A New Juvenile Specimen of *Lufengosaurus Huenei* Young, 1941 (Dinosauria: Prosauropod) from the Lower Jurassic Lower Lufeng Formation of Yunnan, Southwest China

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Abstract: A skull and a series of associated cervical vertebrae (ZLJ0112) discovered from the Lower Lufeng Formation (Lower Jurassic) are determined as a juvenile specimen of *Lufengosaurus huenei* Young 1941 based on amended autapomorphies. Differences between ZLJ0112 and the holotype (subadult specimen) are considered as ontogenetic characteristic changes of *L. huenei*. Since some of these differences are present in other prosauropod dinosaurs (i.e., forms of the maxillary vascular foramen are irregular; the frontal contribution to the dorsal margin of the orbit is substantial; the frontal contribution to the supratemporal fossa is absent; the supratemporal fenestra is visible in lateral view; the supraoccipital inclined at 75 degrees; the parapophyseal rostrum lies level with the occipital condyle; the retroarticular process is short; the axial postzygapophysis project caudally beyond the end of the centrum) they may be common ontogenetic changes in prosauropod dinosaurs.

Key words: Prosauropod, *Lufengosaurus huenei*, juvenile, ontogeny, phylogeny, Lufeng County, Yunnan Province

1 Introduction

Traditionally, Prosauropoda is divided into three families: Theropoda, Plateosauridae and Melanosauroidae (Romer, 1956; Upchurch, 1997). In Plateosauridae, the cranial end of the infratemporal fenestra does not extend ventrally beneath the orbit and the mandibular articulation is well below the dentary tooth row (Galton and Upchurch, 2004; Upchurch et al., 2007). ZLJ0112 shares these two features, and therefore belongs to Plateosauridae. *Lufengosaurus huenei* Young 1941 was erected based on an almost complete cranium and postcranial skeleton (IVPP V15). Barrett et al. (2005) redescribed the skull and mandible of holotype and proposed emended four cranial diagnoses.

*Lufengosaurus huenei* Young 1941 (Prosauropod: Dinosauria) is one of the oldest dinosaurs discovered from China. It was erected based on an almost complete skull and skeleton (holotype: IVPP V15) from the Lower Lufeng Formation (Early Jurassic) of Lufeng County, Yunnan Province, Southwest China. In this area, quite a lot of vertebrate fossils including fish, amphibians, reptiles, dinosaurs and mammals have been discovered (Dong, 1992; Sun et al., 1985). Especially, prosauropod dinosaurs are abundant, including eight species of five genera. However, there are different opinions about their availability (Barrett et al., 2005; Galton and Upchurch, 2004; Rozhdestvensky, 1965).

Prosauropods constitute basal group of early sauropomorph dinosaurs. Although several growth stages’ specimens were reported such as juvenile individual of *Thecodontosaurus* (Benton et al., 2000), *Massospondylus* (Hinic, 2002), *Mussaurus* (Bonaparte and Vince, 1979), *Sellosaurus* (Galton and Bakker, 1985) and *Lufengosaurus* (Evans and Milner, 1989), ontogenetic study of these taxa are still rare (Gow, 1990; Weishampel and Horner, 1994). Recognition of ontogenetic characteristic changes of *Lufengosaurus* will be useful for future clarification of the availability of certain taxa and early evolution of sauropodomorph dinosaurs.

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Here, we report a new specimen of a juvenile individual of Prosauropod (ZLJ0112). We will describe its morphological features, and shows that it belongs to a juvenile specimen of *Lufengosaurus huenei*. Compared with adult specimen (IVPP V15) of *L. huenei* points out some ontogenetically-related character changes.

## 2 Geological Settings

ZLJ0112 was found from the Red Bed of the Dawa Dinosaur Mountain, 30km West from Lufeng Town. The surrounding area distributes the Lower and the Upper Lufeng formations in ascending order, which covers the Etouchang Formation of Kunyang Group (Yunnan Geological Bureau, 1966) (Fig. 1).

