第 42 卷 第 2 期
2004 年 4 月

古 脊 椎 动 物 学 报
VERTEBRATA PALASIATICA

pp. 120～129
fig. 1

辽宁下白垩统九佛堂组伊克昭龙一新种[1)]

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摘要: 伊克昭龙(*Ikechosaurus*)是一类长吻的离龙类,以前根据内蒙古的材料建立了孙氏种(*I. sunailinae* Sigogneau-Russell, 1981)及高氏种(*I. gaoi* Lü et al., 1999)。根据蒙古的材料建立的 *Tchoiria magnus* Efimov, 1979 也于 1983 年被原作者归入本属。本文记述了辽宁义县皮家沟九佛堂组新发现的一个近于完整保存的骨架(中国科学院古脊椎动物与古人类研究所标本编号: IVPP V 13283),并建立一新种:皮家沟伊克昭龙(*Ikechosaurus pijiagouensis* sp. nov.)。

新种以下列特征区别于伊克昭龙其他种:轭骨前伸约至泪骨之半;眶间距小于眼眶短径;眶后骨与后额骨不愈合;髂骨片前突不发育,颈区不收缩;四肢中桡胫骨与肱股骨之比相对较小。另外其荐前椎数目与孙氏种相同,为 25 枚,比鳄龙属(*Champsosaurus*)少 1 枚;坐骨明显比孙氏种短;桡肱骨长度之比为 0.58,胫股骨长度之比为 0.60,在所知新离龙类(Neochoristodera)中属最小;前肢腕骨至少 7 块,后肢跗骨至少 6 块;指/趾式均为 2-3-4-4-3。在正型标本中其第二远侧跗骨在左右脚中不对称。

提出眶后骨与后额骨的愈合与分离以及轭骨眶后支发育程度不能作为 Simoedosaridae 和鳄龙科间的鉴别特征;股骨内转子与股骨头分离不该作为高氏种的鉴定特征;新离龙类中指/趾式应该均为 2-3-4-4-3。

伊克昭龙与 *Tchoiria* 有不少仅限于二者的特征:它们的吻部约为头长之半,上颞孔位于下颞孔之上稍后,荐前椎后关节突下有小的棘突但没有附属面,肩胛骨腹侧强烈扩展,坐骨后边缘缺乏明显的瘤状突起;这表明二者关系可能最近。认为长吻的离龙类与鳄类生活方式相近。

关键词: 辽宁义县,早白垩世,九佛堂组,热河生物群,离龙类
中图法分类号: Q915.864 **文献标识码**: A **文章编号**: 1000-3118(2004)02-0120-10

A NEARLY COMPLETE SKELETON OF IKECHOSAURUS PIJIAGOUENSIS SP. NOV. (REPTILIA: CHORISTODERA) FROM THE JIUFOTANG FORMATION (LOWER CRETACEOUS) OF LIAONING, CHINA

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Abstract A nearly complete skeleton of a choristodere is described and *Ikechosaurus pijiagouensis* sp. nov. is erected on the basis of this specimen. This new species is distinguished from other species of

1)国家自然科学基金和科技部国家重点基础研究发展规划项目(编号:TG2000077706)资助。
收稿日期:2003-12-02

the genus *Ikechosaurus* by the following features: the jugal extends anteriorly to about the middle of the lacrymal; the interorbital bar is narrower than the diameter of the orbit; the postorbital separated from the postfrontal; the anterior process of the iliac blade is less pronounced; there is no distinct neck region between the acetabulum and iliac blade; the ratio of epipodials to the propodials are relatively small. The morphology of this specimen reveals that certain characters like the fusion of the postfrontal and postorbital and the lack of a prominent postorbital process of the jugal cannot be used to diagnose the Simoedosaridae and Champsosauridae. Comparison with other choristoderes suggests that *Ikechosaurus* is more closely related to *Tchoiria* than with *Champsosaurus* and *Simoedosaurus*.

Key words Yixian, Liaoning, Early Cretaceous, Jiufotang Formation, Jehol Biota, Choristodera

1 Introduction

The Choristodera is an amphibious diapsid group. Choristoderans are known from medium to large-sized, long snouted gavialiform forms, a small alligator-like form and long-necked forms (Gao et al., 2000). These three morphotypes all have representatives in the Jehol Biota of China: *Ikechosaurus*, *Monjurosuchus*, and *Hyphalosaurus* (Brinkman and Dong, 1993; Endo, 1940; Endo and Shikama, 1942; Gao et al., 1999, 2000).

