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Author: LIU, JUN

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A Juvenile Specimen of *Anshunsaurus* (Reptilia: Thalattosauria)

JUN LIU[1]

ABSTRACT

A marine reptile from the Ladinian deposits near Xingyi is described and identified as a juvenile of *Anshunsaurus wushaensis* on the basis of similar skull proportions and many postcranial characters. Based on this specimen and observations of the holotype of *A. wushaensis*, there is no distinct ontogenetic differentiation in the length of the jugal. The absence of an astragalus in the holotype, and the greater length of metacarpal V relative to metacarpal IV, could be due to intraspecific variation. Ossification is not synchronous for corresponding elements on both sides of the body.

INTRODUCTION

The thalattosaur genus *Anshunsaurus* from Guizhou, China, includes two species: *A. huangguoshuensis* and *A. wushaensis* (Liu, 1999; Rieppel et al., 2000; 2006). The previously described two specimens of *A. huangguoshuensis* (IVPP V11834, 11835) are all adults of at least 1.5 m presacral length (Liu and Rieppel, 2005). The holotype of *A. wushaensis* (IVPP V13782) is smaller than those but is considered to represent an adult (Rieppel et al., 2006). No juvenile of either species has been described, and ontogenetic variation remains unknown in *Anshunsaurus*. Furthermore, little information of ontogenetic variation has become available for thalattosaurs generally, although growth stages are available for some species such as *Xinpusaurus suni*. In this paper, a juvenile specimen of *Anshunsaurus* will be described, and ontogenetic variation in this species will be discussed for first time.

INSTITUTIONAL ABBREVIATIONS: **IVPP** Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of

[1] Division of Paleontology, American Museum of Natural History; Lamont-Doherty Earth Observatory, Columbia University, Palisade, New York, NY 10964 (liujun@amnh.org).
Current address: Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences; Beijing, China 100044 (liujun@ivpp.ac.cn)

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Sciences; Beijing. **KM** *Kueichousaurus* Museum, Xingyi.

THALATTOSAURIA MERRIAM, 1904
ASKEPTOSAURIDAE KUHN, 1952
ANSHUNSAURUS LIU, 1999

Anshunsaurus wushaensis Rieppel, Liu et Li, 2006

REFERRED SPECIMEN: KM 512, a skeleton missing the tail and part of the limbs; a cast of this specimen is preserved in IVPP.

LOCALITY AND HORIZON: Wusha Town, Xingyi City, Guizhou Province, China; Zhuganpo Member of Falang Formation, Ladinian of Middle Triassic.

DESCRIPTION

This specimen is exposed in dorsal view with the exception of the anterior cervical vertebrae, which are exposed in lateral view (fig. 1). Most of the skeleton is well-preserved except for the tail and some elements in both hands and feet. The skull measures 132 mm in length, the neck measures approximately 200 mm, and the trunk measures approximately 330 mm.

SKULL

The skull is complete but dorsoventrally compressed as is also the case in IVPP 11835 (holotype of *Anshunsaurus huangguoshuensis*) (fig. 2). The sutures are distinct and the pattern is similar to that of the previously described specimens of *Anshunsaurus*. The snout is long and slender, similar in relative size to that of IVPP V13872 but relatively shorter than in *A. huangguoshuensis*. The distance from the tip of the snout to the anterior margin of the orbit is only slightly longer than the distance from the anterior margin of the orbit to the posterior tip of the supratemporal. The snout is formed mostly by the premaxillae, but the maxillae also contribute to the lateral sides of the rostrum.

The external nares are poorly preserved. Their exact contours cannot be delineated, but they do appear to be relatively small openings. The external naris is bordered dorsally (medially) by the nasal and perhaps premaxilla, and ventrally (laterally) by the maxilla.

The paired premaxillae form a V-shaped posterior process, which inserts between two anteromedial processes of the frontals, thus separating the nasals from each other. The tip of this posterior process extends posteriorly to a level behind the posterior margin of the external naris and close to the anterior border of the orbits. The maxillae extend anteriorly not too far beyond the external nares. The maxillae are asymmetric on the two sides. The right maxilla forms a distinct dorsal process between the nasal and the prefrontal, which is absent on left side. The anterior margin of the nasals is only slightly anterior to the base of the posterior processes of the premaxillae; the posterior tip of the nasal extends far beyond the anterior border of the orbits; the length of the nasal within the interorbital region is about one-quarter the length of the orbit.