The Proterozoic Etouchang Formation (Qiu et al., 2003) is dark gray slate, which is mainly composed of phyllites, quartzites, crystalline limestones, mica- and calc-schisists, with crushed quartz veins (Bien, 1941). The base of this formation is invisible in Dawa area, and the thickness is at least 260 m.

The Lower Lufeng Formation is divided into so-called ‘Dull Purplish Bed’ and ‘Dark Red Bed’ in ascending order (Young, 1951), which covers the Kunyang Group in unconformity. ZLJ0112 was discovered from the ‘Dark Red Bed.’ The total thickness of the Lower Lufeng Formation is 695m in the southern part and 787m in the north part of the Dawa area. The lower part is composed of purple mudstone or siltstone accompanying bluely white mosaic siltstone, which would be paleosol sediments. The upper part of the Lower Lufeng Formation is red-brown mudstone or siltstone, about 230m thick in north part. Both are mainly massive, but some parts are parallel or cross laminated. The most upper part of the latter is blight red color. The middle of the Lower Lufeng Formation contains more than 5 meters of green gray silty sandstone layer.

The Upper Lufeng Formation consists of parallel laminated alternative beds of obscured purplish siltstone and light yellow silty sandstone. Their thickness is of great variety from about few centimeters to a meter. The boundary between Upper and Lower Lufeng formation is reported as unconformity, but in this area distinct unconformity boundary is invisible. Fossil records are quite rare from the Upper Lufeng Formation (Bien, 1941; Young, 1940).

Based on the vertebrate fauna (*Clevosaurus, Dibothrosus* and so on), the geological age of the Lower Lufeng Formation is estimated as Early Jurassic (Luo and Wu, 1995). Other taxa including conchostracans, ostracods, bivalves, and charophytes also consist with this age assignment (Pang et al., 2002).

![Fig. 1. Geological map of Dawa Dinosaur Mountain. Star mark shows the discovered locality of ZLJ0112.](image)

## 3 Materials

ZLJ0112: An almost complete skull (Fig. 2) and three articulated cervical vertebrae (Figs. 4-6) collected by the staff of Lufeng Dinosaur Museum (LDM) in 1987. The specimens are housed at the Dinosaur Research Center of Lufeng.

**Systematic Paleontology**

- **Dinosauria** (Owen, 1842)
- **Saurischia** (Seeley, 1887)
  - **Sauropodomorpha** (Huene, 1932)
  - **Prosauropoda** (Huene, 1920)
  - **Plateosauridae** (Marsh, 1895)
  - **Lufengosaurus huenei** Young, 1941
Fig. 2. Prosauropod dinosaur *Lufengosaurus huenei* Yong, 1941, new cranial specimen ZLJ0112 from the Middle Lower Lufeng Formation near Lufeng County, Yunnan province, China, in dorsal (A), left lateral (B), right lateral (C), ventral (D) and caudal (E) views. Photographs (A1, B1, C1, D1, E1) and interpretive outlines (A2, B2, C2, D2, E2). Shaded portion showing reconstructed area and black out area representing opening.

4 Description

The skull is 17 cm long, and wider than high (Fig. 2). It is almost completely articulated but the right caudolateral part is significantly deformed. The rostral half of the skull roof is significantly narrow, which is different from the condition in other prosauropods. The ratio of the maximum skull width to height is 1.05, lower than 110% (contrary to the autapomorphy of *Massospondylus*). The skull and lower jaw are compressed and adhered to each other. The axis, 3rd and 4th cervical vertebrae are preserved; most of the neural arches of the latter two are missing. Some fragments of axis are caked with occipitals.

4.1 Skull

The **antorbital fenestra** is a small sub-triangular shaped opening. The height of the skull at the antorbital opening is quite less than 50% of the length, which is different from that of *Yimenosaurus youngi* (Bai et al., 1990). The antorbital fossa occupies a small area at the caudal margin of the base of maxillary ascending process.