Ikechosaurus represents the long-snout morphotype in China. This genus was erected by Sigogneau-Russell (1981) on the basis of one snout fragment which had previously been identified as the crocodilian *Eotomistoma* (Young, 1964). Two species from Nei Mongol were referred to *Ikechosaurus*: *I. sunailinae* from the Laohongdong (Luohandong) Formation and *I. gaoi* from the Jiufotang Formation, of Early Cretaceous (Aptian) in age (Lü et al., 1999; Sigogneau-Russell, 1981; Zhou et al., 2003). Incomplete choristodere material from the Aptian of Mongolia originally assigned to *Tchoiria magnus* Efimov, 1979 was later reassigned to *Ikechosaurus magnus* (Efimov, 1983), but Ksepka et al. (in review) regarded it as Neochoristodera *incertae sedis*. In recent years, many complete skeletons of gavialiform choristoderes have been unearthed in western Liaoning. Here I describe one nearly complete skeleton and erect a new species based on it.

2 Systematic paleontology

Class Reptilia Linnaeus, 1758
Subclass Diapsida Osborn, 1903
Order Choristodera Cope, 1876
Family Simoedosaridae Lemoine, 1884
Genus Ikechosaurus **Sigogneau-Russell, 1981**
Ikechosaurus pijiagouensis **sp. nov.**
(Fig. 1)

Etymology Pijiagou, the name of fossil locality.

Holotype IVPP (Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences) specimen number V 13283, an articulated and nearly complete skeleton with skull and lower jaws (Fig. 1A).

Locality and horizon Pijiagou, Yixian, Liaoning Province, China; Jiufotang Formation, Aptian of Lower Cretaceous.

Diagnosis This species differs from other species of the genus *Ikechosaurus* by the following features: jugal extends anteriorly to about the middle of the lacrymal; interorbital width narrower than diameter of orbit; postorbital separated from postfrontal; ilium with undeveloped anterior process on the iliac blade, and without distinct neck region between the acetabulum and iliac blade; the ratio of epipodials to the propodials are relative small.

Description The described specimen (IVPP V 13283) is an articulated skeleton consisting of a complete skull, mandibles and nearly complete postcranial skeleton including most of the vertebral column, limb girdles and limbs. Except for the left forelimb, which is positioned below the trunk, the entire skeleton is fully exposed in dorsal view. The mandibles and part of the pectoral girdle

clearly deviate from their natural position. The length of the preserved portion of the specimen is 1.7m (other measurements see Table 1).

Table 1 Measurements of Ikechosaurus pijiagouensis **sp. nov.** (IVPP V 13283) (mm)

Skull total length	275	Length of iliac blade	52
Skull length in midline	213	Humerus height	99
Skull width	131	Humerus width of distal end	46
Preorbital region length	129	Femur height	130
Lower jaw length	238	Length of metacarpal I	16
Lower jaw height	24	Length of metacarpal II	22
Atlas length	9	Length of metacarpal III	24
Axis length	19	Length of metacarpal IV	24
Length of neural spine of the axis	26	Length of metacarpal V	17
Height of neural spine of the axis	7	Length of metatarsal I	20
Length of 4th cervical rib	23	Length of metatarsal II	28
Length of 5th cervical rib	27	Length of metatarsal III	35
Length of 6th cervical rib	33	Length of metatarsal IV	36
Length of 7th cervical rib	36	Length of metatarsal V	26
Scapula height	67	Proximal width of metatarsal I-IV	c. 10
Scapula upper width	20	Proximal width of metatarsal V	15
Scapula lower width	42		

2.1 The skull and lower jaw

The skull of this specimen (Fig. 1B) is similar to but larger than other specimens of *Ikechosaurus*. The skull is flattened even after excluding the effect of dorsoventral compression. It has a long narrow snout and a flared postorbital region. The snout is similar to other species of *Ikechosaurus*. It is wider and shorter than the snout of *Champsosaurus*, but much more slender than the snout of *Simoedosaurus* (Erickson, 1972, 1987; Gao and Fox, 1998). The preorbital region is less than half of the total skull length. The posterior skull margin is deeply incised; the angle between the posterior borders of the superior temporal fenestrae is smaller than in *I. sunailinae* (specimens V 9611). The posterior skull margin reaches the level of the fourth cervical vertebra. The bones of skull roof are covered with coarse ridges and striations.