The frontal forms a narrow anterolateral process between the nasal and the prefrontal. The anterior tip of this process is level with the anterior margin of the orbit; its anterior extension is shorter than that of the anteromedial frontal process. The frontal narrowly enters the dorsal margin of the orbit, separating the prefrontal from the postorbitofrontal. The slender posterolateral process of the frontal extends backward between the postorbitofrontal and parietal to the level of the posterior margin of the pineal foramen; the frontal fails to contact the anterior tip of the supratemporal. In its middle portion, the posterior end of the frontal meets the parietal in a transversely oriented, complexly interdigitating suture located at the level of the postorbital arch.

The jugal is drawn out posteriorly into a long and slender process that to a large degree closes the lower temporal fenestra ventrally. The oval pineal foramen is enclosed by the parietals. It is located narrowly behind the fronto-parietal suture. Its longitudinal length is only 6 mm, and thus it is relatively shorter than IVPP 11835, but similar in relative length to IVPP 13872.

POSTCRANIAL SKELETON

The number of presacral vertebrae is more than 38 in IVPP 11835, and about 39 in IVPP

Fig. 1. The skeleton of a juvenile *Anshunsaurus wushaensis* (specimen KM512) (scale bar = 10 cm). The tail is a reconstruction.

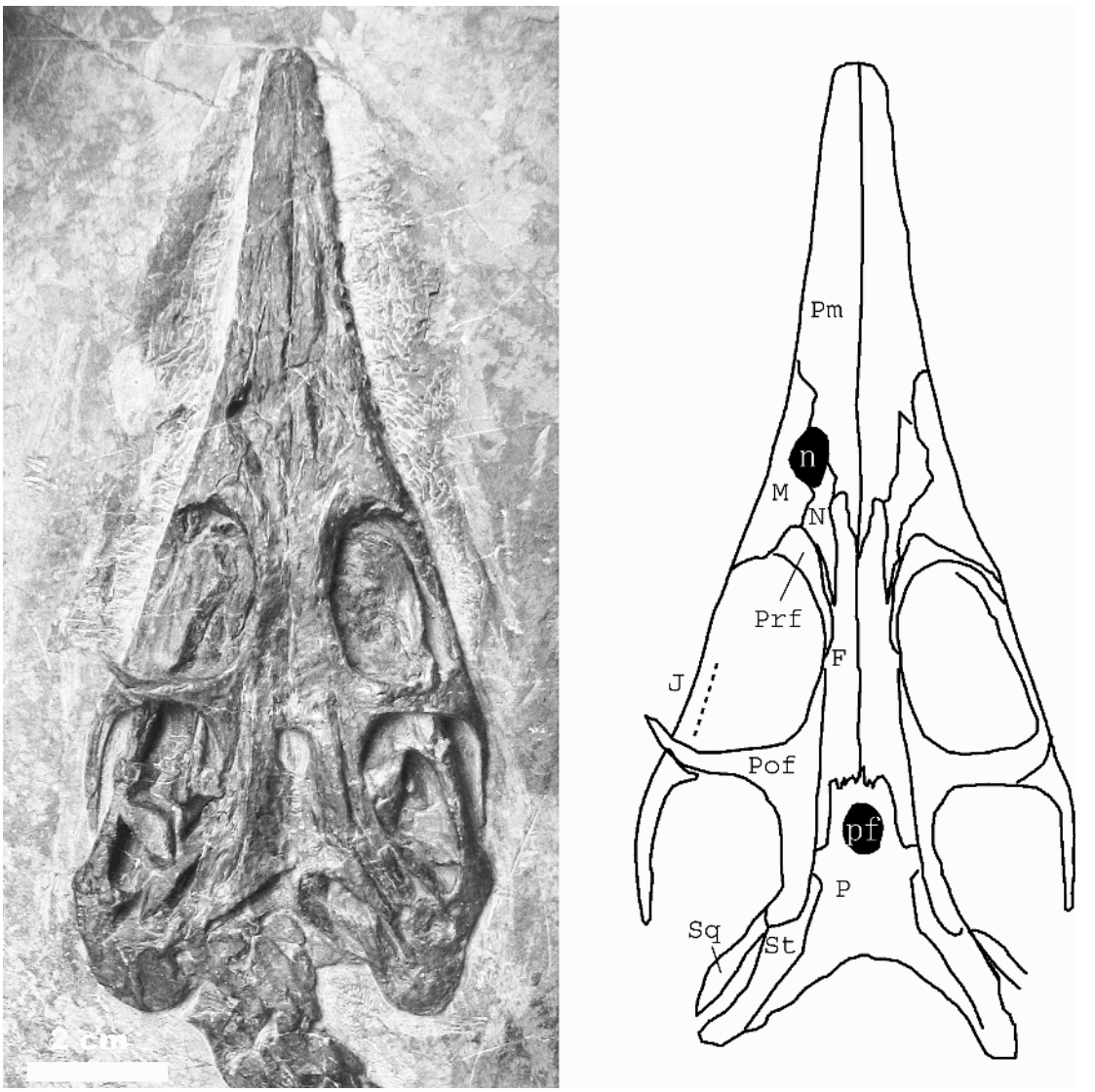


Fig. 2. Juvenile *Anshunsaurus*, skull in dorsal view (specimen KM512). Abbreviations: F, frontal; J, jugal; M, maxilla; N, nasal; n, naris; P, parietal; pf, pineal foramen; Pm, premaxilla; Pof, postorbitofrontal; Prf, prefrontal; Sq, squamosal; St, supratemporal.

V13872 (Liu and Rieppel, 2005; Rieppel et al., 2006). The presently described specimen has 41 or 42 presacral vertebrae, which is the first unequivocal count for this genus.