The orbital fenestra is rather dorsoventrally longer than high; the maximum length is 4.96 cm and the height is 2.28 cm. Its length-height ratio is 2.17, which is extremely larger than in other prosauropod, but it may be caused by preservation.

The premaxilla is almost broken with only fragments of its caudal parts preserved; some of them are fused with the maxilla. It is not sure, whether the rostral prominence of the premaxilla, which is shown in *Riojasaurus incertus* (Bonaparte, 1967) is present or not.

Both maxillae are relatively well preserved. The dorsolateral surface of the main body is slightly concave.
The maxilla has three rami: rostral, dorsal and caudal processes. The rostral process of the right maxilla has a large vascular foramen, which oriented laterally on the lateral surface. The dorsal process is relatively thin at its base and becomes wide towards the tip, though it is not as wide as in *Coloradisaurus brevis* (Bonaparte, 1978). Because it does not amount 50% of length, it does not refer to *Yimensaurus youngi* (Bai et al., 1990). The dorsal process inclines medially and caudally which is different from *Musaurus patagonicus* (Bonaparte and Vince, 1979); bony boss in the holotype of *Lufengosaurus hueni* (Young, 1941) proposed by Barrett et al. (2005) are present but slightly convex. The caudal process is the longest; its middle part is constricted in dorsolateral view, and the width decreases toward the middle. The upper margin of the caudal process inclines medially, which is similar to *Jinshanosaurus xinwenensis* (Zhang and Yang, 1994). The dorsal margin of the caudal ramus is blunt, and it is not distinct inside the muscular canal. A lamina presents on the lateral surface as in other prosauropods; but it is very weak, short and merges with the body of the maxilla. The dorsomedial margin of the caudal process and caudal margin of the ascending process attribute to the connotorial fenestra.

The right nasal is also mostly crushed and remains only a short stick-like small fragment. Its caudal end contacts with the lacrimal. The lateroventral surface contributes to the rostrodomal rim of antorbital fenestra, and the rostrodomal surface has two prominent ridges along the longitude. The fragment contacts rostrally with the dorsal process of maxilla and with the rostral tip of lachrymal caudally. Nasal hides the contact of maxilla and lachrymal, but it may largely be due to transformation, thus the original situation is uncertain. If the rostral tip of upper jaw fitted with dentary, the nasal does not attain to the half of skull roof, it does not refer to *Plateosaurus longiceps* (Jaekel, 1913-14).

The lachrymals are slender shafts which are directed craniodorsally and slightly medially toward to the skull roof. The base of the lachrymal is rostrocaudally wide, contacting with the dorsal surface of the jugal. Its rostral margin contributes to the caudal rim of antorbital fenestra and rostroventral rim of orbital fenestra caudally. There is not any obvious antorbital fossa. The left lachrymal abruptly tapers dorsally and has a lateral conspicuous crest, which inclines rostrally due to compression and transformation. On the other hand, the right lachrymal does not have crest. The right side curved sigmoidly due to transformation. Lachrymal foramen is absent, which is contrary to that of the holotype of *L. hueni* (Young, 1941a).

The left part of the prefrontal is entirely broken and reconstructed by plaster. The right prefrontal remains only a caudal portion, as a small plate-like piece with lateral edge. It does not insert to frontal as much as in the holotype of *L. hueni*. Transverse cross-section of the edge is sub-triangular and its tip directs dorsally. So the lacrimo-prefrontal crest is rather projective than rounded of *R. incertus*. Its lateral surface contributes to the dorsal margin of the antorbital fenestra but shortly. The prefrontal contacts with frontal caudomedially.

The frontals are sub-triangle thin plates which have a wing-like caudolateral process. The dorsal surface is concave at its middle portion; consequently the lateral part inclines up toward lateral side. The central suture forms a distinct ridge dorsocaudally. The caudal margin contacts with the parietal and the caudomedial wing contacts with rostral process of postorbital ventrolaterally. The lateral margin of caudolateral wings contribute largely to the dorsal rim of the orbital fenestra, which is similar to *Sellosaurus gracilis* (Galton, 1985). Frontal is excluded from the supratemporal fossa as in other prosauropods.