The external narial opening is terminal and confluent. The length of this opening is nearly equal to the width. This may be interpreted as supportive of Brinkman and Dong's suggestion (1993) that the length being greater than the width in the external narial opening of *I. sunailinae* is due to the immaturity of the specimen. The dorsally directed orbits are relatively large, oval openings separated from one another by an interorbital bar that is narrower than the minimum diameter of the orbit. Due to the enlargement of the orbits, the interorbital bar and the bar between the temporal fenestrae and orbits are relatively narrower than those in *I. sunailinae*. A parietal foramen is absent.

The superior and inferior temporal fenestrae are anteroposteriorly elongate openings. The relative position of superior and inferior temporal fenestrae is same as in *I. sunailinae*. The superior temporal fenestra is wider and much longer than the inferior fenestra, as in *Champsosaurus*, but in contrast to the state of *I. sunailinae*. The inferior temporal fenestrae are dorsolaterally directed as in *I. sunailinae*, differing from the laterally directed inferior temporal fenestrae of *Simoedosaurus*.

The paired premaxillae form the tip of the snout and extend dorsally posterior to the external naris to meet the nasal. There is no dorsal process at the midline. A single nasal extends from the

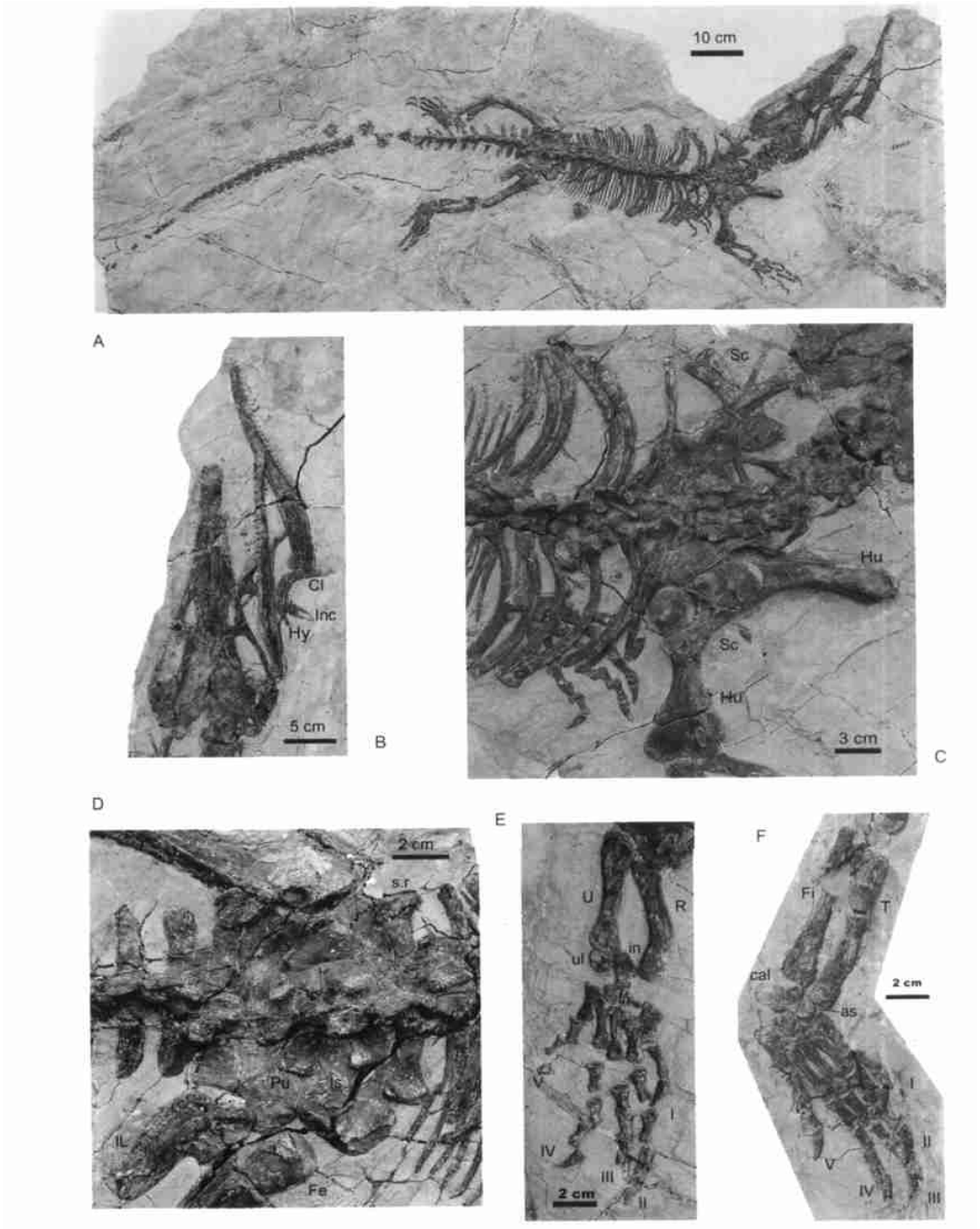

Fig. 1 *Ikechosaurus pijiagouensis* sp. nov., IVPP V 13283

A. in whole; B. skull and lower jaws; C. neck and pectoral girdle; D. pelvic girdle; E. right forelimb; F. right hindlimb