The number of cervical vertebrae is 15 or 16, but the nature of the ribs articulating with vertebrae 15 and 16 remains unclear; the ribs articulating with the 17th presacral element are typical dorsal ribs. The atlas cannot be observed. The centrum of the axis is 10 mm in length, 8 mm in height. The neural spine is low and distinctly elongated to 15 mm; its dorsal margin is straight. The following cervical centra slightly increase in size, with a length of about 12 or 13 mm in general. The neurocentral suture is unfused in the cervicals. The neural arch shows well-developed pre- and postzygapophyses. The neural spines are low. The cervical ribs are articulated with vertebrae at least from the axis; they are

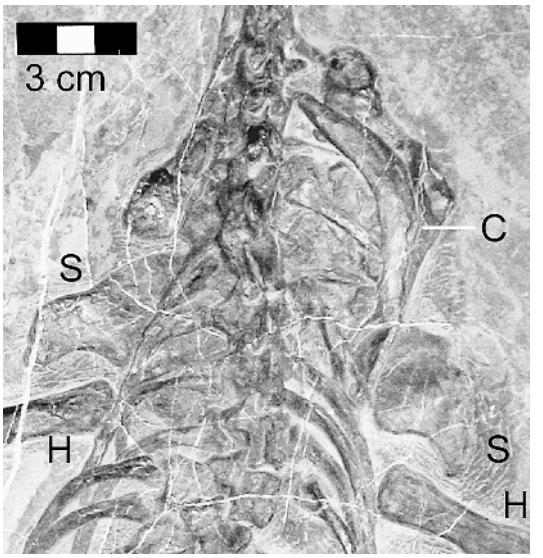


Fig. 3. Juvenile *Anshunsaurus*, pectoral region (specimen KM512). Abbreviations: C, clavicle; H, humerus; S, scapula.

dichocephalous, increasing in length posteriorly.

The neural spines in the dorsal region are generally taller than those in the cervical region; but their height does not exceed their anteroposterior length. Vertical grooves and ridges are observed on the lateral surface of the neural spines near their dorsal margin in IVPP 13872 (Rieppel et al., 2006). The same is also observed in the presently described specimen, e.g., on the 24th presacral vertebra, although it is not as distinct as in the holotype of *A. wushaensis*. The neural arches do not fuse to the centra; as preserved, they are separated from the centra in the 30th through 37th vertebrae. The 43rd vertebra is identified as a sacral element based on the shape of its rib.

In the pectoral area, the left and right scapulae and the right clavicle can be identified (fig. 3). The clavicle is widest in the curved area; its anterior part is a little bit wider than its posterior part but of nearly the same length. In IVPP 11834 and 11835, its anterior part is remarkably shorter and slightly narrower than its posterior part. The scapula is relatively taller than those of IVPP V 11834. The left and right scapulae differ slightly in shape, and the right one is slightly larger than the left one. The dorsal margin amalgamates with the anterior margin on right scapula as in IVPP 11834, but the transition is clear on the left one. The anterior margin meets the ventral margin in an acute angle on left side, differing from the generally obtuse angle in adults. This part is covered on the right side. The differences in the shape of the scapulae may be due to different ossification of the cartilage.