Parietals construct the main part of caudal skull roof, which have rostrolateral process and caudolateral processes. The dorsal surface of the main body is eminent smoothly and has some suture lines or cracks asymmetrically. The cranial lateral processes become narrow outwardly as a wing and convex dorsally, but the base of which is concave. They contact with frontal rostrally, and with postorbital laterally at their tips. Caudolateral processes gently gain its width toward outside, the dorsal surface slightly convex. The bony boss as in the holotype of *L. hueni* reported by Barrett et al. (2005) is absent. It contacts with the squamosal laterally and with the supraoccipital caudally. The rostral surface of the caudal process contributes to the narrow supratemporal fossa. Lateral margin of parietals form most of the supratemporal fenestra rim, but they contribute quite narrow or no supratemporal fossa.

The postorbital is composed of three processes: rostrodorsal, ventral, and caudal processes. The rostrodorsal process is robust and gains its transverse width toward its tip, which contact to lateral end of frontal and parietal wing smoothly. Most of the ventral process is snapped and lost except its root; it is stout and its transverse cross-section is subcircular, with little dorsocaudally longer than wide. The caudal process of the left postorbital tapers and directs caudodorsally, its medial surface overlaps the lateral surface of squamosal and quadrate slightly. The caudal process of the right postorbital contacts to the distal surface of rostral process of the squamosal, and it should be caused by depression. The lateral margin of the rostrodorsal process and the rostral margin of the ventral process form the dorsocaudal
rim of the orbital fenestra. The medial margin of the rostroventral and caudal process contribute to the supratemporal fenestra without fossa. The caudal margin of the ventral process and ventral margin of the caudal process contribute to rostroventral rim of the infratemporal fenestra.

Left jugal remains rostral tip and isolated middle piece. In the right side, only the rostral part remains. Both of them are heavily damaged, and it is difficult to identify. In lateral view, the rostral part is a triangular shaped robust fragment that contacts with the caudal process of maxilla and the base of lachrymal dorsomedially. Its lateral surface is slightly convex; it could be a rudimentary bony boss of *L. huenei* proposed by Barrett et al. (2005). The middle surface is almost flat. The separated piece is a thin flat plate, which has two processes: one is slender and oriented caudodorsally, and the other is spatulate and oriented caudally. The angle of those two processes is about 55 degrees.

The quadratojugal is heavily damaged. On the left side remains two pieces of fragments; one is a small triangle shaped plate and the other seems to be the ventral end of main body. The former is an ascending process which medially attaches to the rostroventral margin of quadratojugal. Though the rostral process which contact with jugal is missing, the remained rostroventral margin contributes to the caudal rim of infratemporal fenestra. The right side is significantly damaged, thus it is impossible to be observed.

The squamosal is also compressed and adhered to the surrounding bones; i.e. quadrate, postorbital, parietals, and paroccipital process. The squamosal has rostroventral, ventral and caudal processes. The rostroventral process becomes to a blunt tip, and its medial surface constructs the rostroventral rim of the supratemporal fenestra. The ventral process is a short danging process, which tapers immediately. It contacts to the rostral surface of quadratojugal. The caudal process also tapers in lateral and dorsal view, and elongates toward the paroccipital process. Its lateral surface contacts with dorsomedial surface of quadratojugal head and contacts with paroccipital caudomedially. The base of caudal process slightly separates from the main body due to damage. The main body of the squamosal medially contacts with the caudolateral process of parietal.