简字说明 Abbreviations: as. astragalus **距骨**; cal. calcaneum **跟骨**; Cl. clavicle **锁骨**; Cr. coracoid **乌喙骨**; Fe. femur **股骨**; Fi. fibula **腓骨**; Hu. humerus **肱骨**; Hy. hyoid **舌骨**; IL. ilium **髂骨**; in. intermedium **间中骨**; Inc. interclavicle **间锁骨**; Is. ischium **坐骨**; Pu. pubis **耻骨**; R. radius **桡骨**; Sc. scapula **肩胛骨**; s. r. sacral rib **荐肋**; T. tibia **胫骨**; U. ulna **尺骨**; ul. ulnare **尺侧腕骨**; I, II, III, IV, V. digits **第 1 至第 5 指/趾**

prefrontals to the external narial opening and contacts the maxillae and premaxillae laterally. It projects forward into the external narial opening where its anterior end reaches the anterior border of the opening and divides the opening into two parts at lower portion. The upper portion of the external naris is completely open. The maxillae have strongly inrolled dorsal parts and tooth-bearing medial shelves ventrally. The nasal is narrow between the inrolled dorsal parts of maxillae. Its suture with prefrontal is unclear, but it appears narrow.

The prefrontals meet one another along the midline anterior to the frontals and contact the lacrymal and maxilla laterally. The frontal-prefrontal suture is located at about the middle of the interorbital bar, but the exact shape and place is unclear. The lacrymal forms the anterior margin of the orbit between the prefrontal and jugal. The jugal forms the ventral margin of the orbit and the anterior end of the lower temporal bar. The anterior end of the jugal extends between the maxilla and lacrimal and then into a notch on the maxilla, reaching the middle of the lacrymal. The relative position of the anterior end of the lacrymal and jugal is a bit different from that of *I. sunailinae* where the jugal extends as far forward as does the lacrymal. The postorbital process of the jugal is prominent, as in a new specimen of *Tchoiria* (Ksepka et al., in review).

The postfrontals and postorbitals are separate bones. The sutures between them are clear and symmetrical on two sides. The postfrontals run from the posterior margin of the orbit contacting both the frontals and parietals along their upper margins. Laterally, the postfrontals are excluded from the inferior temporal fenestra by the contact of the postorbitals with the jugals. Posteriorly, the postfrontals and the postorbitals meet obliquely. The position of the posterior end is not so clear, but it looks like that the postfrontals do not enter the superior temporal fenestrae. The postorbitals are flat and smooth bones forming the superior temporal bar with the squamosals. The postorbitals are excluded from the orbitals by the postfrontals anteriorly. They extend posteriorly and are covered by the squamosals, the actual suture between the postorbital and squamosal cannot be determined because the anterior part of the squamosal is missing in this specimen.

The parietals form the skull roof posterior to the frontals, but the suture between them is unclear. The supraoccipital is not exposed dorsally on the skull roof. The squamosals form the posterolateral edges of the skull. The lateral and occipital surfaces of the skull are separated by a sharp crest on the squamosal. The sutures on the posterior part of the skull are not clear. The dorsal side of the pterygoid can be viewed through the orbits. Occipital windows in the occiput are absent in this specimen as in *I. sunailinae*.

The marginal dentition is partly exposed. The teeth under the left orbit are rather large and sparsely arranged, as in *I. gaoi*. Most conical teeth on the maxilla show little disparity in size, but a few small teeth are present in the middle. These could represent new erupted teeth.

Two separated mandibles (Fig. 1A, B) are preserved to the right of the skull and exposed in lateral view. They are slender and greatly elongated. The state of the mandibular symphysis cannot be observed. The dentary is the largest bone in the lower jaw; it is longer than 2/3 of the whole lower jaw length. The splenial is observable in the middle of the left mandibula. The coronoid can be seen in medial side of the right mandibula. It forms a low prominence with the posterior end of the dentary and surangular. The surangular forms the lateral surface of the postdentary region and the dorsal surface of the lower jaw posterior to the coronoid. A short retroarticular process of the articular is developed behind the surface of the articulation with the quadrate.