The elements of the left pelvic girdle are not so well preserved, but those of the right side are partly exposed (figs. 1, 4). The bone anterior to the left femur is identified as the blade of the left ilium. It expands posterodorsally as in the holotype of *A. wushaensis*. Although three right elements are available, the lateral one is difficult to identify. It should be the right ilium based on its position and relationship with the other two bones, but its shape is quite different from the left one. It is interpreted as the ilium missing the dorsal process here.

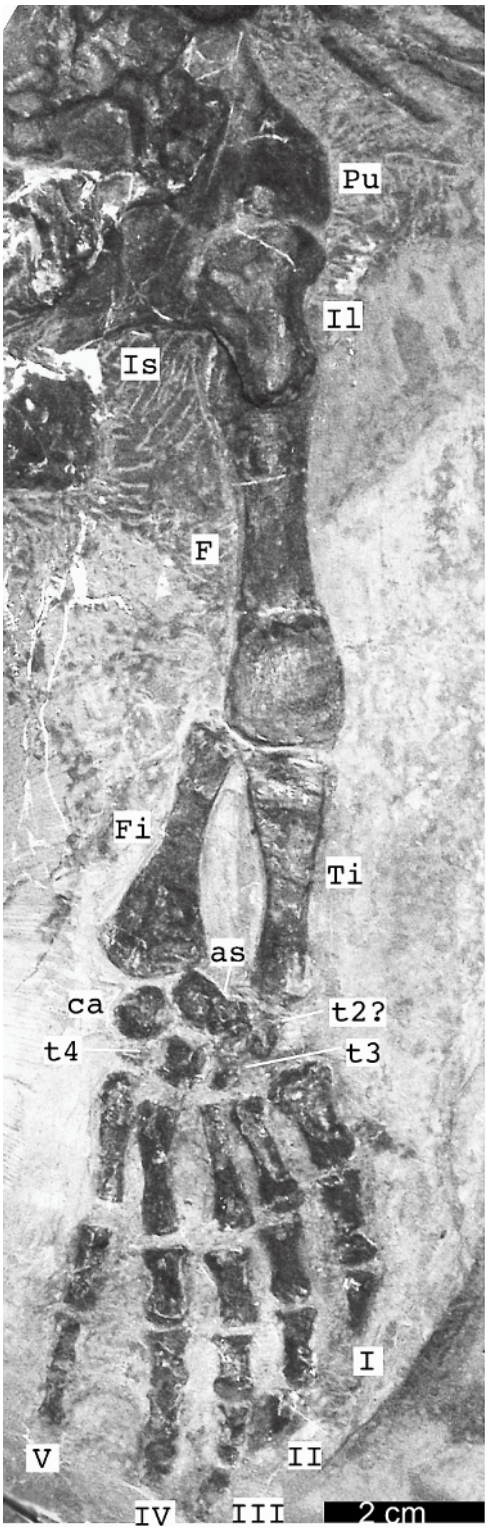
The long bones of the limbs show little morphological differentiation, so detailed structures such as muscle scars, processes, and epiphyses are not preserved or are at least very difficult to identify (figs. 4, 5). As in most tetrapods, the femur is longer than the humerus (table 1). In contrast to IVPP 11834 and 11835 but similar to IVPP 13872, the width of the proximal end of the radius is greater than its distal width.

Seven carpal ossifications can be identified, but the identification of the intermedium remains equivocal. An element lies distal to the radius, between it and the first metacarpal. It is similar in size to distal carpals II and III, and conspicuously smaller than distal carpal IV and the centrale. It is here interpreted as the first distal carpal rather than the radiale.

Metacarpals II, III, and IV are similar in length but markedly longer than metacarpals I and V. In IVPP 13782, metacarpal V is the longest. The phalangeal counts for digits IV and V are unavailable.

At least five bones are ossified in the right tarsus, but their exact number cannot be determined due to poor preservation. The largest element is identified as the astragalus. It meets the calcaneum laterally and other tarsals distally.

The length of the metatarsals gradually increases from the first through the fourth,



the latter being equal in length to the fifth metatarsal. This is similar to *A. wushaensis* but different from *A. huangguoshuensis*, in which metatarsal V is shorter than metatarsal IV.

COMPARISON AND DISCUSSION

Anshunsaurus is currently represented by two species, *A. huangguoshuensis* and *A. wushaensis*. *A. wushaensis* differs from *A. huangguoshuensis* in the following characters (Rieppel et al., 2006):

- relatively smaller skull relative to the glenoid-acetabulum length;
- short posterior process of the jugal that does not extend backward beyond the midpoint of the lower temporal fossa;
- neural spines in the posterior dorsal region that are not taller than their anteroposterior width and with a distinct ornamentation of vertical grooves and ridges near their dorsal margin;
- cruciform interclavicle with a broad-based anterior process;
- ectepicodylar groove and notch on humerus distinct;
- entepicondyle well developed, with ridge on ventral side of medial margin but no foramen;
- metacarpal V slightly longer than metacarpal IV;
- loss of one phalanx in fourth digit;
- iliac blade posterodorsally expanded;
- seven ossified tarsals.