The quadratojugal is a caudally bowed stout shaft forming into an arch (contrary to *Jingshanosaurus xinwaensis*, where the shaft of the quadratojugal is straight) the upper half directs caudodorsally and lower half directs caudoventrally. The upper part contacts with squamosal rostroventrally, with paroccipital caudally and with parietal dorsally. The lower half is slightly twisted medially and has a distinct groove on its midline of caudolateral surface. The lower part contacts with quadratojugal rostrolaterally. It’s also fused with dorsal surface of articular due to compression. The ventral articulation surface for the mandible is mid-laterally elongated crescent shaped, which is divided into two condyles by a rostrolaterally directed short groove. The outer condyle is higher than the inner one. The articulation level with the mandible is slightly lower than the ventral level of maxilla, which is different from that of *R. incertus* (Bonaparte & Pumares, 1995).

Distinct identification and detail description of the pterygoid is difficult because of its poor preservation. There is a slightly sigmoid curved short sharp ridge at the nearly central of ventral side of the skull; it may be a palatine process of pterygoid. At the far back of the ridge has a large rounded condyle, it may be a portion of the sphenoid. And a thin plate which besides the sphenial may be the ventral margin of palate. Distal end of basipterygoid process resembles to be a small condyle, which is not expanded as in *Riojasaurus* (Bonaparte, 1967).

A very thin plate which is laterally convex may be the right palatine. That is pressed and adhered to medial surface of splenial, due to crushing. Left side is not preserved.

### 4.2 Braincase

Due to the crush and sticking matrix, identification and original situation are questionable especially for the internal elements and right parts.

The supraoccipital is divided to three pieces of blocks, one is a sub-rounded condyle-like small piece, and the others locate caudally, which are divided from side to side by the midline of the skull. The left one is a caudodorsally elongated sub-rectangular, concave at the central part. The right one is sub-trapezoidal shape in caudodorsal view, and bearing a large angular condyle at the proximal half of the dorsal surface. The latter two contact with the parietal rostrolaterally, with paroccipital caudolaterally, and contribute to the dorsal rim of the foramen magnum. The caudodorsal surface inclines about 45 degrees.

The exoccipital and ?opisthotic are fused and comprise paroccipital process. The left side is very complex; and the main wing directs laterally and slightly ventrally, which is different from what in *Thecodontosaurus caducus* (Yates, 2003); laterally and slightly dorsally, a fragment of axis exists. The wing is vertical, broad, and becomes thin distally. Its distal edge is rounded with some small notches. The rostroventral process becomes elongated toward the caudal edge of quadrate. The rostroventral surface contacts with caudal process of the squamosal. On the right side, the distal wing is broken at its base; the
cross section is elliptical. The ventral process has three condyles, medial one contacting with basioccipital, and lateral one contacting with the quadrate on its tip. The bases of them contact with paroccipital medially and with parietal and quadrate laterally.

The basioccipital is an almost round, caudoventrally directed condyle (same as in *J. xinwaensis*). The caudodorsal surface of the occipital condyle is slightly concave. At both lateral sides, it contacts with paroccipitals and forms the occipital condyle together as in most other prosauropods. Slightly convex dorsal surface contributes to the ventral rim of the deep foramen magnum.

Basiphenoid, parasphenoid, and laterosphenoid are heavily damaged, crushed, so they are difficult to be identified. A small rounded process directing downward may be the basipterygoid process, at the left side of ventral surface. Long axis of its distal end directs rostrocaudally. That converges dorsally but does not form v-shaped depression due to lack of right basipterygoid process. Basal tubera develop more ventrally than basipterygoid process, a character which was not observed in *Anchisaurus polyzelus* (Marsh, 1885).

### 4.3 Mandible

Because of dorsoventral compression, both sides of the mandible elements are crushed and adhered tightly to the ventral surface of the upper jaw. The left side is relatively well preserved, but the right side, especially the caudal margin is heavily smashed.