About 40～50 thecodont teeth are present in each mandible. The tooth row is bordered medially by a raised ridge. The anterior teeth are large and sparse. They decrease in size and become densely packed posteriorly.

Two hyoid elements, interpreted as the first branchial horns, are preserved along with the right mandibula. They are slender and rod-like.

2.2 The axial skeleton

The vertebrate column (Fig. 1A) is almost continuously preserved, with 25 presacral vertebrae, 3 sacral vertebrae and 39 caudal vertebrae. Only a few caudal vertebrae are lost.

The neck includes 9 cervical vertebrae. The atlas and the axis are exposed in dorsal view. The neural spine of the axis is low and long. The centra of the 3rd, 4th, 5th, 8th, 9th cervical vertebrae were exposed in dorsal view, their neural arches are displaced laterally. They are similar to one another, measuring 18 mm in length and 16 mm in width. The open neurocentral sutures are triangular. The neural spines are not well-preserved, but they are higher than the neural spine of the axis.

Cervical ribs are preserved starting with the 4th vertebra. They gradually increase in size posteriorly. These ribs are double-headed and taper to a point distally. The ribs on the 8th and 9th vertebrae are nearly equal to the ribs of the dorsal region in length (about 90 mm), but they come to a point distally and are more slender than the ribs after the 10th vertebra, so they are probably not continued distally in cartilage. This indicates that there are 9 cervical vertebrae.

Most dorsal vertebrae are exposed in right lateral view other than a few anterior vertebrae, which are exposed in dorsolateral view. One isolated centrum is exposed in anterior or posterior view, and this side is flat. The centra are sub-cylindrical and similar in size, with lengths of 20 mm, widths of 17 mm, and heights of 14 mm. Neurocentral sutures remain open. The neural spines are trapezoid in shape and slightly tilted posteriorly.

The dorsal ribs are thick, arc-like, and single-headed with expanded distal ends. The length of the anterior ribs is about 9～10 cm, the posterior five ribs gradually decrease in length.

Three sacral vertebrae are present. Their neural spines are about equal in height to those of the posterior dorsal vertebrae. This differs from the state in V 9611 (Brinkman and Dong, 1993). The sacral ribs have a narrow shaft and expanded lateral ends. The expansion is distinct in the first sacral. The distal expansion of the third sacral is slightly less than the expansion in the first and second sacrals. The anterior and posterior margins of the third sacral rib are nearly straight, quite different from the first sacral rib which has curved margins.

The first 10 caudal vertebrae are exposed in dorsal view and most of the remaining caudals are exposed in left lateral view. The centra decrease in size posteriorly, and are distinctly diminished after about the 30th caudal vertebra. The neural spines of the posterior caudals are slightly titled posteriorly. There are short ribs on the anterior 15 caudals, with the articular surface shared proximally by the neural arch and centrum. Distally, the ribs are confined to the centrum. There is a suture between the rib and the vertebra, but this is an immovable joint. No ribs are visible posterior to the 17th vertebra (possibly 16th, uncertain due to the preservation). The size of the ribs diminishes gradually backwards. The chevrons are visible from the 12th caudal, the chevrons around the 14th caudal are equal to or longer than the ribs.

Gastralia are arranged in close transverse rows over the entire length of the trunk, starting under the ribs of the 15th vertebra and ending under the last dorsal vertebra. The gastralia are more slender than the dorsal ribs, about 1/3 the width of the latter. There are about 33 rows in place, similar to the 35 or 36 rows in *Champsosaurus gigas* (Erickson, 1985).

2.3 The appendicular skeleton

The pectoral girdle (Fig. 1A, C) is represented by an interclavicle, a clavicle, scapulae and coracoids. The scapulae and coracoids nearly lie *in situ*, but the interclavicle and clavicle are displaced and lie beside the skull and under the lower jaw. The interclavicle is a T-shaped bone with a pointed posterior end, it resembles that of *Ikechosaurus sunailinae* (IVPP V 9611-1) (Brinkman and Dong, 1993) in having a long, slender stem. The claviclar facets on interclavicle run continuously across the midline in a smooth curve. The clavicle is a robust U-shaped bone.