The skull of KM 512 is more closely comparable to that of *A. wushaensis* than to that of *A. huangguoshuensis* in terms of the proportions of different elements in the skull roof. The length of the snout is a little bit greater than half the skull length in KM512 and IVPP 13872, but about 60% of the skull length in IVPP 11835. The relative size of the pineal foramen and the length of the parietal

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Fig. 4. Juvenile *Anshunsaurus*, right pectoral girdle and hind limb (specimen KM512). Abbreviations: as, astragalus; ca, calcaneum; F, femur; Fi, fibula; Il, ilium; Is, ischium; Pu, pubis; Ti, tibia; t2–4, distal tarsals 2 through 4; I–V, digitals I through V.

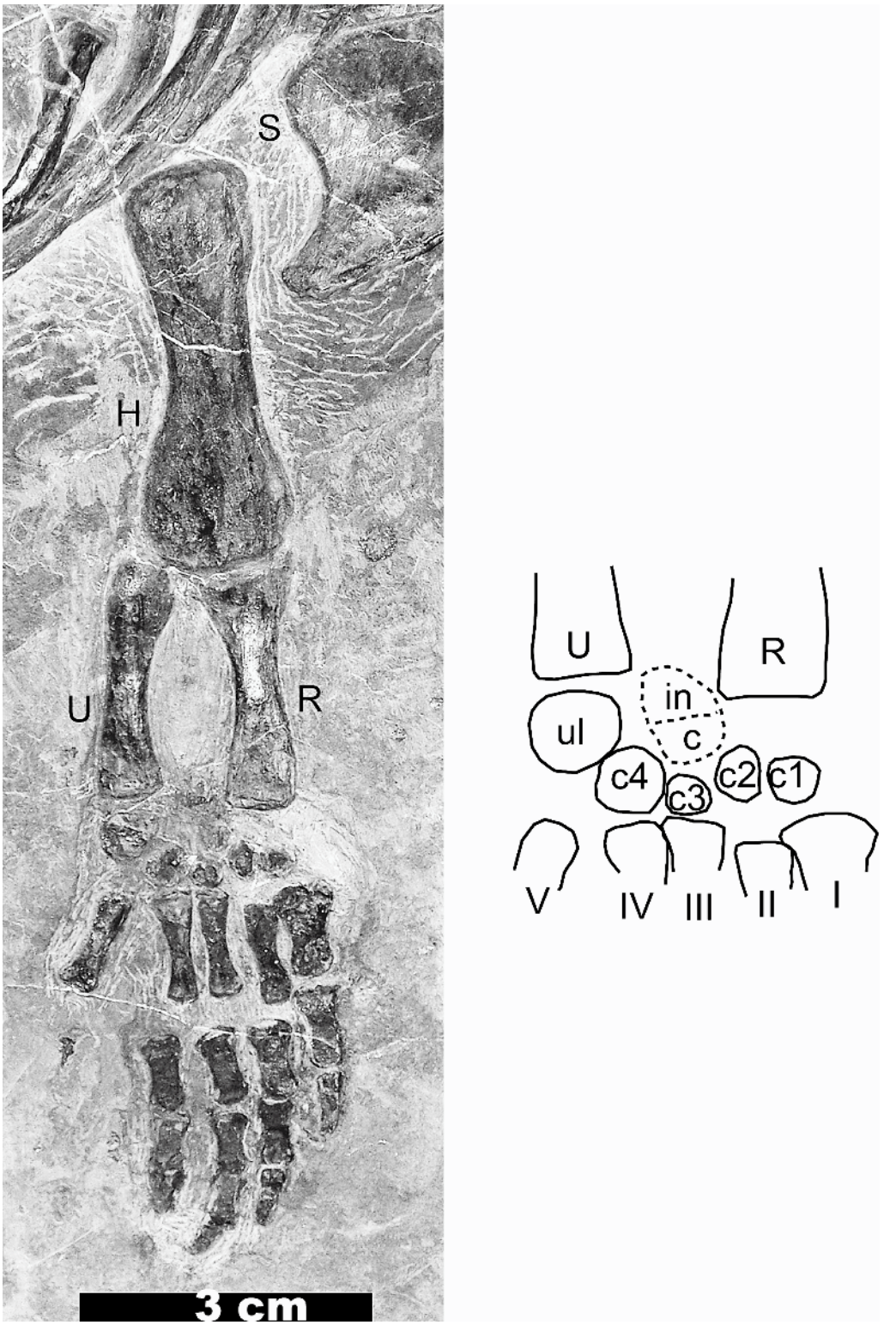

Fig. 5. Juvenile *Anshunsaurus*, right forelimb (specimen KM512). Abbreviations: c, centrale; c1–4, distal carpals 1 through 4; H, humerus; in, intermedium; R, radius; S, scapula; U, ulna; ul, ulnare; I–V, metacarpals I through V.

TABLE 1
Measurements of Specimen KM512
(L= left; R = right. All measurements in millimeters)

	Humerus		Radius		Ulna		Femur		Tibia	Fibula
	L	R	L	R	L	R	L	R	R	R
Length	49.6	48.6	27.9	29.1	27.5	28	56.1	—	31.0	32.1
Proximal width	—	15.4	9.2	12.2	~10.5	~8.4	16.0	—	10.6	7.7
Minimal width	10.0	10.0	5.2	5.3	5.8	5.2	9.9	8.9	5.7	5.0
Distal width	19.0	18.3	7.6	8.4	8.6	7.9	18.8	15.0	8.5	14.4

	I	II	III	IV	V
Left metacarpal	11.2	12.8	13.4	14.0	12.8
Right metacarpal	12.3	13.3	13.6	13.7	12.6
Right metatarsal	14.1	15.3	16.3	16.8	16.9

behind the pineal foramen in KM512 are similar to those of IVPP 13872 but quite different from those of IVPP 11835. The ratio of the skull length to the length of the trunk (glenoid—acetabulum) is approximately 0.4 in KM512, whereas it is 0.38 in IVPP 13872 (holotype of *A. wushaensis*), but about 0.5 in IVPP 11834 and 11835. Because the skull generally exhibits negative allometric growth in tetrapods, this specimen is unlikely to represent a juvenile individual of *A. huangguoshuensis*.

In the skull, the major difference between *A. huangguoshuensis* and *A. wushaensis* is the degree of extension of the posterior process of the jugal. In KM512, the jugal extends beyond the midpoint of the lower temporal fossa. If this specimen is considered a juvenile of *A. wushaensis*, the extension of the process would be explained as negative allometric growth of this part. However, it also could be explained by the jugal extending