The dentary retains almost same height from rostral to caudal end and slightly bows laterally in the ventral view. Its length is less than half of the mandibular, and this character does not refer to *Thecodontosaurus caducus* (Yates, 2003). In lateral view, the ventral margin is almost straight and the rounded rostral tip directs downward only. The lateral surface of the rostral half has remarkable lamina along its length which becomes blunt crest at the mid-length. Dentary has a caudal process which contacts with surangular caudodorsally and angular caudoventrally. There is a significantly wide groove between the dentary and the splenial in ventral view; they must be sutured in life. Visible dentary teeth are five on the left and one on right, which containing two sockets. Only one of them remains crown, right one tooth remains its root only. It should have more teeth in life but hidden by adhered maxilla. There is short distance between the rostral most teeth and rostral tip of the dentary. The labial side is higher than lingual, and alveoli are mostly along the curved dentary.

The **left splenial** is heavily broken and fragmented, and the right one is identifiable. It is a medially slightly convex thin plate, which contacts to the dentary from medial side. The splenial increases its thickness and height caudally, which reaches the connecting position of the dentary and angular. Ventral edge of splenial is sharp in the rostral half and the latter half is bluntly rounded.

**The right angular** is significantly broken; the left side is also damaged but relatively well preserved. The left angular tapers rostrally, forming the ventral sharp rim of the external mandibular fenestra; its lateral surface is convex and inclined medially. That contacts with caudal surface of the dentary and with the surangular dorsally. The angular is highest at its rostral third, and decreases caudally. Right angular remains only a trapezoidal thin plate-like fragment, the lateral surface is flat and smooth. The ventral end also inclined to medially though perhaps that is attributed to compression. The external mandibular fenestra is not small such as *J. xinwaensis*.

**The right surangular** is damaged and deformed. The left surangular seems to be a robust, gently curved shaft. Its dorsal surface is smoothly convex, which forms the coronoid eminence and falls down caudally. Surangular comprises retroarticular process with articular and extends below the quadrate. The left side is broken at its base and preserves relatively short retroarticular process, and its distal end is well rounded.

It is difficult to identify the prearticular because of damage. **The left prearticular** is covered by other bones and mostly invisible, but only a small thin flat plate which might be a front part of the prearticular attaching to medial surface of the angular is remained. That contacts with angular laterally. Right side is a sub-triangular shaped thick plate, contacting with surangular medially and articular caudally; its medial surface is very uneven.

**The left articular** remains the rostral half only and it is a squared medium trapezoidal block, which contacts with the ventral surface of the quadrate dorsally and with medial surface of the surangular laterally. The right side is sub-ellipse shaped in medial view and moved medially. The medial edge has a large condyle, which may comprise the coronoid process. Its distal end is well rounded and dorsoventrally elongated, which forms the retroarticular process and its medial surface is nearly flat and the lateral surface is significantly convex.

### 4.4 Dentition

The premaxillary and maxillary teeth are invisible since adhesion of mandibular to the upper jaw. The dentary teeth are poorly preserved (Fig. 3); i.e. three left rostral dentary teeth, one right dentary tooth and two alveoli are preserved. There are short gaps between each tooth. Only one of them remains crown, which curves to mesiodorsally and increases thickness dorsally from root
Table 1 Measurements of the cervical vertebrae of ZLJ0112 (cm)

<table>
<thead>
<tr>
<th>Axis</th>
<th>Lc</th>
<th>Wca</th>
<th>Wepo</th>
<th>Hca</th>
<th>Hopo</th>
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<tbody>
<tr>
<td>c.v.3</td>
<td>4.4</td>
<td>2.0</td>
<td>1.8</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td>c.v.4</td>
<td>6.6</td>
<td>2.0</td>
<td>2.1</td>
<td>1.9</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Lc: length of the centrum; Wca: Width of cranial surface of the centrum; Wepo: Width of caudal surface of the centrum; Hca: Height of cranial surface of the centrum; Hopo: Height of caudal surface of the centrum.

Toward two-third of tooth. The crown is covered by enamel and convex labially, slightly concave lingually. The serration is very weak and coarse not as in *Saturnalia* (Langer et al., 1999). There is no “neck” on its root suggested as an autapomorphy (Gauffre, 1993) of *Azendohsaurus lauroussi* (Dutuit, 1972). The lateral surface is smooth with a very weak ridge directed apicobasally. Upper half of the crown has serrations (different from *Yunnanosaurus*), which is quite fine and weak, direct mostly parallel or low angled against longitudes.

