part of radius; cmcu, craniomedial convex of lower part of ulna; cmp, craniomedial process; dpc, deltopectoral crest; lap, lateral accessary process; lp, lateral part of proximal surface; map, medial accessary process; mep, medial part of proximal surface; mip, middle part of proximal surface; lap, lateral accessary process; plc, proximolateral corner; plp, proximolateral process.

The left ulna is well preserved (Figure 3; see Table 2 for measurement). The ulna is longer than the radius. The proximal end is triradiate, similar to that in other sauropods. The craniolateral and craniomedial processes are prominent and robust, which together in proximal view make up a 'L' shape and form a deep cranial groove that receives the proximal end of the radius. The angle between the two processes is 85 degrees, close to those in *Omeisaurus tianfuensis* (about 85 degrees) and *Huangshanlong* (about 75 degrees). The craniomedial process is more developed than the craniolateral process. The length of the craniomedial process is 1.5 times that of the craniolateral process (the distal end of the craniomedial process is not well preserved), that in *Huangshanlong is* 1.7, and *Omeisaurus tianfuensis* is about 1.0. The caudal process is weakly developed, and the olecranon process is also weak. Along the craniolateral process, the maximum length is 31% of the total length of the ulna, and along the craniomedial process, the maximum length is 45% (*Huangshanlong* is 40% and 44% respectively; *Omeisaurus tianfuensis* is 21% and 21% respectively). The middle part of the craniomedial process is penetrated by a craniocaudal groove, differing from the condition in other mamenchisaurids (e.g. *Omeisaurus tianfuensis*, *O. maoianus*, *Mamenchisaurus youngi*, *Chuanjiesaurus*, and *Huangshanlong*).

The 'L' shape of the proximal surface is transformed into an elliptical cross section at mid-shaft, resembling to the condition in *Huangshanlong*, *Vulcanodon*, *Chuanjiesaurus*, and *Rapetosaurus*, but the majority of sauropods have a circular cross section, such as in *Mamenchisaurus youngi*. On the craniolateral surface of the proximal portion, there is a raised coarse area that matches a similar area on the surface of the radius (Figure 3, rca).

The distal surface of the ulna is oval, and the cranial part is a little flat (the cranial is not preserved very well); in contrast, the shape of the corresponding region in *Omeisaurus tianfuensis* is more compressed, and those of *Mamenchisaurus youngi* and *Chuanjiesaurus* share a subquadrilateral shape. The maximum length of the distal end is 21% of the total length, similar to that in *Huangshanlong* (0.24). The distal portion of the craniomedial surface is mildly convex where it received the caudomedial surface of the distal end of the radius. *Huangshanlong, Vulcanodon, Omeisaurus tianfuensis, Mamenchisaurus youngi*, and *Chuanjiesaurus* also share this morphology (Figure 3, cmcu). The surface of the distal end is nearly flat, with the center a little convex. The maximum angle between the distal surface and long axis of the shaft is 78 degrees, nearly similar to *Huangshanlong*, *Omeisaurus tianfuensis*, *Apatosaurus*, and *Amargasaurus* (Huang et al. 2014; He et al. 1998; Upchurch et al. 2004; Salgado and Bonaparte 1991). And still, it is larger than the early-diverging sauropods (e.g. *Vulcanodon* and *Shunosaurus lii*), *Barapasaurus*, *Alamosaurus*, *Opisthocoelicaudia*, *Lirainosaurus* (Borsuk-Bialynicka 1977; Cooper 1981; Dong et al. 1983; Company et al. 2009). Moreover, as an autapomorphy, the total length of the ulna is 56% of the total length of the humerus, which is the lowest value among mamenchisaurids (Table 3).

Table 2. Measurements of the left ulna (in cm).

Total length	59
Width of the proximal end (from the caudal surface to the tip of the craniomedial process)	26
Width of the proximal end (from the caudal surface to the tip of the craniolateral process)	18
Transverse width of mid-shaft	11
Craniocaudal width of mid-shaft	5.5
Transverse width of distal end	14
Maximum craniocaudal width of the distal end	11

Table 3. Ratios of total length of ulna/total length of humerus (U/H) and total length of radius/total length of humerus (R/H) in mamenchisaurids. '-': not applicable.