beyond the midpoint of the lower temporal fossa in the holotype of *A. wushaensis*. A small fragment that lies just behind the discerned posterior end of the left jugal could be part of the jugal in IVPP V13782. A long posterior process of the jugal would then be characteristic of the genus *Anshunsaurus*, not just of one species. This hypothesis needs to be confirmed by more specimens.

This specimen is similar to the holotype of *A. wushaensis* in the following postcranial characters: height of the low neural spines of the dorsal region is less than their anteroposterior length, with a distinct ornamentation of vertical grooves and ridges near the dorsal margin; iliac blade is posterodorsally expanded; the width of the proximal end of the radius is greater than its distal width; the length of metatarsal 4 is equal to that of the metatarsal 5.

But the specimen also shares the following two characters with *A. huangguoshuensis:* metacarpal IV longer than metacarpal V and presence of a large astragalus.

This specimen is unquestionably juvenile because of its smaller overall size, the clear sutures on the skull, and the separation of the neural arches from their respective centra. However, it cannot be too young because the carpal and tarsal elements are well ossified. Although the specimen here described is not identical in all aspects of its morphology with either species, it is not regarded as representing a new species. It is closer to *A. wushaensis* than to *A. huangguoshuensis*, and therefore is tentatively referred to the former species. Should this be correct, some of the characters previously believed to differentiate the two species of *Anshunsaurus* would be due to intraspecific variation instead, e.g., the relative length of metacarpals IV and V, and the presence or absence of an astragalus. However, the relative length of metacarpals IV and V could still be a valid character for adults if there is a positive allometric growth of metacarpal V relative to metacarpal IV in *A. wushaensis*. More specimens are needed, however, to corroborate this conclusion.

The specimen here described is remarkable with respect to the asymmetry of the maxillae, scapulae, and ilia. The scapular and iliac asymmetry is due to different degrees of ossification. It indicates that the corresponding elements on two sides are not synchronous in the process of ossification.

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