### 4.5 Postcranioc Skeleton

Almost complete axis, 3rd and 4th cervical vertebrae are preserved; the latter two preserve centra and the bases of neural arches (Figs. 4-6, Table 1).

The axis is deeper than the longer. The centrum is amphicoelous, but the proximal end is slightly concave. It has a prominent neural spine which is relatively higher than that of other Chinese prosauropods except *Yunnanosaurus youngi*. The cranial half of the centrum has a ventral keel. The postzygapophysis projects slightly caudolateradly beyond the caudal end of the centrum.

The centrum, some parts of the neural arch, and postzygapophysis of the third cervical vertebra are preserved. The centrum is constricted ventrally and laterally in the anterior one-third, and the articular surfaces are amphicoelous. The distal articular surface is more concave than proximal one. The dorsal surface of the base of neural arch represent wavy suture. The neural canal is elliptical.

The centrum and base of the neural arch of the fourth cervical vertebra are preserved. The articular surface is circular, amphicoelous and deeper than the preceding ones. The centrum is constricted both ventrally and laterally at the mid length. The cranial one-third has weak ventral keel as in other prosauropods (*Anchisaurus*, *Coloradisaurus*, *Saturnalia* and *Lufengosaurus* (Marsh, 1885; Bonaparte, 1978; Langer et al., 1999; Young, 1941, respectively).

### 5 Discussion

#### 5.1 Identification and comparison

The specimen (ZLJ0112) is assigned to *Lufengosaurus*, based on the following characters: low tuberosity on lateral surface of ascending process of maxilla; low boss on central portion of jugal at junction of the three jugal processes; prominent boss on dorsal surface of rostrolateral process of parietal; and presence of ridge on caudal part of lateral surface of maxilla (Barrett et al., 2005). However, ZLJ0112 has a weak bulge on the lateral surface of maxillary ascending process and jugal. The dorsal surface of the rostrolateral process of parietal is slightly convex. The lateral ridge on the lateral surface of the maxilla is not as abrupt as in IVPP V15, but moderately convex. Thus, ZLJ0112 could be identified as *Lufengosaurus huenei*. In addition, it bears the following unique characters: transverse width of the frontal is especially narrow in dorsal view; parietal is stretched laterally; axis is relatively high compared to other prosauropods. Here, we considered these characters as intraspecific variation.

Morphological similarities and differences of ZLJ0112 to other Chinese prosauropods are compared herein. Holotype (IVPP V82) of *L. magnus* (Young, 1947) does not have skull and proximal cervical vertebrae preserved. In additional specimens, a right dentary of *L. magnus* (V41) decreases its height caudally (Young, 1947), unlike in ZLJ0112.

The skull of *Gyposaurus sinensis* (Young, 1941b) is also poorly preserved; holotype (V26 and V27) are incomparable. The prezygapophysis of the third cervical vertebra of V27 is also elongated as in ZLJ0112. The neural spine of ZLJ0112 is higher than that of V26 and V27. Young (1947) identified a left maxilla (V43) as *G. sinensis*, and it is similar to ZLJ0112 as gain its height posteriorly; however in *Gyposaurus*, the diaphysis of the 3rd cervical vertebra developed more than ZLJ0112.

Barrett et al. (2007) re-describe and advocated autapomorphies of *Yunnanosaurus huangi*: expanded intermariar bar, unusual midline cranial bosses, and elongate maxillary tooth crowns lacking marginal serrations. ZLJ0112 does not have these bosses, and its left dentary tooth has serrations. Compared with *Y. huangi*, orbital region of prefrontal is longer and wider, and the neural spine of third cervical vertebra is significantly higher.