Taxa	U/H	R/H
Omeisaurus jiaoi	0.75	0.71
Omeisaurus maoianus	0.62	0.65
Omeisaurus tianfuensis	-	0.70
Mamenchisaurus anyuensis	0.76	0.69
Mamenchisaurus constructus	-	-
Mamenchisaurus fuxiensis	-	-
Mamenchisaurus hochuanensis	-	-
Mamenchisaurus youngi	0.69	0.65
Mamenchisaurus sinocanadorum	-	-
Mamenchisaurus jingyanensis	0.66	0.60
Eomamenchisaurus yuanmouensis	-	-
Chuanjiesaurus	0.68	0.62
Qijianglong	-	-
Huangshanlong	0.67	0.58
Xinjiangtitan	-	-

The left radius is well-preserved and complete (Figure 4; see Table 4 for measurement). Proximally, the maximum width is 26% of the total length. The proximal end is nearly quadrilateral with a broad medial surface that met the craniomedial process of ulna. The quadrilateral shape of the proximal end is similar to that in *Apatosaurus* (Upchurch et al. 2004), and different from the oval shape of that in early-diverging sauropods (e.g. *Vulcanodon, Shunosaurus lii*), some mamenchisaurids, *Barapasaurus*, and *Camarasaurus* (Dong et al. 1983; Cooper 1984; He et al. 1996; McIntosh et al. 1996; Tang et al. 2001; Bandyopadhyay et al. 2010). The surface of the proximal end is nearly flat with a slightly concave area in the center, and there is a bump craniomedially, a condition also present in *Huangshanlong*, *Omeisaurus tianfuensis*, *Patagosaurus*, *Camarasaurus* and *Saltasaurus* (Bonaparte 1986; He et al. 1988; Powell 1992; McIntosh et al. 1996; Huang et al. 2014). The mid-shaft of the radius is elliptical in cross section. A prominent longitudinal ridge occurs on the proximal half of the radius and it is slightly twisted (Figure 4, lr). In lateral view, the caudal outline is

Table 4. Measurements of the left radius (in cm).

Total length	53
Width of the proximal end	10.5
Craniocaudal width of the proximal end	14
Transverse width of mid-shaft	6
Craniocaudal width of mid-shaft	8.5
Transverse width of distal end	10
Maximum craniocaudal width of the distal end	15.5

prominently incurve. The surface of the proximal end is nearly perpendicular to the axis of the shaft. This condition is similar to *Omeisaurus tianfuensis, Patagosaurus*, and *Camarasaurus* (Bonaparte 1986; He et al. 1988; McIntosh et al. 1996).

The distal surface of the radius is flat, with an elliptical shape. A prominent elongated convex area exists on the caudomedial surface of distal portion. The distal radial condyle with respect to the long axis of shaft is nearly perpendicular (the maximum angle is less than 20 degrees), which is similar to most of sauropods (e.g. *Vulcanodon*, *Shunosaurus lii*, mamenchisaurids, *Apatosaurus*, and *Alamosaurus*).

Phylogenetic analysis

A phylogenetic analysis was conducted to assess the affinities of *Anhuilong diboensis* within Sauropoda (Figure 6). A maximum parsimony analysis used the data set of Xing et al. (2015b), with 344 original characters plus eight new forelimb characters (See the Supplementary Data). New characters based on descriptions and revisions (e.g. Upchurch 1998; Upchurch et al. 2004; Wilson and Sereno 1998; Huang et al. 2014; Mannion et al. 2013; Wilson and Upchurch 2003), and entirely novel characters presented on the appendices, based on our personal observations and an extensive review of the literature. We did not exclude characters based on a priori assumptions about their level of homoplasy. Where possible, we tried to quantify, or at least more precisely define characters and state boundaries to remove ambiguity (see some similar attempts by Harris 2006). Both *Anhuilong* and *Huangshanlong* were added to the matrix. All characters were treated as unordered. The complete character list, including references, as well as our MESQUITE versions of the data matrices. The matrix was subjected to a heuristic search in TNT v. 1.5 (Goloboff et al. 2016), with multiple TBR + TBR search strategy (1000 replicated of trees, random addition sequence, tree bisection reconnection branch swapping algorithm, ten trees saved per replicate).