The scapular and coracoidal plates are exposed in medial view. The scapula is a tall and broad

sheet of bone, with an expanded ventral surface. Its hatchet-shape is quite different from that in IVPP V 9611-1, but this difference may be due to the juvenile status of that specimen. The ventral expansion of the scapula is much stronger than that in the genera *Champsosaurus* and *Simoedosaurus*, but similar to that of *Tchoiria namsarai* (Efimov, 1975). The coracoidal plates are partly covered by vertebrae and ribs. The small coracoid foramen, beneath the anterior end of the glenoid, is exposed near the scapular border at about the center of the element.

The right forelimb (Fig. 1E) is complete and articulated, while the left one has been displaced to the right. The following description is mainly based on the right forelimb.

The humerus is similar to that of *I. gaoi* (Lü et al., 1999). It is a stout bone with a slender shaft and wide expansion at both ends. The shaft is twisted causing about 80° of rotation between the proximal and distal ends. The proximal end of the humerus is partly hidden, but it is clear that the deltopectoral crest is mildly developed and close to the humeral head. The deltopectoral crest in the holotype of *I. gaoi* (IVPP V 11477) is similar. All condyles are full developed. The entepicondyle has a broad smooth dorsal surface. A marked ectepicondylar sulcus is developed between the supinator process and the ectopicondyle, as in an adult specimen of *Champsosaurus natator* (Erickson, 1972).

The radius is like that of *I. gaoi* in its S-shaped outer margin and strongly concave inner margin. It is about 58 % the length of the humerus. The ulna is slightly massive and longer than the radius. It has an expanded proximal head. The margin in dorsal view is convex, not concave as in *C. gigas* (Erickson, 1972). The shaft expands near the distal end. The ulna articulates with the ulnare and intermedium at a simple convex surface.

The right carpus is either incompletely preserved or incompletely ossified and 7 carpals can be observed. The left carpus is covered by ribs, but the preservation is much better than in the right carpus. The radial is missing as in *C. laramiensis* (Erickson, 1972). The ulnare is a fan-shaped bone with a convex distal margin. The intermedium is quadrilateral in shape and approximately the same size as the ulnare. Articulated *in situ* with the distal end of the intermedium is a small element that is interpreted as the proximal centrale. The four remaining distal elements are the first, second, third and fourth carpals. The second distal carpal is the smallest one. The fourth is larger than the proximal centrale, which is the third largest element in the carpus.

The manus is similar to that of *C. laramiensis* (Erickson, 1972). It is composed of five elongated metacarpals and five digits. The phalangeal formula is 2-3-4-4-3. The metacarpals are flat dorsoventrally, constricted medially, and flared proximally. Their distal ends are only slightly expanded. The proximal width is similar (9～11 mm) and decreases gradually from the first to the fifth metacarpal. The phalanges decrease in length distally. The unguals are claw-like.

All portions of the pelvic girdle were preserved nearly *in situ* (Fig. 1A, D), so only the ilia are completely exposed. The left ilium was preserved in medial view, and the right ilium in lateral view; the main part of right pubioischiadic plate was exposed in dorsal view.

The shape of the ilium is similar to that of *I. sunailinae* (V 10596.9) (Brinkman and Dong, 1993). The base of the ilium is broad with anterior and posterior surfaces that angle ventrad to receive the pubis and ischium, respectively. Laterally, there is a large, smooth concavity that contributes to the acetabulum. Above this is a roughened buttress. The lateral surface of the ilium is slightly concave above the buttress. The posteriorly extending iliac blade is parabolic in form. The length of the blade is much greater than the height of the entire bone (c. 34 mm). This is the same as in *I. sunailinae* and *I. gaoi*, but in contrast to *C. gigas*. The anterior process of the iliac blade is less well developed, so the anterior border is only slightly concave, differing from *I. sunailinae* and *I. gaoi*. The neck region between the acetabulum and iliac blade is nearly unconstricted, as in *I. sunailinae*.

The height, the length of the base, and the length of the blade vary ontogenetically relative to the length of the neck in *Champsosaurus* (Erickson, 1972). The constricted neck is distinct in

adults of *Champsosaurus*. If similar growth changes occur in *Ikechosaurus*, this specimen and IVPP V 10596.9 (Brinkman and Dong, 1993) should be regarded as juveniles. However, this specimen is at least a subadult (see the discussion), so this state can be considered a diagnostic character. The anterior margin of the ilium is nearly straight only in extremely young *Champsosaurus*; even juveniles have a distinct concave anterior margin. Most of the surface is smooth with only a few rugosities present on the dorsal margin of the blade. This is also considered a juvenile character in *Champsosaurus*. The holotype of *I. gaoi* is smaller than this specimen, but the ilium is more constricted than in this one.