ZLJ0112 differs from *Yunnanosaurus robustus* (Young, 1951) in that the rostral dentary tooth of ZLJ0112 bears course serrations, whilst that of *Yunnanosaurus robustus* (Young, 1951) does not bear serrations. ZLJ0112 differs from *Yunnanosaurus youngi* (Lü et al., 2007) in that cervical vertebrae do not bear prominent ventral keels, the diaphysis and parapophysis are not developed, the axis does not have epipophysis, and the anterior articular surface of 4th cervical vertebra is concave.
anterior articular surface of 4th cervical vertebra is concave.

One of the autapomorphies of *J. xinwaensis* is small (less than 5% of mandibular) external mandibular fenestra (Galton and Upchurch, 2004), but that of ZLJ0112 is not so small (14.4%). Furthermore, frontal does not occupy large amount of orbital, and supraoccipital inclined more than 50 degrees.

Regarding *Yimenosaurus youngi* (Bai et al., 1990), the proportion of its skull is different from that of ZLJ0112, which is much higher than longer. The maxilla of ZLJ0112 is longer and much slender than that of *Yimenosaurus*.

5.2 Growth stage

ZLJ0112 possesses some features which represent growing stages as follows: the relatively large orbital fenestra (diameter ratio of orbital to antorbital is 0.50; that of *L. huenei* is 0.70), unfused parietals (Kermack, 1984), and unfused surface of the neural arch to the centrum (Lehman and Coulson, 2002). According to these characters, we suggest that ZLJ0112 is a juvenile individual. The boss on dorsal surface of rostrodorsal process of parietal and ridge on the caudal part of lateral surface of maxilla are not prominent. We consider this immaturity depend on ontogenetic reason.

5.3 Ontogeny of *Lufengosaurus huenei*

Compared with relatively large specimen of *Lufengosaurus huenei* (IVPP V15; holotype), ZLJ0112 possesses some differences as follows: forms of the maxillary vascular foramen are irregular; the frontal contribution to the dorsal margin of the orbit is substantial; the frontal contribution to the supratemporal fossa is absent; the supratemporal fenestra is visible in lateral view; the supraoccipital inclined at 75 degrees; the parasphenoid rostrum lies level with the occipital condyle; the retroarticular process is short (this character is present in CUP2037 also, juvenile of *L. huenei* (Evans and Milner, 1989); and the axial postzygapophysis project caudally beyond the end of the centrum.

Some of these character changes mentioned above are present in other prosauropod dinosaurs. The directions of maxillary foramen of *Massospondylus carinatus* (BP/1/4376) are irregular in juvenile (Galton and Bakker, 1985) contrast to adult specimen. The supratemporal fenestra is visible in lateral view in juvenile *Massospondylus* (Gov et al., 1990). Parasphenoid rostrum lies level with the occipital condyle, and the axial postzygapophysis project caudally beyond the caudal end of the centrum in juvenile of *Sellosaurus gracilis* (SMNS 12667, Galton and Bakker, 1985). Therefore, these character changes could be common in some prosauropod dinosaurs.

6 Conclusion

A skull and articulated proximal cervical vertebrae (ZLJ0112) from the Lower Lufeng Formation (Early Jurassic) are identified as *Lufengosaurus huenei* Young 1941 based on retrieved autapomorphies suggested by Barrett et al. (2005). The relatively large orbit and unfused parietal and cervical neural arch in ZLJ0112 suggest it as a juvenile specimen. Compared with sub-adult specimen, it possesses some differences which could be considered as ontogenetically related: forms of the maxillary vascular foramen are irregular; the frontal contribution to the dorsal margin of the orbit is substantial; the frontal contribution to the supratemporal fossa is absent; the supratemporal fenestra is visible in lateral view; the supraoccipital inclined at 75 degrees. The parasphenoid rostrum lies level with the occipital condyle; the retroarticular process is short; the axial postzygapophysis project caudally beyond the end of the centrum. Since some of these differences are present in other prosauropods, these could be common ontogenetic character changes in prosauropod dinosaurs.

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