A strict consensus of all 450 most parsimonious trees (tree length = 1103; consistency index = 0.397; retention index = 0.638;) supports a monophyletic Mamenchisauridae. *Anhuilong* is recovered as the sister taxon of *Huangshanlong*,

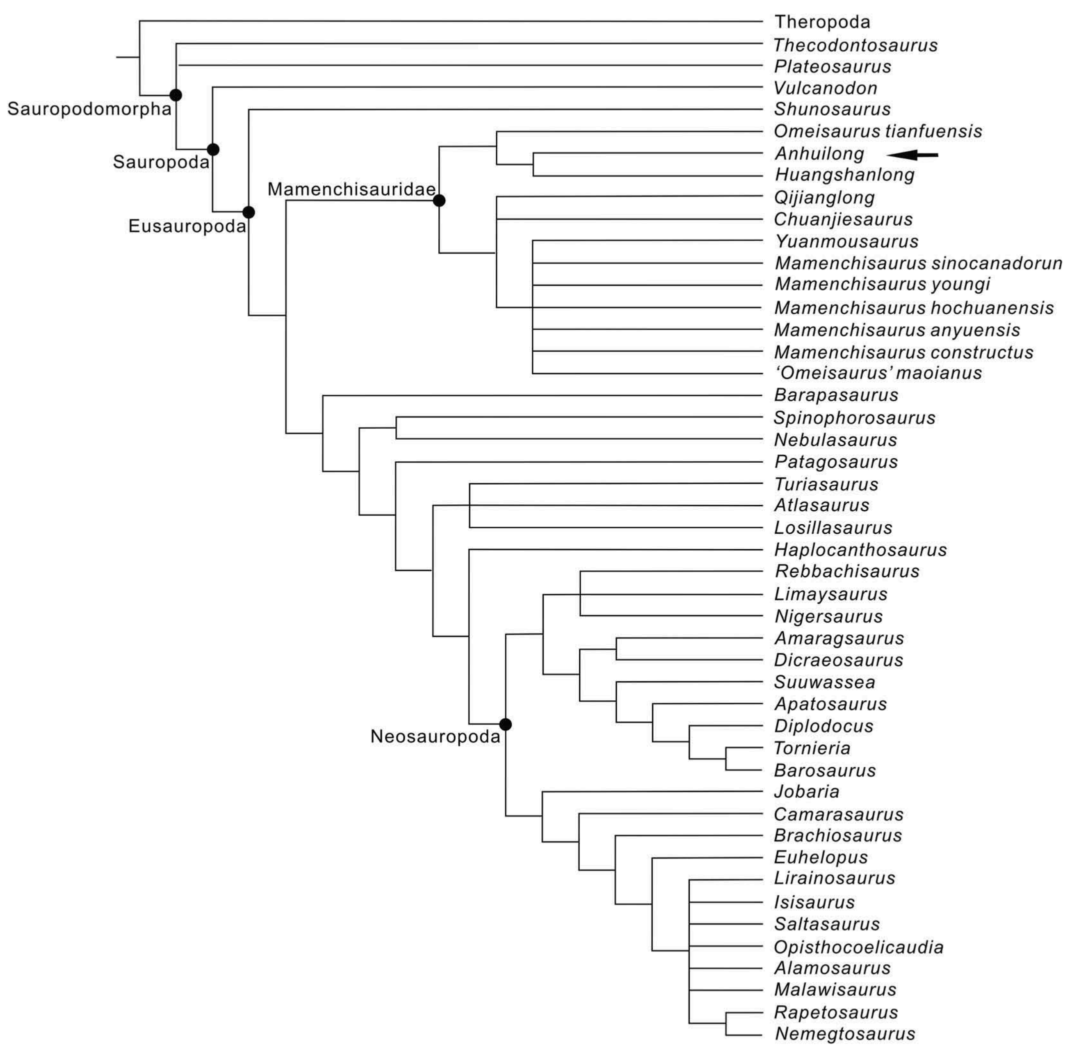

Figure 6. Strict consensus of 450 MPTs (TL = 1104) from phylogenetic analysis (46 taxa, 352 characters). The data matrix follows Xing et al. (2015), with the addition of 8 character codings for *Anhuilong diboensis* gen. et sp. nov. (see Appendix 1).

and they together are closely related to *Omeisaurus tianfuensis* than to the clade including all other mamenchisaurids. Xing et al. (2015b) suggested that *O. maoianus* and *O. tianfuensis* are likely not congeneric, and *O. maoianus* is more closely related to *Mamenchisaurus*. Our phylogenetic analysis also supports this result. For this reason, all the statements of *Omeisaurus* just represents *O. tianfuensis* in this paper.