The posterior border of the pubis contacts the anterior border of the ischium in a straight line. An obturator foramen is located toward the heavy end of the pubis. The pubis and ischium resemble those of *Champsosaurus* and *Simoedosaurus*, but differ from *I. sunailinae* in that the ischium is much shorter. The length of the ischium in IVPP V 9611-5 (Brinkman and Dong, 1993) is approximately equal to that in this specimen, but the ratio of the total body size is about 2/3 based on the vertebrae and limb.

The hindlimb (Fig. 1A, F) is apparently longer than the forelimb, this is due to the lengthening of corresponding parts of the propodial and epipodials in the hindlimb.

The femur is a long bone with a twisting shaft and a well-developed internal trochanter. The boundary between the internal trochanter and the head is clear. All these characters are present in other specimens of *Ikechosaurus*. The separation of the internal trochanter from the head occurs ontogentically in *I. sunailinae* (Brinkman and Dong, 1993), so this must be regarded as intraspecific variation and cannot be used as a diagnostic character for *I. gaoi* as suggested by Lü et al. (1999). The distal end of the femur lacks clearly defined condyles in *I. sunailinae* (Brinkman and Dong, 1993), but two condyles are clear in *I. gaoi*. The condition in this specimen is unclear.

The tibia is only 60 % the length of the femur. It is characterized by a greatly swollen proximal end. The shaft is slender and curved with a concave inner margin. The slightly expanded distal end is reflected toward the fibula and cut by a flat astragular facet.

The fibula is paddle-shaped, showing only feeble swelling proximally. It is a bit shorter (2 mm less) than the tibia. The shaft begins to flare about 3/5 of the way down and finally terminates in a wide, arcuate surface embraced by the tarsus.

The tarsus is well-preserved in the right foot. Six elements comprise the tarsus: the calcaneum, the astragalus, and four distal tarsals. The calcaneum is a thin, flat, approximately quadrilateral bone that is thickened medially for contact with the astragalus. Its proximal border has a narrow face to match the fibula. Its distal margin is concave with a narrow face to articulate with the fourth distal tarsal. The astragalus is a larger bone with slightly concave proximal border and a convex distal border. The proximal concave facet is for the tibia. Just adjoining to this facet at a right angle is the articular surface for the fibula. The distal margin of the astragalus articulates with the four distal tarsals. The first, second, and third distal tarsals are articulated *in situ* with the first, second, and third metatasals, respectively. The fourth distal tarsal contacts the 4^{th} and 5^{th} metatarsals. The second distal tarsal is the smallest in the tarsus of the right foot, but the second distal tarsal in the left foot is much larger than the right one. As in the carpus, the fourth distal tarsal is much larger than other distal tarsals, and is the third largest element in the tarsus.

The pes is composed of five elongated metatarsals and five digits. The phalangeal formula is 2-3-4-4-3. The distal ends of the metatarsals are similar in width, and only a bit wider than the shaft. The phalanges have normal terminal flaring and facets and decrease in length distally. The unguals are also claw-like.

3 Discussion and conclusion

This specimen is an adult judged by the following evidence: the sutures in the skull are not clear, the elements of the carpus and tarsus are well-ossified, the long bones and girdle elements

exhibit high degrees of curvature. The skull length is 27 cm, much shorter than 50 cm in some adults of *Champsosaurus* and *Simoedosaurus*. It has some characters of juvenile *Champsosaurus*, e. g., indistinct iliac constriction and a smooth iliac surface, but these characters cannot be regarded as indicative of a juvenile status here. The holotype of *I. gaoi* is smaller than this specimen, but the ilium is more constricted, similar to the subadult of *Champsosaurus*.

Based on the description above, this specimen closely resembles the two previously described species of *Ikechosaurus* and can be assigned to that genus. *I. pijiagouensis* can be distinguished from other species of *Ikechosaurus* by the following characters: it differs from *I. sunailinae* in the separation of postorbital and postfrontal, anterior extension of the jugal only to the middle of the lacrymal; it differs from *I. gaoi* in possessing an ilium with an undeveloped anterior process on the iliac blade without a distinct neck region between the acetabulum and iliac blade. It needs not be compared with *I. magnus* for the lack of diagnostic characters in the latter.

Some differences of the postcranial skeleton have also been observed between this specimen and other specimens. The hindlimb is relatively long: the humero-femoral ratio is only 0.77. The ratio is 0.80 in *Champsosaurus gigas* and 0.83 in *C. laramiensis*. The epipodials are short relative to the propodial in this specimen compared with most other species. The radius is about 58% the length of the humerus in this specimen. This ratio is 61% in *C. laramiensis*, 63% in *I. gaoi* and 67% in *I. sunailinae*, only slightly greater than that of *C. gigas*. The tibia is 60% the length of the femur, less than in *I. sunailinae*, *C. gigas* (69%), and *C. laramiensis* (74%). Limb length and individual limb bone ratios are nearly constant within a species regardless of age in *Champsosaurus* (Erickson, 1972), so the difference among the specimens of *Ikechosaurus* could be due to the interspecific variation.

The long-snouted Neochoristodera include *Simoedosaurus*, *Tchoiria*, *Ikechosaurus* and *Champsosaurus*. The former three make up the Simoedosauridae, the last one the Champsosauridae (Evans and Manabe, 1999; Gao and Fox, 1998; Ksepka et al., in review). The two families can be differentiated by the snout length, the separation or fusion of the postorbital and postfrontal, and prominence of the postorbital process of the jugal (Gao and Fox, 1998). More knowledge about these characters is available after the discovery of new materials.

The postorbital and postfrontal could be discrete in *Tchoiria*, e. g., as in specimen GIN39-54-01 (Evans and Manabe, 1999). It is clear that this is also true in *Ikechosaurus* as the specimen described here. Both fused and separate postfrontals and postorbitals are present in specimens of the species *Champsosaurus lindoei* (Gao and Fox, 1998). So the fusion or separation of the postfrontal and postorbital is only an interspecific or intraspecific character. Another character used to diagnose the Simoedosauridae is little or no postorbital process of the jugal (Gao and Fox, 1998), but this process is prominent in a new specimen of *Tchoiria* (Ksepka et al., in review) and of *I. pijiagouensis*, so this character is also undiagnostic of the Simoedosauridae.

The four limbs, especially the manus and pes, were not well preserved in other described specimens of *Ikechosaurus*. It is clear that the carpus and tarsus are most complete in this specimen of the Neochoristodera, with 7 ossified carpals and 6 ossified tarsals. The digital formulae in the manus and pes are 2-3-4-4-3. The formula 2-3-4-5-4 in the manus was suggested by Russell (1956) for *C. natator*, but only 0-0-2-3-3 are preserved in that specimen, so its formula could be the same as in other specimens and other Neochoristodera. The number of the presacral vertebrae, 25, in *I. pijiagouensis*, is the same as in *I. sunailinae*. This number is one less than that of *Champsosaurus*.

The skull shape of *Ikechosaurus* is intermediate between that of the blunt-snouted *Simoedosaurus* and the narrow-snouted *Champsosaurus*. It is similar to that of *Tchoiria*. The snout is of moderate width and about half the total skull length. The narrow interorbital bar has a width close to the width of the orbit, the superior temporal fenestrae lie above and slightly posterior to the inferior temporal fenestrae. *Ikechosaurus* differs from *Tchoiria* in that the supraoccipital is exposed dorsally in the latter genus. *Ikechosaurus* and *Tchoiria* also have some common characters of the postcra-

nial skeleton not shared by *Simoedosaurus* and *Champsosaurus*, e. g., there are small spinous processes below the presacral postzygapophyses but without accessory facets, the ventral side of the scapula is strongly expanded, the ilium is low and wide without a distinct neck region (excluding *I. gaoi*), and the prominent tubercle on the posterior edge of the ischium is absent. All these characters suggest a close relationship of *Ikechosaurus* and *Tchoiria*, perhaps closer than suggested by some researchers (Evans and Manabe, 1999; Gao and Fox, 1998; Ksepka et al., in review).

Choristoderes are considered to be amphibious reptiles that spent some, possibly much, of their time in water (Evans and Manabe, 1999). The fossil record indicates that the long-snouted choristodere *Champsosaurus* preferred areas of low crocodile concentration (Erickson, 1985). There are no crocodiles reported from the Jehol Biota up to now, but many choristodere fossils had been uncovered (Zhou et al., 2003). This indicates long-snouted choristoderes had similar lifestyles to crocodiles and competed for a similar niche.

Acknowledgements The author is indebted to the IVPP Liaoxi Project field team, especially to Dr. Zhou Zhonghe, Dr. Wang Xiaolin and Mr. Li Chun; to Mr. Ding Jinzhao who prepared the specimen; and to Mr. Zhang Jie who took the photos. Daniel Ksepka revised the grammar and gave helpful comments. The author also thanks Mr. Liu Zhongyun and Ms. Zhen Fang for help during visiting IVPP.

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