The mamenchisaurid clade is supported by ten unambiguous synapomorphy ('0' to '1' for character 64; 100; 102; 144; 146; 148; 307; 337; 347; '4' to '6' for character 105). *Anhuilong*, *Huangshanlong* and other mamenchisaurids clade is supported by the appearance of two cranial facing accessory processes on the craniodistal edge of humerus (character 347). The (*Anhuilong*+ *Huangshanlong* + *Omeisaurus*) clade is supported by two synapomorphies ('0' to '1' for character 238, 241): the stout ulna with high proximal breadth/proximodistal length ratio (character 238); radius distal/mid-shaft breadth ratio of 1.5–1.9 (character 241); Moreover, the sister-group relationship between *Anhuilong* and *Huangshanlong* is supported by one unambiguous character change ('1' to '0' for characters 349): the average of the greatest widths of the proximal end, mid-shaft and distal end/total length of humerus less than 0.27 (character 349).

Discussion

Though excavated in the same area, an analysis of morphology suggests that *Huangshanlong* (Huang et al. 2014) is different from *Anhuilong*. Frist of all, the shape of the humerus is stout compared to the comparatively gracile humerus of *Anhuilong*. Proximally, lateral and proximal humeral surfaces of *Huangshanlong* meet each other at an abrupt angle to produce a squared proximal end, making the proximolateral end a prominent process. On the contrary, the surfaces of *Anhuilong* merge smoothly with each other to produce a transversely rounded proximal end. The deltopectoral crest of *Huangshanlong* is much more robust than *Anhuilong*. The lateral humeral edge of *Huangshanlong* extends craniolaterally, whereas, the lateral edge of the deltopectoral crest turns caudolateral in *Anhuilong*. Both *Huangshanlong* and *Anhuilong* preserve lateral and medial accessory process, as most mamenchisaurids do. The radial accessory process of *Huangshanlong* is more robust than the ulnar counterpart like other mamenchisaurids, while *Anhuilong* possesses the opposite condition. Many ridges exist on the ulna of *Huangs hanlong*, while the ulna of *Anhuilong* has smooth texture. Moreover, the ratio of the ulnar length to the humeral length of *Huangshanlong* is much larger than *Anhuilong* (*Huangshanlong* is 0.67; *Anhuilong* is 0.56), also indicating an interesting fact that the antebrachium of *Anhuilong* is relatively short among mamenchisaurids.

Anhuilong also possesses some autapomorphies such as lowest ratio of ulnar length to the total length of humerus and the lowest ratio of radial length to the total length of humerus among mamenchisaurids. The ratio of ulnar length to total length of humerus is 0.56, which is the lowest value among all the taxa of Mamenchisauridae at present. This ratio values on other taxa among the matrix are all about 0.60–0.80. And still, the ratio of radial length to total length of humerus is 0.50, also the lowest value among all mamenchisaurids so far, the values of other taxa are about 0.55–0.75. The functional implications of such a short antebrachium merits exploration by future studies.

Conclusions

The new genus *Anhuilong* shares characters with Mamenchisauridae. Our study confirms previous assignment of *Huangshanlong* as a member of Mamenchisauridae. Within this clade, the new genus is the sister taxon of *Huangshanlong*, and they together are more closely related to *Omeisaurus* than to the clade including all other mamenchisaurids.

Anhuilong enriches the diversity of early branching sauropods and provides additional information to help understand the evolutionary history of sauropods in Eastern China. This discovery indicates that Mamenchisauridae was already a diverse endemic sauropod lineage during the Middle Jurassic of Asia, and the interrelationships within mamenchisaurids need to be further explored.

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Disclosure statement

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ORCID

Hai-Lu You http://orcid.org/0000-0003-2203-6461

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